Power Grid Company of Bangladesh Limited

Bidding Document for Procurement of

Design, Supply, Installation, Testing and Commissioning of 400/230 kV GIS Substation at Kaliganj on turnkey basis (Package-5)

[Contract No.: PGCB/ADB/L3853/AIIB/L8374/DWZTGEP/GIS/P5]

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Project	:	**Dhaka and Western Zone Transmission Grid Expansion Project**
Loan No	:	ADB-L3853/AIIB-L8374-BAN
Employer	:	Power Grid Company of Bangladesh Ltd. (PGCB)
Country	:	The People's Republic of Bangladesh
RFB Ref. No	:	27.21.0000.101.07.412.21.5538
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1. Scope of Works

1.1 Description of Overall Project

The one of the objective of this project is to strengthen and to contribute to an efficient power transmission system in Dhaka region of Bangladesh. The project area comprises theKaliganj areas.

In order to strengthen the Dhaka region, establishment of 400/230kV GIS substation at Kaliganj through LILO of Kaliakoir– Bhulta 400kV D/c line has been planned, which will improve system stability and reduce losses. Kaliakoir– Bhulta 400kV D/c line shall be cosntrcuted in spearte project.

Kaliganj 400/230kV substation shall become one of the node point of Dhaka 400kV transmissiom ring. Sevral existing 230kV lines shall be connected to this station through LILO arrangement. Moreover, a new 400/230/132kV substation at Purbachol shall also be connected to Dhaka 400kV transmissiom ring through new Kaliganj substation.

1. 2 Description of Works

1.2.1 New 400/230 kV indoor GIS substation at Kaliganj

The scope of work under this turnkey project is design, supply, delivery, installation, testing & commissioning of new 400/230kV indoor Gas Insulated Switchgear (GIS) substation and associated three (3) buildings and civil works. The configuration of the 400kV busbar shall be Double busbar scheme and the 230kV busbar shall also be Double Busbar scheme.

The scope of work also includes design, supply, delivery, installation, testing & commissioning of 400/235/34.5kV (three phase) Auto Transformers and associated civil works.

The scope of work also includes associated control, protection, fiber optic multiplexer equipment for communication & protection, substation automation, digital fault & disturbance recorder (DFDR), station power facilities, including towers and gantry structures, and associated equipment, local control kiosks, 33kV tertiary equipment, cable trenches, water supply & sewerage, fences, access road & internal roads, security guard stations, and all other necessary substation facilities and supply of mandatory spare parts and maintenance & special tools.

The scope of works shall also include Transient study to ascertain Over-voltages & mitigation techniques to control the over-voltages for the substations.

The exact location and measurement of the proposed land with road layout may be obtained from the Project Director office.

1.2.1.1 420kV Gas Insulated Switchgear (GIS)

Complete 420kV GIS consisting of eight (08) line bays (including two spare bays) and three (03) transformer bays (including one spare bay) and two (02) bus-coupler bays, two (02) bus-section bays to connect six new 400kV lines (Kalikoir-1&2, Bhulta-1&2, Purbachal-1&2), & two (02) new 400/235/34.5kV transformer.

Space provision shall be kept for future extension of six (06) 400kV line bays and two (02) bus reactor bays. Also, space provision for future 132kV GIS building and line termination facility shall be kept

The position of Bus VT with High-Speed ES shall be kept such that, it shall decrease the interruption hours when an extension.

The configuration of the 420kV busbar shall be double busbar scheme.GIS design shall include sufficient jointing plugs/adapter, interface module with double isolator & earth switch in-between at both ends of GIS bus for adding future bays of different make/manufacturer.
GIS Design shall consider appropriate Buffer zones both in bays & in Busbar suitable for best MRE (& testing) practice so as to minimize downtime time & maintenance complexity.

All GIS shall be installed in the building excluding GIL and Gas-to-Air Bushing for Transmission Lines and Transformers connection.

1.2.1.2 245kV Gas Insulated Switchgear (GIS)

Complete 245kV GIS consisting of ten (10) line bays (four spare bays), three (03) transformer bays (one spare bay) and two (02) bus-coupler bays, two (02) bus-section bays to connect six (06) new 230kV lines (Ghorashal New [400kV line but charged at 230kV]-1&2, Ghorashal Old-1&2, Tongi Old-1&2), & two (02) new 400/235/34.5kV transformer banks.

Space provision shall be kept for future extension of six (06) 230kV line bays.

The position of Bus VT with High-Speed ES shall be kept such that, it shall decrease the interruption hours when an extension.

The configuration of the 230kV busbar shall be double busbar scheme with section. GIS design shall include sufficient jointing plugs/adapter, interface module with double isolator & earth switch in-between at both ends of GIS bus for adding future bays of different make/manufacturer.

GIS Design shall consider appropriate Buffer zones both in bays & in Busbar suitable for best MRE (& testing) practice so as to minimize downtime time & maintenance complexity.

All GIS shall be installed in the building excluding GIL and Gas-to-Air Bushing for Transmission Lines and Transformers connection.

1.2.1.3 145kV Gas Insulated Switchgear (GIS) (Not Applicable)

1.2.1.4 400kV & 230kV Air Insulated Switchgear (AIS)

400kV lightning arrester and 400kV Capacitive Volatge transformer shall be used for 400kV bays. 230kV lightning arrester shall be used for 230kV bays

1.2.1.5 36kV Air Insulated Switchgear (AIS) and Connection

Two (2) sets of 36kV Switchgear for two (2) Aux. power TRs and tertiary connection with Al Bus shall be installed.

New 33kV AIS switchyard and switches for station power service facilities with 400/235/34.5kV tertiary side switchyard and connection.

1.2.1.6 400/235/34.5kV three phase Auto-transformer

Two (2) banks outdoor type three-phase power auto-transformers (400/235/34.5 kV, 520/750 MVA per bank).

Space provision shall be kept for future extension of one (01) three-phase power auto-transformer.

1.2.1.7 400/135/34.5kV three phase Auto-transformer (Not Applicable)

Two (2) banks outdoor type three-phase power auto-transformers (400/135/34.5 kV, 250/325 MVA per bank).

Space provision shall be kept for future extension of two (02) transformer banks.

1.2.1.8 33/0.415kV Earthing/ Auxiliary three phase transformer

Two (2) bank outdoor type station earthing/auxiliary transformers with the capacity of 3-phase, 33/0.415kV, 500kVA each, which shall be connected to tertiary side of two (2) new 400/235/34.5kV three phase auto-transformers.

1.2.1.9 Shunt Reactor & Associated works (Not Applicable)

1.2.1.10 Control, Protection, Substation Automation, Metering & DFDR

Associated local & Remote control panel, metering panel, protection equipment, synchronizing scheme and substation automation system (SAS) & DFDR for complete substation. Monitoring of status of Bus PT & Bus ES need to be included in the SAS. Necessary works to be performed so that Air temperature in the SPRs can be controlled and monitored through SAS.

1.2.1.11 SCADA system and Telecommunication system

1) Complete design, supply, delivery, installation, testing & commissioning of hardware and software to provide the telecontrol &telemetering facilities required at the existing National Load Dispatch Center(NLDC) at Rampura and Biddut Bhaban for integration of complete new 400/230 kV substation. All required electrical signals shall be transmitted to the NLDC through the Industrial Gateway of the substation automation system. All HV breakers, motorized disconnectors, tap changer, etc. shall be controlled form NLDC through the Gateway of the substation automation system using IEC 60870-5-104 protocol. All necessary modification works in the software of master station at NLDC and Biddut Bhaban are to be carried out.

The contractor shall provide with their Bid Detail BOQ for complete SCADA system as per Bid requirement.

2) Fibre Optic Multiplexer Equipment for Communication and Protection

Indoor type Fibre Optic Multiplexer and digital PABX Equipment for protection & communication.

3) Power Line Carrier, Teleprotection and communication Equipment

Power Line Carrier Equipment shall be installed on the 400kV Transmission lines.

1.2.1.12 DC and LVAC System

Complete set of DC and LVAC system with all necessary materials required for the plant being installed with 25% spares for future use of 110V DC battery & battery charger, 48 V DC battery & battery charger, DC distribution board and LVAC distribution board.

During execution stage the battery capacity shall be confirmed with calculation by the contractor considering the bays under scope of work and future bays. Also the battery with higher capability, if required after calculation, shall be supplied by the Contractor within the same Contract price.

The charger rating shall be based on the load & boost charging rate and during execution stage after calculation if the higher charging charger is found to be required, it shall be supplied by the Contractor within the same Contract price.

All DC status excluding control & protection (DC voltage status for each bus including coupling breaker on/off status, fail with alarm, status of DC MCB/MCCB at SPR with fail alarm etc.) shall be incorporated in substation automation system.

1.2.1.13 Civil Works, Building and Foundation

The total land of Kaliganj substation is 18.05 acres and the entire land requires development upto required level.

Completion of land development of land area by cutting, landfilling, compacting up to a suitable elevation level of 3.0m height, including slope protection is included in the scope of works.

Contractor shall complete design, supply and construction of all civil items required for the outdoor or indoor works, including 400kV and 230 kV gantry foundation; 400kV and 230 kV equipment foundation, power transformer and auxiliary transformer foundations, blast wall, oil/water separator, substation main gate and guardhouse, security boundary wall and internal fencing, access road, internal roads, and parking, concrete culvert, surface, and switchyard drainage system including outfall, cable trench including soak pit, related pipes, switchyard surface finishing and gravel surfacing.

Contractor shall complete design, supply and construction of all civil items including all necessary architecture & structural requirements and facilities for new 400kV, 230kVGIS and control buildings, and Fire suppression water feeding (CAFS) & Emergency Aux. Power DG building and other all buildings in switchyard with cable trays or pipe basement, including foundation, works, superstructure works, finishing works like rendering, painting, water supply, sanitary, floor finishing, rainwater drainage system, air-conditioning, lightning protection, and lighting and fire extinguish system, telecom. system, CCTV and etc.

Contractor shall complete design, supply and construction of water supply including deep tube well for drinking water, pump house, pump, water reservoir, water pipelines, etc., sewage facilities including the septic tank, etc.

Contractor shall complete design, supply and construction of fire-fighting system (CAFS) for all transformers including water pipe network and reservoir at normal pressure. Necessary Sizing calculation shall have to be submitted for approval during execution stage.

1.2.1.14 Terminal Points

1) Transmission Line Circuit Connections

The slack spans including overhead earth wires between the 400kV and 230 kV overhead line terminal towers and the substation gantry structures shall be supplied and terminated by the overhead line Contractors. All required insulators and hardwires shall also be supplied by the overhead line Contractors.

Eyebolts/U-bolts or other suitable fixtures for terminating the slack spans on the switchyard gantry shall be provided under this substation contract.

The overhead line Contractor shall provide a jumper from the slack span of sufficient length to terminate on the substation entry equipment. The supply of appropriate clamps and the actual termination of the jumper to the substation equipment shall be carried out under this contract.

PLC facilities such as line trap and coupling capacitor, new or currently used in existing substations shall be carried out under this contract.

Bonding of the incoming earth wire to the station earthing screen and supply of earthing conductor and connection of the terminal tower earth electrode into the substation earth grid shall be carried out under this contract.

The overhead line Contractor shall terminate the OPGW at the substation gantry in the terminal joint boxes provided by the overhead line Contractors. The connection between OPGW joint boxes at the substation gantry and control room building via underground optical fibre cables shall be carried out under this contract; it includes supply & installation of fibre optic cable of a size similar to the OPGW.

1.2.1.15 Mandatory Spares, Erection &Test Equipment

Supply of complete mandatory spare and spare parts of transformer, switchgear, control equipment, protection relays, meters, erection & test equipment, which is specified in Volume 3 and same ones supplied by Contractor as per the approved for construction by PGCB. The quantity is mentioned in Schedule B1(Mandatory Spare, Maintanence & Test Equipement Supplied from Outside the Employer's Country) of Volume 3. Test equipment is preferably to be supplied from Europe, UK, USA or Japan origin or from other eligible countries with equivalent quality. Printed catalogue, operation and service manual are to be provided. The materials shall have to be handed over to the designated store as per instruction of the Engineer. (for Details, refer to the Schedule A & schedule B)

1.2.1.16 Engineering Services

1) General

The engineering services shall be provided by the Contractor to the necessary extent and detail of a turnkey project. They shall include drawings, instructions and all other technical documents required to allow the Contractor to build, erect, commission, operate and maintain the Substation(s) under the scope of work, even if these are not specifically mentioned in these Technical Requirements.

2) Design Services

The Contractor shall design in detail the general layout of the Primary & secondary electrical & mechanical system and civil design & works, based on the preliminary design and modifications agreed. This general layout shall be submitted to the Employer / Employer's Representative for approval and comments. It shall also include all detailed structural drawings, detailed descriptions and reports required to permit an exact understanding of the solution adopted.

These engineering services shall also include:

- Design calculation & Reports
- Complete Drawings of All System
- Integration in the Existing System (if any).

1.2.1.17 Requirements (Kaliganj S/S)

The equipment to be designed, supplied, installed, tested & commissioned as stipulated in bid specification and shown in bid drawings:

Item Description

All the Equipment shall comply with the particular requirements as detailed in the Technical Specification and Requirements in Schedule A and E of Volume 3.

1.3 Training and Inspection

The Contract Price shall include all costs of training & inspection of Employers and the instruction of staff on-site for the following:

(a) International Training

The following engineers nominated by the Employer shall be provided with training at a Manufacturers' premises /factory as follows. The final schedule with contents shall be finalized during execution stage.

SL NO.	Description (a)	No. of Engineer	Duration (weeks)
1.	**HV GIS Substation & Equipment Design, Testing and MRE (as per IEC)**	03	02
2.	**Protection & Substation Automation System**	03	02

(b) International Witnessing

The following engineers nominated by the Employer shall participate in the inspection and witnessing of FAT (factory acceptance tests) at manufacturers' works as follows:

No. of visit and duration shall be fixed by ITP (Inspection Test Plan) submitted by Manufacturer and approved by PGCB. ITP shall include Type test, Routine test, Special test and Site test.

SL No.	Description (b)	No. of Engineer	No. of Visit & Duration (excluding travelling time)
1.	Transformer	02	2 visits: - 2 visits for 400/230kV Tr.: 14 days for one visit and 10 days for another visit.
2.	GIS	02	2 visits: - 1 visit for 420kV GIS: 7 days - 1 visit for 245kV GIS: 7 days
3.	Control, protection & SAS	02	2 visits: -1 visit for 400kV Control, protection & SAS: 10 days -1 visit for 230kV Control, protection & SAS: 10 days

During factory witnessing the following sample rate of the tested Equipment shall be applied:

All transformer & shunt reactor shall be factory tested in front of Employers Engineers.

For GIS, at least one from each type of bay, such as Bus Coupler bay, Transformer bay, Line bay, Cable bay (if any), Bus PT bay shall be tested.

For CRP, at least one from each type of relay, such as Busbar protection relay, Transformer protection relay, Line protection relay, Cable protection relay (if any) shall be tested.

For SAS, point-to-point communication, Relay communication protocol (PRP, HSR, RSTP etc. if applicable) test, inter-operability test (if applicable) shall be performed.

(c) Local Training

On-site instruction/training by the manufacturer’s engineer on operations and maintenance

SL No.	Description (c2)	No. of Engineer	Duration (working days)
1.	HV GIS switchgear	10	06
2.	Protection & Substation automation system	10	06
3.	Utility Communication	10	06

The Contractor shall be responsible for bearing all costs for the trainees and inspectors (for item (a) & (b)), including air fares, accommodation, meal, healthcare, transportation, visa fees etc. The payment of daily allowance of **US$ 80** per day excluding travel time for each of the Employer's trainee for item (a). The air ticket class shall be Economy class. The Employer's engineer attending the Pre-shipment inspection (as mentioned in item no. b) shall be provided with the same facilities except the payment of daily allowance which is to be **US$ 100** per day

excluding travel time**.** For on-site instruction training, (item no. c), the contractor shall not be responsible for any costs for trainees and the aforementioned onsite trainings shall have to be arranged at any Substation's respective local Grid Circle or GMD area with the consultation of Superintending Engineer, Grid Circle.

In "Schedule B4.2: Installation and Other Services" of the Price Schedule, cost of Employer's Factory Acceptance Tests Witness, International Training and Local O&M Training are given as provisional sum. These costs are fixed ceiling and will be included in total price. But the payment shall be at actual.

Due to any unavoidable circumstances, if any pre-shipment inspection can't be witnessed by the engineers nominated by the Employer, such inspection may be witnessed by any 3rd party inspector nominated by the Employer, or may not be witnessed by the employer's representatives. In such case, the contract price shall be adjusted in accordance with the relevant contract provisions.

Note: The Contractor shall have to submit the Schedule of each Training & FAT and take approval from the Employer prior to each Training & FAT. The International training shall have to be arranged within one (1) year from the date of contract signing.

1.3.1 Training Contents

The minimum requirements for different trains are described here. The final schedule with contents shall be finalized during execution stage

a) HV GIS Substation & Equipment Design and Testing (as per IEC)

SL	Topics	Contents
1.	GIS Substation Design	1. Layout design of GIS Substation upto 800kV 2. Insulation coordination including PSCAD for EMTP 3. Selection of Continuous & Short circuit current rating of series equipment 4. Selection of Protection Scheme & SAS Protocol 5. Different Calculations: DSLP Calculation, switchyard & Building, CT-PT sizing, DC System Design, Earthing design for GIS Switchyard, Conductor sizing for Bus & cable sizing, Cantilever strength Sizing, Lighting Design for Indoor & Outdoor, LVAC system Design including HVAC Design 6.GIS Design (Bus, Encloser, CT, PT, DS, ES, FES, LCP, Wiring, Jointing, PD monitoring, Voltage & pressure co-ordination, temperature limit, accessories etc.) 7. Maintenance, Repair and Extension of GIS maintaining required service continuity 8. Testing as per IEC
2.	Circuit Breaker design	1. Selection of CB arc extinction principle including PIR & CSD 2. Operating mechanism Design

SL	Topics	Contents
		3. Arcing chamber design for EHV (400kV & above) 4. Arcing Contact design 5. Testing as per IEC
3.	Lightning Arrester Design	1. Design of ZnO Block for HV to EHV, Design of Energy Absorption Capability, Selection of Voltage rating & current rating, Design of housing, Design of LA 2. Testing as per IEC
4.	MRE	1. Design of MRE for O&M 2. Erection and QC

b) Utility Communication & SAS

SL	**Topics**	**Contents**
1.	Utility Communication	1. Basic Architecture: a) ADM b) SDH/SONET & PDH 2. Use of Boosters 3. Network management Server 4. Fiber Optic Technology - Utility Perspective 5. PLCC in Utility – Digital & Analog 6. Testing & Commissioning as per IEC: Pros & Cons - Routine, Design & Special test
2.	SAS	1. SCADA & Protocols 2. Protection Schemes a) Line Distance Protection/Line Differential Protection b) Transformer & Busbar Protection c) Other Protection 3. Substation Automation as per IEC 61850 a) PRP b) HSR c) RSTP 4. Interlock scheme a) Hardware b) Software 5. Panel, Wiring & Testing 6. Fault Recorder a) Acquisition b) I/O selection c) other design d) Data Analysis software & Testing

e) Protection & Substation automation system

SL	Topics	Contents
1.	Line Impedence Protection	1. Basic principles of impedance protection 2. Zones of impedance protection 3. Zone 1 extension scheme 4. Mho and Quadrilateral characteristics 5. Zone reach calculation (ph-ph and ph-ground) 6. Load encroachment area: basics, setting calculation and testing 7. Power swing detection: basics, setting calculation and testing 8. Pole slip protection: basics, setting calculation and testing 9. Fuse failure detection: basics, setting calculation and testing 10. Switch on to fault: basics, setting calculation and testing 11. Communication aided schemes, their advantages and disadvantages: a. Direct transfer trip b. Permissive under-reach transfer trip c. Permissive over-reach transfer trip d. Current reversal guard logic e. Weak-end infeed condition f. CB echo logic g. Blocking and unblocking schemes 12. Testing of various functions
2.	Auto-reclosing	1. Application of auto-reclosing a. Dead time b. Reclaim time c. Single shot or multi shot 2. Operation features and cycles of auto-reclose 3. Auto-reclose lock-out 4. Auto-reclosing of HV distribution networks 5. Factors influencing HV auto-reclosing scheme 6. Auto-reclosing of EHV transmission lines 7. High-speed auto-reclosing of EHV system 8. Single phase auto-reclosing 9. High-speed auto-reclosing of lines employing distance schemes 10. Delayed auto-reclosing of EHV system 11. Auto-reclose schemes 12. Master and follower auto-reclosing 13. Setting calculation 14. Testing
3.	Line Differential	1. Line differential protections principles 2. Biased differential characteristics

SL	Topics	Contents
	Protection	3. Harmonics component blocking 4. Differential stability with Open CT, CT saturation and external faults 5. Unrestrained differential tripping 6. Negative sequence differential protection 7. Communication principles of line differential protection 8. High impedance line differential protection 9. Additional line differential protections: a. Phase to phase current variation b. Zero sequence current variation
4.	Current Protection	1. Over-current and earth-fault protection: Time based characteristics a. Directional b. Non-directional 2. Relay co-ordination procedure 3. Breaker failure protection 4. Stub protection 5. Broken conductor check: basics, setting calculation and testing 6. Communication aided scheme for earth-fault protection 7. Over current and earth fault setting calculation for various types of networks 8. Testing of different functions
5.	Transformer Protection	1. Types of faults in transformer 2. Magnetizing inrush of transformer 3. Thermal protection a. Oil temperature monitoring b. Winding temperature monitoring 4. Transformer differential protection 5. CT requirement for differential proteciton 6. Biased differential characteristics 7. Harmonics component blocking 8. Filtering zero sequence components 9. Differential stability with open CT, CT saturation, magnetizing inrush and external fault 10. Negative sequence differential protection 11. High impedance differential protection a. Ratio correction b. Phase compensation c. Zero sequence elimination 12. Restricted earth-fault protection for different types of transformers: a. Low impedance b. High impedance i. Current operated

SL	Topics	Contents
		ii. Voltage operated 13. Fault current calculation for different types of transformers in different types of faults 14. Auto transformer protection 15. Earthing transformer protection 16. Overfluxing protection 17. Oil and Gas protection: a. Pressure relief device b. Buchholz protection c. Sudden pressure rise protection 18. Neutral displacement detection 19. Balanced earth fault 20. Sensitive earth fault 21. Setting calculation for different protections 22. Transformer testing procedures 23. Testing procedures of all protection functions
6.	Busbar Protection	1. Types of busbar faults 2. Protection requirements a. Speed b. Stability c. Zone coverage 3. Types of busbar protection 4. Different bus arrangements and their protection schemes 5. Principles of bus differential protection 6. Biased characteristics of bus differential protection 7. CT requirements and location for bus differential protection 8. High impedance differential protection a. Principle b. Stability c. Setting calculation 9. Low impedance differential protection a. Principle b. Stability c. Setting calculation 10. Secondary circuit supervision 11. Stability for open CT, CT saturation, Disconnector switch movement 12. External and internal fault discrimination a. Amplitude measurement b. Phase angle comparison 13. Discriminating and check features 14. Numerical busbar protection relays

SL	Topics	Contents
		a. Types b. Principles c. Communication principles
7.	Fault Calculation	1. Different Types of faults 2. Symmetrical component analysis of three phase network 3. Positive, negative and zero sequence network of different faults 4. Fault equations of different faults 5. Current and voltage distribution of network due to fault 6. Current distribution of different types of transformers due to different types of faults 7. Effect of earth fault in different types of earthed systems 8. Sequence equivalent circuits of different types of transformers 9. Fault current calculation of different types of networks
8.	Protective Relays	1. Brief introduction, description and overview of each supplied protective relay. 2. Setting calculation guidelines of all protection functions including examples for each supplied protective relay. 3. Procedure of parameterization of supplied relays 4. Testing procedure of the supplied relays 5. Comprehensive handling procedure of engineering software
9.	SAS	1. Basic concept 2. Description of the architecture 3. Operation and Maintenance procedure 4. Procedure of Troubleshooting 5. Procedure of Engineering 6. Procedure of reporting

For each Training, Trainers shall have a minimum of 10 years of experience in the related fields. The trainers shall be from a reputed International training Organization. For Transformer & HV substation training, the trainer shall be an experience of at least 420kV Class, 500MVA Substation & transformer design experience for at least 10 years. The CV of proposed trainers shall be submitted to employer & taken approval during execution. If the proposed trainer does not meet the minimum requirement mentioned here, the Employer shall preserve the right to ask the contractor to change the trainer as per requirement.

1.4 System Electrical Parameters

1.4.1 System Conditions

Equipment supplied under this contract shall be suitable for the following system conditions:

Description	Unit	Required			
Nominal system voltage between phases	kV	400	230	132	33
System frequency	Hz	50			
Rated voltage between phases	kV	420	245	145	36
Rated lightning impulse withstand voltage	kV	1425 for GIS/PI 1300 for P.TR	1050	650	170
Rated Switching Impulse withstand voltage	kV	1125 for GIS/PI 1050 for P.TR	NA	NA	NA
Rated power frequency withstand voltage	kV, 1 min	650	460	275	70
Rated symmetrical short-circuit current					
For Kaliganj 400/230kV Substation	kA, 3 sec	63	63	40	31.5

1.4.2 System Earthing

All Main Transformer Neutrals shall be solidly earthed (The 400/235/34.5kV Auto-Transformers are solidly earthed.)

The Grid system Voltage is solidly earthed at transformer Neutrals in each different voltage levels, i.e. 400kV, 230kV &132kV.

1.4.3 Minimum Substation Clearances

Air insulated connections shall have electrical clearances as listed in the following table:

Description	Unit	Required			
Nominal system voltage	kV	400	230	132	33
Minimum clearance between live metal parts and earth	mm	3500	2100	1300	380
Minimum clearance between live metal	mm	4000	2400	1500	430
Minimum safety clearance between ground and the nearest point not at earth potential of an insulator	mm	2700			

Description	Unit	Required			
Minimum safety clearance between ground and the nearest live unscreened conductor (BS 7354: Safety Working Clearance) / Section Clearance	mm	6400	4270	3500	2740
Minimum insulator creepage distance (at rated voltage between phases)	mm/kV	31			

1.4.4 Low Voltage AC System

Description	Unit	Required
Rated service voltage (3 phase, 4 wire 50 Hz)	V	415 / 230
Tolerance on rated voltage	%	+15%, -10%
Switchgear symmetrical breaking capacity	kA	15 kA, 3 sec
System earthing	-	solid

1.4.5 Low Voltage DC System

For D.C. motor driven auxiliaries, relays, tripping, indicating lamps and controls.

Description	Unit	Required for equipment	Required for system design
Nominal DC voltage	V	110	110
Tolerance on rated voltage	%	+15%, -15%	+10%, -10%

For telecommunication & SCADA

Description	Unit	Required for equipment	Required for system design
Nominal DC voltage	V	48	48
Tolerance on rated voltage	%	+15%, -15%	+10%, -10%

1.5 Climatic Conditions

All plant and equipment supplied under the contract shall be entirely suitable for the climatic conditions prevailing at site.

The project area and vicinity is close to sea level and is in a tropical climate.

The ambient shade temperature variation is between 4°C and 40 °C with periods of high humidity.

Between May and November, low-lying areas are subject to flooding. Flooding countermeasure shall be taken for the civil design, so as not to affect any substation equipment during the wet season. As per the recorded past maximum flood water levels in the project area, sufficient ground level height for land formation is required at the Contractor's responsibility. On certain sites, the flooding can be taken as an advantage in that the heavy loads may be floated on barges to close proximity of the sites.

The project area is a designated zone of moderate earthquake intensity. The seismic factor is 0.2 g. Atmospheric pollution is moderate and no special insulator design or washing is required. The area is subject to high winds of typhoon strength.

Description	Unit	Required
Maximum ambient shade temperature	°C	40
Minimum ambient shade temperature	°C	4
Maximum daily average temperature	°C	35
Maximum annual average temperature	°C	25
Maximum wind velocity	km/h	160
Minimum wind velocity for line rating purposes	km/h	3.2
Solar radiation	W/m²	1000
Rainfall	mm/year	2500
Relative humidity, maximum	%	100
Relative humidity, average	%	80
Altitude	m	< 1000
Atmospheric pollution	-	medium
Icing		no ice or snow expected
Seismic factor	g	0.2
Soil type	-	alluvial
Soil temperature (at 1.1m)	°C	30 °C at 1.1 meter depth

Description	Unit	Required
Soil thermal resistivity	°Cm/W	1.5
Isokeraunic level (thunderstorm days/year)	days/year	80

The information in this clause is given solely for the general assistance of Bidders and no responsibility for it will be accepted nor will any claim based on this clause be considered.

2. Ancillary Mechanical and Electrical Apparatus

2.1 Scope

This section of the technical specifications describes the general requirements for mechanical and electrical designs of all the plant being supplied under the contract, electrical aspects being covered in another section of the Specification. It shall be read in conjunction with the General Conditions, Drawings, the Schedules and other sections of these technical specifications covering particular aspects of the plant. In the event of a conflict between the general and special contract requirements, the latter shall take precedence.

2.2 References

2.2.1 ISO Standards

- ISO 68 General Purpose Screw Threads
- ISO 261 General Purpose Metric Screw Threads
- ISO 262 Selected sizes for screws, bolts & nuts
- ISO 272 Fasteners-hexagon products-widths across flats
- ISO 274 Copper tubes of circular section.
- ISO 448 Gas cylinders for industrial use-marking.
- ISO 885 General-purpose bolts and screws-metric series
- ISO 888 Bolts, screws and studs-nominal lengths, and thread lengths
- ISO 965 / 1, 2, 3 General purpose Metric screw threads
- ISO 4759-1 Tolerances for fasteners
- ISO 9000 Quality management and quality assurance standards
- ISO 9001 Quality management systems-Requirements

2.2.2 IEC Standards

- 60034 Rotating Electrical Machines
- 60038 IEC Standard Voltage
- 60044-1 Instrument transformers - Part 1: Current transformers
- 60044-2 Instrument transformers - Part 2: Inductive voltage transformers
- 60044-5 Instrument transformers - Part 5: Capacitor voltage transformers

- 60051 Direct-acting indicating analog electrical measuring instruments and their accessories
- 60055 Paper insulated metal-sheathed cables up to 15 / 30 kV
- 60059 IEC Standard Current ratings
- 60072 Dimensions and output series for rotating electrical machines
- 60073 Coding of indicating devices and actuators by colours
- 60079 Electrical apparatus for explosive gas atmospheres
- 60085 Thermal evaluation and classification of electrical insulation
- 60137 Bushings for alternating voltages above 1000 V
- 60168 Tests on indoor and outdoor post insulators of ceramic material
- 60228 Conductors of insulated cables
- 60228 A first supplement. Guide to dimensional limits of circular conductors
- 62155 Tests on hollow insulators for use in electrical equipment
- 60269 Low voltage fuses
- 60273 Characteristics of indoor & outdoor post insulators above 1000 V
- 60282 High voltage fuses
- 60296 Specification for unused mineral insulating oils for transformers & switchgear
- 60305 Characteristics of string insulator units of the cap & pin type
- 60332 Tests on electrical cables under fire conditions
- 60364 Electrical installations of buildings
- 60376 Specification and acceptance of new sulphur hexafluoride
- 60383 Insulators for overhead lines above 1000 V
- 60417 Graphical symbols for use on equipment
- 60423 Conduits for electrical purposes
- 60433 Characteristics of string insulator units of the long rod type
- 60437 Radio interference test on high voltage insulators
- 60439 Low voltage switchgear and control gear assemblies
- 60455 Solventless polymersable resinous compounds used for electrical insulation
- 60502 Extruded solid dielectric insulated power cables from 1-30 kV
- 62052 Electricity metering equipment
- 60529 Degrees of protection provided by enclosures (IP Codes)
- 60587 Test methods for evaluating resistance to tracking
- 60614 Conduits for electrical installations-Specification
- 60621 Electrical installations for outdoor sites under heavy conditions

- 60644 Specification for high-voltage fuse links for motor circuit applications
- 60660 Tests on indoor post insulators of organic mats. between 1-300 kV
- 60672 Specification for ceramic & glass insulating mats.
- 60898 Circuit Breakers for overcurrent protection for households etc.
- 60947-1 Low-voltage switchgear and controlgear - Part 1: General rules
- 60947-2 Low-voltage switchgear and controlgear - Part 2: Circuit breakers
- 60947-3 Low-voltage switchgear and controlgear - Part 3: Switches, disconnectors switch-disconnectors and fuse-combination units
- 60947-5-1 Low-voltage switchgear and controlgear - Part 5-1: Control circuit devices and witching elements
- 60981 Extra heavy-duty steel conduits for electrical installations
- 61035 Specification for conduit fittings for electrical installations
- 61084 Cable trunking & ducting systems for electrical installations
- 62271-1 High-voltage switchgear & controlgear - Part 1: Common specifications
- 62271-100 High-voltage switchgear & controlgear - Part 100: High-voltage alternating-current circuit breakers
- 62271-102 High-voltage switchgear & controlgear - Part 102: Alternating current disconnectors and earthing switches
- 62271-105 High-voltage switchgear & controlgear - Part 105: Alternating current switch fuse combinations
- 62271-200 AC metal-enclosed switchgear & control gear for 1 kV and above
- 62271-203 Gas-insulated metal-enclosed switchgear for rated voltages of 52 kV and above
- 62271-209 Cable connections for gas-insulated metal-enclosed switchgear for rated voltages of 52 kV and above

2.2.3 British Standards

- BS EN 10250-2 Specification for Carbon steel forgings
- BS 182 Specification for galvanised line wire for telephone & telegraphic purposes
- BS EN 10244-2 Specification for testing zinc coatings on steel wire
- BS 499 Welding terms & Symbols
- BS 709 Method & testing fusion welded joints
- BS 729 Specification for hot dip galvanised coatings on iron & steel articles
- BS 970 Specification for wrought steels for mechanical & allied Engineering

• BS EN 12540	Specification for electroplate coatings of nickel and chromium
• BS1710	Specification for identification of pipelines & services
• BS EN 837-1	Specification for Bordon tube pressure and vacuum gauges
• BS 1858	Specification for bitumen based filling compounds
• BS EN 60068-218	Environmental Testing
• BS 2569 Pt 2	Protection of iron & steel against corrosion at elevated temperature
• BS EN 1435	Radiographic examination of fusion welded butt joints in steel
• BS 2765	Specification for dimensions of temperature detecting elements
• BS 2910	Radiographic examination of fusion welded circumferential butt joints
• BS 3858	Specification for sleeves for electric cables & wires
• BS 3923 Pt 1	Methods of examination of fused welds and butt joints & Pt 2
• BS 4211	Specification for ladders for permanent access to chimneys, other high structures, silos and bins
• BS4395-1-2	Specification for High Strength Grip Bolts
• BS 4479	Recommendations for coatings. Pts 1-9
• BS EN 1412	Industrial type flooring, walkways and stair treads
• BS 4604 Pt 1-2	Spec for high strength friction bolts
• BS EN 10250-3	Spec for alloy steel forgings.
• BS 4800	Schedule of Paint Colours for building
• BS 4675 Pt 2	Mechanical vibration of rotating and reciprocating machinery
• BS 4872 Pt 1	Fusion welding of steel
• BS 5395-3	Code of Practice for the design of industrial type stairs, permanent ladders, etc.
• BS 5493	Code of practice for protective coating of iron & steel structures against corrosion
• BS 381C	Specification for Colour Identification
• BS 1133	Packaging Code Section 6. Temporary Protection of Metal Surfaces against Corrosion (During Transport and Storage)
• BS 2451	Chilled Iron Shot and Grit

- BS EN ISO 9934 Method for penetrant flaw detection
- BS EN 50262 Specification for metallic cable glands
- BS 6121-2 Specification for polymeric cable glands
- BS 6121-3 Specification for special corrosion-resistant cable glands
- BS 6180 Code of Practice for barriers in and about buildings
- BS 6231 Specification for PVC insulated cables for switch & control wiring
- BS EN 571-1 Method of penetrant flaw detection.
- BS 7079 Preparation of steel substrates before application of paints

2.2.4 BS European Standards

- BS EN 287 Approval testing of welders for fusion welding-1 &-2
- BS EN 288 1-8 Specification & Approval of welding procedures

2.3 Definition of Terms

The definition of terms shall be as set out in the General Conditions of Contract.

2.4 Statutory Regulations

The Works and all equipment and materials forming part of this Contract shall comply in all respects with any relevant statutory regulations, by-laws or orders currently in force in Bangladesh.

2.5 Design Standards and Codes

2.5.1 General Compliance with International Standards and Codes

The Contract Works shall comply with the relevant standards as specified. Provided there is no conflict with the standards, and unless otherwise stated, all parts of the Works shall comply with the relevant international standards and design codes. Where suitable international standards do not exist, internationally accepted national standards or other approved standards shall apply.

2.5.2 Standards Named in Specification

Although the Works shall generally comply with international standards, any instruction in this specification that a particular aspect of the Works shall comply with a named code or standard which shall take precedence and that particular aspect of the works shall comply with the named code or standard.

2.5.3 Hierarchy of Standards

In the event of any conflict in standards, the hierarchy of standards shall be as follows, with the standards occurring first in the list taking precedence over any standards later in the list:

(a) Statutory regulations of Bangladesh
(b) Standards named in the specification
(c) Other international standards
(d) Other standards approved by the Engineer

Where equipment is specified to a particular standard, the Contractor may supply equipment of an equivalent standard, if approved by the Engineer.

2.5.4 Substitution of Standards and Design Codes

The Contractor may offer works that comply with international standards, or internationally recognized national codes or standards, which differ from those specified. However the Contractor may offer works, which comply with the different standards or codes, only if, when requested by the Engineer, he is able to demonstrate to the Engineer's satisfaction that the Works offered are equal or superior to that which would have resulted had the specified code or standard been used. This substitution of codes or standards for those specified will only be accepted if the manufacturing organization in question has extensive experience with the alternative code or standard offered.

Any Contractor offering contract works or part of those works to standards and codes that differ from those specified shall declare the fact to the Engineer. If requested to do so by the Engineer, the Con-tractor shall supply to the Engineer, at his own cost, with two copies in English of the relevant code or standard which he proposes to substitute for that specified.

2.6 Erection Marks

All members comprising multipart assemblies, e.g., towers, steel frameworks, piping installations, etc., shall be marked with distinguishing numbers and/or letters corresponding to those on the approved drawings or material lists. These erection marks, if impressed, must be completed before painting or galvanizing, shall be clearly readable afterward.

Colour banding to an approved code shall be employed to identify members of similar shape or type but of different strengths or grades.

2.7 Cleaning and Painting

2.7.1 General

Following the award of the contract, the Contractor shall submit the name of the proposed paint supplier and applicator, together with a quality assurance program, for approval. All paints for the equipment on the Contract shall be provided by one Manufacturer and preferably shall be manufactured in one country to ensure compatibility. All painting of equipment shall be carried out strictly in accordance with the paint system Manufacturer's recommendations and the application shall be checked and approved, in writing, by an authorized representative of the paint Manufacturer.

The painting of the plant shall be carried out in accordance with the appropriate schedule later in this section. The work is generally covered by the schedules but where particular items are not referred to specifically, they shall be treated in a manner similar to other comparable items as agreed with the Engineer.

The Contractor shall ensure that precautions are taken in packing and crating, to avoid damage to the protective treatment during transportation to the site. Any damage to the paintwork that occurs during transport shall be made good at the site.

The schedules indicate standards of surface preparation and painting which are intended to give a minimum life of 10 years in a severe environment, with the need for only minor remedial work in that period.

Steel sections and plate shall be free from surface flaws and laminations prior to blast cleaning and shall not be in worse condition than ISO 8501-01.

Where paint coatings are proposed for the protection of surfaces of equipment exposed to corrosive conditions, such as plant items exposed to brine or seawater, or immersion in liquids or wet gases, the coatings shall be formulated to be suitably corrosion-resistant and shall be high voltage spark tested at works and at Site prior to commissioning. The test procedure shall be based on the use of a high voltage direct current. The voltage used shall be 75% of the breakdown voltage of the coating. This breakdown voltage shall first be separately determined using test plates coated with the specified coating formulation and thickness. The coating on the test plate shall also be micro-sectioned by the applicator to show that it is free from vacuoles and other defects likely to invalidate the test procedure.

If the defects revealed by the above test procedure do not exceed one per 5 m² of the coating surface, the coating need not be re-tested after the defects have been repaired. If the defects

exceed one per 5 m² of the coating surface, the repairs shall be re-tested after any curing is complete, and this procedure shall be repeated until the defects are less than one per 5 m² of the coating surface. After repair of these defects, the equipment can be placed in service without further testing.

All coatings proposed for the internal protection of domestic water storage tanks and desalination plants shall be certified as suitable for use in potable water installations by an approved independent authority and shall meet the non-tainting requirements of BS 3416.
The Engineer will consider alternative paint schemes to meet the requirements of fabrication using modern automated materials handling systems, provided that the Contractor is able to demonstrate that they offer the same standards of surface protection and service life as those intended by the Schedules.

All paints shall be applied by brush or spray in accordance with the schedule, except for priming coats for steel floors, galleries, and stairways where dipping will be permitted.

Where paint is to be applied by spray, the applicator shall demonstrate that the spray technique employed does not produce paint films containing vacuoles.

All planished and bright parts shall be coated with grease, oil or other approved rust preventative before dispatch and during erection and this coating shall be cleaned off and the parts polished before being handed over.

Where lapped or butted joints from part of an assembly that is assembled or part assembled prior to the final painting, the jointed surfaces shall be cleaned free from all scales, loose rust, dirt and grease and given one brush-applied coat of zinc phosphate primer before assembly.

Paint shall not be applied to surfaces that are superficially or structurally damp and condensation must be absent before the application of each coat. Painting shall not be carried out under adverse weather conditions, such as low temperature (below 4°C) or above 90 % relative humidity or during rain or fog, or when the surfaces are less than 3°C above the dew point, except to the approval of the Engineer or his duly appointed representative.

Priming coats of paint shall not be applied until the surfaces have been inspected and preparatory work has been approved by the Engineer or his duly appointed representative. No consecutive coats of paints, except in the case of white, shall be of the same shade. Thinners shall not be used except with the written agreement of the Engineer.

On sheltered or unventilated horizontal surfaces on which dew may linger, more protection will be needed and to achieve this, an additional topcoat of paint shall be applied.

The schedules differentiate between "Treatment at Factory" and "Treatment at Site after Completion of Erection" but the locations at which different stages of the treatments are carried

out may be modified, always providing that each change is specifically agreed to by the Engineer and the painting is finished or made good at Site to the Engineer's satisfaction.

The schedules also refer to "Indoor" and "Outdoor" locations. In this context, the interiors of all buildings without air conditioning or forced ventilation shall be treated as "Outdoor".

All paint film thicknesses given are minima and refer to the dry film condition. All thicknesses shall be determined by the correct use of approved commercial paint film thickness measuring meters.
All painting shall be checked prior to the issue of the final certificate and no visible corrosion or spotting shall be present. Slight loss of gloss may acceptable. In the event of visible corrosion being present, the Employer will retain the right to withhold such an amount from the Contractor as may be necessary to repaint the entire exterior part of the works.

The painting requirements shall be interpreted in accordance with the requirements and recommendations of the Standards and Codes of Practice referred to and the paint Manufacturer's special instructions where applicable, colors being in accordance with BS 1710 and BS 4800, or equivalent material standards

2.7.2 Schedules for Indoor Surfaces Finishes

Treatment at Factory	Treatment at Site after Completion of Erection
General	
(a) Structural and supporting steelwork, plant items above ground, tank external surfaces. All not above 95°C (or 65°C for chlorinated rubber finishes).	
Blast clean to BS 7079 2nd quality (SA 2.5) profile amplitude 40-75 microns. Then apply within 4 hours one coat (13 microns) weld able holding primer for 12 months x match protection. After fabrication is complete dress all welds, thoroughly clean to remove corrosion products, oil, grease, and dirt and apply one coat (50 microns) of two-pack epoxy zinc phosphate primer followed by two coats two pack epoxy micaceous iron oxide (250 microns total).	• Thoroughly clean to remove oil, grease, and dirt. • Paint coats to be touched up where necessary. • Then apply one tie coat to finish (30 microns) and one coat alkyd gloss (25 microns)
(b) Steel floors, chequer plates, galleries, stairways, treads, kick stops.	
Galvanize to BS 729	Thoroughly clean to remove oil, grease and dirt.

Treatment at Factory	Treatment at Site after Completion of Erection
	Where galvanizing is damaged, wire brush to BS 7079 3rd quality (SA2) and apply 1 coat zinc-rich epoxy primer (50 microns). Then apply: • 1st coat of etch primer • 2nd coat epoxy zinc chromate • 3rd coat 2-pack epoxy micaceous iron oxide (50 microns). On galleries and stairways top surfaces apply: • 4th coat non-skid epoxy deck paint (30 microns).
(c) Galvanised iron and steel requiring paint finish	
Galvanise to BS 729	Thoroughly clean to remove oil, grease and dirt. Then apply: • 1st coat of etch primer • 2nd coat of zinc chromate primer (30 microns) • 3rd coat alkyd undercoat (30 microns) • 4th coat alkyd gloss (25 microns).
(d) Stainless steel, aluminium alloys and non-ferrous alloys requiring paint finish.	
Not Applicable	Thoroughly clean to remove oil, grease and dirt. Then apply: • 1st coat alkyd undercoat (30 microns) • 2nd coat alkyd gloss (25 microns).
(e) Bitumen dipped items	
Bitumen dipped.	Thoroughly clean to remove oil, grease and dirt. Then apply: • 1st coat general purpose aluminium paint (18 microns) • 2nd coat alkyd undercoat (30 microns) • 3rd coat alkyd gloss (25 microns).
Battery Rooms (open top batteries), Chlorination Plant Rooms, Electrolytic Cell Rooms	
(a) Steelwork	
Blast clean to 2nd quality BS 7079 (SA2.5) profile amplitude 40-75 microns	Thoroughly clean to remove oil, grease and dirt. Priming coat to be touched up where necessary. Then apply: • 1st coat chlorinated rubber primer to Manufacturer's instructions

Treatment at Factory	Treatment at Site after Completion of Erection
	• 2nd coat high build chlorinated rubber (80 microns) • 3rd coat high build chlorinated rubber (80 microns).
Bright Parts	
Coat with a mixture of oil, grease or approved proprietary inhibitor.	Clean and polish
Instrument Panels, Relay Panels, Control Panels, 400V A.C. Boards, 110V D.C. Boards, Telemetry Marshalling Kiosks, Lighting and Small Power Distribution Boxes, Battery Charger Cubicles, Metal Clad Switchgear	
Acid pickle or blast clean to 1st quality BS 7079. Then apply: • 1st coat zinc chromate primer (30 microns) Stop and fill. Then apply: • 2nd coat alkyd undercoat (30 microns). Rub down with fine abrasive paper. Then apply • 3rd coat alkyd undercoat (30 microns) Rub down with fine abrasive paper. Then apply: • 4th coat alkyd matt (25 microns) • 5th coat alkyd matt (25 microns) • 6th coat alkyd matt (25 microns) Total film thickness (125 microns).	Touch up if necessary and burnish

2.7.3 Schedules for Outdoor Surfaces Finishes

Treatment at Factory	Treatment at Site after Completion of Erection
General	
(a) Structural and supporting steelwork, plant items above ground, tank external surfaces. All not above 95°C (or 65°C for chlorinated rubber finishes).	
Blast-clean to BS 7079 2nd quality (SA2.5) profile amplitude 40-75 microns. Then apply within 4 hours one coat (13 microns) weld able holding primer for 6 months protection or (25 microns) weldable holding primer for 12 months protection	Thoroughly clean to remove oil, grease, and dirt. Paint coats to be touched up where necessary. Then apply one tie coat to match finish (30 microns) and one coat alkyd gloss (25 microns)

Treatment at Factory	Treatment at Site after Completion of Erection
After the protection period, thoroughly clean to remove oil, grease, and dirt and apply one coat (50 microns) of two-pack epoxy zinc phosphate primer followed by two coats two-pack epoxy micaceous iron oxide (250 microns total).	
(b) Steel floors, chequer plates, galleries, stairways, treads, kick stops	
Galvanized to BS 729	Thoroughly clean to remove oil, grease, and dirt. Where galvanizing is damaged, wire brush to BS 7079 3rd quality (SA2) and apply one coat zinc-rich epoxy primer (50 microns). Then apply: • 1st coat epoxy etch primer • 2nd coat epoxy zinc chromate (30microns) • 3rd coat two-pack epoxy micaceous iron oxide(100 microns) On galleries and stairways top surfaces apply: • 4th coat non-skid epoxy deck paint (30 microns).
(c) Galvanised iron and steel requiring paint finish	
Galvanized to BS 729	Thoroughly clean to remove oil, grease, and dirt. Then apply: • 1st coat etch primer • 2nd coat zinc chromate primer (30microns) • 3rd coat alkyd undercoat (30 microns) • 4th coat alkyd gloss (25 microns).
(d) Stainless steel, aluminum alloys and non-ferrous alloys requiring paint finish	
Not applicable.	Thoroughly clean to remove oil, grease, and dirt. Then apply: • 1st coat alkyd undercoat (30 microns) • 2nd coat alkyd gloss (25 microns).
(e) Bitumen dipped items	
Bitumen dipped.	Thoroughly clean to remove oil, grease, and dirt. Then apply:

Treatment at Factory	Treatment at Site after Completion of Erection
	• 1st coat general purpose aluminium paint (18 microns) • 2nd coat alkyd undercoat (30 microns) • 3rd coat alkyd gloss (25 microns)
Bright Parts	
Coat with a mixture of oil, grease or approved proprietary inhibitor.	Clean and polish
Instrument Panels, Control Panels, Marshalling Kiosks, Lighting and Small Power Distribution Boxes and Junction Boxes etc.	
Blast clean, primer, undercoat and paint in accordance with the painting schedule for structural and supporting steelwork, with finish coat of paint applied at Manufacturer's works	Clean and touch up as necessary
Water and Oil Storage Tanks-Internal Surfaces	
The epoxy paint formulation shall be to the approval of the Engineer. The finished coating shall be capable of being tested with a high voltages spark tester for absence of pinholes and porosity. For oil storage tanks, solvent-free epoxy paint formulation shall be used.	
For tanks delivered to site in plate sections, the plates shall be blast cleaned to BS 7079 1st quality (SA3) profile amplitude 40-75 microns and then within 4 hours coat with a weldable holding primer dry film thickness 25 microns	Welded Construction at Site. After erection all welds shall be dressed to remove rough edges and burrs and all sharp edges shall be radiused 3 mm Prior to painting, all surfaces shall be sweep blast cleaned to a sound surface free from rust and debris. Then apply within 4 hours: • 1st coat Isocyanate or amine cured epoxy primer 25 microns • 2nd coat Isocyanate or amine cured high build epoxy (125 microns) • 3rd coat Isocyanate or amine cured high build epoxy (125 microns).
Sectional Construction: Prior to assembly, all component items to be blast cleaned to BS 7079 1st quality (SA3) profile amplitude 40-75 microns. Then apply:	Sectional Construction: Touch up damaged areas as necessary.

Treatment at Factory	Treatment at Site after Completion of Erection
• 1st coat Isocyanate or amine cured epoxy primer (25 microns). After assembly, clean all surfaces free from rust, grease and dirt. Priming coat to be touched up as necessary. Then apply: • 2nd coat Isocyanate or amine cured high build epoxy (125 microns) • 3rd coat Isocyanate or amine cured high build epoxy (125 microns).	
Radiators	
Radiators shall be thoroughly cleaned and treated externally by phosphating or other approved rust inhibiting process and given, preferably by flood painting, the same number and type of coats specified in General Sub-Clause of this Clause. Radiators that are hot dip galvanised to BS.729, Part 1, shall be artificially weathered and given one coat of zinc chromate primer followed by the same number and type of paint coatings specified in Clause. Radiators shall be painted with Munsell colour No. 5Y 7/1.	

2.8 Rating Plates, Nameplates, and Labels

2.8.1 General

The Contractor shall supply and install all labels, name, rating, instruction and warning plates necessary for the identification and safe operation of the Works. Samples shall be submitted for the approval of the Engineer.

Nameplates or labels shall be of non-hygroscopic, non-deteriorating and non-warping material with engraved lettering of a contrasting color or, in the case of indoor circuit breakers, starters, etc., a white plastic material with black lettering engraved thereon.

Items of a plant such as valves, mounted outdoors or subject to harsh operating conditions, shall be provided with engraved chromium-plated brass or stainless steel nameplates or labels with engraving filled with black enamel.

All the above labels and plates shall be securely fixed to items of plant and equipment with stainless steel rivets, plated self-tapping screws or other approved means. The use of adhesives will not be permitted.

Individual plant items and all relevant areas within the contract works where a danger to personnel exists shall be provided with plentiful, prominent and clear warning notices.

These warning notices shall draw attention to the danger or risk with words in the language specified which attract attention and summarise the type of risk or danger. The notices shall also carry a large symbol that graphically depicts the type of risk.

All equipment within panels and desks shall be individually identified.

Items of plant, such as valves, which are subject to handling, shall be provided with nameplates with permanent inscriptions thereon.

2.8.2 Rating Plates

Each main and auxiliary item of plant shall have attached to it in a conspicuous position, a rating plate upon which shall be engraved all appropriate technical data and any identifying name, type or serial number, and the requirements of the Standard specific to the item of plant. In addition, the Engineer may require including details of the loading conditions under which the item of plant in question has been designed to operate, such as the short-time rating of switchgear.

2.8.3 Circuit Labels

Each main item of a plant shall be provided with an identification plate. The inscriptions shall be approved by the Engineer.

In addition, the device number allocated by the Engineer to each item of plant shall be displayed in text height 30 mm on all operating mechanisms and 60 mm or larger in height on principal items of Plant, e.g. busbars, transformers etc. The same device number shall be displayed on control cubicles in text height 10 mm or larger as may be required by the Engineer.

2.8.4 Pipe Service Identification

A colour-banding scheme shall be used to identify pipework included within this Contract. The colours employed shall be in accordance with the painting specification herein. Colour

bands shall be painted on each side of all valves and items of equipment in the piping systems. The use of adhesive-backed colour bands is not permitted.

Valve labels shall be circular and fitted under the hand-wheel captive nut. For check valves and small valves, the Contractor may provide rectangular labels fitted to the valve or secured close by the valve.

The inscription or "name" on each valve label shall summarise the duty of the valve, and the number shown on each valve label shall be the number in the unified plant valve-numbering scheme.

Where the direction of flow through a valve or other device is an important requirement for correct functioning, the body of the valve or device shall be legibly marked with a cast on or a properly secured arrow, showing the direction of flow. Pipework shall be provided with plentiful large painted arrows or other secure and durable arrow markings to allow the flows of fluids around the plant to be readily understood.

2.9 Environmental Protection & Tropicalisation

2.9.1 General

All equipment shall be designed to operate in the environmental conditions specified.

Outdoor equipment shall be designed so that water cannot collect at any point. The undersides of all tanks shall be ventilated in an approved manner to prevent corrosion.

Where applicable, equipment should tolerate the effects of freezing and air pollution.

The outdoor plant shall be rated and constructed so that its performance, operation, reliability, maintenance and or life shall meet the specified design and operating conditions.

Where personnel has to be in attendance frequently, or maintenance has to be regularly carried out, permanent means weather protection or sunshades shall be provided.

Where the performance, reliability or life of the plant would be adversely affected by solar radiation, including the effects of prolonged exposure to ultraviolet light, suitable sunshades shall be provided. Such sunshades shall be constructed from materials that are able to withstand the effects of the ambient conditions on site without suffering any deterioration in material strength or effectiveness.

Sunshades need not be provided on outdoor plant or equipment provided the Manufacturer could satisfy the Engineer that the materials employed will not be adversely affected or the

temperature rise due to internal heat generation plus that due to solar radiation will not exceed the equipment design temperature. However, equipment requiring manual operation shall be provided with sunshades to ensure that surface temperatures will not exceed 50°C.
Sunshades shall protect plant and personnel when the sun is more than 45°C above the horizon. They shall not impede the operation or maintenance of the plant or the movement of ventilating air and shall include adequate artificial light as necessary.

Facilities such as lighting, lifting beams and rainwater drainage shall be provided wherever necessary to the approval of the Engineer as an integral part of the sunshade structure.

2.9.2 Tropicalisation

In choosing materials and their finishes, due regard shall be given to the humid tropical conditions under which equipment shall work, and well-proven practices shall be followed unless otherwise approved by the Engineer. Some relaxation of the following provisions may be permitted where equipment is hermetically sealed but it is preferred that tropical grade materials should be used wherever possible:

- Metals: Iron and steel are generally to be painted or galvanized as appropriate. Indoor parts may alternatively have chromium or copper-nickel plating or other approved protective finish. Small iron and steel parts (other than stainless steel) of all instruments and electrical equipment, the cores of electromagnets and the metal parts of relays and mechanisms shall be treated in an approved manner to prevent rusting.
- Screws, nuts, springs, etc. The use of iron and steel shall be avoided in instruments and electrical relays wherever possible. Steel screws shall be zinc, cadmium or chromium-plated, or when plating is not possible owing to tolerance limitations, shall be of corrosion resisting steel. Instrument screws (except those forming part of a magnetic circuit) shall be of brass or bronze. Springs shall be of non-rusting material, e.g., phosphor bronze or nickel silver, as far as possible.
- Rubbers: Neoprene and similar synthetic compounds, not subject to deterioration due to the climatic conditions shall be used for gaskets, sealing rings, diaphragms, etc.

2.10 Platforms, Stairways, Ladders and Hand-Railing

2.10.1 General

The Contractor shall provide all platforms, galleries, stairways and ladders necessary to give access to the various sections of the plant being supplied under this contract. They shall provide adequate means of access for all operation, inspection and overhaul purposes and shall be of sufficient strength to support workers, tools and portions of plant that may be placed on them during overhaul and inspection periods.

Galleries, platforms and stairways shall be designed generally for a load of 7.5 kN/m² but where loads in excess of this are likely to be imposed during operation or maintenance, the Contractor shall make due allowance for the increased loads in the design. Particular care shall be given to their rigidity. All the necessary supports from the floors, buildings and foundations shall be supplied under this contract.

Galleries and platforms around plants subject to significant expansion shall be designed to allow for such expansion and to provide safe and adequate access for both hot and cold conditions.

Platforms and galleries shall have a minimum width of 850 mm clear passageway and shall be enclosed by hand railing on both sides. In cases where there is a space not exceeding 200 mm on one side of a passageway, hand-railing need is supplied for one side only but an edging strip shall be provided on the side without a handrail. The minimum headroom on platforms and galleries shall be 2100 mm.

Ladders will only be permitted where stairways are impractical and access is required for maintenance. All platforms, stairways, ladders and other access ways, shall comply with the requirements of BS 5395 Part 3 unless otherwise stated. As far as practical the flooring, stair treads and handrails shall conform to a uniform pattern throughout the whole of the Contract Works.

2.10.2 Flooring

The flooring of all platforms, galleries and staircase treads shall consist of an approved type of galvanised mild steel open grid flooring except in those cases where chequer plate is specified.

Toe plates extending to a height of not less than 100 mm above the platform or gallery level and of a thickness of not less than 6 mm shall be supplied. Any opening which it is necessary to cut in the open grid flooring or chequer plate shall be finished off with an edging strip similar to that on the floor panels.

The open grid flooring and stair treads shall be from an approved Manufacturer and generally in accordance with BS 4592. The pattern of open grid flooring and chequer plate shall be uniform and laid with the pattern in one direction.

Open grid floor panels shall be not less than 25 mm in depth and shall be fitted neatly between curbs and clamped with nuts and bolts in such a manner as to permit ready removal or replacement. The design of the clamps shall be for approval and only minimal protrusion above the floor level will be permitted.

Where chequer plate is supplied it shall be galvanized mild steel to an approved design. No chequer plate shall be less than 10 mm thick and all plates shall be secured to the supporting steel by galvanized countersunk screws of not less than 10 mm nominal size.

2.10.3Hand-Railing and Protective Barriers

Hand-railing and protective barriers shall be provided wherever necessary to protect operation or maintenance personnel from hazards, and shall comply with BS 6180.

Double hand railing shall be provided unless otherwise specified. Each length shall be joined by internal ferrules and all joints shall be neatly finished by the removal of all burrs.

The top rail shall be not less than 30 mm diameter and mounted at a height of not less than 1100 mm from the gallery or platform level. The intermediate rail shall be not less than 25 mm diameter and mounted at a height of not less than 535 mm from the gallery or platform level. Handrails for stairways shall have the top rail at a height of not less than 900 mm and lower rail at not less than 420 mm above the stairway pitch line.

Tubular or solid forged stanchions shall be provided, spaced at a maximum distance of 1750 mm, and to which hand-railing shall be firmly attached.

The stanchions shall be firmly and directly attached to the body of the platform, gallery, stairway or ladder steelwork by bolting, and when erected shall be vertical. They shall not be attached to toe-rails.

In designing hand-railing and its supporting stanchions particular attention shall be paid to the provisions of BS 6180 relating to design loads and to permissible deflections and flexibility.

2.10.4Stairways

Where specified, main stairways shall have a minimum stair tread width of 1100 mm; other stairways shall have a minimum width of 750 mm. Wherever possible, the angle of slope of stairways shall be standardised. Angles exceeding 42° to the horizontal shall not be used.

No flight of stairs shall have more than 16 risers. Where a stairway requires more than 16 risers, each flight shall have an approximately equal number of risers and shall be separated by a landing. Risings shall be between 190 mm and 210 mm, and goings shall be between 220 mm and 250 mm in width. Minimum headroom shall be 2.3 m.

2.10.5 Fixed Access Ladders

Ladders shall comply with BS 4211. The minimum width of ladders shall be 500 mm and inclination shall be not less than 70°, and not more than 80° to the horizontal.

2.11 Nuts, Bolts, Studs and Washers

The threads and other details of fasteners shall comply with the relevant ISO Standards for metric series fasteners. Nuts and bolts for pressure parts shall be of the best quality steel. Nuts, bolts, studs and washers shall be of materials most suitable for the service operating conditions and designed to ensure the stresses arising in normal operation shall not exceed those necessary to ensure that the specified plant life is achieved.

Nuts and bolts for incorporation in the plant are preferably to conform to ISO Metric Coarse to ISO 272. Other sizes or threads are permitted for threaded parts not to be disturbed in normal use or maintenance. Where the Contract includes nuts and bolts of different standards, then the tools to be provided in accordance with this Specification shall include spanners, taps, and dies for these nuts and bolts.

Fitted bolts shall be a driving fit in the reamed holes they occupy, and they shall have the screwed portion of a diameter such that it will not be damaged in driving and shall be marked in a conspicuous position to ensure correct assembly at site.

Stud holes in those parts of the plant that are subjected to heat in use shall be adequately vented.

The threaded portion of any bolt or stud shall not protrude more than 1.5 threads above the surface of its mating nut.

Where practicable the use of slotted head screws shall be avoided in machinery component assemblies, hexagon socketed screws being preferred.

On outdoor equipment all bolts, nuts and washers shall be of non-rusting material where they are in contact with non-ferrous parts in conductor clamps and fittings and elsewhere where specifically re-quired by the Engineer.

All washers shall be included under this contract, including locking devices and anti-vibration arrangements, which shall be subject to the approval of the Engineer. Taper washers shall be fitted where necessary.

2.12 Forgings

The Contractor shall supply a list of all important forgings and draw up material specifications for each one. Copies of this list and specifications shall be supplied to the Engineer for his use. In each case the quality and inspection requirements shall be clearly stated.

Wherever possible steel forgings shall be in accordance with the requirements of BS Standards 29, 970 or 4670, the equivalent ISO Standards or agreed national standards.

Test blocks from which mechanical test pieces will be machined shall be cut from forgings at positions to be agreed by the Engineer. On large and important forgings several test pieces shall be taken from radial and longitudinal directions.

Forgings shall be free from cracks externally or internally, extensive non-metallic inclusions and surface defects. The Contractor shall carry out non-destructive testing of forgings during machining to verify that no unacceptable defects are present.

Repairs by welding or other means shall not be undertaken on forgings at any stage of the production cycle.

Each forging shall be suitably branded with an identification number that shall be transferred throughout all final machining stages. The identification number shall be marked on all documents and test certificates relative to the forging.

2.13 Castings

2.13.1 General

Test pieces shall be provided from medium and large castings for all necessary material and chemical tests that are to be witnessed by the Engineer. If required by the Engineer any castings for rotating or highly stressed parts are to be subjected to non-destructive testing by approved methods, including radiographic and ultrasonic, the cost of which shall be borne by the Contractor.

All castings shall be homogeneous and free of shrinkage, pipes, under-sizing, porosity or voids. "Bum-in" repairs shall not be acceptable and no welding, filling, interlocking or plugging of defective parts shall be done without the Engineer's approval in writing. All repairs shall be subjected to non-destructive examination (ultra-sonic, X-rays, gamma-rays) after heat treatment. Welding repairs to castings that will be in contact with corrosive liquids, such as seawater or brine, will only be permitted under special circumstances.

2.13.2Steel Castings

The Contractor shall prepare material purchasing specifications for all important castings. Each document shall indicate fully the quality and inspection requirements for the component casting covered. Copies of the specifications shall be issued to the Engineer for his use.

Castings may be repaired by welding providing the approval of the Engineer be first obtained. The Contractor shall submit drawings, sketches or photographs showing the location and principal dimensions of the defect together with the proposed weld repair procedure. The maximum size of defect for which weld repair will be permitted is:

- Maximum length of defect 20 mm
- Maximum width of defect 10 mm
- Maximum depth of defect no greater than 10% of the wall thickness

Only welders who have passed an appropriate qualification test shall be employed on the repair of castings. All repairs shall be carried out by the metal arc process. Ultrasonic inspection shall be applied to all important castings to locate the extent of sub-surface defects and to check the wall thickness.

All castings shall be identified by stamped or cast-on reference marks, which shall be entered on all relevant documents and test certificates. The Engineer may require that certain castings be examined using radiographic techniques. The Contractor shall include for this eventuality and shall comply with the Engineer's instructions when issued.

2.13.3Iron Castings

Cast iron shall not be used for any part of equipment which is in tension or which is subjected to impact, or to a working temperature exceeding 200°C, unless specifically approved by the Engineer. Nor shall it be used for chambers of oil filled apparatus.

Weldable grades of iron castings may be repaired by welding provided the approval of the Engineer is first obtained. The Contractor shall submit full details of the proposed weld repair procedure and weld procedure qualification test prior to making any weld repairs.

The maximum size of defect for which weld repair will be permitted is:

- Maximum length of defect 20 mm
- Maximum width of defect 10 mm
- Maximum depth of defect no greater than 10% of the wall thickness

Test blocks shall be integrally cast on all medium and large castings. The Engineer may require that certain castings be checked using radiographic techniques. The Contractor shall include for this eventuality and shall comply with the Engineer's instructions when issued.

2.13.4 Aluminium Bronze Castings

The Contractor shall prepare material purchasing specifications for all important castings. Each document shall indicate fully the quality and inspection requirements for the component casting covered. Copies of the specifications shall be issued to the Engineer for his use.

The inspection and quality requirements shall include an analysis of each cast, mechanical testing of test pieces from each cast, pressure testing, penetrant flaw detection and radiographic examination of selected critical areas.

Weldable grades of aluminium bronze may be repaired by welding, provided the written approval of the Engineer is first obtained. The Contractor shall submit full details of the proposed weld repair procedure and weld procedure qualification test prior to making any weld repairs. The maximum size of defect for which weld repair will be permitted is:

- Maximum length of defect 20 mm
- Maximum width of defect 10 mm
- Maximum depth of defect no greater than 10% of the wall thickness

On completion of repairs, welded areas shall be ground smooth and carefully blended into the parent material. The repaired areas shall be examined for defects using penetrant flaw detection and radiography. Crack-like linear defects shall not be permitted.

2.14 General Welding Requirements

2.14.1 General

All welding shall conform to the relevant British Standards, or other British or National Standard Specification as agreed by the Engineer. Where there is a conflict between Codes and/or Standards the Engineer's decision will prevail.

2.14.2 General Fabrication

The Engineer shall be notified at least two days prior to commencement of any assembly or fabrication work on site. The CO2 and flux-cored welding process will not be acceptable for site welding.

2.14.3 Weld Procedure Documents

Complete and fully detailed weld procedure documents shall be kept by the Contractor and these shall be made available to the Engineer on request. Prior to commencement of welding the Contractor shall submit to the Engineer for approval the welding procedures to be used in the fabrication of the relevant sections of work.

The weld procedure documents shall be fully detailed and each shall indicate clearly which item it is intended to cover. The procedures shall be in accordance with the requirements of BS 499 Part 1, Appendices A-G.

2.14.4 Weld Procedure Qualification Tests

Weld procedure qualification tests shall be carried out in accordance with the requirements of BS EN 288, or agreed National Standard for the item of plant under consideration. Provided that the Contractor confirms that the basic parameters of the procedure have not been changed since approval, the resultsof weld procedure qualification tests previously carried out under the supervision of an internationally recognized inspecting authority may be accepted by the Engineer.

The Contractor shall inform the Engineer of any proposed changes to the welding procedures before such changes are implemented. If in the opinion of the Engineer a further qualification test is required as a result of such changes, then the Contractor shall perform the required test without additional charge.

The results of all tests shall be made available, for examination by the Engineer, if required.

2.14.5 Welder's Qualification Tests

All welders and welding operators shall be qualified for the work and shall hold current welders' qualification certificates in accordance with BS EN 287, BS 4872 or agreed National Standard for the work.

All welders' tests shall be witnessed and/or approved by the Engineer before the welder or operator is permitted to work. The decision of the Engineer regarding the acceptability of any test or existing qualification tests, shall be final.

Records showing the date and results of the qualification tests performed by each welder and weld operator, together with the identification number assigned to him, shall at all times be available for scrutiny by the Engineer.

2.14.6 Storage of Welding Consumables

Welding consumables shall be stored in a manner that will protect them from all forms of deterioration prior to use and shall be properly identified. Gas cylinders for use with burning

or welding equipment shall be marked in accordance with the requirements of BS 349 or IS0448. Site storage procedures for gas cylinders will require the approval of the Engineer.

2.14.7 Welding Equipment

Any welding equipment that in the opinion of the Engineer is unsuitable or unsatisfactory for the purpose for which it is being used shall be replaced by the Contractor.

2.14.8 Visual Weld Inspection

Each weld shall be subjected to a stringent visual inspection and shall be free from undercut, excessive spatter, craters, cracks, porosity and other surface imperfections. Welds shall be of regular contour, even weld ripple and indicative of good workmanship. Fillet welds shall be checked for dimensional tolerance and form using a fillet weld gauge. Fillet welds should be slightly concave in form and each leg of the weld shall have equal length.

2.14.9 Internal Examination

The internal root bead of tube butt welds shall be examined by intra-scope or other suitable optical device.

2.14.10 Non-destructive Examination

All non-destructive examinations shall be supervised by a fully qualified and experienced specialist appointed by the Contractor. Individual operators in each of the respective techniques shall be qualified and trained in the respective subject and shall have reached a standard comparable with the Certification Scheme of Weldment Inspection Personnel in the United Kingdom.

Testing shall be in accordance with the requirements of BS 709 "Methods of Testing Fusion Welded Joints and Weld Metal in Steel" or an agreed National Standard.

2.14.11 Ultrasonic Examination

Ultrasonic examination of welds shall be carried out in accordance with BS 3923 Part 1 and Part 2 and any other relevant British Standards or agreed National Standards.

2.14.12 Magnetic Crack Detection

Magnetic crack detection shall be carried out in accordance with BS 6072 or an agreed National Stand-ard.

2.14.13 Dye Penetrant Tests

Dye penetrant tests shall be in accordance with BS 6443 or any other relevant British or agreed National Standards.

2.14.14 Quality Requirements for Welds

All welds subjected to non-destructive tests shall be entirely free from cracks or crack like defects, lack of root fusion, lack of sidewall fusion, root bum through, or tailed pores. The standard for porosity and slag inclusions will be as indicated in the agreed standards for design and welding.

2.14.15 Weld Repairs

The Engineer's approval shall be obtained prior to commencement of any repair or rectification work. Weld repairs shall be made to the same procedure as for the original weld. All tests shall be repeated after the repair has been completed and reports on radiographic and ultrasonic tests shall be marked to indicate that the report refers to a repaired weld.

2.14.16 Mandatory Inspections

All transition welds between dissimilar materials, such as high alloy steels to carbon steel, or austenitic steels or non-ferrous materials to steels, shall be subjected to 100% ultrasonic examination or crack detection wherever practicable. In addition, all butt welds between dissimilar materials shall be subjected to 100% radiographic examination.

All welds in ferritic alloy steels, e.g. having a carbon equivalent value in excess of 0.40%, and high yield-strength steels, e.g. having yield strength greater than 300 MPa, shall be subjected to 100% ultrasonic examination and crack detection wherever possible. In addition, all butt welds in these materials shall be subjected to 100% radiographic examination.

A minimum of 10% of all butt welds on all classifications of work shall be radiographically examined, unless otherwise agreed with the Engineer.

2.15 Galvanised Work

All materials to be galvanised shall be of the full dimensions shown or specified and all punching, cut-ting, drilling, screw tapping and the removal of burrs shall be completed before the galvanising process commences.

All galvanising shall be done by the hot dip process, not less than 98% of which must be pure zinc and in accordance with BS 729 or BS 443 as applicable. No alternative process shall be used without the approval of the Engineer. Bolts shall be completely galvanised including the threads, but the threads of nuts shall be left uncoated and shall be oiled. The zinc coating shall be uniform, clean, smooth and as free from spangle as possible.

Galvanised wire shall comply with the requirements of BS 182 and the thickness of the coating and testing thereof shall comply with BS 443. Nuts and bolts and small components shall be tested in accordance with BS 729. The Engineer may select for test as many components to be weighed after pickling and before and after galvanising as he may think fit.

Galvanised steel shall be treated after galvanising with Sodium Dichromate solution or Pretan W20 to prevent formation of white Storagstan. In addition, plastic or other non-metallic non-hygroscopic spacers shall be used between packed members to facilitate ventilation of the zinc surface during shipping.

All galvanised parts shall be protected from injury to the zinc coating due to abrasion during periods of transit, storage and erection. If, in the opinion of the Engineer, the extent of the damage found on Site to a galvanised part appears to be capable of repair the Contractor may, after receiving such agreement, attempt to affect a repair by approved methods. The agreement to attempt the repair shall not bind the Engineer to accept the repaired part when this is re-offered for inspection.

Should an emergency arise on Site necessitating drilling, cutting or any other process likely to damage the protective zinc surface, this will be permitted only in extreme circumstances and with the Engineer's express authority. In such a case, the bared metal will be coated with an approved zinc rich paint of not less than 92 percent zinc content.

2.16 Chromium Plating

The chromium plating of those components of the Plant where specified and where offered by the Contractor shall comply with the requirements of BS 1224.

2.17 Pumps

Pumps should be of the centrifugal type unless strong technical or economic reasons dictate that a positive displacement pump, either rotary or reciprocating, is more appropriate.

Preventive and routine maintenance time should be minimized by the selection of appropriate designs of pump, preferably those that leave casing to piping joints intact, i.e. horizontal split-casing types for large centrifugal pumps and horizontal, back pull-out types for smaller units.

Where a significant saving in floor space or improvement of layout can be shown, a vertical pump may be acceptable.

Pumps shall be capable of continuous operation with minimum maintenance.

2.18 Pipework

During the contract Engineering, the Contractor shall supply to the Engineer schedules of the pipework provided under this contract. These schedules shall state, for each pipework system or part of a pipe-work system, the design and operating pressures and temperatures, the fluid transmitted, the piping and valve materials, the types of valves, any corrosion allowance, the pipework design code, insulation proposals, pipe supports and any other data relevant to the mechanical design of the pipework system or part of a pipework system.

All piping shall be routed to provide a neat and economical layout requiring the minimum number of fittings. Piping shall be arranged so that full access is provided for the operation and maintenance of equipment and so that removal or replacement of equipment can be achieved with the minimum dis-mantling of piping.

The Contractor is to be responsible for ensuring that the internal surface of each pipe line is thoroughly clean both during erection and before the pipe line is placed in commission.

The procedure for internal cleaning of pipes adopted by the Contractor is to include the following:

- Thorough cleaning of all internal surfaces prior to erection to remove accumulations of dirt, rust, scale etc., and welding slag due to site welding before erection.
- Thorough cleaning of all pipework after erection by blowing through to atmosphere to ensure that no extraneous matter is left in the system.

The Contractor is to provide all the necessary facilities for carrying out these requirements.

Pipework shall be supported and anchored in an appropriate manner in accordance with the provisions of US Standard ANSI B31.1 or the Standard to which the pipework is designed. The whole of the pipe-work and accessories included in this Contract are to be supported and mounted in an approved manner. All necessary slings, saddles, structural steelwork, foundation bolts, fixing bolts and all other attachments are to be supplied. The number and positions of all supports and the maximum weight carried by support is to be subject to the approval of the Engineer.

2.19 Valves

All valves shall be suitable for the service conditions under which they are required to operate. The design, construction and choice of materials shall take into account all operational deviations including pressure surge and thermal shock.

All valve hand operating mechanisms shall be easily operable by one man. The mechanisms shall be such that the total force at the rim of the hand-wheel or other point of application of manual action shall not need to exceed 400 N (normally 200 N pull plus 200 N push) to exercise any valve. Special attention shall be given to the operating mechanism for large size valves with a view to ensuring that a minimum of maintenance is required and to obtaining quick and easy operation.

All valves shall be closed by rotating the hand-wheels in a clockwise direction when looking at the face of the hand-wheel. In cases where the hand-wheel is not directly attached to the valve spindle suitable gearing shall be introduced to ensure clockwise closing. The face of each hand-wheel shall be clearly marked "open" and "shut" or "closed" with arrows indicating the direction of rotation to which they refer.

Plastic valve hand-wheels will not be acceptable, except where such hand-wheels are in the Employer's best interests. All valve spindles shall be fitted with indicators so that the valve opening can be readily determined. In the case of valves fitted with extended spindles, indicators shall be fitted both to the extended spindles and to the valve spindles.

Valves of 50 mm nominal bore and over are to be provided with indicators showing when the valve is open or closed.

All valve hand wheels are to be fitted with nameplates complying with this Specification.

Suitable means are to be provided to protect the operating mechanisms of all valves against mechanical damage and dust or dirt.

Valves that it will be necessary to lock in the open or closed position are to be provided with a non-detachable locking arrangement.

2.20 Pressure Vessels

All vessels shall be designed, constructed and otherwise comply with appropriate international or national pressure vessel design codes unless the vessel in question falls into one of the following groups:

- vessels with a water containment capacity of fewer than 454 liters for the containment of water under pressure, including those containing air, the compression of which serves only as a cushion.
- hot water storage vessels heated by steam or any other indirect means when none of the following limitations is exceeded:
  - a heat input of 58kW
  - a water temperature of 93°C
  - a nominal water containment capacity of 454 litres.
- vessels having an internal or external design pressure not exceeding 1.03 bar gauge, this design pressure being not less than the maximum expected difference that may exist between the inside and outside of the vessel at any time.
- vessels having an internal diameter not exceeding 150 mm.
- vessels and equipment covered more appropriately by boiler or pipework design codes.

Should any difficulty arise in the decision as to whether a particular vessel shall comply with a pressure vessel code, the vessel shall be "coded" unless specifically excluded in clause U- 1 of the US ASME Boiler and Pressure Code, Section VIII, division 1, dealing with the scope of that code.

Notwithstanding the foregoing exclusions, if it is stated elsewhere in the Specification that a particular vessel shall comply with a pressure vessel design code, then a vessel complying with a suitable design code shall be provided.

In respect of the design codes to which "coded" vessels shall comply, attention is drawn to the provisions of this Specification relating to design codes and standards.

2.21 Lubrication

The Contract is to include for the supply of flushing oil for each lubrication system when the item of plant is ready for preliminary tests and the first filling of approved lubricants for the commercial operation of the plant.

A schedule of the oils and other lubricants recommended for all components of the Contract Works is to be submitted to the Engineer for approval. The number of different types of lubricants is to be kept to a minimum. Copies of this schedule shall be included in both the draft and final copies of the operating and maintenance instructions. In the case of grease lubricated roller type bearings for electric motors a lithium based grease is preferred.

The Contractor shall supply at least one grease gun equipment for each type of nipple provided. Where more than one special grease is required, a grease gun for each special type shall be supplied and permanently labelled.

2.22 Oil Level Indicators

Oil level indicators of approved design are to be fitted to all oil containers such as transformer tanks etc. The indicators are to show the level at all temperatures likely to be experienced in service, are to be marked with the normal level at 20°C clearly visible from normal access levels and are to be easily dismantled for cleaning. In addition, the normal filling level of all removable containers is to be marked on the inside.

2.23 Pressure Gauges

Pressure gauges are to comply with the requirements of BS 1780.

All pressure gauges are to be fitted with stop cocks immediately adjacent to each gauge and all pressure gauge piping is to be fitted with an isolating valve at each point of connection to the main system. Where pressure gauges are mounted on panels, the stop cocks are to be suitable for the connection of a test gauge.

Gauges shall be calibrated to read pressure at the tapping point and a sealed pressure transmitting system shall be used. All pressure gauges are to be clearly identified by means of labels of approved type and lettering. All pressure gauge piping is to be of corrosion resistant steel or copper tube.

2.24 Thermometer Pockets

Thermometer pockets and instrument connections of an approved pattern are to be fitted in such positions as may be determined to suit the operation and testing of the plant to the approval of the Engineer. A thermometer pocket is to be fitted adjacent to each point of connection for distant remote temperature indication unless specifically stated to the contrary. Where necessary, the pocket is to be of approved alloy material suitable for the required service.

All thermometer pockets are to comply with the requirements of BS 2765.

2.25 Gauge Cubicles and Panels

Gauges and instruments are to be grouped whenever possible and housed in suitable cubicles. Where circumstances do not justify cubicle accommodation, they may be secured to flat back panels but in such cases the approval of the Engineer is first to be obtained.

Cubicles are to be sheet metal having a thickness of 3 mm. The construction shall employ folding technique with the use of standard rolled sections or other reinforcement where necessary. The stiffness shall be such as to prevent mal-operation of relays or other apparatus by impact. The front of the panel is to have a smooth well finished surface and, if of the "desk" type, the desk is not to protrude so far as to hinder the easy reading of instruments and the operation of the controls.

2.26 Locking Facilities

Locking facilities including padlocks shall be provided under this contract for:

- Control position selector switches in all positions provided, except where other electrical or mechanical interlocking is approved.
- Marshalling, operating and terminal kiosks or cubicle access doors and panels.
- Isolating valves in open or closed positions.

Locking facilities shall be of an approved dead latch type. Three keys shall be supplied for each lock and all locks and keys shall be non-interchangeable. Where a set of locks is provided under a particular section of the Plant, a group master key shall be supplied in addition.

A schedule of locks and keys shall be submitted to the Engineer for approval.

All locks and padlocks shall be of brass and where they are fitted to switchboards or similar cubicles shall have the visible parts chromium plated.

Where a group of locks is supplied under any part of the Contract, a rack or cabinet of approved design shall be supplied for the accommodation of all padlocks and/or keys while not in use. The padlocks and keys shall be engraved with an agreed identifying code or inscription and this shall be repeated on the racks or cabinets on engraved labels.

Where a mechanism is to be locked in a specific position, provision shall be made at that part of the mechanism where the operating power is applied and not to remote or ancillary linkages.

Provision for locks shall be designed, constructed and located on the equipment so that locks will remain serviceable in the climatic conditions specified without operation or maintenance for continuous periods of up to two years and with suitable maintenance shall be fit for indefinite service.

2.27 Electrical Equipment

2.27.1 General

The works shall be designed to ensure continuity of operation under all working conditions obtaining at the Site as the first consideration and to facilitate inspection, maintenance and repairs. All reasonable precautions shall be taken in the design of equipment and of the works, to ensure the safety of personnel concerned with the operation and maintenance of the works.

Outdoor equipment shall be designed so that water cannot collect at any point. The undersides of all tanks shall be ventilated in an approved manner to prevent corrosion.

Mechanisms shall be constructed to prevent sticking due to rust and corrosion, and the bearings of exposed operating shafts shall be designed so as to prevent moisture seeping along shafts into the interior of the equipment.

Corresponding parts of similar equipment, and equipment liable to renewal, shall be fully interchange-able and the Contractor will be required to demonstrate this feature to the Engineer's and Employer's satisfaction.

All equipment shall operate without undue vibration and with the least practical amount of noise.

All equipment shall be designed to minimise corona or other electrical discharges, to comply with local electromagnetic compatibility (EMC) standards and in accordance with IEC standard 61000.

All electrical components shall be adequately rated for their most onerous duty and the specified ambient temperature. When equipment is mounted in panels, cubicles etc., due account shall be taken of any heat generated by the equipment therein and the components shall be appropriately selected, rated or de-rated as necessary to suit the most onerous operating temperatures within the enclosure.

Except where a different meaning is stated in an equipment standard, the term "low voltage" (LV) shall refer to voltages up to and including 1 kV, and "high voltage" (HV) shall refer to all voltages exceeding 1 kV.

Fuses, circuit breakers and other electrical switchgear components shall comply with the relevant clauses, for low voltage ac switchgear.

2.27.2 Electrical Equipment Enclosures

Equipment enclosures for electrical equipment shall comply with IEC 60079, IEC 60529 and IEC 60947-1 as applicable. Equipment enclosures for use in hazardous areas other than explosive gas atmosphere shall comply with National and Local Regulations relating to this application. Unless otherwise specified, minimum equipment enclosure classifications for non-rotating electrical equipment shall be as follows:

- Indoors only in totally enclosed rooms with provision for limiting the ingress of dust: IP 31
- Indoors, except as noted otherwise: IP 54
- Outdoors, and indoors in areas subject to water spray, or heavy condensation: IP 55W

The enclosure classification of main and auxiliary cable boxes with the cable(s) terminated shall not be less than that of the associated equipment, subject to a minimum classification of IP54.

2.28 Current Ratings

2.28.1 Normal Current Ratings

Current ratings in accordance with IEC 60059 shall be adopted unless otherwise agreed with the Engineer.

Every current-carrying part of the equipment shall be capable of carrying its site rated current continuously under the site ambient conditions as specified and shall not be rated on the basis of air-conditioned rooms even when these are specified. In no conditions shall the specified maximum temperature be exceeded.

The current ratings specified are the continuous current ratings required at the Site, under the specified maximum temperature conditions.

2.28.2 Temperature Rise

Full provision shall be made for solar heat gain on all outdoor apparatus and any differential temperatures attained as a result of the impingement of solar heat.

The allowable temperature rise shall be in accordance with the relevant Standard, except where the ambient temperature exceeds the maximum permitted in that Standard when the permitted temperature rise shall be reduced by one degree Celsius for every degree Celsius the maximum ambient temperature exceeds the maximum permitted in the Standard.

To allow for high ambient site temperatures, the allowable temperature rise for transformers shall be reduced by a maximum of 10°C from the standard value in IEC60076.
In such cases where the Contractor is unable to guarantee the permitted maximum temperature reached under site conditions, taking account of solar heating, then sunshades shall be provided to the Engineer's approval.

The maximum temperature attained by components under the most onerous service conditions shall not cause damage or deterioration to the equipment or to any associated or adjacent components. The Contractor shall submit his calculations to the Engineer to prove that all plant has been sufficiently de-rated to suit the site conditions and any changes required by the Engineer shall be made at no extra cost.

2.28.3 Short-Time Current Ratings

Electrical equipment shall be adequately supported and braced to withstand the forces associated with the maximum short-circuit currents specified or pertaining, whichever is the greater, and assuming that the inception of the short-circuit is at such a time that gives maximum peak currents. No provision for current decrement shall be made unless specifically permitted by the appropriate Standard, or else-where in this Specification.

Equipment shall be so constructed as to withstand the specified maximum short-circuit currents for the time specified in the Schedules without the temperature exceeding the specified maximum short-time temperature or value stated in the relevant standard, under these conditions. The equipment shall be considered as being operated at the maximum permitted continuous temperature prior to the inception of the short circuit.

The final temperature attained as a result of the passage of short-circuit current shall not cause permanent damage, or deterioration sufficient to reduce the normal operating characteristics below the specified or most onerous operating requirements, whichever is the highest.

2.29 Voltage Ratings

2.29.1 Normal Voltage Ratings

Unless otherwise specifically stated, any reference to voltage rating shall be deemed to refer to the nominal rated voltage or voltages of electrical equipment. Standard voltage levels in accordance with IEC 60038 shall be adopted, unless otherwise specified by or agreed with the Engineer.

All electrical equipment shall, except where otherwise specified, be capable of continuous operation at a voltage in the range of ±10% of the nominal voltage and at a frequency in the range of 47 to 51 Hz coincidentally without deterioration.

The temperature rise of electrical equipment continuously operating at the specified extreme voltage and frequency shall not exceed the temperature rise when operating at nominal voltage and frequency by more than 5°C

2.29.2Short-Time Voltage Ratings

All electrical equipment shall be so designed such as to withstand abnormal system voltages as required by the applicable BS, IEC or acceptable International Standard.

2.30 Electrical Insulation

Insulating materials shall be suitably finished so as to prevent deterioration of their qualities under the specified working conditions. The account shall be taken of the IEC 60085 recommendations.

Ebonite, synthetic resin-bonded laminated material and bituminized asbestos cement-bonded panels shall be of suitable quality selected from the grades or types in the appropriate IEC, or approved National Standard.

The insulation of all machine windings, solenoids, etc. other than those immersed in oil or compound, shall be of Class F materials unless otherwise specified elsewhere.

All cut or machined surfaces and edges of resin-bonded laminated materials shall be cleaned and then sealed with an approved varnish as soon as possible after cutting.

Linseed oil and untreated materials of fibre, leatheroid, press pan, asbestos or other similar hygroscopic types of materials shall not be used for insulation purposes. Untreated leatheroid and presspahn may be used for mechanical protection of winding insulation.

The use of asbestos is not permitted without the permission of the Engineer.

Wherever practicable, instrument, apparatus and machine coil windings, including wire wound resistors, with the exception of those immersed in oil or compound, shall be thoroughly dried in a vacuum or by other approved means and shall then be immediately impregnated through to the core with an approved insulating varnish. Varnish with a linseed oil base shall not be used.

No material of a hygroscopic nature shall be used for covering coils. Where inter-leaving between windings in coils is necessary, only the best manila paper, thoroughly dried, which permits penetration by the insulating varnish or wax, shall be used.

Polychlorinated Biphenyl (PCB) type materials shall not be used anywhere in the equipment or in any component.

2.31 Insulating Oil

Insulating oil shall comply with the requirements of IEC 60296. Insulating oil shall be provided by the Contractor for all oil-filled apparatus and 10% excess shall be provided for topping up purposes in sealed drums. The Contractor shall provide at no additional cost any oil treatment facilities he may require for his own use in order to ensure that insulating oil meets the requirements of the specification.

2.32 Control and Selector Switches

Control switches shall be of the three-position type with a spring return action to a central neutral position and without a locking feature. Circuit breakers shall have control switches which shall be labelled open/N/close or (0/N/I) and arranged to operate clockwise when closing the circuit breakers and anti-clockwise when opening them.

Control switches of the discrepancy type shall be provided where specified. Such discrepancy control switches shall be arranged in the lines of the mimic diagram. Such switches shall include lamps and be of the manually operated pattern, spring loaded such that it is necessary to push and twist the switch past its indicating position for operation.

The lamp shall be incorporated in the switch base and shall flash whenever the position of the controlled device is at variance with the position indicated by the control switch. Hand dressing of the control switch to the correct position shall cause the lamp to extinguish.

Pushbutton test switches shall be provided along with the control panel that will illuminate all indicating discrepancy lamps as well as spare lamps on the control panels. The scheme shall be complete with all necessary diodes and other equipment required for satisfactory operation.

Switches for other apparatus shall be operated by pushbuttons, shrouded or well recessed in their housings in such a way as to minimise the risk of inadvertent operation.

Multi-position selector switches shall have a lockable stayput action. Each position of the selector switches shall be suitably labelled to signify the functions in accordance with the approved wiring diagrams. The switch handle shall be of the pistol grip spade type to the approval of the Engineer.

It shall not be possible at any time to close any switching device from more than one location simultaneously, and suitable lockable selector switches shall be provided to meet this requirement. Tripping signals from all locations shall function at all times.

Particular variations of the above requirements may be agreed with the Engineer for special instrument or control equipment, viz. main control room desks and panels, and electrical equipment cubicles.

The contacts of all control and selector switches shall be shrouded to minimise the ingress of dust and accidental contact, and shall be amply rated for voltage and current for the circuits in which they are used.

2.33 Panels, Desks and Cubicles

Unless otherwise specified, panels, desks and cubicles, shall be of floor-mounted and free-standing construction and be in accordance with the enclosure classification specified elsewhere. All control and instrumentation panels in any one location shall be identical in appearance and construction. Where new panels are supplied for existing substations, these shall match existing panels in appearance, arrangement and devices and colour finishes.

Panels shall be rigidly constructed from folded sheet steel of 3mm minimum thickness to support the equipment mounted thereon, above a channel base frame to provide a toe recess.

Overall height, excluding cable boxes, shall not exceed 2.5m. Operating handles and locking devices shall be located within the operating limits of 0.95m and 1.8m above floor level. The minimum height for indicating instruments and meters shall be 1.5m unless otherwise approved by the Engineer.

Panels shall be mounted on an approved form of anti-vibration mounting whenever necessary.

All panels, desks and cubicles shall be vermin-proof. All cable entries to equipment shall be sealed against vermin as soon as possible after installation and connecting-up of the cables to the approval of the Engineer.

All cubicles, desks and panels shall be provided with a natural air circulation ventilation system. All control equipment shall be designed to operate without forced ventilation.

For outdoor equipment, metal to metal joints shall not be permitted and all external bolts or screws shall be provided with blind tapped holes where a through-hole would permit the ingress of moisture. For harsh environments, all nuts, bolts and washers shall be tropicalized as appropriate.
Door sealing materials shall be provided suitable for the specified site conditions. Doors shall be fitted with handles and locks. Where walk-in type panels are supplied the door shall be capable of being opened from inside the panel without the aid of a key after they have been locked from the outside. Hinges shall be of the lift-off type and shall permit the doors when

open, to lie back flat so as not to restrict access. Means shall be provided for securing the doors in the open position.

Cubicles and cubicle doors shall be rigidly constructed such that, for example, door-mounted emergency trip contacts can be set so that mal-operation will not be possible due to any vibrations or impacts as may reasonably be expected under normal working conditions.

The bottom and/or top of all panels shall be sealed by means of removable gasket steel gland plates.

Gland plates for bottom entry shall be at least 250mm above the floor of the cubicle.

Panels shall be suitably designed to permit future extension wherever appropriate or specified.

Each panel shall include rear access doors internal power sockets and door-operated internal lighting, and be clearly labeled with the circuit title at front and rear, with an additional label inside the panel. Panel sections accommodating equipment at voltages higher than 125V (nominal) shall be partitioned off and the voltage clearly labeled. Each relay and electronic card within panels shall be identified by labels permanently attached to the panel and adjacent to the equipment concerned. Where instruments are terminated in a plug and socket type connection both the plug and the socket shall have permanently attached identifying labels.

Instrument and control devices shall be easily accessible and capable of being removed from the panels for maintenance purposes.

Terminations, wiring, and cabling shall be in accordance with the requirements of this section of the specification.

For suites of panels inter-panel bus-wiring shall be routed through apertures in the sides of panels and not via external multicore cabling looped between the panels.

All panels, whether individually mounted or forming part of a suite, shall incorporate a common internal copper earthing bar onto which all panel earth connections shall be made.

Suitable studs or holes to the Engineer's approval shall be left at each end of the bar for connection to the main station earthing system and possible future extension.

Earth connection between adjacent panels shall be achieved by extending the bar through the panel sides and not by interconnecting external cabling.
Where intrinsically safe circuitry is routed from a hazardous area to a safe area instrument panel, it shall be connected through Zener Barriers located in the safe area (instrument panel) of suitable rating and mounted on an insulated earthing busbar having facilities for connection of a separate dedicated out-going cable to a "clean earth" system.

Control supplies in desks, panels and cubicles shall be derived from a duplicate standby/UPS system, except if specified otherwise in this specification. The following alarms shall be provided to monitor thesystems: voltage high, voltage low, no volts and earth fault. The alarms shall be signalled to the Control Room.

Instruments having pressure pipe connections containing oil, water, steam or flammable or toxic fluids shall be excluded from the Control Room.

All cubicles, desks and panels shall be painted externally with a high gloss paint of Munsell 5Y7/1 colour. The interiors of all cubicles, desks and panels shall be painted matt white.

All cubicles, or panels mounted external to control and apparatus rooms shall be fitted with thermostat controlled anti-condensation heaters.

2.34 Instruments & Meters

2.34.1 Indicating Instruments

All indicating instruments shall be of the flush-mounted pattern with dust and moisture-proof cases complying with BS 2011, Classification 00/50/04, and shall comply with IEC 60051-1.

Unless otherwise specified, all indicating instruments shall have 96 mm or 144 mm square cases to DIN standard or equivalent circular cases.

Instrument dials in general should be white with black markings and should preferably be reversible where double scale instruments are specified.

Scales shall be of such material that no peeling or discolouration will take place with age under humid tropical conditions.

The movements of all instruments shall be of the dead beat type. Wherever possible, instruments shall be provided with a readily accessible zero adjustment.

2.34.2 Electrical Meters

All electrical meters shall comply with IEC 62053 and other relevant IEC standards and, unless other-wise specified, shall be of accuracy Class 1, except Class 0.2 for energy meters. Three-phase power measuring instruments shall be of the three-phase unbalanced load pattern wherever the current and voltage references permit.

Where precision grade metering is specified meters shall be calibrated to precision grade accuracy to IEC standards.

Due allowance shall be made for the errors of current and voltage transformers with which they shall work and whose accuracy class shall be Class 0.2.

Where commercial grade metering is specified the meters shall be calibrated to commercial grade ac-curacy to IEC standards.

Meters shall be single directional and shall be fitted where required with suitable devices for the trans-mission of impulses to a summator. Var-hour meters shall be complete with phase shifting transformers as necessary.

Front of panel test terminal blocks shall be provided for all meters.

Summators shall be equipped to summate the circuits specified and shall be equipped where required with suitable contacts for the re-transmission of impulses to a printometer. They shall register in kilo-watts the value of the impulses received from each kilowatt-hour meter. Printometers shall be of an approved type having the specified demand interval.

Each 230 kV and 132 kV feeder shall be provided with Main 1 and Main 2 energy meters.

The energy meter shall be 3-element, 4-wire arrangement of programmable digital type and shall have proven performance and shall consist of different types, either from the same Manufacturer or different Manufacturers. The accuracy class of the energy meter shall be 0.2.

2.35 Indicating Lamps and Fittings

All indicating lamps shall be adequately ventilated and as far as practicable, lamps of a common type and manufacture shall be used throughout the Contract.

Lamps shall be easily removed and replaced where possible from the front of the panel by manual means preferably not requiring the use of extractors.

Where specified every circuit breaker panel shall be equipped with one red and one green indicating lamp, indicating respectively circuit closed and circuit open and an amber lamp for indicating 'auto-trip'. Where specified for in the lines of mimic diagrams, indicating lamps may be of the three-lamp single-aspect type.

The variety of indicating lamps provided shall be rationalised to reduce maintenance and spares requirements.

The lamps shall be clear and shall fit into a lamp holder. The rated lamp voltage shall be at least 20% in excess of nominal supply voltage, whether A.C. or D.C. The lamps shall have an operating life of at least 10,000 hours, under site conditions. In the event that other indicating

devices, such as light emit-ting diodes, are used in place of lamps then these shall have the same life expectancy and performance capability as the lamps they replace.

The lamp glasses shall comply with IEC 60073 and be in the standard colours, red, green, blue, white and amber. The colour shall be in the glass and not an applied coating. Transparent synthetic materials may be used instead of glass subject to the approval of the Engineer.

Where illuminated pushbuttons are used for control purposes, the illuminated pushbuttons shall be engraved with a clear instruction such as 'push to open' or 'push to close', and the lamp shall illuminate in accordance with the above colour code after the instruction has been carried out and the device has operated.

Unless otherwise agreed with the Engineer all lamp colours shall conform to the following practice:

- Red energised or operative position
- Green De-energised or inoperative position
- Amber fault or abnormal condition
- White healthy or normal condition
- Blue other purposes, to be used with descriptive label

Lamp test facilities shall be provided for all switchboards, control panels etc. to enable all lamps to be tested whilst the equipment is in service. Operation of the lamp test facility shall not cause any other device to operate. Indication circuits shall be fused.

2.36 Anti-Condensation Heaters

All switchboards, panels, cubicles and the like shall incorporate thermostat controlled electric heaters capable of providing movement of sufficient heated air to avoid condensation. The apparatus so protected shall be designed so that the maximum permitted rise in temperature is not exceeded if the heaters are energised while the apparatus is in operation.

The switchboard anti-condensation heaters shall be fed from an LV single phase and neutral supply, manually switched by a two-pole switch with red lamp, mounted on the back of the board, panel or cubicle and bus-wired through the board. Labels shall be provided on the switch stating "Heater Supply". Heater terminals shall be shrouded and labelled "Heater".

Motor anti-condensation heaters where fitted shall be fed from an LV single phase and neutral supply bus-wired through the board. The supplies shall be individually fused and will be switched by auxiliary contacts on the contactor and isolated by auxiliary contacts on the contactor isolator.

2.37Control and Instrument Panel Wiring, Cable Terminations and Terminal Boards

2.37.1 General

All electrical equipment mounted in or on switchgear, panels and desks, shall have readily accessible connections and shall be wired to terminal blocks for the reception of external cabling.

The wiring shall comply with BS 6231 and shall be capable of withstanding without deterioration the conditions at Site, due allowance being made for such temperature conditions as may arise within any enclosure. The insulating material shall be flame retardant in accordance with IEC 60332.

All wiring shall be of adequate cross-sectional area to carry prospective short-circuit currents without risk of damage to conductors, insulation or joints.

The following classes of copper conductor, as defined in IEC 60228, shall be used for panel wiring:

- Class 1: conductors up to a maximum of 0.9 mm diameter where necessary for wire-wrapped terminations and similar techniques,
- Class 2: conductors except where specified otherwise,
- Class 5 and Class 6: conductors between points subject to relative movement.

The following minimum conductor sizes shall be used:

- 1.5 mm^2 except where specified otherwise,
- 2.5 mm^2 for current transformer secondary circuits with a rated secondary current of not exceeding 1A.
- 4 mm^2 for current transformer secondary circuits with a rated secondary current exceeding 1A.

Where an overall screen is used, this shall be a metallic screen or low resistance tape, with a drain wire as above.

Wiring shall be supported using an insulated system that allows easy access for fault finding and facilitates the installation of additional wiring.

Small wiring passing between compartments that may be separated for transport shall be taken to terminal blocks mounted separately from those for external cable connections.

Connections to apparatus mounted on doors or between points subject to relative movement shall be arranged so that they are subjected to torsion rather than bending.

Ribbon cables or similar preformed cables with plug and socket connectors may be used for light current wiring. Plug and socket connectors shall be polarised so that they can only be inserted into one another in the correct manner.

If so required, the Contractor shall submit for the Engineer's approval samples of the types of wire, numbered ferrules, and terminal washers or lugs as appropriate which he propose to use.

2.37.2 Identification of Wires

All wiring and cores in control and instrument cables shall be identified in accordance with the associated schematic and/or wiring diagrams either by means of discrete wire numbers or wire colours, except when an automatic or proprietary system of wiring is used, e.g. point-to-point wiring on a mother board.

When a wire numbering system is used, it should be in accordance with IEC standards or with a functional marking system. Both ends of every wire and core in control and instrument cables shall be fitted with interlocking ring ferrules of white insulating material indelibly marked with black characters, com-plying with BS 3858. Heat shrink marking sleeves may be used, but adhesive markers are not acceptable.

When plug and socket connectors are used, they shall be uniquely identified as mating pairs and each connector pin shall be numbered. Wiring which is permanently connected to plugs or sockets need not be identified.

Each core of multi-pair wiring shall be identified by colour and terminal block identification together with an identification tracer per bundle.

Permanent identification of all terminals, wires and terminal blocks shall be provided.

A consistent system of wiring numbering shall be used throughout the plant, and it shall be agreed with the Engineer at the start of the Contract.

2.37.3 Terminals and Terminal Blocks

Terminal blocks shall have separate terminals for internal and external connections, and not more than one wire shall be connected to each terminal.

Adjacent terminals to which wires of different voltage, polarity or phase are connected shall be separated by a protruding insulating barrier. This requirement also applies to terminals carrying wires of the same voltage but originating from different sources.

Trip circuit wiring and instrument transformer secondary wiring shall be connected using hook type crimped terminations in screw clamp, spring loaded insertion type terminals.

Where clamp type terminals are used, Class 1 and Class 2 conductors may be terminated without lugs. Crimp lugs shall be used for Class 5 and Class 6 conductors. Means shall be provided for retaining the identifying ferrules of the wire end when it is disconnected.

Pinch screw type terminals shall not be permitted.

Subject to approval of the Engineer, "wire-wrap", "termipoint" or equivalent methods of terminations of single strand conductors may be used.

Wires shall be grouped on the terminal boards according to their functions.

All terminal blocks shall provide a degree of protection of not less than IP2X when correctly installed, either inherently or by provision of insulating covers.

Terminal boards shall be mounted vertically, not less than 150 mm above the gland plates, and spaced not less than 100 mm apart, on the side of the enclosure and set obliquely towards the rear doors.

Sufficient terminals shall be provided to permit all cores on multicore cables to be terminated. Terminals for spare cores shall be numbered and be located at such position as will provide the maximum length of spare core. At least 10% spare terminals shall in all cases remain after commissioning.

The tails of multicore cables shall be bound and routed so that each tail may be traced without difficulty to its associated cable. All spare cores shall be made off to terminals.

When two lengths of screened cable are to be connected at a terminal block (i.e. junction box) a separate terminal shall be provided to maintain screen continuity.

In the main and local control and equipment rooms, means shall be provided on the terminal blocks of panels, desks, cubicles, etc., for testing all the instrument circuits without the need to remove the internal or external wiring from the block.

The Contractor shall submit full details and specification of the proposed means of termination where wire wrapping, soldering and similar methods are used. The adopted methods shall be to the Engineer's approval.

The Contractor shall identify all special tools, such as wire wrapping tools required for termination, and shall make provision for their supply in sufficient numbers.

The use of pre-formed factory tested cable connections to field mounted marshalling boxes shall be to the Engineer's approval.

2.38 Cable Boxes and Glands

2.38.1 General

Electrical equipment shall be provided with all necessary cable boxes, which shall be complete with all required fittings. All cable boxes shall be of adequate size to allow for the correct termination of the cable sizes required or specified, taking into account the crossing of cores to achieve the correct phasing, and to accommodate all cable fittings, including stress cones or other means of cable insulation grading, if required. All cable boxes shall be designed in such a manner that they can be opened for inspection without disturbing the gland plate or incoming cable.

All main cable boxes shall be air insulated for the termination of all types of cable at voltages up to and including 33 kV nominal system voltage, unless otherwise specified elsewhere in this Specification. Compound-filled cable boxes may only be used for paper insulated cables, where specified elsewhere.

The enclosure classification of main and auxiliary cable boxes on motors with the cable(s) terminated shall not be less than that of the associated motor, subject to a minimum classification of IP54.

Clearance and creepage distances shall be adequate to withstand the specified alternating current volt-ages and impulse voltages for service under the prevailing site conditions.

Means shall be provided for preventing accumulation of dirt, dust, moisture, vermin or insects such as to maintain the anticipated life of the equipment.

The terminals for 3 phase cables shall be clearly marked with the specified phase designations to enable the cables to be terminated in the correct sequence.

Flexible connections shall be provided between cable lugs and bushings for all cables of 300 mm^2 section and greater.

There shall be no possibility of oil entering the cable box from an associated oil filled compartment.

Inner sheaths shall be arranged to project at least 25 mm above the gland plate to avoid moisture collecting in the crutch.

All cable boxes shall be designed to withstand the high voltage D.C. cable tests prescribed in IEC 60055, IEC 60502 or other applicable standard.

Cable lugs and terminations for the receipt of all power, control and instrumentation cable cores shall be provided.

Where air insulated terminations are used, the cable crutch within a cable box or equipment panel shall be protected by the use of a heat-shrink plastic trifurcating sleeve or equivalent placed over the cores and crutch.

The Contractor shall provide full information and instruction for his proposed method of terminating HV cables.

Removable gasketted steel gland plates shall be provided for multicore cables. The cable entry into the cable box shall be arranged so that there is adequate space to manipulate the cable for glanding and termination.

When single core cables are used, particularly for currents in excess of 500 A, adequate steps must be taken to minimise the effects of eddy currents in the gland and bushing-mounted plate.

Gland plates for externally mounted marshalling boxes shall be in the form of removable gasketted steel plates, forming part of the underside of the box. Indoor marshalling boxes may be fitted with gland plates on all four sides.

2.38.2 Additional Requirements for Compound-filled Cable Boxes

Cable boxes for paper insulated cables shall be complete with universal tapered brass glands, insulated from the box in an approved manner and including an island layer for testing purposes, together with removable shorting links.
Filling and venting plugs, where required, shall be positioned so as to avoid the possibility of air being trapped internally and adequate arrangements shall be made for expansion of compound, etc.

Compound-filled chambers shall be clean and dry and at such a temperature before filling that the compound does not solidify during the filling process. Filling orifices shall be sufficiently large to permit easy and rapid filling.

2.38.3 Cable Glands

Cable glands for extruded solid dielectric insulated cables (PVC, EPR, XLPE) shall be of the compression type and as specified in BS 6121 Part 1.

All glands shall be provided with an earthing tag or equal facility. For cables having conductors not larger than 4 mm² serrated washers may be used in place of earthing tags to provide earth continuity.

Glands for armoured or screened cables greater than or equal to 240 mm² and all insulated glands for power cables shall be provided with an integral earthing lug. On cable glands up to and including 40 nominal size, the earthing connection shall have a short circuit rating of at least 25 kA for 1 second and of at least 40 kA for 1 second on larger sizes.

Insulated glands shall be provided with removable connections for bonding across the gland insulation. The gland insulation shall withstand a wet insulation voltage withstand test of at least 2 kV A.C. for 1 minute.

Under conditions of severe corrosion, corrosion-resistant cable glands complying with BS 6121 Part 3 may be used, or the Contractor may use an alternative solution with the approval of the Engineer.

Polymeric cable glands complying with BS 6121 Part 2 may be used, but only when terminating un-armoured cables.

Glands for MICS cables shall be to the approval of the Engineer.

2.39 Box-Filling Compounds

The type of compound shall be to the approval of the Engineer, who shall be supplied with sufficient information by the Contractor. The Contractor shall supply all compound required together with an additional quantity of not less than 10% of normal requirements.

Where hot-pouring compounds are employed the pouring temperature shall be verified by use of thermometers or similar instruments and the metallic case of all joints and terminal boxes shall be adequately pre-warmed to drive off moisture.

The Contractor shall take particular care to adhere to the recommended topping-up procedures and to ensure that no leakage or migration of the filling compound occurs.

Should leakages occur during the maintenance period the Engineer will require the joint to be re-made at the Contractor's expense.

2.40 Oil or Compound-Filled Chambers

All joints of oil- or compound-filled fabricated chambers, other than those that have to be broken, shall be welded and care shall be taken to ensure that the chambers are oil-tight. Defective welded joints shall not be repaired but maybe re-welded subject to the written approval of the Engineer.

Insulating compound shall comply with BS 1858.

The correct oil or compound filling level shall be indicated on the inside and outside of chambers.

2.41 Joints and Gaskets

All joint faces are to be flat and parallel to the approval of the Engineer and arranged to prevent the ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of oil or air. Oil-resisting synthetic rubber gaskets are not permissible, unless the degree of compression is accurately controlled. For gaskets of cork or similar, oil resisting synthetic rubber may be used as a bonding medium.

2.42 Valves on Electrical Equipment Fluid Lines and Vessels

Valves shall comply with the requirements of Clause 2.19. All drain and filter valves shall be provided with gun metal adaptors suitable for connecting a flexible hose having a screwed coupling of approved size. Captive-screwed caps shall be provided for all such adaptors.

2.43 Junction and Marshalling Boxes

Junction and marshalling boxes for use in non-hazardous areas shall be of substantial sheet aluminium anodised coating construction to prevent corrosion, having an enclosure classification in accordance with the requirements of clause 2.27.2. They shall be fitted with external fixing lugs and finished in accordance with the requirements of the specification for cleaning, painting and finishing. The boxes shall allow ample room for wiring, with particular regard to the routing of wires from the point of entry. Boxes made from aluminium shall be subject to agreement with the Engineer.

Outdoor boxes shall have an anti-condensation finish and all boxes shall be designed such that any condensed water cannot affect the insulation of the terminal boards or cables. No cables shall be terminated into the top of outdoor boxes unless specifically approved by the Engineer.

All outdoor kiosks, cubicles and panels shall be provided with sun/rain shades. All kiosks, cubicles and panels not in air-conditioned rooms shall be provided with thermostat controlled anti-condensation heaters. All kiosks, and cubicles shall be fitted with door operated internal illumination lamps. All necessary gland plates shall be provided undrilled.

Boxes shall be complete with suitably inscribed identification labels. Boxes for use in hazardous areas shall have all entries factory pre-drilled. Every unused screwed entry shall be sealed by means of a tamperproof screwed plug in accordance with IEC 60079. Hazardous area boxes with bolted or screwed lids shall require the use of special keys or spanners, for lid removal, protected against the ingress of moisture, by an approved means, compliant with local standards.

All box covers are to be arranged for padlocking and padlocks with keys shall be supplied.

All boxes shall be provided with adequate earthing bars and terminals.

2.44 Conduit and Accessories

Conduit installations shall comply with IEC standards 60364, 60621, 60981 and 61035. Installations shall also be compliant with local regulations, unless otherwise approved by the Engineer.

All conduit and conduit fittings shall comply with IEC 60423 and IEC 60614. Unless otherwise approved, all conduit and conduit fittings shall be threadable steel conduit with minimum enclosure classification IP55, heavy mechanical protection and high resistance to corrosion inside and outside.

No conduit smaller than 20mm diameter shall be used.

Standard circular boxes or machined face heavy duty steel adaptable boxes with machined heavy type lids shall be used throughout. For outdoor mounting all boxes shall be galvanised, weatherproof and fitted with external fixing lugs.

Where conduit is terminated so that the bare end of the conduit is exposed the conduit end shall be fitted with a brass bush.

The use of running threads, solid elbows and solid tees will not be permitted.

Conduit ends shall be carefully reamed to remove burrs. Draw-in boxes shall be provided at intervals not exceeding 10 m in straight-through runs.

Conduit runs shall be in either the vertical or horizontal direction, unless otherwise approved, and shall be arranged to minimise accumulation of moisture. Provision for drainage shall be made at the lowest points of each run.

Conduits shall be supported on heavy galvanised spacer saddles so as to stand off at least 6mm from the fixing surface.

All conduits run in any circuit are to be completed before any cables are pulled in.

Flexible metallic conduit shall be used where relative movement is required between the conduit and connected apparatus, and a separate earth continuity conductor shall be provided.

2.45 Trunking

Steel trunking may be used for running numbers of insulated cables or wires in certain positions to the approval of the Engineer. The trunking thickness shall not be less than 1.2 mm. Connection of conduit to trunking shall be with socket and male bush. All trunking shall be manufactured from hot-dip zinc coated steel sheet and conform to IEC 61084.

2.46 Electric Motors

2.46.1 General

Motors shall comply with the requirements of IEC 60034 and IEC 60072 as amended and supplemented by this specification.

2.46.2 Type and Rating

Except where specified otherwise or economically justified, all A.C. motors shall be of the constant speed, cage induction type with windings adequately braced for direct-on-line starting at the rated volt-age. They shall be suitable for control by either circuit breaker or fused contactor.

Motors shall be continuously rated, Duty Type S1. Exceptions shall be permitted only when the intermittent or short time duty cycle can be accurately defined by the Contractor.

Three phase A.C. motors shall be rated for the voltages specified elsewhere in the Specification. The minimum rated output of HV motors shall comply with IEC 60034-1. The maximum rated output of LV motors shall not exceed 150 kW, except where approved by the Engineer.

2.46.3 Insulation

Motors shall be insulated with materials complying with IEC 60085. All motors shall have Class F insulation but the temperature rise shall not exceed the limits applicable to Class B.

2.46.4 Conditions of Operation

A.C. motors shall be capable of continuous operation under the service conditions within the Zone A voltage and frequency variations specified in IEC 60034-1 Figure 13 or as covered in Clause 4.1 which-ever is the most onerous. Unless otherwise specified, the motors shall be capable of continued operation at 75% rated voltage and rated frequency for a period of 5 minutes without injurious heating. In the event of loss of supply, all motors shall be suitable for restarting against the full residual voltage in the motor winding during motor run-down.

2.46.5 Starting Performance

Unless otherwise specified or required, cage induction motors up to and including 40 kW shall have a starting performance better than or equal to Design N in accordance with IEC 60034 (External inertias for 50 and 60 Hz motors shall be in accordance with BS 4999 Part 112). Cage induction motors above 40 kW shall have a starting performance better or equal to Design D in accordance with BS 4999 Part 112. The starting current at full voltage shall not exceed 6 times full load current.

The starting torque at 80% voltage shall be adequate for starting the driven load under the most arduous conditions, such as open fan vane or open pump discharge valve. The accelerating torque at any speed and 80% rated voltage shall be not less than 10% of motor rated torque. In any event the motor starting torque at 100% rated voltage, and at all speeds between standstill and the speed at which breakdown torque occurs, shall be not less than 1.7 times the torque obtained from a load curve which varies as the square of the speed and is equal to 100% motor rated torque at rated speed.

The margins between the torques of the motors and driven plant shall include suitable allowances for impeller wear, fouling etc. during the life of the plant.

Electric motors shall be suitable for two successive starts with the motor already at full load working temperature, subject to the motor being permitted to decelerate to rest under operating conditions be-tween successive starts. After a cooling period of 30 minutes at rest another starting sequence of two successive starts shall be permissible.

2.46.6 Bearings

The type of bearings used in the motor shall be fully compatible with those used in the driven equipment. The type of bearing, bearing numbers and regressing interval shall be stamped on each motor rating plate. Bearings shall comply with the applicable ISO standards. Bearings shall be designed to exclude the ingress of dust and water and sealed to prevent leakage of lubricant along the shaft.

2.46.7Enclosures and Methods of Cooling

The degree of enclosure protection for motors shall be as follows unless otherwise specifically approved by the Engineer:

- IP54 for indoor locations not subject to hosing.
- Not less than IP 55W for outdoor locations, and indoor locations subject to hosing.
- Where motors are exposed to solar radiation, sunshades shall be fitted, if required by the Manufacturer to meet his guarantees.

The cooling classification for motors shall be as follows unless otherwise specifically approved by the Engineer:

- IC4AlA1 or IC5AIA1 for LV motors, or IC4AIAO for small power LV motors.
- IC4AlAl, IC5AlAI, IC6A1A1 or IC7AlW7 for HV motors.
- Ferrous metals should be used for the frames and end shields of all ratings of motors.

Aluminium and its alloys shall only be used when the Manufacturer can demonstrate that such materials are entirely suitable for the particular application at its installation location. Fans of identical motors shall be interchangeable without affecting motor balance.

2.46.8 Anti-condensation Heaters

To minimise condensation in all outdoor 400V and intermittently used 400 V motors when out of service, heaters of an approved type and rating, suitable for operation from a 230 V A.C. single phase supply, shall be fitted inside the lower half of the stator frame.

The control of anti-condensation heaters shall be so arranged that they are normally enegised when the motor is not running.

2.46.9 Terminals and Terminal Boxes

Winding terminations shall generally comply with BS 4999 Part 145. Separate non-compound filled, terminal boxes shall be provided for each of the following, as applicable:

- Main (line) connections.
- Star point connections.
- Anti-condensation heater connections.
- Instrumentation and alarm devices.

All terminal boxes with the cables terminated shall have an enclosure classification not less than that of the motor itself. All terminal boxes shall be of an adequate size for the satisfactory termination of the cable(s) required or specified, including all applicable termination components. All HV terminal boxes shall be provided with a desiccant indicator, externally sealed.

Terminals and terminal leads shall be to approval and shall be substantially designed for connection to a system having the symmetrical short circuit rating of the source switchboard, as limited by fuses, where applicable. The clearances and creepage distances shall apply also to insulated terminals and connectors. Porcelain terminal bushings and insulators shall not be used.

Main and star point terminal boxes of HV motors shall be of steel. Cast iron may only be used for LV motor terminal boxes and auxiliary terminal boxes. Star point terminal boxes shall only be provided where required to accommodate neutral end current transformers and shall be positioned opposite the main terminal box.

Main HV terminal boxes at voltages exceeding 7.2 kV (Um) shall be of a type that restricts internal faults to earth faults only. Where pressure relief terminal boxes are used, they shall be designed to relieve the products of an internal fault safely to the outside, and not into the interior of the motor.

Provision shall be made for earthing the cable armour and the cable insulation screens, where applicable, in accordance with the cable termination method being used. In auxiliary cable boxes either stud terminals or clamp terminals shall be provided. The anti-condensation heater terminal box shall have a warning label adjacent to it, stating "motor heater-terminals live".

2.46.10 Earth Terminal

All motors shall be provided with a means of earthing the frame, which shall be to the approval of the Engineer.

2.46.11 D.C. Motors

D.C. motors that are to operate from batteries shall be capable of operating under the service conditions at any voltage in the range of 80% to 110% of the nominal value.

Motors of the constant speed type shall be designed to operate with a permanent series resistor of suitable rating and with a contactor such that starters with tagged resistors are not required.

All D.C. motors shall be provided with brush-gear that does not require to be moved to suit load conditions.

Motors connected to rectifier equipment shall meet the conditions of supply voltage and frequency specified for A.C. motors. Where necessary, rectifier equipment shall be fitted with a current limiting device.

2.47 Motor Starters and Contactors for Separate Mounting

In special cases for motors below 30 kW, and non-essential non-plant auxiliaries, such as roller shutter doors, and where approved by the Engineer, separately mounted starters for motors may be provided. Each such motor starter shall be equipped with two or three pole control gear, as appropriate, for direct-on-line starting and shall be complete with a fully shrouded lockable isolating switch, mechanically interlocked with the means of access. All starters shall be supplied by one Manufacturer, except where otherwise approved by the Engineer.

Contactors shall be of robust design and shall comply with IEC 60947. All contactors and their associated apparatus for minor motors shall be capable of operating without overheating for all specified motor operating conditions, and including for a period of five minutes at normal frequency if the supply voltage falls to 80% of nominal voltage.

For motors up to 30 kW rating motor starters shall be provided with direct connected thermal overload and phase failure industrial pattern protection tripping devices, integral with the motor contactor. Phase failure protection shall operate with out-of-balance currents not exceeding 85% of motor full load cur-rent. Separate contacts for a remote trip alarm shall be provided, and connected up if required.

For motors above 30 kW starters shall not be wall mounted but included in a switchboard. For such circuits motor protection relays with a more accurate and easily adjustable overload setting shall be used, which are sensitive to out-of-balance currents not exceeding 20% of full load, and shall include instantaneous earth fault elements. Alternatively, instantaneous earth fault protection may be incorporated in the motor circuit breaker. The earth fault protection shall not operate for unbalanced current surges during motor starting.

2.48 Pushbuttons and Separately Mounted Pushbutton Stations

Pushbuttons, which may be of the illuminated or non-illuminated type, shall be shrouded or well recessed in their housings in such a way as to minimise the risk of inadvertent operation. In instances where "enable" pushbuttons are required they shall be electrically interlocked with the normal control such that deliberate operation of the "enable" push-button is required before the normal control can take place.

- The colour of pushbuttons shall be as follows:
- When mounted on pushbutton stations adjacent to running plant:
  - the stop button shall be coloured red and
  - the start button coloured green.
- When mounted on the front of the contactor panel:
  - the stop button shall be coloured red and
  - the start button coloured green.
- When mounted on panels or desks with adjacent indication lights, unless required otherwise by the Engineer:
  - both buttons shall be coloured black

Loose pushbutton stations, unless supplied as weatherproof free standing enclosures, shall be of the metalclad weatherproof type suitable for wall or bracket mounting with a minimum enclosure classification of IP55.

All outdoor mounted pushbutton stations shall incorporate a protective cover or guard (e.g. toughened glass door) to prevent inadvertent operation.

Control stations shall be clearly labelled showing the duty or drive to which they are applicable. Location of ammeters shall be agreed with the Engineer.

Any necessary pushbuttons used on covered desks, panels etc. have to be of special types (e.g. miniature, illuminated). The specifications and requirements for these special pushbuttons shall be agreed with the Engineer.

Emergency stop pushbuttons shall be provided adjacent to all motors and machinery with exposed moving parts, couplings etc. to prevent danger, and on main and local control panels. These push buttons shall have a large "mushroom" head, be coloured red and incorporate a protective cover or guard to avoid accidental operation. These buttons shall automatically lock in the depressed position, requiring twist or key resetting. Contacts shall be provided to cause tripping of the associated circuit, prevent restart of the circuit and bring up an alarm in the Central Control Room.

Stop pushbuttons mounted local to motors shall trip the associated circuit breaker or contactor regard-less of the control position selected.

The contacts of all pushbuttons shall be shrouded to minimise the ingress of dust, and accidental con-tact, and shall be amply rated for voltage and current for the circuits in which they are used.

2.49 Miniature Circuit Breakers, Fuses and Links

Facilities shall be provided for protection and isolation of circuits associated with protection, control and instruments. They shall be of approved type and grouped, as far as possible, according to their functions. They shall be clearly labelled, both on the panels and the associated wiring diagrams.

Facilities shall be provided to enable the control circuits for any circuit breaker to be individually isolated for maintenance purposes.

Facilities for protection and isolation of control and tripping circuits are preferably to be mounted on the outside of control panels in approved positions.

All fuses shall incorporate HRC cartridges to BS 88 or IEC 60269.

Fuse holders shall be designed to lock the cartridges firmly into position without the use of screw clamping devices.

Miniature circuit breakers (MCB's) shall comply with IEC 60898.

Where MCB's are used on control, protection and alarm supplies, tripping shall cause an alarm to be displayed.

2.50 Earthing and Bonding

The main earthing conductors for connection to all electrical equipment, cables, motors, panels, etc., shall be provided for connection to the main earthing system.

All non-current carrying metal parts of electrical equipment shall be bonded to an earth terminal or terminals mounted on the equipment and readily accessible.

All equipment terminals provided for an external earth connection shall be identified by indelible means unless such terminals are directly and visibly mounted on metallic equipment frames or earth bars, when such marking may be omitted.

Identification marks for earth terminals shall comprise the colours green/yellow in combination or a reproduction of the symbol no. 5019 in IEC 60417.

Assemblies containing electrical equipment, including switchboards, control boards and control desks, shall be provided with a separate copper earth bar running the length of the assembly. All metal parts and the earth terminal or terminals shall be bonded to this earth bar. Earthing connections shall not depend upon the bolting of steel/steel joints between adjacent panels or cubicles.

Earth bars shall be of adequate size and suitably supported and braced to carry the rated short circuit current for the associated electrical circuits for the rated short-circuit current duration, without damage or excessive heating likely to damage joints, associated or adjacent components.

Switchgear and control gear assemblies shall be provided with two or more earth terminals unless otherwise specified. The copper earth bar shall be sized to withstand the maximum system earth fault current for three seconds without deterioration.

The size of the copper earth bar in control panels, control desks or similar enclosures containing low voltage apparatus shall be such as to comply with the specified requirements for withstanding prospective short-circuit currents. The size of this bar shall be a minimum of 100 mm² cross sectional area, providing that sufficient mechanical integrity is provided by adequate supports and terminals, and also providing this size is not less than the size of the largest incoming power supply conductor.

The metal cases of all instruments, relays and the like shall be connected to the panel earth bars by copper conductors of not less than 1.5 mm² cross-sectional area, or by other means to the approval of the Engineer.

If the plant contains electronic equipment that is vulnerable to possible conductive interference, or if the equipment generates electrical noise, which could interfere with other plant or equipment, then separate earth may be supplied and the actual means of interconnecting with the station earth system shall be agreed with the Engineer.

3. HV Switchgear and Outdoor Equipment

3.1.Scope

3.1.1. These clauses describe the general technical requirements for the new 420 kV, 245 kV and 145kV Gas Insulated Switchgears (GIS) with 420kV and 36kV Switchgears (AIS), which shall be read in conjunction with the project requirements, schedules and drawings in the specification.

3.1.2. The Contractor shall demonstrate that the switchgear has been designed, built and installed in accordance with the relevant international standards and the specification. It shall also operate and perform on a site in accordance with the requirements of the specification and in the environment defined therein.

3.1.3. The design shall be proven by the submission of test certificates at the time of bidding covering all specified tests deemed to be pertinent to the plant and to the conditions in which it will operate.

3.1.4. The requirement for switchgear spares, tools and appliances, including test, maintenance and handling equipment shall be as stated in the Bid document. All devices necessary for operation and earthing shall be provided within the contract price.

3.1.5. **Installation, testing and commissioning of all switchgears shall be done by the switchgear engineer(s) of the switchgear(s) manufacturer(s).**

3.2. References

3.2.1. IEC Standards

Except where modified by this specification, the switchgear and/or accessories shall be designed, manufactured and tested in accordance with the latest IEC Standards and other publications quoted in these Standards.

- IEC 60044 Instrument transformers
- IEC 60060 High voltage test techniques
- IEC 60071 Insulation coordination
- IEC 60099 Surge arresters
- IEC 60137 Bushings for alternating voltages
- IEC 60265-1 High-voltage switches - Part 1: Switches for rated voltages above 1 kV and less than 52 kV
- IEC 60265-2 High-voltage switches. Part 2: High-voltage switches for rated voltages of 52 kV and above
- IEC 60269 Low voltage fuses

- IEC 60273 Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000V
- IEC 60282 High voltage fuses.
- IEC 60305 Insulators for overhead lines with a nominal voltage above 1000V - Ceramic or glass insulator units for ac systems - Characteristics of insulator units of the cap and pin type.
- IEC 60358 Coupling capacitors and capacitor dividers
- IEC 60364 Electrical installation of buildings
- IEC 60376 Specification of technical grade sulphur hexafluoride (SF6) for use in electrical equipment
- IEC 60383 Insulators for overhead lines with a nominal voltage above 1000V
- IEC 60815 Guide for the selection of insulators in respect of polluted conditions
- IEC 60865-1 Short-circuit currents - Calculation of effects
- IEC 61639 Direct connection between power transformers and gas insulated metal enclosed switchgear for rated voltages of 72.5 kV and above
- IEC 62155 Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1000 V
- IEC 62271-1 HV switchgear and controlgear - part 1: common specifications
- IEC 62271-100 HV switchgear and controlgear - part 100: AC circuit breakers
- IEC 62271-103 Switches for rated voltage above 1 kV and less than 52 kV
- IEC 62271-104 Switches for rated voltage of 52 kV and above
- IEC 62271-102 HV switchgear and controlgear - part 102: AC disconnectors and earthing switches
- IEC 62271-200 HV switchgear and controlgear - part 200: A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
- IEC 62271-203 HV switchgear and controlgear - part 203: Gas insulated metal-enclosed switchgear for rated voltages 52 kV and above
- IEC 62271-209 HV switchgear and controlgear - part 209: Cable connections for gas insulated metal-enclosed switchgear for rated voltages of 52 kV and above

3.2.2. British Standards

- BS 7884 Specifications for hard-drawn copper and copper cadmium conductors for overhead power transmission purposes
- BS EN 60383-2 Insulators for overhead lines with voltage greater than 1000V.
- BS 159 Specifications for HV busbars and busbar connections
- BS 215S Specifications for aluminium conductors for overhead transmission
- BS EN 13600 Specifications for high conductivity copper tubes for electrical purposes
- BS 2898 Specifications for wrought aluminium for electrical purposes. Strip with drawn or rolled edges.
- BS 3288 Insulator and conductor fittings for overhead power lines.
- BS 3938 Current Transformers
- BS 6651 Lightning Protection
- BS 7354 Code of practice for design of HV open terminal stations.

3.3. Design Principles

3.3.1. General Requirement

3.3.1.1. The GIS shall be designed, manufactured and tested in accordance with the best international engineering practices under strict quality control to meet the requirement stipulated in the technical specification. Adequate safety margin with respect to thermal, mechanical, dielectric stress and insulation coordination etc. shall be maintained during design, selection of raw material, manufacturing process etc. so that the GIS provides long life with least maintenance. The workmanship shall be of the highest quality and shall conform to the latest modern practices for the manufacture of high technology machinery and electrical switchgear.

3.3.1.2. The GIS assembly shall consist of separate modular compartments e.g. Circuit Breaker compartment, Bus bar compartment filled with SF6 Gas and separated by gas tight partitions so as to minimize risk to human life, allow ease of maintenance and limit the effects of gas leaks failures & internal arcs etc. These compartments shall be such that maintenance on one feeder may be performed without de-energising the adjacent feeders. These compartments shall be designed to minimize the risk of damage to adjacent sections and protection of personnel in the event of a failure occurring within the compartments. Rupture diaphragms with suitable deflectors shall be provided to prevent uncontrolled bursting pressures developing

within the enclosures under worst operating conditions, thus providing controlled pressure relief in the affected compartment.

3.3.1.3. The switchgear, which shall be of modular design, shall have complete phase isolation. The conductors and the live parts shall be mounted on high graded epoxy resin insulators. These insulators shall be designed to have high structural strength and electrical dielectric properties and shall be free of any voids and free of partial discharge at a voltage which is at least 5% greater than the rated voltage. These shall be designed to have high structural and dielectric strength properties and shall be shaped so as to provide uniform field distribution and to minimize the effects of particle deposition either from migration of foreign particles within the enclosures or from the by-products of SF6 breakdown under arcing conditions.

3.3.1.4. All circuit breakers, disconnect switches and other component of GIS having identical rating shall have identical and interchangeable parts and operating mechanism as far as possible.

3.3.1.5. Gas barrier insulators shall be provided so as to divide the GIS into separate compartments. These shall be suitably located in order to minimize disturbance in case of leakage or dismantling. They shall be designed to withstand any internal fault thereby keeping an internal arc inside the faulty compartment. Further, it is prohibited to work adjacent to a gas compartment while it is fully pressurized on the other side. For such cases, the gas pressure in the adjacent compartments needs to be reduced.

3.3.1.6. The switchgear shall be of the free standing, self-supporting with easy accessibility to all the parts during installation & maintenance with all high-voltage equipment installed inside gas-insulated metallic and earthed enclosures. GIS manufacturer shall ensure the service continuity requirement and GIS should be suitably sub-divided into individual arc and gas-proof compartments preferably for:

i) Bus bars
ii) Intermediate compartment
iii) Circuit breakers
iv) Feeder Disconnect Switch
v) Voltage Transformers
vi) Gas Insulated bus duct section between GIS and XLPE cable/Overhead/ Conductor.
vii) Gas Insulated bus section between GIS & Oil filled Transformer/ Reactor (if applicable)

3.3.1.7. For Double Busbar scheme, the Bus design shall consider busbar Disconnector in separate compartment. Moreover, at-least two interlock bypass switch shall be provided, one for Busbar side ES and other for all other equipment.

3.3.1.8. Service continuity requirement:

The GIS equipment with the given bus switching arrangement is divided into different gas compartments. During the work such as a fault repair or major maintenance, requiring the dismantling of a gas compartment for which more than one compartments may need to be de-gassed. Working conditions, method statements and procedures are to be furnished by the GIS manufacturer in order to ensure equipment and operating personnel's safety and to achieve following Service continuity conditions to the extent possible:

i) For One & half breaker bus switching scheme during a fault in CB compartment, No bus bar and feeder is permitted out of service during maintenance and repair/replacement.

ii) For Double Main bus switching scheme during a fault in CB compartment, No bus bar permitted out of service during maintenance and repair/replacement.

iii) During a fault in GIS compartment other than CB compartment, maximum one bus bar and/or one feeder permitted out of service during maintenance and repair/replacement.

3.3.1.9. The material and thickness of the enclosures shall be such as to withstand an internal flash over without burns through for a period of 300 ms at rated short time withstand current. The material shall be such that it has no effect of environment as well as from the by-products of SF6 breakdown under arcing condition. This shall be validated with Type Test.

3.3.1.10. Each section shall have plug-in or easily removable connection pieces to allow for easy replacement of any component with the minimum of disturbance to the remainder of the equipment. Inspection windows (View Ports) shall be provided for Disconnect Switch and both type of earth switches i.e. Maintenance and fast operating.

3.3.1.11. The material used for manufacturing the switchgear equipment shall be of the type, composition and have physical properties best suited to their particular purposes and in accordance with the latest engineering practices. All the conductors shall be fabricated of aluminum/ copper tubes of cross-sectional area suitable to meet the normal and short circuit current rating requirements. The finish of the conductors shall be clean and smooth so as to prevent any electrical discharge. The conductor ends shall be silver plated and fitted into finger contacts or tulip contacts. The contacts shall be of sliding type to allow the conductors to expand or contract axially due to temperature variation without imposing any mechanical stress on supporting insulators.

3.3.1.12. Each pressure filled enclosure shall be designed and fabricated to comply with the requirements of the applicable pressure vessel codes and based on the design temperature and design pressures as defined in IEC-62271-203.

3.3.1.13. The maximum SF6 gas leakage shall not exceed 0.1% per year for the whole equipment and for any individual gas compartment separately and the leakage rate shall be guaranteed for at least 10 years. In case the leakage under the

specified conditions is found to be greater than 0.1% after one year of commissioning, the manufacturer will have to supply free of cost, the total gas requirement for subsequent ten (10) years, based on actual leakage observed during the first year of operation after commissioning.

3.3.1.14. Each gas-filled compartment shall be equipped with static filters, density switches, filling valve and safety diaphragm. The filters shall be capable of absorbing any water vapor which may penetrate into the enclosures as well as the by-products of SF6 during interruption. Each gas compartment shall be fitted with non-return valve connectors for evacuating & filling the gas and checking the gas pressure etc.

3.3.1.15. The switchgear when installed and operating under the ambient conditions shall perform satisfactorily and safely under all normal and fault conditions. Even repeated operations up to the permissible servicing intervals under 100% rated and fault conditions, shall not diminish the performance or significantly shorten the useful life of the switchgear. Any fault caused by external/internal reasons shall be positively confined to the originating compartment and shall not spread to other parts of the switchgear.

3.3.1.16. The thermal rating of all current carrying parts shall be minimum for one second. for the rated symmetrical short-circuit current.

3.3.1.17. The arrangement of the individual switchgear bays shall be such so as to achieve optimum space-saving, neat and logical arrangement and adequate accessibility to all external components.

3.3.1.18. Layout of the substation equipment, bus bars and switchgear bays shall preferably be based on the principle of “phase grouping”. Switchgear layout based on the “mixed phases” principle shall not be accepted without mutual agreement between supplier and employer. The arrangement of the equipment offered must provide adequate access for operation, testing, repair and maintenance.

3.3.1.19. All the elements shall be accessible without removing support structures for routine inspections. The removal of individual enclosure parts or entire breaker bays shall be possible without disturbing the enclosures of neighboring bays and LCC panels.

3.3.1.20. It should not be possible to unwillingly touch live parts of the switchgear or to perform operations that lead to arcing faults without the use of tools or brute force. All interlocks that prevent potentially dangerous mal-operations, shall be constructed such that they cannot be operated easily, i.e. the operator must use tools or brute force to over-ride them.

3.3.1.21. In general the contours of energized metal parts of the GIS and any other accessory shall be such, so as to eliminate areas or points of high electrostatic flux concentrations. The surfaces shall be smooth with no projection or irregularities which may cause visible corona. No corona shall be visible in complete darkness which the equipment is subjected to specified test voltage. There shall be no radio interference from the energized switchgear at rated voltage.

3.3.1.22. The GIS shall be designed, so as to take care of the VFT over voltages generated as a result of pre-strikes and re-strikes during isolator operation. Maximum VFT over voltages peak shall not be higher than rated lightning impulse withstand voltage (LIWV) of the equipment. Necessary measures shall be under taken by GIS manufacture to restrict maximum VFT over voltages lower than the LIWV. Manufacturer shall submit the study report of VFTO generated for GIS installation.

3.3.1.23. The enclosure shall be of continuous design and shall meet the requirement as specified in of IEEE 80-2013 (special considerations for GIS). The enclosure shall be sized for carrying induced current equal to the rated current of the Bus. The conductor and the enclosure shall form the concentric pair with effective shielding of the field internal to the enclosure.

3.3.1.24. The fabricated metal enclosures shall be of Aluminum alloy having high resistance to corrosion, low electrical loses and negligible magnetic losses. All joint surfaces shall be machined and all castings shall be spot faced for all bolt heads or nuts and washers. All screws, bolts, studs and nuts shall conform to metric system.

3.3.1.25. The elbows, bends, cross and T-sections of interconnections shall include the insulators bearing the conductor when the direction changes take place in order to ensure that live parts remain perfectly centered and the electrical field is not increased at such points.

3.3.1.26. The enclosure shall be designed to practically eliminate the external electromagnetic field and thereby electro-dynamic stresses even under short circuit conditions. The average intensity of electromagnetic field shall not be more than 50 micro-Tesla on the surface of the enclosure.

3.3.1.27. The switchgear shall have provision for connection with ground mat risers through copper connections. This provision shall consist of grounding pads to be connected to the ground mat riser in the vicinity of the equipment.

3.3.1.28. For GIS, wherever required, stairs, fixed ladder, platforms, and walkways for operation and maintenance access to the operating mechanism and monitoring devices should be provided to permit access. The structures shall be either aluminum or hot-dipped galvanized steel. All structures, stairs, platforms, and walkways shall conform to the relevant occupational health and safety regulations and designed in accordance with the latest industry standards and guidelines. The platforms and walkways shall have anti-skid surfaces that can be walked on. Handrails shall be provided where necessary. The GIS supplier shall provide 3-D arrangement drawing to show the location of equipment and access to it.

3.3.1.29. In addition to above suitable portable scissor lift shall be provided for access of distant portion of GIS installation.

3.3.1.30. New gasket, O-ring, sealant and desiccant shall be installed for permanent sealing of all site/field assembled joints. No gaskets & no O-rings are to be reused for any permanent seal broken or disturbed in the field/site.

3.3.1.31. The enclosure & support structure shall be designed such that person of 1780 mm in height and 80 kg in weight is able to climb on the equipment for maintenance.

3.3.1.32. The sealing provided between flanges of two modules / enclosures shall be such that long term tightness is achieved.

3.3.1.33. Alarm circuit shall not respond to faults for momentary conditions. The following indications including those required elsewhere in the specifications shall be generally provided in the alarm and indication circuits.

i) Loss of Gas Density
ii) Any other alarm necessary to indicate deterioration of the gas insulating system.
iii) Low operating pressure
iv) Loss of Heater power
v) Loss of operating power
vi) Loss of control supply
vii) Pole Discordance.

3.3.1.34. The equipment will be operated under the ambient conditions defined in the Chapter 1.7.

3.3.1.35. Temperature rise of all current carrying parts and enclosures shall be limited to the values stipulated in IEC-62271-1, under rated current and the climatic conditions as specified.

3.3.1.36. All cabinet heaters shall be rated for 230V AC (1-phase) supply and shall be complete with thermostat, control switches and fuses, connected as a balanced 3-phase 4-wire load. The heaters shall be so arranged and protected as to create no hazard to adjacent equipment from the heat produced.

3.3.1.37. Bellows or Compensating Units: Adequate provision shall be made to allow for the thermal expansion of the conductors & enclosures and for differential thermal expansion between the conductors and the enclosures. The bellows metallic (preferably stainless steel) with suitable provision for permitting the movement during expansion and contraction may be provided and shall be of following types:

i. Lateral / Vertical mounting units: These shall be inserted, as required, between sections of busbars, on transformer, shunt reactor and XLPE cable etc. Lateral mounting shall be made possible by a sliding section of enclosure and tubular conductors.

ii. Axial compensators: These shall be provided to accommodate changes in length of busbars due to temperature variations.

iii. Parallel compensators: These shall be provided to accommodate large linear expansions and angle tolerances.

iv. Tolerance compensators: These shall be provided for taking up manufacturing, site assembly and foundation tolerances.

v. Vibration compensators: These bellow compensators shall be provided for absorbing vibrations caused by the transformers and shunt reactors when connected directly to SF6 switchgear by oil- SF6 bushings.

3.3.1.38. The electrical connections across the bellows or compensating units shall be made by means of suitable connectors. For sliding type compensators, markers/pointers shall be provided to observe expansion or contraction during climatic conditions.

3.3.1.39. Indication and verification of switch positions: Indicators shall be provided on all circuit breakers, isolators and earth-switches, which shall clearly show whether the switches are open or closed. The indicators shall be mechanically coupled directly to the main contact operating drive rod or linkages and shall be mounted in a position where they are clearly visible from the floor or the platform in the vicinity of the equipment. Inspection windows shall also be provided with all isolators and earth switches so that the switch contact positions can be verified by direct visual inspection.

3.3.1.40. Pressure relief device: Pressure relief devices shall be provided in the gas sections to protect the gas enclosures from damage or distortion during the occurrence of abnormal pressure increase or shock waves generated by internal electrical fault arcs (preferably in downward direction). Pressure relief shall be achieved either by means of diaphragms or plugs venting directly into the atmosphere in a controlled direction. If the pressure relief devices vent directly into the atmosphere, suitable guards and deflectors shall be provided.

3.3.1.41. Pressure vessel requirements: The enclosure shall be designed for the mechanical and thermal loads to which it is subjected in service. The enclosure shall be manufactured and tested according to the Pressure Vessel Code (ASME/CENELEC code for pressure Vessel.) The bursting strength of Aluminum castings has to be at least 5 times the design pressure. A bursting pressure test shall be carried out at 5 times the design pressure as a type test on each type of enclosure. Each enclosure has to be tested as a routine test at 1.5 times the design pressure for one minute.

3.3.1.42. Grounding:

3.3.1.42.1. The grounding system shall be designed and provided as per IEEE-80-2013 and CIGRE-44 to protect operating staff against any hazardous touch voltages and electro-magnetic interferences.

3.3.1.42.2. The GIS supplier (contractor) shall define clearly what constitutes the main grounding bus of the GIS. The contractor shall supply the entire material for grounding bus of GIS viz conductor, clamps, joints, operating and safety platforms etc. The contractor is also required to supply all the earthing conductors and associated hardware material for connecting all GIS equipment, bus ducts, enclosures, control cabinets, supporting structure, GIS surge arrestor etc. to the ground bus of GIS.

3.3.1.42.3. The enclosure of the GIS may be grounded at several points so that there shall be grounded cage around all the live parts. A minimum of two nos. of grounding connections should be provided for each of circuit breaker, bushing terminals, surge arrestors, earth switches and at each end of the bus bars. The grounding continuity between each enclosure shall be effectively interconnected either internally or externally with Copper/Aluminum bonds of suitable size to bridge the flanges. Subassembly to subassembly bonding shall be provided to bridge the gap & safe voltage gradients between all intentionally grounded parts of the GIS assembly & between those parts and the main grounding bus of the GIS.

3.3.1.42.4. Each marshaling box, local control panel, power and control cable sheaths and other non- current carrying metallic structures shall be connected to the grounding system of GIS via connections that are separated from GIS enclosures.

3.3.1.42.5. The grounding connector shall be of sufficient mechanical strength to withstand electromagnetic forces as well as capable of carrying the anticipated maximum fault current without overheating. At least two grounding paths shall be provided to connect each point to the main grounding bus. Necessary precautions should be under taken to prevent excessive currents from being induced into adjacent frames, structures of reinforcing steel and to avoid establishment of current loops via other station equipment.

3.3.1.42.6. All flexible bonding leads shall be tinned copper. All connectors, for attaching flexible bonding leads to grounding conductors and grounding conductors to support structures shall be tinned bronze with stainless steel or tinned bronze hardware.

3.3.1.42.7. The contractor shall provide suitable measure to mitigate transient enclosure voltage caused by high frequency currents due to by lightning strikes, operation of surge arrestor, phase to earth fault and discharges between contacts during switching operation. The grounding system shall ensure safe touch & step voltages in all the enclosures.

Best patterns for GIS earthing and bonding include the following:

i. All earthing conductors should be as short as possible.
ii. The earthing mesh and links should be in a position of conduct the system's fault currents without violating the thermal and mechanical boundaries.
iii. All exposed earthing conductors should be saved against mechanical destruction and placed so as not to present a "trip hazard" to operation staff.
iv. Adequate earthing and bonding methods, such as more conductors or voltage limiters, are needed at all separations within the GIS equipment. This includes SF6 gas-to-air links, SF6 gas-to-cable links, SF6 gas-to-oil links, and where GIB exits the building.
v. Make sure all metallic building spaces, GIS support structures, and GIS maintenance platforms are adequately earthed.
vi. GIS building slabs should include an imbedded GIS earthing mesh and reinforced steel, which should be bonded to the earthing mesh every 3 meters in both directions.
vii. All secondary cables should be shielded with both ends of each cable shield earthed to mitigate potential electromagnetic interference.

3.3.1.43. UHF sensors for PD detection:

Adequate number of UHF sensors shall be provided in the offered GIS for detection of Partial discharge (of 5 pC and above) as per IEC 60270. The number and location of these sensors shall be based on laboratory test on typical design of GIS as per recommendations of CIGRE Document No. 654 (Application Guide for Sensitivity Verification for UHF Partial Discharge Detection System for GIS). Offered numbers and location of UHF sensors shall be submitted based on above said criteria along with attenuation calculation for approval of the employer. Further UHF sensors shall necessarily be provided in close proximity to VT compartments. In case during site testing, additional UHF sensors are required, the same shall also be supplied & installed to complete the technical requirement. The calibration and frequency response of PD couplers shall be as per NGC Technical Guidance note TGN (T) 121, issue 1, 1997. Data sheet shall be submitted for the UHF couplers meeting this requirement.

3.3.1.44. GIS Building & GIB layout:

GIS Building & GIB shall be designed based on the following criteria

3.3.1.44.1. The buildings shall house each voltage class Gas Insulated Switchgear (GIS) and other associated equipment inside each of the GIS buildings. GIS building(s) shall be constructed for the specified number of bays/diameters as per section project.

3.3.1.44.2. For finalizing the dimensions of GIS building the requirement of Turning radius to rotate the largest removable component for assembly/disassembly shall be taken in to consideration.

3.3.1.44.3. Wherever GIS Building of already exists, then the existing GIS Building(s) for respective voltage class shall be suitably extended keeping the width of the building same to accommodate the number of bays/diameters as specified in the Technical Specification.

3.3.1.44.4. The contractor shall submit the design & construction proposal of the building along with necessary information, data, and drawings during the detailed engineering according to the complete requirements.

3.3.1.44.5. The contractor shall finalize the dimensions of GIS Building according to the equipment offered by them providing enough space & access for erection, operation and maintenance.

3.3.1.44.6. The contractor shall place their panels i.e. Bay level units, bay mimic, relay and protection panels, RTCC panels, Communication panels etc. in a separate Relay Panel Room in the GIS building. The size of the room shall be such that all the panels for the bays/ diameters as per clause 16.1 shall be accommodated in the above room. The panel room shall be air-conditioned. Further, the temperature of the room shall be monitored through substation automation system by providing necessary temperature transducers.

3.3.1.44.7. Maximum weight of gas in a gas tight section of GIB shall not exceed 400 kg (for 400 kV)/ 250 kg (for 230 kV & 132 kV).

3.3.1.44.8. GIB shall be generally in horizontal layer. However, in exceptional circumstance GIB in vertical layers can be provided with the approval of employer.

3.3.1.44.9. The minimum vertical ground clearance of GIB at road crossing shall be 5.5 meters.

3.3.1.44.10. The horizontal clearance between GIB and GIS building /any other building wall shall be preferably three (3) meters.

3.3.1.44.11. The GIB route inside the GIS Hall shall not obstruct easy access to GIS and control room buildings and shall not obstruct movement of crane, equipment including HV test equipment for maintenance works.

3.3.1.44.12. The GIB clear height outside the GIS hall in switchyard area shall be minimum 3.5 meter, so as not to obstruct easy access to GIB, movement of crane for maintenance work.

3.3.1.44.13. Optimization of outdoor GIB length using overhead AIS connection with Bus Post Insulator of respective voltage class is generally acceptable subject to meeting the electrical clearances as stipulated.

3.3.1.44.14. For the maintenance of GIB of one circuit, only that circuit shall be isolated. Adequate clearance between bus ducts of two circuit shall be ensured by the contractor during layout finalization.

3.3.1.44.15. GIS manufacturer as per their design shall preferably use maximum three standard straight horizontal outdoor bus duct lengths for entire GIS installation to optimize the spare requirement.

3.3.1.45. Extension of GIS

3.3.1.45.1. The arrangement of gas sections or compartments shall be such as to facilitate future extension of any make without any drilling, cutting or welding on the existing equipment. To add equipment, it shall not be necessary to move or dislocate the existing switchgear bays.

3.3.1.45.2. As the GIS is likely to be extended in future, during detailed engineering stage, the contractor shall make available the complete design detail of interface module such as cross section, enclosure material, enclosure dimensions (inner & outer), Flange diameter (inner & outer), conductor cross-section & connection arrangement, bolt spacing & dimension, rated gas pressure, Gasket detail etc. Further GIS manufacturer supplying GIS under present scope shall furnish all the required details in addition to mentioned above necessary for design and successful implementation of an interface module during later stage while extending GIS by any other GIS manufacturer, without any help of GIS manufacturer who has supplied the GIS equipment in present scope.

3.3.1.45.3. The Interface module shall be designed to provide Isolating link with access hole on enclosure. The Isolating link shall be provided in such a way so that HV test can be performed on either side of the interface module separately, keeping other side of GIS remained isolated. Interface Module drawing with necessary detail shall be submitted for approval.

3.3.1.45.4. Further the contractor who is extending the existing GIS installation, it shall be his responsibility to provide interface module matching with the existing GIS interface module. The drawing of existing GIS interface/end piece module shall be provided by the employer. However it shall be the responsibility of contractor to verify the existing details during site visit. The Contractor shall optimally utilize the space inside the GIS hall (including the extension portion) for accommodating the interface module being supplied under the contract.

3.3.1.46. SF6 GAS

3.3.1.46.1. The SF6 gas insulated metal-clad switchgear shall be designed for use with SF6 gas complying with the recommendations of IEC 60376, 60376A & 60376B, at the time of the first charging with gas. All SF6 gas supplied as part of the contract shall comply with the requirements of IEC & should be suitable in all respects for use in the switchgear under all operating conditions.

Necessary statutory clearances from concerned authorities for import of the Gas and for storage of the Gas shall be obtained.

3.3.1.46.2. The high pressure cylinders in which SF6 gas is supplied & stored at site shall comply with the requirements of standards & regulations.

3.3.1.46.3. SF6 gas shall be tested for purity, dew point, air, hydrolysable fluorides and water contents as per IEC:60376, 60376A & 60376B and test certificates shall be furnished to the Employer indicating all test results as per IEC standards for each lot of SF6 gas. Further site tests for dew point and purity shall be done during commissioning of GIS. Gas bottles should be tested for leakage during receipt at site.

The contractor shall indicate diagnostic test methods for checking the quality of gas in the various sections of GIS during service. The method proposed shall have as a minimum check the moisture content & the percentage of purity of the gas on annual basis.

The contractor shall also submit clearly the precise procedure to be adopted by maintenance personnel for handling equipment that are exposed to the products of arcing in SF6 Gas so as to ensure that they are not affected by possible irritants of the skin and respiratory system. Recommendations shall be submitted for suitable protective clothing, method of disposal of cleaning utensils and other relevant matters.

The contractor shall also indicate the details and type of filters used in various gas sections, and should also submit the operating experience with such filters.

3.3.1.46.4. SF6 gas monitoring devices and alarm circuits: Dial type temperature compensated gas density monitoring devices with associated pressure gauge will be provided. The devices shall provide continuous & automatic monitoring of gas density. A separate device shall be provided for each gas tight compartment so that it can be monitored simultaneously as follows:

3.3.1.46.4.1. “Gas Refill level”: This will be used to annunciate the need for the gas refilling. The contractor shall provide a contact for remote indication.

3.3.1.46.4.2. “SF6 low level”: This will be used to annunciate the need for urgent gas filling. A contact shall be provided for remote indication.

3.3.1.46.4.3. “Breaker Block level”: This is the minimum gas density at which the manufacturer will guarantee the rated fault interrupting capability of the breaker. At this level the breaker block contact shall operate and the closing & tripping circuit shall be blocked.

The density monitor/pressure switch contacts shall be in accordance with the above requirement.

It shall be possible to test all gas monitoring relays/devices without de-energizing the primary equipment & without reducing pressure in the main section. It shall also damp the pressure pulsation while filling the gas in service, so that flickering of the pressure switch contacts does not take place.

3.3.1.46.5. Gas Supply: The contractor shall include the supply of all SF6 gas necessary for filling & putting into operation the complete switchgear installation being supplied. The empty gas cylinders shall be returnable to the contractor.

3.3.1.47. The normal operations will be affected from the National Load Dispatching Centre (NLDC). The Bidder shall take into consideration the unmanned operation of the substation in his design.

3.3.1.48. Control facilities shall be simple and clearly designated with the respective function and instructions on operation and maintenance shall be unambiguous.

3.3.1.49. The following provisions shall be made for control and indications:

3.3.1.49.1. Local control cubicle to equipment - control of circuit breakers, disconnectors and earthing switches where power operated, complete with electrical indications, mimic diagram, gauges and alarm annunciator.

3.3.1.49.2. Remote control panel in the protection room on each substation site - control of circuit breakers, disconnectors and earthing switches where power operated, complete with electrical position indications, mimic diagram in each instance.

3.3.1.49.3. Local SCADA system in the control room on each substation site – supervisory control and monitor all equipment.

3.3.1.49.4. Supervisory control from NLDC - provision of control of circuit breakers and disconnectors switches where power operated, with position indication in each instance.

3.3.1.50. All necessary local/remote and remote/supervisory control relays, interposing relays and selector switches are to be provided as part of this Contract.

3.3.1.51. Circuit identifying labels shall be fitted at the front and rear of each individual circuit assembly and on the local control cubicle. In case of labels not visible when standing on the floor, additional name plate shall be fixed at a suitable location.

3.3.1.52. A single line diagram shall be marked along each bay showing the location of all items of switchgear.

3.3.1.53. In the event of leakage of SF6 gas from any compartment, equipment shall withstand rated voltage with SF6 at atmospheric pressure.

3.3.1.54. The insulation levels shall be able to withstand test voltages in accordance with the relevant standards for Synchronizing operations for Breakers.

3.3.1.55. Busbar connections and enclosures shall be designed to absorb the effects of thermal expansion without the application of stress to the supporting structure.

3.3.1.56. Equipment foundation requirement details complete with floor and structure fixings consistent with the switchgear design offered are to be provided at an early stage in order for these to be incorporated in the civil works design.

3.3.1.57. Painting: All enclosures and structures, panels supplied by Contractor shall be painted (or galvanized) as per manufacturer's procedure.

3.3.2. Availability for Maintenance, Repair, Extensions, Testing

3.3.2.1. Maintenance, repair or extension (MRE) and HV testing on one busbar with directly connected apparatuses shall be possible with the other busbar in normal operation.

3.3.2.2. MRE and HV testing on one switchgear bay shall be possible with all other switchgear bays in normal operation on one busbar.

3.3.2.3. MRE and HV testing on/of bus coupler bay shall be possible with one busbar at the time in normal operation and all switchgear bays in normal operation.

3.3.2.4. Maintenance access to each module shall be possible without necessitating the outage of adjacent modules.

3.3.2.5. GIS design shall consider Appropriate Buffer zone and section in Busbar & GIS compartment suitable for best MRE practice so as to minimize the interruption zone & time during MRE. The proposal shall be approved by the employer during execution. Any modification required thereof in the GIS design, shall be done without any commercial implication.

3.3.3. Design Review and Performance

3.3.3.1. Design Review

3.3.3.1.1. Design reviews shall be conducted by Employer; however, the entire responsibility of design shall be with the supplier.

3.3.3.1.2. Employer may also visit to the supplier's works to inspect design, manufacturing and test facilities.

3.3.3.1.3. The design review will commence after placement of award with the successful contractor and shall be finalized before commencement of manufacturing activity. These design reviews shall be carried out in detail to the specific design with reference of the GIS under the scope of this specification. Employer reserve the right to waive off the design review during detailed engineering.

3.3.3.1.4. The design review shall be conducted generally following the, "User Guide for the application of Gas Insulator Switchgear (GIS) rated voltage of 72.5kV and above" – CIGRE report No. 125 prepared by CIGRE Working Group 23.10.

3.3.3.1.5. The manufacturer will be required to demonstrate the use of adequate safety margins for thermal, mechanical, dielectric, insulation coordination and vibration etc. design to take into the account the uncertainties of his design and manufacturing processes.

3.3.3.1.6. The scope of such a design review shall at least include the following:

3.3.3.1.6.1. Dielectric Stress of Solid Insulation like Gas Barrier, support insulator etc.
3.3.3.1.6.2. Dielectric stress of SF6 Gas Volume.
3.3.3.1.6.3. Mechanical strength of enclosure, expansion joints etc.
3.3.3.1.6.4. Criteria for providing expansion joint.
3.3.3.1.6.5. Sealing system
3.3.3.1.6.6. Insulation coordination
3.3.3.1.6.7. Thermal stress and resulting increase in gas pressure during short circuit condition.
3.3.3.1.6.8. Earthing of enclosure w.r.t circulating current.
3.3.3.1.6.9. Seismic design, as per IEC 62271-207
3.3.3.1.6.10. Circuit Breaker.
3.3.3.1.6.11. Isolator and Earth switch.
3.3.3.1.6.12. Voltage transformer.

3.3.3.1.6.13. Current Transformer.
3.3.3.1.6.14. Surge Arrester.
3.3.3.1.6.15. Bushing.
3.3.3.1.6.16. Ducting.
3.3.3.1.6.17. Corrosion protection.
3.3.3.1.6.18. Electrical and physical Interfaces with substation.
3.3.3.1.6.19. Testing capabilities.
3.3.3.1.6.20. Inspection and test plan.
3.3.3.1.6.21. Transport and storage.
3.3.3.1.6.22. Maintainability.
3.3.3.1.6.23. Site Test.

3.3.3.1.7. Further, the manufacturer shall furnish the following information during detailed engineering:

3.3.3.1.7.1. Study report of VFTO generated for GIS installation for 400 kV and above.
3.3.3.1.7.2. Calculation for adequacy of UHF sensors to be provided in GIS Installation as per clause no 5.41.
3.3.3.1.7.3. The calculations and documents in support of the average intensity of electromagnetic field on the surface of the enclosure.
3.3.3.1.7.4. Calculations to show that there is no Ferro resonance due to capacitance of GIS for the voltage transformers.
3.3.3.1.7.5. Calculations in support of touch & step voltages in all enclosures and earthing of complete GIS installation.
3.3.3.1.7.6. Measures to mitigate transient enclosure voltage by high frequency currents.
3.3.3.1.7.7. The acceptance criteria and limits of impact (of impact recorder) in all three directions which can be withstood by the equipment during transportation and handling.

3.3.3.2. Performance

3.3.3.2.1. The switchgear shall be suitable for indoor installation and capable of continuous operation under the climatic conditions existing on site.

3.3.3.2.2. It shall be designed to comply with this Specification and relevant IEC and British Standards where applicable. Deviations from these Specifications and Standards shall be stated by the bidder.

3.3.3.2.3. In all cases the ancillary plant necessary to complete installation of the equipment shall be included in the Contract.

3.3.3.2.4. The disposition of plant in any substation is to be such that the operation of any item of plant under the specified service conditions, shall in no way create a condition that could adversely affect the performance of adjacent circuit breakers or any associated equipment.

3.3.3.2.5. The Contractor is to ensure that the complete substation installation will satisfy the requirements of this Specification and the appropriate Standards in respect of insulation, fault levels, mechanical stress etc., and any additional equipment found to be necessary to meet these requirements shall be deemed to have been included in the Contract Price.

3.3.3.2.6. The layout and design of plant and equipment on substation sites shall make provision for the future extensions shown on the layout drawings and shall provide for ready access for operation, maintenance and extension whilst the remaining sections of equipment are alive.

3.3.3.2.7. Electrical clearances provided between isolated equipment and nearest live metal work shall not be less than the distance data as mentioned in sub-clause 1.6 of this specification.

3.3.3.2.8. Insulation creepage distances shall not be less than 25 mm per kV of rated voltage between phases.

3.3.3.2.9. The Contractor shall be responsible for ensuring that insulation co-ordination in accordance with the recommendation of IEC 60071 is achieved.

3.3.3.2.10. Dynamic and temporary overvoltage shall be assumed to be in accordance with normally accepted IEC levels and subject to the approval of the Engineer.

3.3.3.2.11. VFTO analysis using PSCAD tool shall be submitted to Employer/Engineer for approval. No production shall be initiated before approval of the insulation coordination report.

3.3.4. Current Ratings

3.3.4.1. Every current-carrying part of the switchgear including circuit breakers, disconnectors, current transformers, busbars, connections, contacts and joints shall be capable of carrying its specified rated current at rated frequency

continuously, and in no part shall its temperature rise exceed that specified in relevant standards.

3.3.4.2. Every part of the switchgear shall also withstand, without mechanical or thermal damage, the rated instantaneous peak currents and rated short-time current.

3.3.5. Corona

Equipment shall be designed so as to minimize corona or other electrical discharge and radio interference. The Contractor is to confirm and ensure the adequacy of design in terms of corona performance. Tests for corona and radio interference shall be carried out by the Contractor as per the relevant IEC standard.

3.3.6. Local, Remote and Supervisory Control

3.3.6.1. Circuit breakers and motorized disconnectors shall be electrically controlled locally, remotely and by supervisory telecontrol.

3.3.6.2. Position indication of these devices shall be provided on their operating mechanisms and the Contractor shall include the supply and fitting of the necessary auxiliary switches for remote position indication.

3.3.6.3. For supervisory telecontrol, the interface between the telecontrol control equipment and the control equipment being provided under this contract shall be as specified in Section 14

3.3.7. Type of Switchgear

3.3.7.1. General

3.3.7.1.1. The switchgear shall be of the SF6 gas insulated metal-enclosed type capable of continuous operation under the climatic conditions existing at the Site. The Busbar scheme for 420kV, 245kV & 145kV GIS shall be double busbar.

3.3.7.1.2. Busbar Disconnectors are required to facilitate the changeover of individual circuits from one busbar to the other with the circuit on load and a bus coupler closed.

3.3.7.1.3. The arrangement of the switchgear shall be such that all units face in the same direction and particular emphasis is placed on the provision of adequate clearance between chambers and between adjacent bays to facilitate maintenance.

3.3.7.1.4. The design of the switchgear shall be such as to enable extensions to be added at either end with the minimum of disturbance to the installed equipment and with one busbar in service. Suitable arrangement shall be provided with the switchgear for H.V. test to keep the outage of the existing switchgear to a minimum.

3.3.7.1.5. The design shall include all facilities necessary to enable the performance of the specified site checks and tests during pre-commissioning & commissioning tests and after any repair & maintenance. The Contractor shall state the test facilities provided and indicate any attachments or special equipment provided for this purpose.

3.3.7.2. Gas Compartments

3.3.7.2.1. The switchgear units and busbar systems shall be divided into several gas-filled compartments, sealed from each other by gas-tight partitions.

3.3.7.2.2. The various gas zones shall be further sub-divided when necessary to restrict any internal arcing damage, particularly within sections of busbars and to enable gas handling procedures to be completed with the minimum of delay. The partitions should confine any internal faults to a respective section of the switchgear.

3.3.7.2.3. The number of gas compartments shall be such as to limit the amount of switchgear which has to be isolated and taken out of service as a result of gas leakages, planned maintenance or internal faults.

3.3.7.2.4. Proposals for the partitioning of gas zones shall be clearly indicated on the drawings submitted with the tender and the same shall be taken approval from the Employer during execution of the project. Partitioning on the GIS shall be clearly marked with yellow paint on the GIS. Gas volumes and duration of gas handling procedures shall also be indicated in the technical schedules. Each gas zone shall have its own gas monitoring, filling, degassing, re-gassing & gas sampling facility.

3.3.7.2.5. Total time for gas evacuation and filling of the largest chamber shall not exceed 10 hours at site.

3.3.7.2.6. Suitable arrangements shall be provided for the thermal expansion and contraction of the busbars and busbar chambers without detriment to the current carrying capacity or gas volume.

3.3.7.2.7. Devices shall be provided for each section of switchgear as appropriate to allow for pressure relief. All relief devices shall be located such that operation of the devices shall not endanger personnel working on the equipment or in the vicinity of the equipment.

3.3.7.2.8. These devices shall be arranged to give individual compartment alarms in the local control units and initiation of remote alarms. Each gas-filled chamber shall be fitted with static filters to absorb any moisture which may be present. In addition, filters for removal of SF6 decomposition products shall be provided in Circuit Breaker compartments.

3.3.7.2.9. For circuits equipped with double cable isolation, provision shall be made to remove the gas from either cable chamber whilst maintaining the other cable in service. i.e.

3.3.7.2.10. Gas monitoring of the chamber in service shall be maintained at all times.

3.3.7.2.11. In chambers equipped for cable sealing ends a disconnecting link must be provided to allow easy isolation between the cable sealing end and the main connections. It must be possible to remove this link without removal/refitting of the main connections

3.3.7.2.12. In order to compensate for any small variations in floor level each compartment shall be fitted with means of adjustment (jacking screws or similar). Such adjustments shall be fully described in the maintenance manuals provided by the manufacturer. In case such arrangements do not exist, it shall be the responsibility of the manufacturer to ensure acceptable floor level tolerance.

3.3.7.2.13. Enclosures shall be clearly marked to identify gas compartment zones, disconnectors, circuit-breakers, earthing switches, current transformers, voltage transformers, surge arresters and other primary devices contained therein.

3.3.7.3. Gas Barrier and Supporting Insulators

3.3.7.3.1. Gas barriers shall be gas tight and of sufficient strength and factor of safety to withstand short circuit forces and the maximum pressure differential that can occur under internal fault conditions. The gas barrier withstand pressure shall be more than that of bursting disc. It should be possible to vacuum, any chamber with adjacent chambers at operation pressure.

3.3.7.4. Enclosures

3.3.7.4.1. The enclosures for the SF6 gas insulated switchgear shall be of Aluminum or Aluminum Alloy.

3.3.7.4.2. It shall be capable of withstanding maximum differential pressure between adjacent gas zone over a considerable period. Evidence shall be provided to

verify that enclosures have been designed and tested in accordance with established pressure vessel codes.

3.3.7.4.3. Each enclosure shall be tested based on the issuing the test certificate according to ASTM / IEEE /IEC and stamped by the inspecting authority issuing the test certificate.

3.3.7.4.4. Circuit-breakers, isolators, earth switches, VTs, CTs, surge arresters, cable termination chambers, all and any other chambers and components shall have pressure tests on enclosures as per IEC 62271-203 clause 7.101. The withstand pressure of the enclosures shall be well over the bursting disc operation pressure and shall be embossed on all the enclosures at a conspicuous location.

3.3.7.4.5. Voltages induced in the enclosures shall not be allowed to exceed reasonable safe limits. All chambers throughout the equipment shall be earthed at an approved number of points. All necessary earthing bars and associated fixings shall be provided. Approved GIS earthing drawings are to be supplied from the manufacturer of the GIS.

3.3.7.4.6. Each enclosure shall be provided with lifting points to facilitate maintenance or repair works.

3.3.7.5. SF6 Gas

3.3.7.5.1. All SF6 gas supplied for use in the switchgear shall be new and shall comply with the requirements of IEC 60376. Test Reports shall be submitted for review.

3.3.7.5.2. Busbars and items of switchgear shall be supported in the enclosures by insulators of materials compatible with SF6 gas and the products of gas decomposition.

3.3.7.5.3. Gas barrier insulators and bushings including gas-oil and gas-air bushings shall comply with the specified conditions for sealing of enclosures. The Engineer shall be advised of design pressures used and may require test evidence to substantiate performance under extremes of differential pressure and temperature. SF6 immersed insulation shall otherwise comply with the relevant clauses for insulators and bushings.

3.3.7.6. Gas Monitors

3.3.7.6.1. Gas density monitors complete with alarm and lockout contacts or manometers with pressure switch for alarm and lockout shall be provided.

The gas monitor shall be located such that readings can be taken easily standing on the floor. Means shall be provided to enable gas systems to be safely replenished whilst the equipment is in service.

3.3.7.6.2. For circuit breaker compartments, a lockout feature shall be provided to prevent operation whenever SF6 gas pressure is less than that permitted by the design for satisfactory operation. Contacts shall be included to initiate alarms to warn of this condition.

3.3.7.6.3. Two sets of voltage free electrical changeover contacts shall be provided for every alarm for remote SCADA and repeat alarm facilities in addition to alarm fascias incorporated in the local control panel/marshalling kiosk associated with each primary circuit. Contact multiplying relays may be used.

3.3.7.7. Position Indicators

3.3.7.7.1. Position indicators shall be provided for all circuit-breakers, disconnectors and earthing switches to show whether the main contacts of these switches are in the fully open or closed positions. Position indicator should be directly coupled with shaft drive for all three phases.

3.3.7.7.2. Indicators shall be of a reliable mechanical design and be positively driven in both directions by the final drive stage of the contact operating mechanism. Reference marks should be punched or engraved on the main frame for this purpose. Each indicator shall be clearly visible to operating staff at operating control points and access routes provided under this contract.

3.3.7.8. Temperature Rise

3.3.7.8.1. The temperature rise limits shall be in accordance with IEC62271-203. The switchgear shall be capable of carrying the specified rated current at rated frequency continuously in accordance with normal service conditions as defined in IEC 62271-1 as well as site ambient conditions.

3.3.7.8.2. The design of sliding type current carrying connectors and joints shall be such that they meet the afore-mentioned conditions over the full permitted range of movement. Where such joints may be made or adjusted on Site, full details of alignment procedure, together with any necessary alignment tools or gauges shall be described in the maintenance manual and included in the supply of special tools.

3.3.7.9. Arrangement

3.3.7.9.1. The switchgear shall be installed in a building with a cable basement, both being maintained at a slight positive pressure of filtered air such that any SF6 gas released in the building will be discharged externally via pipes from the lowest point.

3.3.7.9.2. The Contractor shall supply the necessary permanent type of ladders and galleries for access to all levels of equipment during normal operation or maintenance.

3.3.7.9.3. The Contractor shall include in his supply power operated lifting appliances with all accessories as appropriate to the size and weight of component parts of the switchgear which require to be lifted in the course of maintenance or repair. The layout arrangement shall allow for full mobility of the gas handling plant ladders, catway walks etc. along the switch room.

3.3.7.9.4. The offer shall include complete special equipment for each GIS Substation:

3.3.7.9.4.1. Fixed platform suitable to reach any equipment,
3.3.7.9.4.2. Handles of manual operation of CB, D/S, E/S and
3.3.7.9.4.3. any special tool required for the operation of the switchgear.
3.3.7.9.4.4. 2 nos. of 63 A sockets shall be provided in the GIS room at suitable location for the gas handling plant and HV test set.

3.3.7.10. Mechanical Construction

3.3.7.10.1. Components that may require to be renewed and standard assemblies that may be transferred from one circuit to another shall be interchangeable and where required this shall be demonstrated by the contractor. Flanges shall comply with an appropriate metric standard as regards both dimensions and drilling, where appropriate.

3.3.7.10.2. Screwed couplings and fittings shall have pipe threads to ISO Recommendations.

3.3.7.11. Testing Facilities

3.3.7.11.1. Testing flanges/adaptor and associated facilities shall be provided for each circuit for HV withstand testing of switchgear. Each testing flange shall be positioned in a separate gas zone compartment which shall be independent of adjacent disconnector and earthing switch gas sections.

3.3.7.11.2. A set of facility for connection to the switchgear shall be provided which will permit the full AC testing of all circuits.

3.3.7.11.3. It shall be possible to connect the test equipment without dismantling other equipment and permit testing three single phase at the same time or separately by connecting the test bushing to the AC high voltage test kit fitted at a suitably safe place inside the switchgear room.

3.3.7.11.4. Adequate precautions shall be taken to ensure that any section of busbars insulated by SF6 gas is not subjected to any testing voltage unless able to withstand such voltages. Hence the bidder shall indicate if there is any deviation.

3.3.7.11.5. The Contractor shall be responsible for the de-gassing, removal of the any chamber links at the remote ends, and re-gassing to facilitate HV Tests and Primary Injection.

3.3.7.11.6. Once the tests are complete the de-gassing, insertion of the links and re-gassing shall be completed thus allowing normal operation of the switchgear. This shall include replacement of gaskets as necessary.

3.3.7.12. Sealing of Enclosures

3.3.7.12.1. To prevent ingress of moisture or leakage of gas during the service life of the equipment, the sealing materials used at all joints and interfaces shall satisfy the following requirements:

3.3.7.12.1.1. Not affected by SF6 gas
3.3.7.12.1.2. Non-hygroscopic, containing no silicon
3.3.7.12.1.3. Non-aging and non-shrinking
3.3.7.12.1.4. Retain resilience for long periods under stress
3.3.7.12.1.5. Stable under all temperature conditions

3.3.7.12.2. Seals including those at compartment partitions shall continue to function correctly throughout the temperature and pressure ranges in service and the pressure differentials, including vacuum and test pressures, during erection, maintenance and subsequent revisions.

3.3.7.12.3. Expansion bellows and diaphragms, pressure relief devices and inspection windows shall be designed to be free of leakage under the same conditions as stated for seals.

3.3.7.12.4. Where the use of cast aluminum is envisaged the Manufacturer shall submit to PGCB evidence of tests carried out for porosity and extended pressure testing to show the quality of the castings used.

3.3.7.13. Gas Losses

3.3.7.13.1. The Manufacturer should be prepared to guarantee the equipment for a gas loss of not more than 0.1% per annum in any single gas compartment, and not more than 0.5% for the total installation.

3.3.7.14. Earthing System

3.3.7.14.1. All metal parts other than those forming part of any electrical circuit shall be earthed to the earthing system. Any necessary terminals on part of the equipment required for this purpose shall be provided by Contractor. The jointing parts of the earthing conductors/strips are to be properly tinned.

3.3.7.15. Partial Discharge

3.3.7.15.1. A portable PD measuring and analyzer shall be provided in each substation. And appropriate numbers of sensors (PD antennas) inside the GIS shall be installed.

3.3.7.16. Gas Handling Equipment

3.3.7.16.1. Gas handling plant shall be provided at each substation to permit emergency topping up of gas in the switchgear in the event of leakage and for use during any maintenance works.

3.3.7.16.2. The mobile gas handling unit, the size of which shall allow full mobility within the switch room, shall be included for the complete sampling, testing, filtering, drying, extraction and refilling of SF6 gas. This unit shall be self-contained and comprise of a wheeled trolley housing all necessary compressors, vacuum pumps, filter, etc. gauges, piping and controls etc., together with a gas storage tank with usable capacity. The unit shall be capable of evacuating air from the switchgear compartments and replenishing them with gas at the end of a maintenance period. Facilities shall also allow for circulation of the gas from a compartment through filters in order to extract moisture pressure.

3.3.7.16.3. Additional mobile or static storage (at least one full cylinder of SF6 gas together with one empty cylinder) shall be provided for use in combination with the gas trolley and to extend storage facilities.

3.3.7.16.4. All necessary pipe work, flexible hoses, couplings, valves, pressure and vacuum gauges shall be included to enable interconnection between the switchgear compartments, gas trolley and storage tanks and the cylinders provided by major producers of SF6 gas.

3.3.7.16.5. To enable safe maintenance to be carried out on any portion of the switchgear when all electrical supplies to the local control unit are switched off two portable gas alarm units shall be provided. The alarm units shall be self-contained and capable of giving clear audible warning should the gas pressure in any adjoining gas-filled chamber become unsafe. The cost of this equipment shall be included in the GIS price.

3.3.7.16.6. Technical Data:

Vacuum Pump	
Nominal suction capacity	m3/h
Achievable final vacuum	< 1mbar
Compressor	
Theoretical. intake volume	3 m3/h
Suction pressure	p = 0,75 to 3 bar (for a short time up to 0, 5 bar)
Max. counter-pressure	p= 50 bar
Storage performance	100 kg SF6
Filling performance	120 kb SF6/h

3.3.7.16.7. An approved portable SF6 gas leakage detector, oxygen analyzer, moisture meter and manual operating handles/tools (for circuit breakers, disconnectors, earth switches) shall be provided for each substation.

3.3.7.17. Nameplates

3.3.7.17.1. Nameplates should have data written in English language(example of CB):

An insulating gas system nameplate with legends showing various gas zones and compartments, piping, interconnections, valves, gauges, monitors, and pressure reliefs should be mounted in a convenient, central location. Many times this location can be near or on an LCC. This nameplate should also provide the nominal (rated) and alarm ranges for gas density, the total weight of gas in the complete GIS or gas compartments, maximum allowable moisture (referenced to a temperature range), and curves showing maximum, rated, alarm and minimum functional pressure versus temperature.

3.3.7.17.2. GIS common nameplates

Nameplates of the following types shall be furnished in a convenient, central location to provide information for operation and maintenance. These nameplates shall be clearly readable and located in an appropriate and accessible location.

3.3.7.17.3. GIS ratings nameplate

The ratings nameplate shall state to which of the GIS equipment the ratings apply. The GIS ratings nameplate shall contain the following information.

a) Manufacturer's name, type and designation, and serial number
b) Year of manufacture
c) Rated maximum voltage (V) or (Ur)
d) Rated lightning impulse withstand voltage (Up)
e) Rated switching impulse withstand voltage (Us), (if applicable)
f) Rated power-frequency withstand voltage (Ud)
g) Rated power frequency (fr)
h) Rated maximum and minimum ambient temperature
i) Rated continuous current (Ir) at maximum ambient temperature
j) Rated short-time withstand current (Ik) and duration
k) Rated peak withstand current (Ip)
l) Rated supply voltage of closing and opening devices and of auxiliary circuits (Ua)
m) Rated supply frequency of closing and opening devices and of auxiliary circuits
n) Contract order number

3.3.7.17.4. One-line diagram nameplate

The one-line diagram nameplate shall show the following information if applicable:

a) Circuit breakers
b) Disconnect switches
c) Grounding switches
d) Instrument transformers
e) Bushings
f) Power cable connections
g) Buses
h) Surge arresters
i) Employers' SCADA identification numbers

When the installation is an expansion of an existing substation, the one-line diagram shall show and identify the existing equipment and the new equipment as specified by the Employer.
The one-line diagram nameplate may be combined with the insulating gas system nameplate (5.10.1.3)

3.3.7.17.5. Insulating gas system nameplate

The insulating gas system nameplate shall contain the following information:

a) Complete gas system schematic including compartmentalization, (including compartment designation), showing location and device number of:

1) Gas density monitors
2) Pressure gauges
3) Interconnections between gas compartments
4) Valves: fill, evacuation, sampling, isolation
5) Pressure relief location and operating pressure

b) Weight of gas in each compartment and total weight of gas in the GIS at rated filling pressure (at
20 °C)
c) Curves for gas showing maximum, rated filling, alarm and minimum functional pressures versus
temperature
d) Maximum allowable moisture level (ppmv)
e) Insulating gas type
f) Insulating gas pressure (at 20 °C), identified in either absolute or relative values:

1) Rated filling pressure
2) Alarm pressures
3) Minimum functional pressure

3.3.7.18. GIS equipment nameplates

Main GIS equipment and operating devices shall be provided with nameplates which are located on the equipment themselves or in a conspicuous adjacent area.

When common information of the GIS is stated on the ratings nameplate (5.10.1.1), individual equipment nameplates can be simplified.

Equipment nameplates shall provide information according to its relevant standard. As a minimum, the information in the following sections is required:

3.3.7.18.1. Circuit breakers

The nameplates for circuit breakers (and their operating mechanisms) shall contain the information described in ~~IEEE Std C37.04.~~ In addition it shall contain the following:

a) Insulating gas pressure (at 20 °C), identified in either absolute or relative values:
1) Rated filling pressure
2) Alarm pressures
3) Minimum functional pressure

3.3.7.18.2. Disconnect switches

The nameplates for disconnect switches (and their operating mechanisms) shall contain the following information:

a) Manufacturer's name, type and designation, and serial number
b) Year of manufacture
c) Rated maximum voltage (V or Ur)
d) Rated power-frequency withstand voltage (Ud)
e) Rated lightning impulse withstand voltage (Up)
f) Rated switching impulse withstand voltage (Us) (if applicable)
g) Rated power frequency (fr)
h) Rated continuous current (Ir)
i) Rated short time withstand current (Ik) and duration
j) Rated peak withstand current (Ip)
k) Rated bus charging breaking current
l) Rated bus-transfer current and voltage
m) Rated filling pressure (pre) at 20 °C
n) Rated auxiliary voltage (Ua)

3.3.7.18.3. Grounding switches

The nameplates for grounding switches (and their operating mechanisms) shall contain the following information:

a) Manufacturer's name, type and designation, and serial number
b) Year of manufacture
c) Rated maximum voltage (V or Ur)
d) Rated power-frequency withstand voltage (Ud)

e) Rated lightning impulse withstand voltage (Up)
f) Rated switching impulse withstand voltage (Us) (if applicable)
g) Rated power frequency (fr)
h) Rated short-time withstand current (Ik) and duration
i) Rated peak withstand current (Ip)
j) Rated short-circuit making current (high-speed grounding switches)
k) Rated number of closings before maintenance at rated short-circuit making current (high-speed
grounding switches)
l) Rated closing time (high-speed grounding switches)
m) Rated filling pressure (pre)
n) Rated auxiliary voltage (Ua)
o) Electrostatically induced current interruption rating (Class A and B high-speed grounding
switches)
p) Electromagnetically induced current interruption rating (Class A and B high-speed grounding switches).

3.3.7.18.4. Operating mechanisms

The nameplates for GIS equipment operating mechanisms may be combined with the equipment nameplates

The operating mechanism nameplates shall contain the following information:

a) Manufacturer's name, type and designation, and serial number
b) Year of manufacture
c) Control voltage range and current
d) Compressor, hydraulic pump, spring charging motor or operating motor voltage range
e) Compressor, hydraulic pump, spring charging motor or operating motor starting and running
currents
f) Low-pressure alarm switch closing and opening pressure (if applicable)
g) Low-pressure lock-out switch opening and closing pressure (if applicable)

3.3.7.18.5. Surge arresters

The nameplates for surge arresters shall contain the information described in applicable surge arrester standards. As a minimum, they shall contain the following information:

a) Manufacturer's name, type and designation, and serial number
b) Year of manufacture
c) Maximum continuous operating voltage (MCOV)
d) Duty cycle voltage rating
e) Nominal discharge current
f) Identification of assembled position (vertical or horizontal)
g) Nominal gas pressure (at 20 °C)

3.3.7.18.6. Current transformers

The nameplates for current transformers shall contain the information described in IEEE Std C57.13 and IEC 60044-1. As a minimum, they shall contain the following information:

a) Manufacturer's name, type and designation , and serial number
b) Year of manufacture
c) Rated frequency
d) Accuracy class and the ratio for which the accuracy is expressed
e) Rated maximum voltage (if applicable)
f) Rated lightning impulse withstand voltage (if applicable)
g) Rated switching impulse withstand voltage (if applicable)
h) Rated primary current
i) Rated secondary current
j) Rated continuous thermal current factor and the associated ambient temperature
k) Rated thermal short-time current

l) Nominal gas pressure (at 20 °C)
m) A connection diagram showing:

1) Full winding development
2) Taps
3) Ratio in terms of primary and secondary currents
4) Polarity

3.3.7.18.7. Voltage transformers

The nameplates for voltage transformers shall contain the information described in IEEE Std C57.13 and IEC 60044-2. As a minimum, they shall contain the following information

a) Manufacturer's name, type and designation , and serial number
b) Year of manufacture
c) Rated power frequency
d) Rated primary voltage
e) Rated lightning impulse withstand voltage
f) Rated switching impulse withstand voltage (if applicable)
g) Rated power-frequency withstand voltage
h) Ratio or ratios
i) Thermal burden rating or ratings at ambient temperature or temperatures, in voltamperes (VA)
j) Accuracy rating at thermal burden rating
k) Nominal gas pressure (at 20 °C)
l) A connection diagram

3.3.7.18.8. High-voltage cable terminations

The nameplates for high-voltage cable terminations shall contain the information described in IEEE Std 48. As a minimum, they shall contain the following information:

a) Manufacturer's name, type and designation, and serial number
b) Year of manufacture
c) Rated maximum voltage (Ur)
d) Rated lightning impulse withstand voltage (Up)
e) Rated switching impulse withstand voltage (if applicable) (Us)
f) Rated power-frequency withstand voltage (Ud)
g) Rated maximum and minimum ambient temperature
h) Rated continuous current (Ir) at maximum ambient temperature
i) Rated short-time withstand current (Ik)
j) Rated duration of short-circuit (tk)
k) Rated peak withstand current (Ip)
l) Nominal gas pressure (at 20 °C)
m) Maximum allowable force applied in any direction at the external terminal

3.3.7.18.9. Bushings

The nameplates of gas to oil bushings and gas to air bushings shall contain the information described in IEEE PC37.017, Draft 4, February 2010. As a minimum they should contain the following information:

a) Manufacturer's name, type and designation, serial number
b) Year of manufacture
c) Rated maximum voltage (Ur)
d) Rated lightning impulse withstand voltage (Up)
e) Rated switching impulse withstand voltage (if applicable) (Us)
f) Rated power-frequency withstand voltage (Ud)
g) Rated maximum and minimum ambient temperature
h) Rated continuous current (Ir) at maximum ambient temperature
i) Rated short-time withstand current (Ik) and duration
j) Rated short-circuit current (rms) and duration (tk)
k) Rated peak withstand current (Ip)
l) Rated oil-side pressure (applicable to gas to oil bushings only)
m) Nominal gas pressure (at 20 °C)
n) Maximum allowable force applied in any direction at the external terminal
o) Maximum angle of mounting if exceeding 30 degrees from vertical
p) Weight
q) Voltage tap, capacitance C1 and C2 (if applicable)

3.3.8. Circuit Breakers

3.3.8.1. The requirements of IEC 62271-100 in respect of type tests, routine tests, service, operation and the making and breaking of fault currents shall apply to the specified circuit breakers.

3.3.8.2. Circuit breakers shall be complete with spring or hydraulic or spring&hydraulic operated mechanisms.

3.3.8.3. Attention is drawn to the transient recovery voltage (TRV) requirements of the IEC Standards. where not specifically stated in the test certificates submitted with the Tender, the Tenderer shall certify that the TRV to which the circuit breaker was subjected during the short circuit tests was the most severe condition that could be imposed by the available test plant for a first phase-to-clear factor of 1.3. Also, GIS(CB) manufacturer shall submit the EMTP study report for TRV.

3.3.8.4. Any device incorporated in a circuit breaker to limit or control the rate-of-rise of restriking voltage across the circuit breaker contacts shall likewise be to PGCB's approval and full descriptions of any such device shall be given.

3.3.8.5. Evidence shall be submitted with the tender to verify that all circuit breakers when interrupting faults on the secondary side of a transformer the transient recovery voltage conditions, that could arise will not exceed the tested interrupting capabilities of the circuit breaker proposed.

3.3.8.6. In addition to the requirements of IEC 62271-100 for interrupting terminal faults all circuit breakers shall be capable of coping with the interrupting duties produced by the switching of low inductive currents associated with reactors and transformer magnetizing currents and by the switching of capacitive cur-rents associated with overhead lines, cables and capacitors banks as may be applicable. Circuit breakers for these duties shall be of the restrike-free type only.

3.3.8.7. All circuit breakers shall also be capable of interrupting currents associated with short-line faults and the out-of-phase switching conditions that may occur in service.

3.3.8.8. The overall fault clearance time including relay operating time shall be in accordance with the requirements specified in this specification.

3.3.8.9. Facilities for measurement of circuit breaker contact resistance and timing tests without removal of covers or SF6 gas filling shall be provided. Full details of the testing procedures shall be submitted with the Bid.

3.3.8.10. Means shall be provided to allow access for the inspection and maintenance of fixed and moving contacts and other enclosed components.

3.3.8.11. Circuit breakers use the SF6 gas conforming to IEC or other approved standard as the insulating medium as well as for arc quenching.

3.3.8.12. Circuit breakers shall operate on the principle of self-generating gas pressure within the interrupter for arc extinction. e.g. puffer type. A lockout feature shall be incorporated to prevent operation of the circuit breaker whenever the gas pressure falls to a value below which it would be incapable of performing in accordance with rated duty. A pressure switch (temperature compensator type) operated SF6 low in CB alarm shall be incorporated at LCC, Remote Control centre as urgent feeder alarm at SCC to give indication of falling gas pressure prior to lockout of the circuit breaker. All lockout relays used for CB shall be of Europe/USA or other eligible countries with equivalent quality.

3.3.8.13. Suitable facilities shall be included for gas sampling and for draining and replenishing the gas volume for maintenance. Absorption of moisture and the decomposition products of arcing or discharge in the gas shall be achieved by integral filters.

3.3.8.14. Sufficient nos. of N/O and N/C auxiliary electrical contacts shall be provided for using interlocking circuits and for states indication at the remote and supervisory control centres and any other requirement. At least 10% spare N/O and N/C contacts shall be wired up to LCC for future use by PGCB.

3.3.9. Operating Mechanisms

3.3.9.1. General

3.3.9.1.1. The circuit breaker operating mechanism shall be power operated and of the type specified. Operation will normally be from a remote or supervisory position but facilities shall be provided for operation locally by electrical release and by direct manual release from stored energy devices when the circuit breaker is isolated for maintenance. It shall be possible to padlock each local control function in the open position. Operation counters shall be fitted to all circuit breaker mechanisms.

3.3.9.1.2. The mechanism and its control scheme shall be such that, in the event of an electrical tripping pulse being applied to the circuit breaker during the closing stroke, or of the mechanism falling to latch in the closed position, the circuit breaker shall open fully and in such a manner as to be capable of interrupting its rated breaking current.

3.3.9.1.3. The mechanism and its control scheme shall be such that the mechanism shall not make repeated attempts to close the circuit breaker when the control switch is held in the CLOSE position in the event of failure to latch on the first closing attempt or in the event of a trip signal being given to the circuit breaker i.e. anti-pumping facility to be provided.

3.3.9.1.4. The electrical closing and tripping devices, including direct acting solenoid coils and solenoid operated valves, shall be capable of operation over the ambient temperature range when the voltage at their terminals is any value within the voltage range stipulated in IEC 62271-100 and in addition over the range of all operating conditions of the batteries and chargers supplied under this Contract.

3.3.9.1.5. The circuit breaker shall be driven by a single mechanism coupled to the three phases or by three mechanisms coupled to each phase separately.

3.3.9.1.6. All circuit breaker operating mechanisms shall be fitted with independent duplicate shunt trip coils suitable for independent operation.

3.3.9.1.7. Power closing mechanisms shall be recharged automatically for further operations as soon as the circuit breaker has completed the closing operation and the design of the closing mechanisms shall be such that the circuit breaker cannot be operated inadvertently due to external shock forces resulting from short-circuits, circuit breaker operation, or any other cause.

3.3.9.1.8. Operating mechanisms shall be capable of storing energy for at least two complete closing and tripping operations or one O-C-O operation, local to the equipment and without recharging. Mechanisms shall preferably utilize DC supplies for recharging duties.

3.3.9.1.9. Means shall be provided for the CB manual (non-electrical) tripping of the circuit breaker, preferably by a shrouded push button and facilities shall be provided for locking off this means of tripping. It shall not be possible to lock mechanically the trip mechanism so as to render the electrical tripping inoperative. Facilities shall be provided to permit manual slow closing and slow opening of the circuit breaker for maintenance purposes. It shall not be possible to "slow close" or "slow open" a circuit breaker when connected in the normal service condition.

3.3.9.2. Spring Charged Mechanisms

3.3.9.2.1. Circuit-breakers fitted with power charged spring operated closing mechanism shall also meet the following requirements.

3.3.9.2.2. When fully charged the spring mechanism shall have sufficient stored energy to permit the operating sequence O-C-O or 2 C-O to be performed following the loss of supply to the charging motor.

3.3.9.2.3. The mechanism shall be charged automatically, for further operations, as soon as the circuit breaker has completed a closing operation. The time required to power charge the spring shall not exceed 30 seconds.

3.3.9.2.4. The spring shall be fully charged before it can be released to close the circuit breaker. It shall not be possible for the breaker to close whilst the spring is being charged.

3.3.9.2.5. Manual Spring charging facility shall be provided.

3.3.9.2.6. A mechanical indicating device shall be provided to indicate the state of the spring. The indication shall be visible with the doors of the mechanism cabinet closed. An auxiliary switch shall give the remote indication of "spring discharged".

3.3.9.2.7. An indicating device shall be provided at the local control panel and the main control room and also over the supervisory system to indicate a spring failing to be charged by a pre-set time after circuit breaker closing.

3.3.9.3. Hydraulically Operated Mechanisms

3.3.9.3.1. Hydraulically operated mechanism shall comprise of operating unit with power cylinder, control valves, high and low pressure reservoir, motor etc.

3.3.9.3.2. The hydraulic oil used shall be fully compatible for the temperature range to be encountered during operation.

3.3.9.3.3. The oil pressure switch controlling the oil pump and pressure in the high pressure reservoir shall have adequate no. of spare contacts, for continuous monitoring of low pressure, high pressure etc. at switchyard control room.

3.3.9.3.4. The mechanism shall be suitable for at-least two close open operations after failure of AC supply to the motor starting at pressure equal to the lowest pressure of auto reclose duty plus pressure drop for one close open operation.

3.3.9.3.5. The mechanism shall be capable of operating the circuit breaker correctly and performing the duty cycle specified under all conditions with the pressure of hydraulic operated fluid in the operating mechanism at the lowest permissible pressure before make up.

3.3.9.3.6. Trip lockout shall be provided to prevent operations of the circuit breaker below the minimum specified hydraulic pressure. Alarm contacts for loss of Nitrogen shall also be provided.

3.3.9.3.7. All hydraulic joints shall have no oil leakage under the site conditions and joints shall be tested at factory against oil leakage.

3.3.9.4. Controlled Switching Device (CSD)

3.3.9.4.1. 400kV & 230kV Circuit Breaker shall be equipped with controlled switching device with consequent optimization of switching behavior, when used in:

i) Switching of transformer (from 400kV and 230kV side circuit breakers only)

ii) Switching of shunt reactor

3.3.9.4.2. The CSD shall be provided in 400kV/230kV Circuit breakers for controlling transformers and reactors (i.e. for breakers of switchable line reactor and in Main& Tie circuit breakers of Transformers, Transmission lines with non-

switchable line reactors and Bus reactors). The requirement of CSD shall be explicitly specified in price schedule.

3.3.9.4.3. Technical Requirement for Controlled switching device:

i) The CSD shall be designed to operate correctly and satisfactorily with the excursion of auxiliary A/C & DC voltages and frequency.

ii) The CSD shall meet the requirements of IEC-61000-4 16 class IV regarding HF disturbance test and fast transient test shall be as per IEC-61000 – 4-4 level IV and insulation test as per 60255 – 5.

iii) The CSD shall have functions for switching ON & OFF the circuit breakers.

iv) The CSD shall get command to operate the breakers manually or through auto reclose relay at random. The controller shall be able to analyze the current and voltage waves available through the signals from secondaries of CTs & VTs for the purpose of calculation of optimum moment of the switching the circuit breaker and issue command to circuit breaker to operate.

v) The CSD shall have an adaptive control feature to consider the next operating time of the breaker in calculation of optimum time of issuing the switching command. In calculation of net operating time of the breaker the controller must consider all factors that may affect the operating time of the breaker such as, but not limited to, ambient temperature, control voltage variation, SF6 gas density variations etc. Schematic drawing for this purpose shall be provided by the contractor. The accuracy of the operating time estimation by the controller shall be better than + 0.5 ms.

vi) The CSD shall have communication port to facilitate online communication of the control switching device with SCADA directly on 61850 or through gateway which shall be under present scope.

vii) The CSD shall be PC compatible for the setting of various parameters and down loading of the settings and measured values date time of switching etc. Window based software for this purpose shall be supplied by the contractor to be used on the owner's PC.

viii) The CSD shall be suitable for current input of 1 amp from the secondary of the CTs. and 110 V (Ph to Ph) from the VTs. The controller shall withstand transient and dynamic state values of the current from the secondary of the CTs and VTs.

ix) The CSD shall have time setting resolution of 0.1 ms or better.

x) The CSD shall have sufficient number of output/input potential free contacts for connecting the monitoring equipment and annunciation system available in the control room. Necessary details shall be worked out during engineering the scheme.

xi) The CSD shall also record and monitor the switching operations and make adjustments to the switching instants to optimize the switching behavior as

necessary. It shall provide self-diagnostic facilities, signaling of alarms and enable downloading of data captured from the switching events.

xii) The provision for bypassing the Controlled switching device shall be provided through BCU and SCADA both so that whenever, the CSD is not healthy due to any reason (including auxiliary supply failure), uncontrolled trip/close command can be extended to the circuit Breaker. Alternatively, in case of any nonoperation of the CSD after receiving a close/trip command after a pre-determined time delay, the CSD should automatically be bypassed so as to ensure that the trip and close commands are extended to the Trip/Close coils through subsequent command.

xiii) The CSD shall be provided with a communication port to facilitate online communication of the CSD with Substation automation system directly on IEC 61850 protocols. If the CSD does not meet the protocols of IEC 61850, suitable gateway shall be provided to enable the communication of CSD as per IEC 61850.

3.3.10. Disconnectors and Earthing Switches

3.3.10.1. Disconnectors including the Earthing Switches shall be supplied as shown on the con-tract drawings and as indicated in the Schedules. Each DC and E/S shall be labeled with SCADA numbers as per SLD by providing permanent engraved stickers.

3.3.10.2. High speed make-proof earthing switch shall be provided as per the single line diagram.

3.3.10.3. Load making and breaking switches with fault making capability shall be provided which shall be suitable for switching on load without detriment to the equipment and under normal duties up to the circuit rating specified.

3.3.10.4. Switch mechanisms shall be so designed that the isolator cannot be opened by forces due to currents passing through it and shall be self-locking in any positions. The mechanism shall open and close all three phases simultaneously.

3.3.10.5. Power operated drives shall be provided which shall be suitable for local, remote and supervisory control (supervisory control of earth switches is not required) and should be fitted with a removable emergency manual operation facility. It should be possible to lock-off the manual and local facility and pad-lock the mechanism in the open and closed positions with the motor automatically disengaged (isolator and earth switch).

3.3.10.6. Transparent window shall have to be provided as required to see the Disconnector and Earth switch contact status (Close or Open).

3.3.10.7. For safe earthing of the busbars and feeders, high speed fault making spring driven earth switches shall be provided. The mechanisms shall be electrically operated with provision for local manual operation. The contacts of these earth switches shall have the same fault making capability as that of the circuit-breaker.

3.3.10.8. Each section of busbar which can be electrically isolated from other sections of busbar by means of isolators or circuit-breakers shall incorporate high speed earthing switches as specified above.

3.3.10.9. Slow speed maintenance earthing switches shall be manually and electrically operated. Positive mechanical and electrical interlocks shall be provided to prevent unintentional use of this earthing equipment.

3.3.10.10. All earthing switches shall be arranged such that, with a minimum use of tools and special fittings, they may be used to facilitate such tests as CT primary injection, contact timing and voltage drop measurement without the necessity to open gas-filled compartments.

3.3.10.11. Sufficient nos. of N/O and N/C auxiliary electrical contacts shall be provided for using in interlocking circuits and for status indications at the remote and supervisory control centres and any other requirement. At least 10% spare N/O and N/C contacts shall be wired up to LCC for future use by PGCB.

3.3.11. Maintenance Earthing Switches

3.3.11.1. Earthing switches shall generally comply with the requirements of IEC 62271-100 and 62271-203.

3.3.11.2. Earthing switches integrally mounted with disconnectors or separately mounted shall be provided for earthing already isolated sections of gas insulated switchgear in order to provide safety maintenance. Motor operated mechanisms shall be provided but it shall be possible to operate the switch manually in emergency conditions.

3.3.11.3. The earthing switch, when in the closed position shall have a short-time current withstand as specified for the feeder. No burning or welding of contacts shall occur.

3.3.11.4. Provisions for testing purposes shall be incorporated in the design of earthing switch to facilitate primary current injection tests and other low voltage checks. Fully insulated designs of earthing shall incorporate removable earth links suitable for the short-time current rating specified. It shall be possible to apply maintenance earths on either side of the test zone or section of GIS which can be electrically isolated from other sections of busbar by means of isolators or circuit-breakers , for safety reasons.

3.3.11.5. All earthing switches shall be mechanically interlocked with associated circuit breakers and disconnectors so that it shall not be possible to close an earthing switch onto a live circuit or to make the circuit alive when the earthing switch is closed.

3.3.11.6. Direct visual indication of the earthing switch position should be provided, with clear markings to show that the device is fully open or closed.

3.3.12. High Speed Earthing Switches

3.3.12.1. These earthing switches shall be capable of making onto a live circuit and suitable for high speed power operation. It shall be impossible to slow close these earthing switches.

3.3.12.2. They shall be located at all feeder terminal points and busbars or other location where there is no certainty that the point to be earthed is not energized.

3.3.12.3. High speed earthing switches shall be capable of interrupting induced currents as may be necessary when opening the earthing switches used for grounding one out of two or more long parallel circuits.

3.3.12.4. The operating mechanism of High Speed Earthing Switches shall be motor wound spring operated type with one of the following features:

i. The closing spring shall remain in discharged position when the switch contacts are in open position. The closing spring shall be charged only when the closing command is given either electrically or manually and the contacts shall close automatically after the spring is fully charged.

ii. If earthing switch is provided with the design in which closing spring is charged and latched in the open & close position of the switch, then mechanical locking

arrangement shall be provided to avoid un-intentional closing of the switch either electrically or manually.

3.3.12.5. In both the designs, facility for padlocking the mechanism in the open position of the switch shall be provided.

3.3.12.6. Facilities integral with the earthing switch for primary current injection or low voltage checks shall be insulated from earth and incorporate a dis-connectable earth strap.

3.3.12.7. These earthing switches shall otherwise be in accordance with the requirements for maintenance earthing switches.

3.3.13. Current Transformers

3.3.13.1. Current transformers shall be supplied suitable for the duty specified and comply with the requirements of IEC 60044-1 and BS 3938 as appropriate.

3.3.13.2. Current transformers, where specified, shall be SF6 gas insulated, shall be compatible with the switch-gear and shall preferably not contain any hygroscopic insulating material which could affect the SF6 gas in either the current transformer or in the associated switchgear chamber.

3.3.13.3. Current transformers shall comply with the requirements of the common sections of this Specification. Where separate terminal boxes are used for current transformer secondary wiring, the identifying labels shall be fitted to the terminal boxes in a conspicuous position but not on removable covers.

3.3.13.4. Current transformers including primary conductors shall have a short time current rating and duration not less than that of the associated switchgear. All current transformers shall have sufficient overload capacity to permit continuous operation.

3.3.13.5. Secondary windings of each current transformer shall be earthed through a withdrawable link at one point only; in the relay panel for protection circuits and in the control panel for instrumentation.

3.3.13.6. Current transformers for tariff metering shall not be used for any other purpose. Current transformers for statistical metering may also be used for other instruments and protection.

3.3.13.7. Where double ratio secondary windings are specified a label shall be provided at the secondary terminals of the current transformer indicating clearly the connection required for either ratio. These connections and the ratio in use shall be shown on the appropriate schematic and connection diagrams.

3.3.13.8. CT sizing calculations shall be submitted to the PGCB for approval.

3.3.13.9. Where multiple ratios are specified and current transformers with multiple windings are tendered, it-shall be possible to select either ratio for each winding without alteration to the number of primary turns.

3.3.13.10. The characteristics of current transformers used for protection circuits shall include the following requirements.

i. For overcurrent protection, they shall not saturate, change ratio or produce harmonic voltages in the secondary winding which will affect the accuracy of the relay with primary currents up to 20 times rates full load current.

ii. For earth fault protection and balanced forms of protection, when connected as in-service, they shall not produce spill currents in excess of half the minimum operating current of the relay but provide stable equipment with primary currents up to 20 times rated full load.

iii. (c) Each protection scheme shall be provided with appropriate current transformers for optimum operation of the scheme. Provision should be made to carry primary injection test of bushing CTs for 100% rating.

3.3.13.11. Terminal boards shall have shorting/disconnecting links to allow testing with the circuit in service and on load. It shall be possible to carry out primary injection testing of the CTs with 100% rating when the switchgear is fully assembled, or retesting of the CTs during the service life of the switchgear without interruption of supply to adjacent circuits or any part of busbar. The testing facilities provide in the design for site testing shall be stated by the Tenderer.

3.3.13.12. The contractor should clearly mention the continuous rating of earth switches and their associated cables for the purpose of primary injection tests. The secondary windings of each set of current transformers shall be capable of being open circuited for one minute with the primary winding carrying the rated current. The secondary wiring of all CT's shall be brought to a common terminal block located within the local control cubicle.

3.3.13.13. The polarity of the primary and secondary windings of each transformer shall be clearly indicated at the respective terminals and in addition labels shall be

fitted in a readily accessible position to indicate the ratio, class and duty of each transformer winding.

3.3.13.14. Neutral CT for REF protection and any other CTs which require to be matched with switchgear CTs will be manufactured by switchgear manufacturers and hand over to transformer manufacturer for installation. Suitable mounting arrangement is to be made by the transformer manufacturer.

3.3.14. Voltage Transformers

3.3.14.1. Indoor voltage transformers, where specified, shall be SF6 gas insulated, shall be compatible with the switchgear and shall preferably not contain any hygroscopic insulating material which could affect the SF6 gas in either the voltage transformer or in the associated switchgear chamber.

3.3.14.2. Voltage transformers shall comply with the common sections of this Specification, comply with the requirements of IEC 60044-2 and shall be provided with requirement mentioned in Appendix.

3.3.14.3. The rated secondary voltage per phase shall be 110/√3 volts in the case of star connected windings and the rated voltage factor shall be 1.2 continuous; 1.5 for 30 seconds.

3.3.14.4. Facilities for isolating the primary connections without having to lift the VT from the switchgear shall be provided. This primary isolation shall be without degassing. The VT isolation link shall be auto & manual operated and have earthing provision. This link will have interlock with FES.

3.3.14.5. It shall not be possible for voltage transformer secondary windings to be connected directly in parallel, except through interposing voltage transformers associated with a synchronizing scheme. To prevent any possibility of back energizing a VT secondary winding via synchronizing circuits, circuit breaker auxiliary contacts which are of the late make-early break type shall be employed.

3.3.14.6. Voltage transformers shall be capable of carrying continuously, without thermal damage 150% of their rated output.

3.3.14.7. Voltage transformers on feeder circuits shall be located on the feeder side of the circuit breaker outside the protected zone covered by the busbar protection. They shall however be included in the protected zone afforded by the feeder protection.

3.3.14.8. Primary connections shall have the same short time current rating as the associated switchgear.

3.3.14.9. Each secondary winding of the voltage transformers shall be protected by suitable approved fuses and links which shall be located as close as possible to the voltage transformer, preferably within the terminal box. All secondary winding connections, including both ends of the secondary winding shall be brought out to the fuses and links. The fuses and links shall be connected to approved terminal blocks for termination of multicore cables. A metallic label shall be provided and fixed at the voltage transformer clearly indicating the connections required for each winding.

3.3.14.10. Separate sets of MCBs shall be provided at the VT for:

i. Each protection scheme
ii. Instruments, disturbance recorder, fault locator etc.
iii. Synchronizing

3.3.14.11. The circuits for each main protection scheme shall be segregated in separate multi-core cables from the VT to the protection panels. An alarm (VT. failure) shall be provided for each set of MCBs.

3.3.14.12. The neutral point of each voltage transformer secondary circuit shall be earthed at one point only via a separate removable link of approved design. The earth link shall be situated in an accessible position and suitably labelled.

3.3.14.13. Fixed ladders and/or cat walk structures with handrails are to be provided for the VTs for inspection/testing/replacement of fuse, etc.

3.3.14.14. Mechanical shock indicators shall be fitted to VTs prior to dispatch from the factory, to indicate how the VT was handled during transit and to determine if detailed inspection is required at Site.

3.3.14.15. Electromagnetic voltage transformers shall be capable of discharging the capacitance of line, cables and switchgear which may remain connected to them during switching operations. The Tenderer shall declare any limitations of the equipment for this duty.

3.3.14.16. The contractor shall ensure that no disruptive over voltages will be generated due to ferro-resonance phenomena and if necessary, by suitably connecting resistors across the secondary of VT after approval of PGCB. All necessary site tests are to be performed on VTs before commissioning. Details of the test procedures and test formats are to be provided.

3.3.15. Bushing and Feeder and Transformer Connections

3.3.15.1. Where stated in the Schedule of Requirements, GIS are to be provided with bushing insulators to connect facilities as per drawings.

3.3.15.2. All bushings shall comply with IEC 60137, 61639, 62271 & 60815.

3.3.15.3. All bushings shall be Resin Impregnated Paper (RIP) bushings with silicon composite housing.

3.3.15.4. The current rating of each bushing shall be equal or greater than the current it will carry at the maximum rating.

3.3.15.5. For quality, reliability and maintenance requirement, the bushings to be supplied under this project shall be from *ABB(Sweden/*Switzerland*)*, *Trench(France/USA), HSP (Germany), GE (Italy) (and/ as specified in Appendix of Requirement) or equivalent.*

3.3.15.6. Bushing outline drawings with stud sizes identified shall be submitted with GIS approval drawings. 4-hole IEC bushing terminal connectors shall be supplied for each bushing. Connectors shall be tinned copper-bronze and finished on both sides. Cut sheets shall be provided showing materials, dimensions and current rating of terminal connectors. Type test of the Busing for Short circuit force withstand capability shall be submitted with the Bid and the same shall be submitted during execution for approval.

3.3.15.7. On all condenser bushings, a tapping shall be brought out to a separate terminal for testing purposes on site.

3.3.15.8. Special precautions shall be taken to exclude moisture from paper insulation during manufacture, assembly, transport and erection.

3.3.15.9. The minimum creepage distance for outdoor bushings shall not be less than 25mm per kV of rated voltage between phases.

3.3.15.10. Bushings shall be of sealed construction suitable for service under the very humid conditions at Site and, additionally, for the very rapid cooling of equipment exposed to direct sunlight when this is followed by sudden heavy rainstorms.

3.3.15.11. Typical sections of bushing insulators showing the internal construction, method of securing the top cap and methods of sealing shall be included in the Bid.

3.3.15.12. Connections shall be suitable for the specified continuous and short circuit current ratings. Where necessary, expansion joints shall be provided to

accommodate differential movements between the switch-gear phase terminals and conductors.

3.3.15.13. The Contractor is required to coordinate design of SF6 filled enclosures such that the integrity of gas and/or oil pressure compartments is maintained.

3.3.15.14. To reduce the effect of solar gain all SF6 or other types of insulated bus ducts exposed to direct sunlight shall be covered with metallic sun shielding, for part of outdoor installation.

3.3.15.15. Some of the above mentioned make, viz., ABB (Sweden/Switzerland), Trench (France/USA), HSP (Germany) & GE (Italy) make bushings are already existed in PGCB's System and their performance is proven. Hence, if the bidder choose to propose bushings from other manufacturers, the proposed manufacturer shall have at least thirty (30) years of manufacturing experience of Resin Impregnated Paper (RIP) bushings prior to the date of bid submission with minimum delivery of at least three hundred (300) nos. of similar or higher rating Resin Impregnated Paper (RIP) bushings with silicon composite housing over the last ten years outside the manufacturer's own country and the bushings similar to or higher rating of the proposed type shall have complete type test report as per relevant IEC standard (IEC 60137) from any independent/STL testing laboratory. The bidders shall have to submit relevant documents with their bids.

3.3.16. Surge Arresters (Gas type)

3.3.16.1. Surge arresters in GIS shall be of the type metal oxide arresters without gaps complete with surge counters and shall fulfill requirements as per IEC 60099-4, IEC 60099-5 and PGCB specification.

3.3.16.2. The Contractor shall demonstrate and verifyby EMTP that the surge arresters will adequately protect the switchgear arrangement proposed.

3.3.16.3. If the additional Surge Arresters are required different from the Surge Arresters proposed on the Single Line Diagrams, those Surge Arresters have to provided free of change and included in the final Bid price.

3.3.16.4. SF6 gas pressure monitors for the surge arresters shall comply with clause 3.3.1 and 3.3.7.

3.3.17. Bus bar (GIB)

3.3.17.1. The bus ducts shall be of the phase isolated or three phase enclosed type as required by design of manufacturer. However, phase isolated design is preferable for HV level (i.e., 230kV & above).

3.3.17.2. The SF6 enclosures shall be constructed from the same materials as the bus bar enclosures provided with the main GIS switchgear. The materials used shall prevent overheating at the specified rated cur-rents. To reduce the effect of solar gain, all SF6 insulated bus duct exposed to direct sunlight may be covered with metallic sun shielding as per the Owner's request. The bus duct shall be complete with all components, enclosures, gas seals, gas monitors, gas compartments, gas filters, gas barrier and sup-porting insulators. The design of the bus ducts shall make full allowance of the thermal expansion associated with the switchgear, bushings and any other equipment between which the bus ducts are connected. The Contractor shall fully co-ordinate the requirements of the SF6 insulated bus duct connections between the GIS switchgear feeders and the overhead line landing gantries, especially with regards to the differential settlement of the concrete floors of the switchgear room and the bus duct supporting structures

3.3.17.3. The bus ducts and their supports shall be designed and tested for the specified rated normal and short time currents and for the maximum system voltage and specified test voltages. The ducts and their supports shall include any nonmagnetic material or insulation necessary to prevent overheating or the induction of over-voltages in the secondary circuits.

3.3.17.4. The GIL shall be supplied & assembled by the manufacturer of GIS.

3.3.17.5. The minimum height of GIL shall be 3.5 meter from the finished ground level.

3.3.18. Local Control Cubicle

3.3.18.1. Each circuit breaker bay shall be provided with a local control cubicle containing local control switches and a mimic diagram for the operation and semaphore for status indication of the circuit breaker and all associated isolators and earth switches together with selector switches to prevent local and remote and supervisory controls being in operation simultaneously. Colors are as follows:

a) 400kV-Purple
b) 230kV-Green
c) 132kV-Red
d) 33kV-Dark Yellow
e) 415V-Pink
f) Earth-Black

3.3.18.2. Closing of the circuit breaker from the local control unit shall only be available when the breaker is isolated for maintenance purposes. Local control cubicle shall be suitable for installation in a separate place or mounted with the GIS bay.

Status indications in the local control cubicle shall be semaphore type or LED type.

3.3.18.3. Circuit breaker control position selector and operating control switch shall be installed in the local control cubicle, while electrical emergency trip push button is to be provided at GCB mechanism. Circuit breaker control from this position will be used under maintenance and emergency conditions only. The emergency trip push buttons shall be properly shrouded.

3.3.18.4. If a disconnector or earth switch is not the fully open or closed position a "Control Circuit Faulty" alarm shall be initiated, and electrical operation shall be blocked. Local manual release facilities shall be pro-vided for closing and tripping the circuit-breaker. The operation of both releases shall be subject to lockout if insufficient stored energy is available. Local manual releases shall be provided with locking off facilities.

3.3.18.5. Sufficient electrical terminals shall be provided for the termination and interconnection of all cabling associated with remote and supervisory control, alarms, indications, protection and local ring main sup-plies. Where control cabling between the local control cubicle and the switchgear are connected by plug and socket boxes, the plugs and sockets shall not be interchangeable.

3.3.18.6. Hydraulic and SF6 auxiliary equipment necessary for the correct functioning of the circuit breakers, disconnectors and earth switches shall be located in a separate cubicle compartment.

3.3.18.7. Operating mechanisms, auxiliary switches and associated relays, control switches, control cable terminations, and other ancillary equipment shall be accommodated in sheet steel vermin proof cubicles. Local control cubicles shall be provided to be free standing or mounted on the GIS with front access, and shall be equipped with anti-condensation heaters. A suitable humidity stat and thermostat shall be included in the heater circuit. The electrical apparatus so protected shall be designed so that the maxi-mum permitted rise in temperature is not exceeded if the heaters are energized while the apparatus is in operation.

3.3.18.8. Cubicles shall be of rigid construction, preferably folded but alternatively formed on a framework of standard rolled steel sections and shall include any supporting steelwork necessary for mounting on the circuit breaker or on concrete foundations. Access to all compartments shall be provided by either removable panels or doors. All fastenings shall be integral with the panel or door and provision made for locking. Doors and panels shall be fitted with weatherproof sealing material suitable for the climatic conditions specified.

Cubicles shall be well ventilated through vermin-proof louvers having anti insect screen.

3.3.18.9. The interior of each cubicle shall be finished with a semi-gloss white surface. An interior lamp suitable for the local LVAC supply, controlled by a door operating switch, shall be fitted at the top of each section.

3.3.18.10. The arrangement of equipment within cubicles shall be such that access for maintenance or removal of any item shall be possible with the minimum disturbance of associated apparatus.

3.3.18.11. All the control switches shall be internal i.e. installed behind a lockable glass door.

3.3.19. Anti-condensation Heaters

3.3.19.1. Anti-condensation heaters of an approved type shall be provided inside each cubicle. They shall be shrouded and located so as not to cause injury to personnel or damage to equipment. The heaters shall have individual humidity stat and thermostatic control and shall be arranged to cut off when the cubicle internal temperature exceeds between 30-35°C and humidity less than 30%. A master heater circuit switch shall be provided on the switchboard or panel with an indicating lamp to show whether the supply is on or off. The location of the heater circuit switch and indicating lamp shall be either on a common panel or in such a location that it does not require moving when extensions are provided. The heaters shall operate from the specified single phase a.c. supply. Isolation facilities for a.c. supply shall be provided in each panel.

3.3.20. Auxiliary Switches and Contactors

3.3.20.1. Auxiliary switches positively driven in both directions shall be provided on all circuit breakers and isolators for local and remote indication, control and interlocking and repeat relays where necessary. Busbar protection has direct driven auxiliary contacts for CT circuits. With each circuit breaker, isolating device, and earthing device, there shall be supplied all necessary auxiliary switches, contactors and mechanisms for indication, protection, metering, control, interlocking, supervisory and other services. All such auxiliary switches shall be enclosed in dust free housing. Not less than eight (4 NO + 4 NC) spare auxiliary switch ways shall be provided with each circuit breaker and not less than six (3 NO + 3 NC) on all other devices. All auxiliary switches shall be wired up to a terminal board in the local control cubicle of the switchgear whether they

are in use or not in the first instance and shall be arranged in the same sequence on appropriate busbar coupling and sectioning equipment that sections or sets of busbars cannot be paralleled by means of the busbar isolating devices unless a parallel circuit is already closed through the circuit breakers of the all equipment.

3.3.20.2. Switches shall be provided to interrupt the supply of current to the tripping mechanisms of the circuit-breakers directly the operation of the latter has been completed. All such switches and mechanisms shall be mounted in approved accessible positions clear of the operating mechanism and shall be adequately protected. The contacts of all auxiliary switches shall be strong and shall have a positive wiping action when closing.

3.3.20.3. Direct acting auxiliary switch make before break contacts shall be used in conjunction with busbar protection schemes.

3.3.20.4. Auxiliary contactors shall be provided only where the circuit requirement cannot be met by the auxiliary switch arrangements and multiple contactors and relays will not be accepted in lieu of auxiliary switches except as specifically approved by PGCB.

3.3.21. Interlocking

3.3.21.1. An interlocking scheme shall be provided which takes into account the following basic requirements.

i. To safeguard maintenance personnel who may be working on one section of the equipment with other sections live.
ii. To prevent incorrect switching sequences which could lead to a hazardous situation to plant, equipment and personnel.
iii. To be designed for the final substation arrangement, avoiding the need for the future modifications

3.3.21.2. The interlocking scheme shall be electrical for all operational interlocks but shall be effective when the equipment is being controlled locally, under emergency hand or from a supervisory position.

3.3.21.3. All electrical interlocks shall so function as to interruption the operating supply and a system of interlocks shall be provided which cover the emergency hand operation of apparatus which is normally power operated. Failure of supply or connections to any electrical interlock shall not produce or permit faulty operation. Visible indication shall be provided to show whether the mechanism is locked or free. Means, normally padlocked, shall be provided whereby the bolt can be operated in the emergency of a failure of interlock supplies.

3.3.21.4. Where mechanical key interlocks are employed, they shall be effective at the point where hand power is applied so that stresses cannot be transferred to parts remote from that point.

3.3.21.5. Where key interlocking is employed, tripping of the circuit breaker shall not occur if any attempt is made to remove the trapped key from the mechanism. Any local emergency tripping device shall be kept separate and distinct from the key interlocking.

3.3.21.6. Circuit breakers closing shall be possible irrespective of the busbar and circuit isolator position.

3.3.21.7. Disconnecting switches shall be so interlocked that they cannot be operated unless the associated circuit breaker is open except that where double busbar arrangements are specified, on-load transfer of feeder circuits from one busbar to another shall be made possible by interlocks which ensure that the associated bus coupler and its isolators are closed. Moreover, disconnecting switches shall be mechanically interlocked with associated Earthing switches .

3.3.21.8. Earthing switches shall be interlocked such that they cannot be operated unless the associated isolator is open. This interlock shall also be mechanical. Moreover, No maintenance earth switch shall be disconnected from ground when 0 voltage is not ascertained.

3.3.21.9. All isolating devices shall be interlocked with associated circuit-breakers and isolators in the same station so that it shall not be possible to make or break current on an isolating device unless a parallel circuit in that station is already closed.

3.3.21.10. In double busbar stations where provision for on-load changeover of busbars is specified, the busbar isolating devices shall be so interlocked with the appropriate busbar coupling and sectioning equipment. In all other circumstances, the busbar isolating devices of equipment other than busbar sectioning and coupling equipment shall be so interlocked that their respective circuit breakers can only be coupled to one set of busbars at a time. It shall not be possible to parallel sections of busbars except through the circuit breakers of the busbar coupling and sectioning equipment.

3.3.21.11. FES shall be interlocked (Electrical & Mechanical) with VT so that VT cannot be isolated if FES is not grounded.

3.3.21.12. For each primary circuit, an interlock bypass switch shall be provided, mounted on the local control cubicle, for use during commissioning of the Switchgear. The switch shall be key operated (common key for each circuit) spring return to normal and provided with sufficient direct drive contacts to enable operation' of the- circuit breaker, isolators and earth switches independent of the electrical interlocking circuitry. By-passing of interlocks shall only lye possible in the local (Maintenance) position.

3.3.21.13. Interlocking philosophy shall be provided by the switchgear manufacturer and shall be submitted for PGCB's approval.

3.3.22. Locking Facilities

3.3.22.1. Locks and locking facilities shall be provided on each item of substation equipment as detailed below and shall be additional to the mechanical interlocking devices specified in the above clause.

3.3.22.2. Where a mechanism is to be locked in a specific position, provision shall be made at that part of the mechanism where the operating power is applied and not to remote or ancillary linkages.

3.3.22.3. The following locking facilities shall be provided with common key operated locks.

i. Circuit breaker mechanisms in the open position and any associated manual operating device in the neutral position.
ii. Isolating switches in both open and closed positions.
iii. Operating cubicle access door

3.3.23. Earthing System

3.3.23.1. The earthing system of the GIS shall mainly comprise an interconnected meshed earthing grid directly connected to the building earthing mesh, having an earth resistance not higher than 0.5 Ohm related to 50 Hz. It shall be on the same potential level as the earthing to all electrical equipment and all metallic parts to form a bonding system on potential equality capable of carrying the fault currents resulting from short circuits.

3.3.23.2. The earthing system shall fulfil the following requirements:

a) Maintain a low overall resistance of the earth mass to limit the potential rise with respect to true earth and ensure protective relay operation in the event of an external fault

b) Provide ground connections to all electrical apparatus enclosures and structural steelworks adequate to carry prospective ground faults without excessive heating or fire risk

c) Ensure the safety of personnel by limiting step and touch voltages to values well within acceptable levels according to IEEE Std. 80 and eliminate interference or damage to sensitive electronic circuits close to as well as in the inner area of the substation

3.3.23.3. The Manufacturer of the switchgear shall be entirely responsible for and must coordinate the design of the switchgear with that of the earthing system as a whole for ensuring that all apparatus and metallic structures are securely and safely connected to this system.

3.3.23.4. Where appropriate, the earthing system shall be designed so as to include all overhead line terminal towers, gantries and outdoor structures, which shall be earthed by extending the system so as to envelope all towers within the earth system.

3.3.23.5. All major equipment shall be connected at least twice to the earthing system at their extreme extent, spur connections shall run in opposite directions. The location of the earthing grids shall be such as to enable all non-current carrying but conductive component to be connected to the earth system by low-inductance via the shortest practicable route.

3.3.23.6. All metal parts other than those forming part of any electrical circuit shall be earthed to the earthing system. Any necessary terminals on part of the equipment required for this purpose shall be provided by Contractor. The jointing parts of the earthing conductors/strips are to be properly tinned.

3.3.24. EarthingMesh of the Building

3.3.24.1. The reinforcement of the floors and the metal support structures and/or reinforcement of the walls are to be included into the main earthing system.

3.3.24.2. The spacing between conductors forming the meshed earthing grid shall be such as to limit the maximum mesh potential to a value not greater than the maximum tolerable contact potential, assuming a fault clearance time equal to that of the backup protective gear being provided, but the maximum shall be 10 m. Possible mechanical expansion joints shall be suitably bridged.

3.3.24.3. It is mandatory to have around the GIS building a ring earth electrode at a distance of 1 m and a depth of 0.5 to 0.8 m, being connected to neighbouring foundation earth electrodes and to the main earthing system of the substation.

3.3.24.4. Where the GIS and its control and protection are located the floor reinforcement shall be properly connected to the main earthing system at a minimum of once per 10 m along the walls. For this purpose the floor additionally shall be equipped with a mesh of galvanised flat steel welded every 3 m to the reinforcement.

3.3.24.5. The steel reinforcing mesh of the continuous floor slab shall be provided with electrical contact points brought out to convenient locations so that both the GIS enclosures and the structural steel in and above the foundation will be at approximately the same potential level.

3.3.24.6. Copper conductors connected to the main earthing system and suitably sized to carry the fault current shall be installed to form one ring inside the GIS room as well as in all other rooms of the building.

3.3.24.7. From the ring conductor inside the respective room connections to the panels, cable trays, conduits, doors, steelworks, buried floor screens, etc., shall be made.

3.3.24.8. Where GIS bus-ducts enter through walls additional earthing shall be provided to ensure an effective earth path. Two connection points per wall penetration from opposite directions are required.

3.3.25. GISBonding and Earthing

3.3.25.1. The Manufacturer of the GIS shall give particular attention to the bonding of the metallic enclosures of the GIS assembly to ensure that these enclosures carry induced currents, which can be of significant magnitude, via specifically designed paths.

3.3.25.2. Two copper conductors shall run along the full length of the switchgear, laid in a maximum distance of eight meters, each connected every five meters to the building earthing mesh for connecting all designated metallic components of the GIS to the main earthing system.

3.3.25.3. The housing of the switchgear bays each shall be earthed through tinned copper earth cable to those two copper conductors, at least at two opposite points, preferably near to the circuit-breaker and at the cable connection assembly. The dimensioning shall be appropriate to meet the requirements of operational and protective earth, most notably regarding maximum rated short time withstand currents and electromagnetic interferences.

3.3.25.4. As an alternative to the two copper conductors two mounting rails may be used, embedded into the concrete slab. In this case the base of each feeder shall be welded to the mounting rails.

3.3.25.5. Surge arresters shall be earthed on shortest way to main earthing system. If no surge arresters are installed within an outgoing GIS feeder earth connection facilities at the bushings shall be provided to allow a direct connection between the GIS housing and the direct ground connection of an air insulated surge arrester. This earth connection facility shall face outwards towards the possible location of surge arresters.

3.3.25.6. Supporting structures are to be earthed separately using these copper conductors as earth potential.

3.3.25.7. At single phase insulated GIS switchgear and bus-ducts, extra attention should be paid to the possibility of unwanted circulation of induced currents. To avoid high currents running through the earthing grid the enclosures of all three phases shall be connected directly by phase interconnections (return current conductors) in suitable distances.

3.3.25.8. Provision shall be made for the connection of power cable sheath bonding systems and cable accessories to the main earthing system. Any integral access platforms provided for operation or servicing shall be integrated into the GIS earthing system by forming an additional mesh.

3.3.25.9. Every conductor as part of the service earthing system, such as neutral conductors, connections to transformer star-points, or any other conductor specially exposed to transient voltage or current surges, shall be of tinned copper and sized (minimum 50 mm). With the exception of the indoor main earthing bus, all other earthing conductors (above ground level) shall consist of tinned,

stranded copper conductors, taking into account a maximum permissible temperature of 200°C under fault conditions. For connections with other metal parts, the ends of such conductors shall be fitted with cable lugs, rigidly connected with the earthing conductor by means of a hydraulic tool. Interconnections between earthing conductors shall be performed with straight joints or T-joints fixed in the same manner.

3.3.25.10. All earth connection points shall be defined, shall be sufficient in number and shall be located to minimize hazardous touch and step voltages within the GIS area.

3.3.25.11. All of the electrical equipment, frames and mechanical apparatus shall be provided with designated earthing points, on metallic parts as e.g. structures and GIS housings preferably of the punch-in type. On cast housings earthing points shall have a machined surface, clean and free of colour to provide an optimum conductivity. Material not being rust-proof has to be protected against corrosion in an approved manner after installing an earth connection. The electrochemical series shall be considered, see IEC 60364-5-54 542.2.5; direct contact between material with a standard electrode potential difference of 1 V or higher will not be accepted, e.g. between Cu and Al (2.01 V), as well as between Cu and Zn (1.11 V).

3.3.25.12. Metallic cable trays and vertical runs are to be connected to the earthing system at least within 20 me-ter intervals. All tray sections must be firmly bolted together to form a continuous metallic link end-to-end.With non-metallic cable trays a continuous earthed conductor shall be provided along the run of the cable trays. The earthing conductor shall be connected at both ends and within 20 meter intervals to the main system earth.

3.3.26. Special Equipment and Tools

3.3.26.1. The Contractor is obliged to deliver all equipment and tools required for installation, dismantling, testing and maintenance of equipment. Special equipment and tools shall be of the highest quality and suitable for field work.

i. A handle for manual operation shall be found in all operating mechanisms.
ii. SF6 gas cylinder with valve and instruments for refilling and SF6 leakage detector

3.3.26.2. All materials to be used shall be new. A list of a special equipment and tools shall be delivered with a bid. The Employer reserves the right to request any other special equipment or tools during training or testing, which he finds necessary, free of charge, although such equipment or tools were not on the list of special equipment.

(a) SF6 Gas leakage detector:

The detector shall be portable, battery operated, hand held type and having a minimum SF6 gas leakage sensitivity of 5gm/year. The sensor shall be connected through a flexible wand for easy accessibility to joints, seals and couplings in GIS equipment and provided with a protection filter. The equipment shall have on/off switch & suitable indicating lamps/LEDs, variable pitch audible signal for leakage indication. The equipment shall have automatic zeroing of background signals suitable for detecting SF6 gas leakage in charged switchyard. The test kit shall be compatible for EMI/EMC environment as per IEC 1000.

(b) Gas filling and evacuating plant: Gas Processing unit

i) The plant necessary for filling and evacuating the SF6 gas in the switchgear shall be supplied to enable any maintenance work to be carried out. This shall include all the necessary gas cylinders for temporarily storing the evacuated SF6 gas. The capacity of the temporary storage facilities shall at least be sufficient for storing the maximum quantity of gas that could be removed from at least one phase of one complete bay (switchgear and associated equipment).

ii) Where any item of the filling and evacuating plant is of such a weight that it cannot easily be carried by maintenance personnel, it shall be provided with lifting hooks for lifting and moving with the overhead cranes.

iii) The minimum capacity parameters of evacuation plant will be as under:

iv) Oil Free Suction (Recovery) Pump: 30 m3/hour

v) Compressor (Two Stage): 15 m3/hour

vi) Oil Free Vacuum Pump: 100 m3/hour

vii) The evacuation equipment shall be provided with all the necessary pipes, couplings, flexible tubes and valves for coupling up to the switchgear for filling or evacuating all the gases. Details of the filling and evacuating plant that will be supplied, as well as the description of the filling and evacuating procedures shall be furnished.

(c) SF6 gas analyzer:

The SF6 gas analyzer should be of portable type and instruments shall have following features.

i) In-built calibration facility.

ii) Sensitivity of the equipment shall not be affected by any atmospheric conditions like dust, humidity, heat, wind etc.

iii) Equipment shall work on zero gas loss principle i.e. gas should be pumped back to the compartment after measurement without any exposure to the atmosphere.

iv) Equipment shall be supplied with suitable regulator which can be used to connect SF6 cylinder if required.

v) Following acidic/impurities products should be detected as per IEC 60480 and IEC 60376

vi) SF6 purity – Range: 0-100 % & Accuracy: +/- 2 deg

vii) Dew point - Range : -60 to +20 deg C & Accuracy: +/- 4 deg C

viii) SO2 - Range : 0-150 ppm & Accuracy : +/- 2 %

ix) HF - Range : 0-10ppm & Accuracy : +/- 10 %

x) Instrument should work on AC source as well as on rechargeable battery

xi) Input pressure: up to 10 bar

xii) It should be housed in a robust IP67 case with wheels

(d) Portable Partial Discharge(PD) monitoring system

i) The equipment shall be used for detecting different types of defects in Gas Insulated Stations (GIS) such as Particles, Loose shields and Partial Discharges as well as for detection of Partial discharges in other types of equipment such as Cable Joints, CTs and PTs.

ii) It shall be capable for measuring PD in charged GIS environment as EHV which shall have bandwidth in order of 100 MHz–2GHz with possibility to select a wide range of intermediate bandwidths for best measurement results. The principle of operation shall be based on UHF principle of detection. The instrument should also be able to detect partial discharges in cable joints and terminations.

iii) Detection and measurement of PD and bouncing particles shall be displayed on built in large LCD display and the measurement shall be stored in the instrument and further downloadable to a PC for further analysis to locate actual source of PD such as free conducting particles, floating components, voids in spacers, particle on spacer surfaces etc. Software for display and diagnosis of PD signals and an expert software system for accurate interpretation of cause of PD shall also be supplied and installed by the contractor.

iv) The equipment shall meet the following requirements

v) Measurement shall be possible in noisy environment.

vi) Stable reading shall be possible in presence of vibrations within complex GIS assemblies, which can produce signals similar to PD.

vii) Equipment should have necessary synchronizing circuits to obtain PD correlation with power cycle and power frequency.

viii) The equipment shall be battery operated with built-in-battery charger. It shall also be suitable for 230V AC/50 Hz input.

ix) Measurement shall be possible in the charged switchyard in the presence of EMI/EMC. Supplier should have supplied similar detector for GIS application to other utilities. Performance certificate and the list of users shall be supplied along with the offer.

x) Instrument shall be supplied with standard accessories i.e., re-locatable sensors with mounting arrangements, connecting cables (duly screened) to sensors, Laptop PC, diagnostic and expert interpretation software, carrying case, rechargeable battery pack with charger suitable for 230V AC, 50Hz supply connecting cables (duly screened) to view in storage.

xi) The function of software shall be covering the following:

- Data recording, storage and retrieval in computer
- Data base analysis
- Template analysis for easy location of fault inside the GIS
- Evaluation of PD measurement i.e, Amplitude, Phase Synchronization etc.
- Evaluation of bouncing/loose particles with flight time and estimation on size of particle.
- Expert software system for accurate interpretation of cause of PD.
- Report generation.
- To prove the suitability in charged switchyard condition, practical demonstration shall be conducted before acceptance.
- Supplier shall have “Adequate after sales service” facility in India and shall provide the document in support of this.
- Necessary training may be accorded to personnel to make use of the kit for locating PD sources inside the GIS.
- Instrument shall be robust and conform to relevant standard.

xii) Calibration: The UHF Couplers have to be first calibrated as per CIGRE Document No. 654 as part of factory acceptance tests to guarantee detection sensitivity of 5pC or better. The GIS of same design shall be used as test specimen during the coupler calibration. The pulse injection level determined through above factory calibration tests shall only be used as reference for site sensitivity checks during commissioning of PDM system. The data sheet/frequency response characteristics shall be submitted for reference.

xiii) Pulse generator, same type as that of used during factory testing for UHF sensor sensitivity test shall be supplied as a standard accessory.

The make of the equipment shall be from EU, UK, USA, Japan or other eligible countries with equivalent quality.

3.3.27. Spare Parts

3.3.27.1. Contractor is obliged to enclose with the bid a list of recommended spares required for operation and maintenance necessary for 2 years period.

3.3.28. Packing, Shipment and Transportation

3.3.28.1. The Contractor is obliged to arrange preparation, packing and transport of the equipment.

3.3.28.2. Each circuit breaker shall be separately packed. It is not allowed to pack parts for more circuit breakers in single package.

3.3.28.3. The equipment shall be packed and ready to be stored for a longer period. All operating mechanisms shall be provided and packed so as the heater can be connected. For this purpose provide a suitable cable with a plug.

3.3.28.4. Sufficient quantity of SF6 gas must be delivered for the first gas filling and eventually refilling.

3.3.29. Inspection and Tests

3.3.29.1. Tests shall be carried out in order to determine whether the material and equipment comply with the required properties. All tests on the materials and equipment shall be made in accordance with IEC 62271-203. Testing shall not impair the properties and reliability of a test object or reduce its lifetime.

i. Type tests shall be performed on each type and rating of the specified equipment with the purpose of proving its properties. Detailed list of type tests shall be attached to the bid along with the copies of the Type tests certificates.
ii. Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.
iii. Factory acceptance test shall be conducted in the Manufacturer's factory in a presence of three representatives of the Employer, before delivery. All costs including visa fee, health insurance, transport, accommodation, food, daily allowance as well as costs for the tests shall be borne by the Contractor and included in the contract price. Acceptance test will be conducted in accordance with the program of routine tests.

3.3.29.2. Type Tests

The following type tests shall be conducted on each type and class of the specified equipment for the purpose of proving its properties:

(a) Complete Swithchgear
- i) Dielectric tests
  iii. Power frequency withstand voltage test (wet and dry)
  iv. Lightning impulse voltage tests
- ii) Measurement of the resistance of the main circuit
- iii) Temperature rise test
- iv) Short time and peak withstand current tests
- v) Pressure test on partitions
- vi) Test under conditions of arcing due to internal fault
- vii) Insulator tests
- viii) Tightness test

(b) Circuit Breaker
- i) Mechanical and environment tests
- ii) Test circuits for short circuit making and breaking tests
- iii) Single-phase and double-earth fault tests
- iv) Short line fault tests
- v) Out of phase making and breaking tests

(c) Disconnector & Earthing Switch
- i) Tests to prove the short circuit making performance of earthing switches
- ii) Operating and mechanical endurance tests
- iii) Bus-transfer current switching tests
- iv) Induced current switching tests

(d) Current Transformer
- i) Short-time current tests
- ii) Temperature-rise test

(e) Voltage Transformer
- i) Temperature-rise test
- ii) Lightning Impulse test

3.3.29.3. Routine Tests

The following type tests shall be conducted on each piece the equipment to be supplied for the purpose of revealing faults in material or construction:

(a) Complete Swithchgear
- i) Dielectric tests

v. Power frequency withstand voltage test (wet and dry)

ii) Measurement of the resistance of the main circuit

iii) Pressure test on partitions

iv) Tightness test

(b) Circuit Breaker

vi. Mechanical and environment tests

(c) Disconnector & Earthing Switch

vii. Operating and mechanical endurance tests

3.3.29.4. On Site Tests

After the GIS Switchgear has been fully installed at site and SF6 gas filled at rated filling density, the complete assembly shall be subjected to the site tests as per IEC-62271-203. Method statement/ procedure of On Site high voltage testing, PD measurement and relevant tests shall be submitted by contractor in advance.

3.3.30. Documentation

3.3.30.1. Documentation attached to the bid shall include minimum the following:

(a) Manufacturer's Authorization
(b) Manufacturer's Quality control certificate
(c) Detailed list of type test for each type and class of the specified equipment
(d) Copies of type test reports
(e) Equipment-related catalogues
(f) Reference list for previous five years
(g) Drawings, schematic diagrams and similar
(h) List of special equipment and tools
(i) List of recommended spare parts
(j) Training plan (if any, as required by specification)
(k) Instruction manuals for installation, testing and maintenance
(l) Test protocol of acceptance testing

3.3.30.2. All documents, tables and rating plates attached to the equipment shall be in English language.

3.3.30.3. The contractor shall prepare and submit to the employer, drawings, details that show the GIS design in order for the employer to verify the equipment conform to the specifications. The Design Document to be submitted for review and approval are as follows:

(a) Design Review Document as per clause no. 3.3.3 of this specification
(b) Single Line Diagram/
(c) Gas Schematic Diagram / Interlocking scheme
(d) GTP-Guaranteed Technical Particulars
(e) GIS layout (Plan and Section) including 3D drawing
(f) GIS Component Drawings
(g) Interface modules drawing for GIS extension
(h) Rating and Name Plate Drawing
(i) GIS/LCC Schematics Drawing
(j) Foundation loading plan and detail
(k) GIS Support Structure Drawing
(l) GIS platforms and Walkway Drawing
(m) GIS grounding plan and details along with design calculation for GIS grounding
(n) GIS key Diagram enlisting and marking each and every GIS Module clearly and separately identifiable (indoor and outdoor). This separately identified module shall be complete along with its enclosure, gasket and all active parts such as conductor, conductor joints, corona shield etc.
(o) Method Statement along with sequential instruction for dismantling and assembling of all major components of GIS exhibiting service continuity requirement
(p) Type Test Reports
(q) Seismic Analysis Report
(r) Study report of VFTO generated for GIS installation for 400 kV and above.
(s) The general arrangement drawing of interconnecting bus-duct from GIS bay module to XLPE cable termination end
(t) The general arrangement drawing of Terminal connection arrangement to connect GIS duct to SF6/Oil bushing and duct mounting arrangement details
(u) Gas handling procedure
(v) The design & construction proposal of the building along with necessary information, data, and drawings according to the complete requirements
(w) Capacity calculation of EOT crane for GIS hall considering a factor of safety
(x) Method statement/ procedure of ON SITE high voltage testing with PD measurement and Switching Impulse test
(y) Additional CB data to be furnished during detailed engineering:
    i) Design data on capabilities of circuit breakers in terms of time and number of operations at duties ranging from 100 % fault currents to load currents of the lowest possible value without requiring any maintenance or checks.
    ii) Curves supported by test data indicating the opening time under close open operation with combined variation of trip coil voltage and hydraulic pressure.
    iii) Contact Travel: Operating mechanism operating shaft travel and contact overlap of Circuit Breaker to be provided

(z) The Sub-station GIS layout as a separate drawing indicating position of spacers, spread over of PD sensors with distance, sensor identification, the detector unit identification etc., total numbers of offered UHF Sensors along with attenuation calculation. And data sheet for the UHF couplers.

(aa) Installation and Operation & Maintenance Manual

3.3.31. Installation of GIS

3.3.31.1. Civil works of GIS Hall shall be completed in all respects before taking up the installation and it shall be ensured that Ventilation System is operational and all dust and dirt in the hall are removed. The GIS hall needs to be in positive pressure before starting Installation.

3.3.31.2. The installation area shall be secured against entry of unauthorized personnel. Only certified manufacturer's engineer and supervisor shall undertake the erection works. Engineers and supervisors of the manufacturer shall submit authorization and competency certificate to PGCB.

3.3.31.3. Un-packaging of GIS modules shall be done outside the GIS hall and in no case module to be taken inside GIS hall with packing.

3.3.31.4. All assembly work shall be done by qualified personnel only who are to be identified and list submitted to PGCB before starting of erection work.

3.3.31.5. Assembly drawing for GIS erection for the section under progress shall be available and displayed in GIS hall at the time of erection work.

3.3.31.6. Working personnel shall clean their shoes or apply covers on shoes before entering the immediate working area. The working clothes of authorized personnel shall be made of non-fluffy material.

3.3.31.7. GIS hall door shall have automatic close facility after entry of personnel to avoid dust and moisture entry. Walls and ceiling shall be in a condition so that neither dirt nor plaster might fall or rub off and formation of condensation water in ceiling shall be prevented under any circumstances.

3.3.31.8. Floor in the installation area shall have a firm surface and shall be kept dust free with a vacuum cleaner. Vacuum cleaning to be done on regular basis.

3.3.31.9. Only T&P and consumables required for GIS erection shall be kept in GIS during erection.

3.3.31.10. In case of outdoor installation of GIS or of GIS components open gas compartments shall be protected from dust and moisture ingress (by tarpaulin covers/protective enclosure/chamber etc).

3.3.31.11. Bus duct exits in the GIS hall's wall shall be kept covered by suitable means until permanent cover is provided after installation of bus ducts.

3.3.31.12. Maintenance room (as a part of LCR room) shall be constructed for carrying out repair works/ small part assembly. All excess material (not required for immediate installation works) test equipment and tools and tackles to be stored separately from GIS hall in this room for rework.

3.3.31.13. Erection agency shall submit method statement and make available formats for checking during each stage of hall preparation, assembly process and final checks to be approved by PGCB before start of erection. Shock recorder down loaded data and analysis shall be submitted preferably before commencement of erection work. In case of violation of shock limits, expert from manufacturer shall visit and do the joint internal inspection and shall submit analysis report before giving clearance for erection. If required the module shall be taken back to factory for further analysis and testing.

3.3.31.14. Cleaning is of utmost importance and hence before assembly, all the loose metal parts, subassemblies and all contact & sealing surfaces shall be cleaned before installation. Cleaning shall be carried out with specified cleaning agents of the manufacturer, in no condition water is to be used except for external surfaces. Further, prior to opening of gas compartment, the same shall be thoroughly cleaned externally. The vacuum cleaning of the installation area shall also be done specially the immediate vicinity of the flanges to be connected.

3.3.31.15. All Civil Work inside building including internal cable trench shall be completed before GIS installation.

3.3.31.16. Installation of flanges shall be done immediately after removal of transport covers. Transport covers, O-rings and other packing material of GIS shall be taken out immediately after removal.

3.3.31.17. O-Rings shall be properly stored and taken out only before installation. O-Rings are also to be cleaned before use with manufacturer authorized cleaning agent.

3.3.31.18. At all points of time during installation authorized personnel shall use suitable gloves to avoid contamination.

3.3.31.19. Cable termination work shall commence only after completion of GIS equipment

3.3.31.20. erection, as during GIS installation period laying and termination of cables interferes with the GIS erection work and affects cleanliness.

3.3.31.21. Approved Field Quality Plan, which should be included Check-list, Witness-point, Holding-point etc., shall be followed during site work.

3.4. Outdoor Equipment

3.4.1. HV Instrument Transformers – Capacitive Voltage Transformers

3.4.1.1. Scope

3.4.1.1.1. This chapter covers the ratings, design, equipment requirements, inspection and testing of the equipment. It states only those general aspects that are meant to ensure minimum requirements with respect of quality and performance.

3.4.1.1.2. Other details and specific data are contained in the Technical Data Schedules.

3.4.1.1.3. Properties, testing and ratings of the equipment shall at least conform to the latest edition of the relevant IEC and British standards.

3.4.1.1.4. The Contractor is obliged to provide complete equipment, even if the details are not mentioned specifically in the following specifications.

3.4.1.2. General Design

3.4.1.2.1. The capacitive voltage transformers shall be for outdoor installation, single phase, hermetically sealed. If weight of related wave trap is not an issue, a vertical W.T on the top of CVT is accepted.

3.4.1.2.2. Capacitive voltage transformers as insulation medium shall be oil-paper immersed or impregnate-mixed dielectric. Inductive voltage transformers as insulation medium shall be oil-paper immersed, only. SF6 gas is not allowed.

3.4.1.2.3. The tgδ for capacitive divider of capacitive voltage transformers shall not be greater than 0.1%. For efficient suppression of the ferro-resonance feature, working induction of intermediate transformer of capacitive voltage

transformer should be ≤ 0.5 T. Such shall be verified during detail design through appropriate document.

3.4.1.2.4. The voltage transformers shall have multi secondary windings appropriate characteristics. Capacitive voltage transformers should be used as capacitor for HF connection. They shall be supported by silicon composite insulator.

3.4.1.2.5. The voltage transformers shall comply with IEC 60044. They shall be equipped with:

i. Expansion chamber/and internal metal bellows type oil gauge diaphragm.
ii. Device for determining insulating medium level
iii. Oil drain cock and sampling device
iv. tgδ measuring connection
v. Low voltage terminal box
vi. Low Voltage MCB with additional NO & NC contacts at secondary box
vii. Adequate earth terminal connection
viii. Tap for target delta measurement
ix. Enable sealing after accuracy class checks (sealing possibilities)
x. terminal connection for anti-ferro-resonance control for capacitive voltage transformers
xi. HF connection terminal for capacitive voltage transformers
xii. Overpressure device

3.4.1.3. High-Voltage Terminals

3.4.1.3.1. High-voltage terminals shall be:

i. horizontal (or vertical, for voltage transformers only),
ii. flat,
iii. for aluminium conductor,
iv. minimum area of 100 x 100 mm, with four holes, 14 mm diameter, at 50 mm distance between each other

3.4.1.4. Permissible Partial Discharges Level

3.4.1.4.1. Instrument transformers should be so designed to have a neglect level of partial discharges. Contractor shall guarantee a partial discharge level lower or equal to maximum allowed according to the IEC standards (IEC 60044). It is desirable that partial discharge level should be as lower as it is possible.

3.4.1.5. Outdoor Insulation

3.4.1.5.1. Outdoor insulation of instrument transformers shall consist of composite silicon insulator element.

3.4.1.5.2. Insulators shall be made of composite silicon, according to technical specifications. Any connection be-tween porcelain and flange shall be made with Portland cement. The connection itself shall be handled with such manner so as to prevent retaining or intrusion of moisture. Metal parts shall be made of aluminium, stainless steel or shall be galvanized with minimum 70 µm zinc layer.

3.4.1.5.3. Minimum creepage distance is 31 mm/kV.

3.4.1.6. Environmental Protection

3.4.1.6.1. Design of Instrument transformers shall be designed to take maximum care of environment.

3.4.1.7. Mechanical Terminal Loads

3.4.1.7.1. Instrument transformers shall fulfil at least mechanical requirements of Class II.

3.4.1.8. Mechanical Protection

3.4.1.8.1. Design of instrument transformers shall provide hermetically sealing of active parts. Secondary terminal box shall be mechanical protection level min. IP54.

3.4.1.9. Anticorrosion Protection

3.4.1.9.1. All outdoor metal parts shall be made of aluminium, stainless steel or shall be galvanized with minimum 70 µm zinc layer. All screws and other connecting material must be made of stainless steel.

3.4.1.9.2. It is not allowed to use material with anticorrosion protection, except metal support structure, which shall be galvanized with minimum 70 µm zinc layer.

3.4.1.10. Packing, Shipment and Transport

3.4.1.10.1. The Contractor is obliged to arrange for preparation, packing and transport of the equipment. Each instrument transformer shall be separately packed.

Copy of a routine test report shall be submitted together with each piece of instrument transformer.

3.4.1.11. Inspection and Tests

3.4.1.11.1. Tests shall be carried out in order to determine whether the material and equipment comply with the required properties. All tests on the materials and equipment shall be made in accordance with IEC standards. Testing shall not impair the properties and reliability of a test object or reduce its lifetime.

i. Type tests shall be performed on each type and rating of the specified equipment with the purpose of proving its properties. Detailed list of type tests shall be attached to the bid along with the copies of the Type tests certificates.
ii. Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.
iii. Special tests shall be performed on each piece of equipment before delivery, during the acceptance test
iv. Acceptance test shall be conducted in the Manufacturer's laboratory in a presence of three representatives of the Employer, before delivery. All costs including visa fee, health insurance, transport, accommodation, food, daily allowance as well as costs for the tests shall be borne by the Contractor and included in the contract price.

3.4.1.11.2. Acceptance test will be conducted in accordance with the program of routine tests.

3.4.1.12. Type Tests of Capacitive Voltage Transformers

3.4.1.12.1. The following type tests shall be conducted on each type and class of the specified equipment for the purpose of proving its properties:

i. Accuracy class test
ii. Temperature rise test
iii. Measurement of capacitance and dielectric dissipation factor
iv. Chopped impulse tests
v. Radio interference voltage measurement test (RIV)
vi. Short-circuit withstand capability test
vii. Lighting impulse tests
viii. Switching impulse test wet
ix. Transient response test
x. Ferro-resonance test
xi. Tightness test of liquid-filed electromagnetic unit
xii. Voltage and phase accuracy test

3.4.1.13. Routine Tests

3.4.1.13.1. The following type tests shall be conducted on each piece the equipment to be supplied for the purpose of revealing faults in material or construction:

Routine Tests - Capacitive Voltage Transformers

i. On capacitive divider of capacitive voltage transformers:
   a. Measurement of capacitance
   b. Measurement of dissipation factor (tgδ)
   c. Power frequency withstand tests
   d. Partial discharge measurement
   e. Measurement of capacitance (again)
   f. Measurement of dissipation factor (tgδ)(again)
   g. Measurement of capacitance separately C1 and C2
   h. Power frequency withstand tests on low voltage terminals of capacitive divider.
ii. On electromagnetic unit of capacitive voltage transformer:
iii. Power frequency withstand tests
iv. Power frequency withstand tests on low voltage terminals of capacitive divider
v. Power frequency withstand tests on secondary windings
vi. On complete of capacitive voltage transformer:
   a. Verification of terminal markings
   b. Ferro-resonance test
   c. Accuracy class test
   d. Galvanizing test

3.4.1.14. Documentation

3.4.1.14.1. Documentation attached to the bid shall include minimum the following:

i. Manufacturer's Authorization
ii. Manufacturer's Quality control certificate
iii. Detailed list of type test for each type and class of the specified equipment
iv. Copies of type test reports
v. Equipment-related catalogues
vi. Reference list for previous five years

3.4.1.14.2. Drawings, schematic diagrams and similar

i. List of special equipment and tools, if any

ii. List of recommended spare parts, if any

3.4.1.14.3. For each instrument transformer, the following documentation shall be delivered:

i. Drawings
ii. Schematic diagrams
iii. Instruction manuals for installation, testing and maintenance
iv. Test protocol of acceptance testing

3.4.1.14.4. All documents, tables and rating plates attached to the equipment shall be in English language.

3.4.2. Surge Arresters (Outdoor type)

3.4.2.1. Scope

3.4.2.1.1. This section covers the ratings, design, equipment requirements, inspection and testing of the equipment. It states only those general aspects that are meant to ensure minimum requirements with respect of quality and performance. Other details and specific data are contained in the Technical Data Schedules.

3.4.2.1.2. Properties, testing and ratings of the equipment shall at least conform to the latest edition of the relevant IEC and British standards.

3.4.2.1.3. The Contractor is obliged to provide complete equipment, even if the details are not mentioned specifically in the following specifications.

3.4.2.2. General Design

3.4.2.2.1. Surge arresters will be metal-oxide, gapless, outdoor. Design shall comply with the requirements of IEC 60099 and other relevant standards, if it is not requested in different manner in this specification. Surge arresters be shall be hermetically sealed type, composite housing, on insulating basement and with counter. Insulating basement shall be delivered together with the Surge arresters.

3.4.2.2.2. The Contractor shall demonstrate and verifyby EMTP that the surge arresters will adequately protect the equipment such as Transformer, Sh.R, etc proposed.

3.4.2.2.3. If the additional Surge Arresters are required different from the Surge Arresters proposed on the Single Line Diagrams, those Surge Arresters have to provided free of charge and included in the final Bid price.

3.4.2.2.4. The metal-oxide blocks shall be manufactured by manufacturers of European countries, USA/Canada, Japan or other eligible countries with equivalent quality.

3.4.2.3. High-Voltage Terminals

3.4.2.3.1. High-voltage terminals shall be as it is defined in a technical schedule:

i. Vertical,
ii. Flat,
iii. For aluminium conductor,
iv. Minimum area of 100 x 100 mm
v. With at least four holes 14 mm diameter, at 50 mm distance between each other

3.4.2.4. Insulating Basement

3.4.2.4.1. Surge arresters shall be equipped with appropriate insulating basement that is part of delivery. They shall be fixed and electrically connected to insulating basement. Earthing shall be fixed and electrically connected to surge arrester directly.

3.4.2.5. Earthing

3.4.2.5.1. Surge arresters will be equipped with appropriate earthing connector.

3.4.2.6. Surge Arresters Housing

3.4.2.6.1. Housing shall be made from silicon and/or composite material in accordance with Technical specification. The connection itself shall be handled with such manner so as to prevent retaining or intrusion of moisture. Minimum creepage distance is 31 mm/kV.

3.4.2.7. Environmental Protection

3.4.2.7.1. Design of surge arresters shall be designed to take maximum care of environment.

3.4.2.8. Nameplates

3.4.2.8.1. Nameplates should have data written in a English language:

i. Manufacturer name
ii. Type of surge arrester
iii. Rated voltage of surge arrester Ur
iv. Continuous operating voltage of surge arrester Uc
v. Nominal discharge current of an arrester (8/20 µs)
vi. Rated short circuit current
vii. Rated frequency
viii. Line discharge class
ix. Number of a unit position in a set (for multi units surge arrester)
x. Mass of surge arrester
xi. Year of production
xii. Serial number

3.4.2.9. Special Equipment, Tools and Drawings

3.4.2.9.1. The Contractor is obliged to deliver all equipment and tools required for installation, dismantling, testing and maintenance of equipment. Special equipment and tools shall be of the highest quality and suitable for field work. All materials to be used shall be new. A list of special equipment and tools shall be delivered with the bid. The Employer reserves the right to request any other special equipment or tools during training or testing, which he finds necessary, free of charge, although such equipment or tools were not on the list of special equipment.

3.4.2.10. Spare Parts

3.4.2.10.1. The Contractor is obliged to enclose with the bid a list of recommended spares required for operation and maintenance necessary for 10 years period. All spare parts to be used shall be new. A list of spare parts shall be delivered with a bid.

3.4.2.11. Packing, Shipment and Transportation

3.4.2.11.1. The Contractor is obliged to arrange for preparation, packing and transport of the equipment to the destination point. The equipment shall be packed and ready to be stored for a longer period.

3.4.2.12. Inspection and Tests

3.4.2.12.1. Tests shall be carried out in order to determine whether the material and equipment comply with the required properties. All tests on the materials and equipment shall be made in accordance with IEC standards. Testing shall not impair the properties and reliability of a test object or reduce its lifetime.

i. Type tests shall be performed on each type and rating of the specified equipment with the purpose of proving its properties. Detailed list of type tests shall be attached to the bid along with the copies of the Type tests certificates.
ii. Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.
iii. Special tests shall be performed on each piece of equipment before delivery, during the acceptance test

3.4.2.13. Type Tests

3.4.2.13.1. The following type tests shall be conducted on each type and class of the specified equipment for the purpose of proving its properties:

i. Dielectric tests
   a. Power frequency withstand voltage test of arrester housing
   b. Lightning impulse voltage tests
   c. Power frequency voltage wet and dry test
ii. Residual voltage test
   a. Steep current
   b. Lightning impulse
   c. Switching impulse
iii. Test to verify long term stability under continuous operating voltage
iv. Repetitive change behaviour verification
v. Operating duty tests
vi. Power frequency voltage versus time
vii. Short circuit test
viii. Weather aging test

3.4.2.13.2. Short circuit test shall be conducted by the STL – Short Circuit Testing Liaison and Short circuit test report shall be certified from STL – Short Circuit Testing Liaison authority.

3.4.2.14. Routine Tests

3.4.2.14.1. The following type tests shall be conducted on each piece the equipment to be supplied for the purpose of revealing faults in material or construction:

i. Measurement of reference voltage
ii. Residual voltage test
iii. Partial discharge and contact noise tests
iv. Seal leakage test

3.4.2.15. Documentation

3.4.2.15.1. Documentation attached to the bid shall include minimum the following:

i. Manufacturer's Authorization
ii. Manufacturer's Quality control certificate
iii. Detailed list of type test for each type and class of the specified equipment
iv. Copies of type test reports
v. Equipment-related catalogues
vi. Reference list for previous five years
vii. Drawings

3.4.2.15.2. For each surge arrester, the following documentation shall be delivered:

i. Drawings
ii. Instruction manuals for installation, testing and maintenance
iii. Test protocol of acceptance testing

3.4.2.15.3. All documents, tables and rating plates attached to the equipment shall be in English language.

3.4.3. Post Insulators

3.4.3.1. Scope

3.4.3.1.1. This Section covers the ratings, design, equipment requirements, inspection and testing of the equipment. It states only those general aspects that are meant to ensure minimum requirements with respect of quality and performance. Other details and specific data are contained in the Technical Data Schedules.

3.4.3.1.2. Properties, testing and ratings of the equipment shall at least conform to the latest edition of the relevant IEC and British standards.

3.4.3.1.3. The Contractor is obliged to provide complete equipment, even if the details are not mentioned specifically in the following specifications.

3.4.3.2. General Design

3.4.3.2.1. Post insulators should be solid core type post insulators, made of porcelain, for outdoor installation in AC system. The post insulators shall comply with the requirements of following standards: IEC 60273, IEC 60437, 60815, 60672, IEC 60168, EN1562, EN1563, EN ISO 1461 and other relevant standards if it is not required in this Specification.

3.4.3.2.2. Post insulators should satisfy the best level of development for this kind of equipment in a field of design, construction and material.

3.4.3.3. Insulator Material

Insulators should be made of high quality aluminium oxide porcelain. Porcelain material shall fulfil requirements of a class C130, which confirms to the standard IEC 60672. Insulators shall be cylindrical with a hard core and metal base. Glazing shall be in brown colour.

3.4.3.4. RIV

The RIV performance of post insulator styles shall be tested in accordance with the standard IEC60437. If corona rings are necessary to reach a certain RIV level for a single insulator column, the appropriate ones shall be delivered with the insulator column.

3.4.3.5. Fittings

Fittings shall be made in malleable cast iron according to standard EN1562 or spheroidal graphite cast iron according to standard EN1563. All fittings shall be hot dip galvanized according to standard EN ISO 1461 with a zinc weight of min. 600 g/m2 (min. 85 µm) as average value. Connection method of Support insulators shall be in accordance with standard IEC 60273. Connection holes shall be equally arrange on a circle meaning concentric with eight insulators. Holes in upper and lower part of connection equipment should be in line and so arranged to allow usage of standard screws with six-angle heads.

3.4.3.6. Cementing

Any connection between porcelain and flange shall be made with Portland cement. The connection itself shall be handled with such manner so as to prevent retaining or intrusion of moisture by a silicone or any other manner.

3.4.3.7. Insulation Level

Post insulators should be designed for standard value of lightning impulses voltage according IEC 60071-1. Minimal value for the height depends of lightning impulses voltage in dry, power frequency voltage in wet and switching withstand voltage in wet where it is in accordance with relevant requirement from coordination insulation point.

3.4.3.8. Dimensions

Rated dimensions of insulator shall be in accordance with values defined in the Technical Data Schedules, with appropriate tolerances referring to parallelism, eccentric and angle deviation, in accordance with standard IEC 60272. Minimum creepage distance is 31 mm/kV.

3.4.3.9. Packing, Shipment and Transportation

The Contractor is obliged to arrange for preparation, packing and transport of the equipment to the destination point. The equipment shall be packed and ready to be stored for a longer period.

3.4.3.10. Inspection and Tests

Tests shall be carried out in order to determine whether the material and equipment comply with the required properties. All tests on the materials and equipment shall be made in accordance with IEC standards. Testing shall not impair the properties and reliability of a test object or reduce its lifetime.

i. Type and special tests shall be performed on each type and rating of the specified equipment with the purpose of proving its properties. Detailed list of type tests shall be attached to the bid along with the copies of the Type tests certificates.
ii. Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.

3.4.3.11. Type Tests

The following type tests shall be conducted on each type and class of the specified equipment for the purpose of proving its properties:

3.4.3.11.1. Dielectric tests

i. Lightning impulse voltage tests
ii. Power frequency voltage wet and dry test
iii. Power frequency withstand voltage test of arrester housing
iv. Long-duration current impulse withstand test
v. Residual voltage test
vi. Internal partial discharge tests
vii. Mechanical failing load test

3.4.3.12. Special Tests

The following type tests shall be conducted on each type and class of the specified equipment for the purpose of proving its properties:

i) Radio interference voltage measurement test (RIV)
ii) Test for deflection under load

3.4.3.13. Routine Tests

The following type tests shall be conducted on each piece the equipment to be supplied for the purpose of revealing faults in material or construction:

i) Routine thermal shock test
ii) Routine visual examination
iii) Routine electrical test
iv) Routine mechanical test

3.4.3.14. Acceptance Tests

The following tests shall be conducted:

i) Verification of dimensions
ii) Temperature cycle test
iii) Dimension tests
iv) Mechanical test
v) Puncture test
vi) Porosity test
vii) Galvanizing test

3.4.3.15. Documentation

3.4.3.15.1. Documentation attached to the bid shall include minimum the following:

i) Manufacturer's Authorization
ii) Manufacturer's Quality control certificate
iii) Detailed list of type test for each type and class of the specified equipment
iv) Copies of type test reports
v) Equipment-related catalogues
vi) Reference list for previous five years
vii) Drawings

3.4.3.15.2. Following documentation shall be delivered together with the equipment:

i) Drawings
ii) Instruction manuals for installation, testing and maintenance
iii) Test protocol of acceptance testing

All documents, tables and rating plates attached to the equipment shall be in English language.

3.4.3.16. Portable Lightning Arrester Diagnostic System (PLADS)

Contractor shall provide two PLADS (one per S/S) to diagnose of the aging state of lightning arrester for condition test and MRE. The specification of PLADS is as follows:

i) Such diagnosis items are able to be measured.
   - Total leakage current

- Resistive leakage current
- Harmonics (3rd, 5th, 7th, 9th) current

ii) Detected sensor shall be a CT sensor.
iii) The electric field shall be reduced in a shielding case.
iv) HMI shall be provided for analyzing the data

3.4.4. Clamp, Connector

3.4.4.1. Scope

Substation clamps are critical components within a substation since they are generally connected in series with the current path. The reliability of the whole power network may be compromised by the failure of clamps if they are not properly designed, manufactured and adequately tested to operate not only under normal operating conditions, but also a range of abnormal conditions as well.
This document gives the minimum requirements for the design, manufacture, testing, supply and delivery of substation clamps for stranded conductors that will ensure adequate performance and operation within the Nation Grid system.
Complete system generally shall be designed in accordance with the requirements of this specification.
After finishing the work, Full set of Design & Drawing documentation shall be provided as reference.

3.4.4.2. References

A. American Standards

ANSI/NEMA CC 1	Electric power connection for substations.
ANSI C119.4	Electric connectors - Connectors to use between aluminium-to-aluminium or aluminium-to-copper conductors.

B. IEC

IEC 60060-1	High-voltage test techniques – Part 1: General definitions and test requirements.
IEC 60273	Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000 V.
IEC 60943	Guidance concerning the permissible temperature-rise for parts of electrical equipment, in particular for terminals
IEC 61854:	Overhead Lines – Requirements and Tests for Spacers
IEC 62271 -1	High-voltage switchgear and control gear – Part 1: Common specifications

IEC 62271-301	High-voltage switchgear and control gear – Part 301: Dimensional Standardization of Terminals
ISO 9001	Quality Management Systems.
ISO 9591	Corrosion of aluminium alloys – Determination of resistance to stress corrosion cracking.

C. Other Standards

EN 10002-1	Metallic materials – Tensile testing – Part 1: Method of test at ambient temperature.
BS 159	Specification for high voltage busbars and busbar connections.
BS EN 1706	Aluminium and aluminium alloys – Castings – Chemical composition and mechanical properties
CISPR 16-1	Specification for radio disturbance and immunity measuring apparatus and methods –Part 1: Radio disturbance and immunity measuring apparatus.
CISPR 18-2	Radio interference characteristics of overhead power lines and high-voltage equipment – Methods of measurement and procedure for determining limits.

3.4.4.3. Definition

Definition	Description
Clamp/connector	A device that joins two or more conductors for the purpose of providing a continuous electrical path
Tension clamp	
Suspension clamp	
Bolted Clamp	Arrangement constitute of multiple parts of bolted connectors in order to carry electrical connection between two or multiple conductors where contacts is achieved between the installed conductors
Flexible connector	Momentum free bolted connector to create connection between two main conductors consisting of tubes or between tube and apparatus terminal.
Compression Clamp	
Parallel grove clamps	Bolted connector for connection between conductors wrapping over each other
Current carrying part	Part of the connector that carries the current between the different connectedconductors.
Pad	A solid, flat, rectangular block
Pad terminal connector	A connector that joins a conductor to the terminal pad of electrical apparatus
Saddle	A clamp that fastens onto a bolted clamp/connector to hold the conductor inplace
Serve spot	
Stem	A solid cylindrical termination
Stem terminal connector	A connector that joins a conductor to the terminal stem of electrical apparatus
Corona extinction voltage	The voltage where no corona (including the negative part) is visible when the voltage is reduced from a level with visible corona.
Keeper	Part of bolted connector clamping the conductor against the current carrying part
Highest voltage for equipment-Um	The highest phase-to-phase voltage for which the equipment is designed. The highest voltage for equipment is designated U m in this document.
Routine tests	Tests done to verify the quality and uniformity of the workmanship and materials used in the manufacture of electric power connectors

Type tests	Tests done on the completion of the development of a new design to establish representative performance data. They need to be repeated if the design is changed to modify its performance or there is a change in the manufacturing process
Sample tests	Tests done to verify the quality of materials and workmanship
	The highest short time current which is caused by either a short-circuit (Ik) or earthfault (3I0)
IACS	International Annealed Copper Standard
EHV	Voltage level 230kV & above
HV	Voltage level greater than 36kV , less than 230kV , including 132kV

3.4.4.4. Deviations & Modification:

In general, the offered equipment should be as per Technical Specification without any deviation. If any modification is deemed to be necessary to improve performance, efficiency and utility of equipment, such proposal must be mentioned in the Schedule of "Departures from The Specification" with reasons duly supported by documentary evidences and advantages. Such modifications suggested may or may not be accepted, but, the same must be submitted along with Pre-Bid Queries and Bid Proposal (if any). The modifications not mentioned in the above Schedule will not be considered.

3.4.4.5. Service Condition

The items supplied under this scope shall be suitable for use in substations under the following outdoors in electrically exposed locations & service conditions. The following items apply: -.

Altitude: up to 1,000 m AMSL

Ambient air temperatures

minimum : -10 °C
maximum : 45 °C
daily average : 35 °C
yearly average : 25 °C
Maximum solar radiation: 1 100 Watts /m2
Minimum Wind speed: 0.44 m/s

The humidity is high and the atmosphere is not salt-laden.

3.4.4.6. Types of Connections & Devices

3.4.4.6.1 Bolted Connection

3.4.4.6.1.1 Bolted clamps shall be equipped with two or more independent saddles in accordance with the requirements specified. Clamping bolts shall have hexagonal heads and shall be made from high tensile steel unless otherwise specified. Bolts shall have a minimum tensile strength of 480 MPa in accordance with NEMA CC 1 -2009.

3.4.4.6.1.2 They shall be of a quality that enables the required torque levels to be achieved without compromising the clamp contact surface pressure. The specific mounting force shall not be less than 120 N per transmitted ampere in the case of stranded conductors.

3.4.4.6.1.3 No bolt shall have a diameter of less than 10 mm unless otherwise approved by PGCB. The design torque that is to be applied to the bolts for optimum performance shall be stated in Technical Datasheet, Appendix A, together with the minimum torque at which operation is guaranteed.

3.4.4.6.1.4 Nuts shall comply with the requirements of SANS 1700. Nuts shall be made of tensile steel . Nuts shall be resistant to corrosion.

3.4.4.6.1.5 Flat washers shall be made of high tensile steel and shall be resistant to corrosion. Flat washers shall be provided under the bolt head only if the bolt head is free to move and captive nuts are provided. Alternatively, if captive bolts are provided, and the nuts are free to move, flat washers shall be provided under the nut. Spring washers are not required.

3.4.4.6.1.6 After the bolts have been tightened, the gap between the saddle and the clamp body shall be not less than 2 mm.

3.4.4.6.1.7 The maximum tightening torque on bolts shall be in accordance with the following:

a) not exceed 75 Nm;

b) not exceed 50 % of the value at which fracture of permanent distortion of the bolts, or fracture of the clamp, occurs. Bolt fracture shall occur before the threads strip; and

c) the maximum specific surface pressure under flat washers shall not exceed 120 N/mm2.

3.4.4.6.2 Compression Connections

3.4.4.6.2.1 A compression clamp shall be any conductor clamp requiring a compression tool capable of exerting a compressive force sufficient to deform the clamp sleeve and all layers of the conductor so that an electrical and mechanical joint is achieved.

3.4.4.6.2.2 The compression sleeves shall be manufactured from extruded tubing having bore sizes to suit conductors , some of them are shown in Table below. The type of tubing, alloy and dimensions used shall be stated in datasheet.

3.4.4.6.2.3 The supplier shall ensure that the sleeve tubing is dimensioned and manufactured properly, taking into consideration the diameter range of the corresponding conductor used in PGCB system. For example of the conductor used, please refre to The sleeve shall be designed in such a way that the conductor shall fit into the tubing with ease and still not compromise the integrity of the entire connection.

3.4.4.6.2.4 Connectors shall perform so well with near perfect stability in both temperature and resistance testing that when subjected the samples to an additional 500 cycles, the clamp shall meet the requirements of less than 5% change in resistance and a temperature range within the factor of 10.

3.4.4.6.2.5 The recommended compression force and the number of compressions per joint shall be stated in Technical datasheet.

Table 01

SL	Conductor	Cross section	Diameter	L before Compression
1	Grosbeak	Refer to Appendix		≥ 464
2	Mallard			≥ 486
3	Chukar			≥ 600
4	Martin			≥ 556

3.4.4.6.2.6 If line boring, or drilling techniques are used in the manufacture of the sleeves, the tolerance on the wall thickness shall not exceed 5%.

3.4.4.6.2.7 All compression clamp sleeves shall be pre-greased and the conductor opening shall have a dust cap applied. The grease shall be applied to cover the entire inner tubing of the sleeve. The type of grease used shall be specified in Technical datasheet.

3.4.4.6.2.8 Compression clamp sleeves shall have a drilled hole with a diameter of 4mm that will serve as a passage for the flow of excess grease during compression.

3.4.4.6.2.9 The compression sleeves are required to be marked externally with the position, the number of compressions required and the across flats dimension. The die size shall also be marked on the compression sleeve.

3.4.4.6.2.10 The compression tool and its head and dies shall be stated in Technical Schedule . Dies shall be made of corrosive resistant material with a high resistance to wear and the die identification shall be embossed on the sleeve after compression. All dies shall be provided with test gauges that will pass

through the associated die when excessive wear has occurred. Details of the compression tool shall be provided.

3.4.4.6.2.11 Each set of tools shall be supplied with a manual, describing the method of operation and detailing maintenance requirements.

3.4.4.6.2.12 Following minimum information shall be marked in the fittings

a) Manufacturer name or symbol
b) Aluminum or copper application
c) Conductor range
d) Catalog number
e) Die size

3.4.4.6.3 Welding

3.4.4.6.3.1 All welds shall be of a quality and type that will ensure “fusing” between the materials involved. Welding shall be done using either a tungsten inert-gas-shielded arc or metal inert gas-shielded arc process.

3.4.4.6.3.2 Welding jigs shall be used to ensure the correct alignment of sleeves. Welds shall be clean, sound, smooth, uniform without overlaps, properly fused and completely sealed.

3.4.4.6.3.3 There shall be no cracks, voids, incomplete penetration, incomplete fusion, undercutting or inclusions. Porosity shall be minimized so as not to affect the mechanical properties of the aluminium alloys. Welds shall be performed by accredited welding personnel and the welding procedure shall be subject to PGCB’s approval.

3.4.4.6.4 Electrical Joint Compound

3.4.4.6.4.1 In order to minimize contact resistance due to oxidation of the aluminium surfaces, a recommendation shall be submitted regarding the cleaning treatment to be adopted, the type of compound to be used, and its properties, including the following:

i. temperature rating, particularly under short-circuit conditions, degree of adhesion,
ii. performance in wet or salt-water conditions,
iii. suitability for use in bolted and / or compression clamps,
iv. need for replenishment and expected life span,
v. availability and sources of supply.

3.4.4.6.4.2 The compound shall not attack the aluminium material.

3.4.4.6.4.3 The compound shall not cause corona.

3.4.4.6.4.4 The drop point of the compound shall be >90 °C.

3.4.4.6.4.5 The flash point of the compound shall be ≥140 °C.

3.4.4.6.4.6 The oil separation of the compound shall be ≤ 1% at 100°C for 4 hours.

3.4.4.6.5 Spacers

3.4.4.6.5.1 Spacers shall be designed to meet all the requirements of IEC 61854.

3.4.4.6.5.2 Bundle spacer is to be used for 'Quadruple' & twin ACSR/TACSR/ACCC conductor

3.4.4.6.5.3 In order to maintain inter group spacing between the sub-conductors of a bundle under all working condition spacers shall be fitted in a bundle. The spacer shall be connected at the interval of suitable longitudinal distance in each phase of line and contractor shall specify the number of spacers to be required per span of 400kV, 230 kV and 132 kV and 33 kV switchyard to avoid rubbing between sub-conductors. The jumper at tension points shall also be fitted with spacers.

3.4.4.6.5.4 The spacer shall have enough strength so as to restore normal spacing between the sub-conductors after displacement by wind, short circuits etc. without damage or permanent deformation. They shall have long life without fatigue or wear and shall have gentle but firm grip on conductors. They shall be able to withstand all the electromagnetic and electrostatic forces under different operating conditions including dead short-circuit.

3.4.4.6.5.5 They shall preferably be of one-piece construction. All bolts shall be captive and nuts shall only be needed slackening not removal in order to fit the spacers to the sub-conductors. The spacer should not slip under any condition and joint with sub-conductors incorporating a flexible medium is acceptable provided such medium cannot slip under any condition.

3.4.4.6.5.6 The spacer shall not damage or chafe the conductor in any way. All nuts used for spacers shall be locked in a manner against vibration loosening.

3.4.4.6.5.7 The spacer shall be flexible enough to avoid distortion or damage of the sub-conductor. The electrical resistance between conductor and spacer shall be reasonable for satisfactory operation. The material of the spacer shall be of aluminum alloy of an approved type.

3.4.4.6.5.8 The spacing shall be so arranged that group spacing between sub-conductors is kept at 250 mm for 230 kV, 200mm for 132 kV and 150mm for 33 kV bus & jumper and 450mm for 400kV Bus and Jumper for new Substation. However, inter conductor spacing is to be matched for existing 400kV, 230kV & 132kV Substation.

3.4.4.6.5.9 The spacer shall not have any projection, cuts, abrasions etc. or chattering parts, which might cause corona & radio interference. They shall also have strength

to resist deformations, which might cause the R.I. performance of the spacers.

3.4.4.6.5.10 The spacers shall conform to ANSI standard. Only Type tested spacers shall be offered.

3.4.4.6.6 Equipotential Ring For 230kV & 400kV Equipment:

3.4.4.6.6.1 In order to reduce dielectric stress & thereby reduce corona, equipotential grading ring is widely used in 400kV & above. When required, they shall be considered for at 230kV level also.

3.4.4.6.6.2 Generally, Equipotential grading rings shall be provided and installed on all live parts of EHV equipment, connections, fittings, where the shape of external surface present sharp corner of any other irregularities resulting from design, manufacture, assembly, erection.

3.4.4.6.6.3 They shall also be provided and installed wherever else, such rings are necessary to reduce the dielectric stress on the line surfaces in order to obviate radio interference and Corona effect. All clamps used for this shall be bolted type.

3.4.4.6.6.4 The sharp and finish of such rings shall be such that the external line surface of the associated equipment is entirely surrounded and that the form of the dielectric field in the immediate vicinities of the line rings is smooth enough to reduce the voltage gradient within safe limits even under the most severe operating and climatic conditions.

3.4.4.6.6.5 The rings shall be constituted by high quality aluminium alloy pipes of adequate diameter. They shall be as light as possible and present the minimum possible moment of inertia.

3.4.4.6.6.6 Provisions shall be made in order:

3.4.4.6.6.7 a) To prevent ingress and accumulation of moisture and impurities inside the ring.

3.4.4.6.6.8 b) To fasten the ring to the associated equipment, in such a way as to prevent loosening under any circumstances.

3.4.4.6.6.9 c) To avoid vibrations or resonance effects during operation.

3.4.4.6.6.10 The design of the ring assemblies shall permit their easy partial or total installation, dismantling and replacement, without disturbing the associated equipment within the limits of an effecting design.

3.4.4.6.6.11 The types of rings shall be standardized as much as possible in order to minimize their variety. All rings of the same type shall be fully interchangeable, without adjustment.

3.4.4.6.6.12 Particular care shall be taken during manufacture and erection in order to obtain

a perfectly smooth surface on the whole pipe. Rings not in perfect conditions shall be rejected.

3.4.4.6.6.13 The design and arrangement of the equipotential rings shall be subject to the approval of PGCB.

3.4.4.6.7 Fittings for tube conductor

3.4.4.6.7.1 Clamp connectors shall be provided for Aluminium tube conductors.

3.4.4.7. Technical Requirements

3.4.4.7.1 Materials

3.4.4.7.1.1 All clamps shall be made of high-quality aluminium or aluminium alloys. The alloy used, its chemical composition, electrical and mechanical properties shall be in accordance with IEC 61854 & IEEE. Heat treating to specification must be certified.

3.4.4.7.1.2 Materials shall be such that, they show proven desired electrical & mechanical characteristics over the lifetime of the equipment. They shall be free from rusting; continuous electrical stress shall not cause deformation so that contact resistance increase becomes unacceptably high; Moreover, continuous mechanical stress shall not cause material deformation such that surface smoothness & contact resistance degrades over time.

3.4.4.7.1.3 The alloys and its chemical composition shall be stated in Technical Schedule . The alloy must not contain more than 0.1% Cu and shall not be prone to stress corrosion, cracking or layer corrosion.

3.4.4.7.1.4 For ACSR conductor fittings, Alloy 6101 or high other high conductivity 6000 series aluminum alloy shall be used to produce the fitting. However, the IACS shall not be less than 55% for ACSR. For ACCC/ACSS applications 1100-H12 or better shall be used with machined inside diameters to a tolerance of ±005”.

3.4.4.7.1.5 The manufacturing method (e.g. cast or wrought) and the alloy shall fulfil the requirements relating to tensile strength, hardness and conductivity. The clamp materials shall be resistant to atmospheric corrosion.

3.4.4.7.1.6 For current caring tube conductor fittings , they shall be made of High tensile strength Alloy. Preferably similar alloy or Series 6000 or better alloy shall be adopted.

3.4.4.7.1.7 For non-current caring tube conductor fittings i.e tube supports, Permanent Mold 356-T6 Aluminum alloy shall be used with 300 series stainless steel Bolts, Washer and Nuts. Nut-Bolt made of Aluminium is also acceptable. I.D of tube fitting must be machined to ±.005” of specification.

3.4.4.7.1.8 Wherever connector will bridge Aluminum & Copper for bimetallic clamps,

pure copper with
tin coated liner having minimum thickness of 2 mm. shall be used.

3.4.4.7.1.9 Non-metallic materials: Non-metallic materials shall have good resistance to ageing and be capable of withstanding temperatures between -50 C and +200°C without change of essential properties. Materials shall have adequate resistance to the effects of ozone, ultra-violet radiation and air pollution over the entire temperature range.

3.4.4.7.1.10 For grounding connector, fittings shall be made with C11000 copper and shall have the ability to carry the equivalent current (or greater) of the conductor, offered connectors shall have conductivity ratings at 101% IACS, ensuring substation has the highest level of performance and reliability possible.

3.4.4.7.1.11 Bolts and nuts shall be made of stainless or acid proof steel and fulfil the requirements for A2-80 or A4-80 in accordance with SS –EN ISO 3506-1 and SS –EN ISO 3506-2.

3.4.4.7.1.12 Washers and thread inserts shall be made of stainless steel, and shall have at least the same resistance to corrosion as steel grade A2 in accordance with SS-EN ISO 3506-1.

3.4.4.7.1.13 Between the screw heads and nuts as will be tightened during installation shall be plane washers. Washers shall be in accordance with SS-EN ISO 887 and SS-EN ISO 7809.

3.4.4.7.1.14 Other steel parts may be made of non-stainless steel but shall be hot-dipped galvanised in accordance with SS-EN ISO 1461

3.4.4.7.2 Machining

3.4.4.7.2.1 The contact areas of all clamps used for current-carrying purposes are to be machined to create true cylindrical surfaces.

3.4.4.7.2.2 The contact surfaces of the current-carrying ends of the clamp, that bolt onto stranded conductor, shall be grooved, with each end of the groove equipped with a so called ‘serve spot‘ to allow easy embedding of the served stranded conductor. It is left to the manufacturer to provide specially designed grooves or ridges on the contact surface.

3.4.4.7.2.3 Pads are to be serrated-machined to guarantee the best current transfer. The surfaces that interface with solid cylindrical conductors e.g. aluminium tubes or stems shall be smooth machined with an average roughness (Ra) ranging from 1.6 to 2.

3.4.4.7.2.4 The damage caused to the conductor by the clamps e.g. by grooves that cut into the conductor, shall be such that the conductor strength is not reduced to less than 90 % of the ultimate strength, nor shall the electrical conductance be impaired.

3.4.4.7.2.5 If line boring, or drilling techniques are used in the manufacture of the sleeves,

the tolerance on the wall thickness shall not exceed ±5%.

3.4.4.7.2.6 All welds shall be of a quality TIG type that will ensure “fusing” between the materials involved. Welding shall be done using a tungsten inert-gas-shielded arc.

3.4.4.7.3 Design Requirement

3.4.4.7.3.1 The connectors shall be designed Corona free. The voltage gradient at any corner surface shall be at a level that will not cause any resultant radio interference.

3.4.4.7.3.2 Flexible connectors shall be made from adequate number of copper/aluminium foil stranded together having suitable current rating. Calculation and details shall be submitted in support during detailed engineering.

3.4.4.7.3.3 All clamps and connectors shall be made from cold forged Aluminum plate i.e. extruded Aluminum having purity of Aluminum not less than 97.5%.

3.4.4.7.3.4 Sharp Corners and edges shall be rounded off.

3.4.4.7.3.5 The connector shall be mechanically strong so that it can withstand loads imposed duringerection, normal service, electro-mechanical force due to temperature variation and shortcircuit condition.

3.4.4.7.3.6 The current density considered for Aluminium & copper shall not be greater than 0.75 & 1.75 A / sq. mm respectively, unless otherwise agreed.

3.4.4.7.3.7 The clamps and connectors shall be of best quality and workmanship, free from blowholes, cracks, cavities, surface blisters, claws and any other defect which may affect the performance of the clamp.

3.4.4.7.3.8 Permanent deformations, cracks or failures shall not occur in connectors for bundledstranded conductors as the result of conductor clash in the event of a short circuit.Surfaces of connectors shall not be treated with the intension of increasing the coefficient of emission.

3.4.4.7.3.9 Manufacturer shall prove the following in-house engineering capabilities

a) Electrostatic Analysis for Corona free design
b) Stress Analysis
c) Photorealistic Rendering
d) Frequency Analysis: Modal Analysis to find resonant frequencies
e) Transient Magnetic: Fault current simulations and resulting temperature rise, forces and stresses.

3.4.4.7.4 Electrical Requirement

Current Rating

3.4.4.7.4.1 The rated normal current of each clamp shall be in accordance with the value stated in the relevant table of this specification.

3.4.4.7.4.2 The clamps and connectors shall be capable of carrying continuously the current specified without exceeding a temperature rise of 30°C above an ambient temperature of 45°C.

3.4.4.7.4.3 When a connection is made between two conductors of different sizes, the current rating of the current carrying clamps used shall not be less than that of the lowest rated conductor.

Corona Characteristics

3.4.4.7.4.4 The clamp/connector assemblies shall be capable of operating at the stipulated voltages (U m) without any signs of visible corona, at altitudes of up to and including 1000 m.

3.4.4.7.4.5 The offered connector for phase conductor shall be free from visible corona at a test voltage, phase – earth of:

3.4.4.7.4.6 Test voltage = $= \frac{U_m}{\sqrt{3}} \times 1.1$

3.4.4.7.4.7 Where Um is 36kV, 145kV, 245 kV and 420 kV respectively.

3.4.4.7.4.8 For 400kV & above voltage level, corona shall not be greater than 120 µV and for 230kV & below level, corona shall not be greater than 100 µV.

3.4.4.7.4.9 Corona Inception & Extinction voltage shall be provided.

3.4.4.7.4.10 These characteristics shall be proven by test.

Resistance

3.4.4.7.4.11 The offered connector for phase conductor shall have a resistance (R1) of maximum 80% of the resistance value for the same length of the conductor, measured from conductor to the conductor, in the vicinity of the connector.

3.4.4.7.4.12 Test result clearly identify this requirement is fulfilled.

Short-Circuit Current

3.4.4.7.4.13 Two types of SC current are defined: symmetrical & Asymmetrical.

3.4.4.7.4.14 The connector shall withstand a short-circuit current that of same as the connected conductors without any deformation.

3.4.4.7.4.15 For rating of symmetrical short circuit current at different voltage levels, please refer to section 01 of the specification.

3.4.4.7.4.16 A minimum of 2.69 times the symmetrical short circuit current shall be applied to get the Asymmetrical short circuit current.

3.4.4.7.5 Mechanical Requirement

3.4.4.7.5.1 Tightening torquesTightening torques for screws and nuts shall be at least 45 Nm for M10 and at least 75Nm for M12.

3.4.4.7.5.2 Threaded holes
Threaded holes shall have at least the same strength as A2-80 nuts in accordance withSS-EN-ISO 3506-2.

3.4.4.7.5.3 Washers
Washers shall have a hardness of HV min 200 at tests in accordance to SS-EN-ISO6507-1.

3.4.4.7.5.4 Contact force

3.4.4.7.5.5 The mean value for the pre-stressing forces in the screws shall for each separate conductor connection be 25 kN for M10 and 35 kN for M12 with respect to the difference in thermal expansion between aluminium and stainless steel at the tightening torques

The connectors shall provide the contact forces specified in Tables 1 to 8. Contact forces are defined in Figures 12 to 14.

3.4.4.7.5.6 Deformation
Permanent deformation shall not occur in current carrying parts or keepers at a torqueof 110% of the torque given in Clause 7.1.

3.4.4.7.5.7 Flexible connectors
Flexible connectors shall fulfil requirements relating to size, angular adjustment,movements and forces as specified below.
> The horizontal size of the connector, perpendicular to the longitudinal centerline of the tube, max 150 mm for the tube diameter 100 mm and 180 mm for tube diameter 150 mm. The dimension as specified refers to the distance from the centreline of the tube to the outer-most part of the connector.
This dimension has been specified to permit the connection of tubes to differenttypes of apparatus.
> Angular adjustment of the tube in relation to the connector, min 15°. The prescribed angle is the angle in any direction from a horizontal line parallel to thelongitudinal axis of the connector to the centre line of the tube.
This angle has been specified to permit connection of tubes between apparatus having different phase distances and elevations.
> Movement of the tube in the connector, min ±25 mm. The prescribed dimensionrelates to the movement of the tube in the longitudinal direction.
This requirement has been determined to allow for the changes in length of the tube which can occur as a result of thermal expansion between the lowest

temperature encountered during the winter and the highest temperature encountered after a short circuit.

> Force in the tube when the tube is moved 50 mm in the connectors in accordancewith the previous, max 500 N. The prescribed force applies when the vertical forcebetween the tube and connector is 1000 N.
This requirement has been determined in order to permit an ice-coated tube to move in connectors without applying excessive forte to the apparatus terminals.
> Movement of the tube in the connector, ±10 mm. The prescribed dimension relates to daily movement of the tube in the longitudinal direction.
This requirement has been determined in order to allow for the changes in lengthof the tube which can arise as a result of temperature changes between the minimum temperature encountered during the night and the maximum temperatureencountered during the day, without giving rise to fatigue failure in the connectors.
Flexible connectors shall impose the least possible tensile, torsion and bending forceson terminals under both normal operating conditions and short-circuit conditions.
Flexible connectors shall not fail through fatigue, nor shall abnormal wear of tubes andconnectors occur during operation. Tubes shall be so supported that it is not possiblefor a direct impact to arise between a tube and terminal in the event of short-circuit.Connectors shall not give rise to audible noise or UHF interference.

3.4.4.8. Quality Assurance

3.4.4.8.1 All materials and workmanship shall be of suitable type and quality to ensure that the Clamp-connector will operate satisfactorily in accordance with the specification.

3.4.4.8.2 Registration to ISO 9001 is desired.

3.4.4.8.3 Connectors shall be class A in accordance with IEC 61238-1.

3.4.4.8.4 All offered items shall be type tested in STL member laboratory.

3.4.4.8.5 The alloy shall be as per specification or better quality.

3.4.4.8.6 Manufacturing technology shall be recognized and acceptable .Special technology by manufacturer is preferred.

3.4.4.8.7 All on site welded connections, compression shall be carried out in accordance with the manufacturer’s recommendation and by certified personnel by manufacturer. Only suitably trained staff shall be permitted to carry out on-site welding.

3.4.4.8.8 For compression, manufacturer recommended tools & die size shall be used.

3.4.4.8.9 The same personnel, components and tools used to carry out the installation shall be involved in the sample exercise.

3.4.4.8.10 PGCB shall be provided with an opportunity to witness the preparation of the samples.

3.4.4.8.11 The samples shall be sent to an independent facility for mechanical (pull) testing according to section 7 of IEC 61238-1.

3.4.4.8.12 The Contractor shall outline their quality procedure to ensure the correct selection and use of crimping dies and tools.

3.4.4.9. Notification of Changes

Any changes in design, material, supplier or sub-contractor shall be notified to PGCB in writing prior to implementation. Such changes must be agreed with PGCB in writing prior to their introduction.

3.4.4.10. Tests

3.4.4.10.1 Type TestClamps

A series of type tests to evaluate performance of the conductor clamps are specified below. These tests are divided into two categories, viz. electrical and mechanical type tests. Some of these tests can be combined as part of the electrical tests since severe shock forces are exerted on the clamps in the case of short circuit tests.

If the clamps/connectors offered have been tested for compliance with an internationally accepted specification, such test reports may be accepted by PGCB in lieu of the tests covered by this specification.

Tenderers are requested to indicate if they comply with such tests at the tendering stage and shall submit these with their tender for PGCB's consideration.

A family of clamps is a group of clamps using similar design criteria. In order to qualify a family of clamps (for a specific type of clamp), all the relevant clamps as specified by PGCB in Table of Appendix C shall be tested.

The clamps to be tested are to be confirmed in writing to PGCB. For all design and type tests, a minimum of three (3) identical clamps shall be tested and none of these clamps shall fail during a test. The design and type test shall be repeated when there is a change in the design or manufacturing process of a clamp.

Extrapolation of mechanical tests shall be allowed across a family of clamps if it is proven that then construction and type of connection is the same. Extrapolation of electrical tests shall be allowed: within a family of clamps; across a family of clamps if it is proven that the construction and type of connection is the same.

The following rule shall apply: Extrapolation shall be allowed downwards only, i.e., the highest rated clamps test results may be used to extrapolate downwards to a lower rated clamp where the construction and type of connection is the same.

Extrapolated test results might have an influence on qualifying a family of clamps and will be reviewed on a case-by-case base, since it deviates from the specified clamps required to be tested in Table 2.

PGCB reserves the right to request or witness any or all of the specified tests. Should PGCB exercise its right to witness testing, its employees and/or appointed representatives shall be given access and permission to the test facility.

Following type test shall be applied for all types of clamp-connector

Heat (Current)-Cycle Test

Heat (current)-cycle tests shall be conducted using the light duty cycle (N = 125 cycles) in accordance with the relevant test procedure and requirements of ANSI C119.4.

Temperature Rise Test

Temperature rise tests shall be conducted in accordance with the relevant test procedure and requirements of ANSI/NEMA CC 1, with the exception that the rated current of the clamps shall be as stated in this specification.

Corona and RIV Test

Corona tests shall be performed according to the test procedure and requirements of ANSI/NEMA CC 1 or IEC 61284. RIV tests shall be performed according to the test and requirements of CISPR 16-1 and CISPR 18-2 or NEMA CC 1.

The test voltage for radio influence voltage shall be 1,1Um/√3, where Um is the maximum system voltage. Correction factors shall be applied in accordance with IEC 60060-1.

Short-Circuit Withstand Test
Short-circuit withstand tests shall be conducted in accordance with the test procedure and requirements of IEC 62271 -1. The test current & duration shall not be less than that of the project specific short circuit withstand requirement.

Bolt Tightening Torque Test

The bolt tightening torque test shall be performed according to the test procedure and requirements of ANSI/NEMA CC1.

Slip/Pull-out Strength Test

The slip/pull-out strength test shall be performed according to the relevant test procedure and requirements of ANSI/NEMA CC 1.

Cantilever Strength of Bus Supports Test

The cantilever strength of bus support test shall be performed according to the relevant test procedure and requirements of ANSI/NEMA CC1.

3.4.4.10.2 Type Tests Acceptance Criteria (Clamps)

Heat (Current)-Cycle Test

The resistance of the clamp shall be stable between the twenty-fifth (25th) cycle and the completion of the number of current cycles required (N). The number of cycles (N) is specified in ANSI C119.4. Stability is when any resistance measurement does not vary by more than 5% from the average of all the measurements at specified intervals during the test.

The temperature of the clamp shall, measured at the intervals specified in ANSI C119.4, shall not exceed that of the reference conductor. The average resistance of the joint over the last 0,5 N cycles shall not exceed the initial resistance of the joint by more than 50 %.

Temperature Rise Test

The temperature rise of an electric power connector at rated current shall not exceed the temperature rise of the conductor with which it is intended to be used. The temperature of the clamps shall be at least 2°C lower than that of the control conductor.

The temperature-rise of a clamp in a test shall not exceed 30°C above an ambient temperature of 40 °C. The temperature rises of an electric power connector that connects conductors of varying sizes shall not exceed the temperature rise of the conductor having the highest temperature rise.

Corona and RIV Test

There shall be no sign of visible corona below the test voltage required for minimum corona extinction. The clamp shall be considered to have passed the test if the radio interference voltage level at 1,1Um/√3 does not exceed 100 µV as per ANSI/NEMA CC 1. For specific voltage level, refer to clause 1.7.4.2 above.

Short-Circuit Withstand Test

Clamps shall be capable of withstanding short-circuit currents without any mechanical damage or
overheating. The short-circuit current withstand ratings of respective clamp shall not be less than the substation fault current withstand value as per scope of work. Peak value shall not be less than 2.69 times the rms value.

Under short-circuit conditions the clamp temperature shall not exceed 200°C. The clamps are specified for service at altitudes of up to 1000 m. If a clamp is tested at an altitude below 1000 m, the limits of operating temperature under normal and short-circuit conditions should be reduced by 2,5 % for each 500 m that the altitude specified exceeds 1000 m.

Bolt Tightening Torque Test

There shall be no evidence of mechanical damage to all the clamp components and the conductor after the test.

Slip/Pull-out Strength Test

The test shall be considered successful if:
a) the clamp does not suffer any mechanical damage,
b) the clamp's mechanical strength should not be reduced to below 90%.
c) the connected conductor does not pull out of the clamp.

Cantilever Strength of Bus Supports Test

There shall be no evidence of mechanical damage to all the clamp components and the conductor after the test.

3.4.4.10.3 Type Tests --Spacers

Corona and RIV Test

Corona tests shall be done according to the test procedure and requirements of ANSI/NEMA CC1 or IEC 61284.

RIV tests shall be performed according to the test procedure and requirements of CISPR 16-1 and CISPR 18-2 or NEMA 107.

Clamp Slip Test

Longitudinal Slip Test
Longitudinal slip tests shall be done according to the relevant procedure of IEC 61854.

Torsional Slip Test
Torsional slip tests shall be done according to the relevant procedure of IEC 61854.

Breakaway Bolt Test: Breakaway bolt tests shall be done according to the relevant procedure of IEC 61854.

Clamp Bolt Tightening Test: Clamp bolt tightening tests shall be done according to the relevant procedure of IEC 61854.

Simulated Short-Circuit Current Test: Simulated short-circuit current tests shall be done according to the relevant procedure of IEC 61854.

Compression and Tension Test: Compression and tension tests shall be done according to the relevant procedure of IEC 61854.

3.4.4.10.4 Type Test Acceptance Criteria --Spacers

Corona and RIV Test: There shall be no sign of visible corona below the test voltage required for minimum corona extinction. The clamp shall be considered to have passed the test if the radio interference voltage level at $1{,}1Um/\sqrt{3}$ does not exceed 100 µV as per ANSI/NEMA CC 1.

Clamp Slip Test

Longitudinal Slip Test
No slippage shall occur at or below the minimum specified value.

Torsional Slip Test
No slippage shall occur at or below the minimum specified value.

Breakaway Bolt Test: The bolt shall not be damaged or broken at the end of the test.

Clamp Bolt Tightening Test: The bolt shall not be broken or damaged. The threads shall not suffer any damage.

Simulated Short-Circuit Current Test: There shall be no damage that will result in the spacer not maintaining the bundle design spacing.

Compression and Tension Test: There shall be no damage that will result in the spacer not maintaining the bundle design spacing after the test.

3.4.4.10.5 Sample Tests -- Clamps

The following sample tests shall be conducted according to the relevant procedures of IEC 61854.

i. Visual examination
ii. Verification of dimensions and material
iii. Tensile test
iv. Clamp bolt tightening test

3.4.4.10.6 Sample Tests - Spacers

The following sample tests shall be conducted according to the relevant procedures of IEC 61854.

i. Visual examination
ii. Verification of dimensions, material and mass
iii. Breakaway bolt test
iv. Clamp bolt tightening test

3.4.4.10.7 Routine Tests --Clamps

Routine tests in accordance with the manufacturer's standards shall be carried out at the works and shall
include a dimensional check of each type of connector on a 10 % sample basis. PGCB reserves the right to inspect and check the equipment at any stage during or after manufacturing, and to witness any of the
routine tests.

Drift Test

i. Every batch of tubes used in the manufacture of sleeves shall be drift tested.

ii. The test shall be performed by expanding the sample, using a drift cone of suitable angle, until the increase in outside diameter of the tube exceeds 25 % or until splitting of the sample occurs, whichever occurs first.
iii. If any test piece splits before 125% of the outside tube diameter is reached, the relevant length of tube shall be scrapped.

Verification of Dimensions, Material and Mass

i. Verification of dimensions shall be undertaken to ensure that clamps are within the specified material properties, dimensions and dimensional tolerances.
ii. The mass and dimensions of the clamps shall also be checked against the manufacturer's drawings to confirm compliance.

Visual Examination

i. Visual examination shall be undertaken to ensure conformity of manufacturing process, shape and surface finish of the clamps with the contract drawings. The quality of the welds shall be checked for integrity and consistency.

ii. For corona-free clamps, visual inspection shall include comparison of the surface finish of sampled clamps with those clamps that passed corona tests.

3.4.4.10.8 Routine Tests -Spacers

The following routine tests shall be conducted according to the relevant procedures of IEC 61854.

i. Visual examination
ii. Verification of dimensions, material and mass

3.4.4.10.9 Type Test Certificates and Reports

Copies of all type-test reports and certificates shall be submitted to PGCB in electronic format at the tender stage. Copies of sample and routine test reports shall be submitted to PGCB on request.

The contractor shall retain copies of sample and routine test reports for a period of at least 2 years.
Type test reports and certificates older than ten (10) years shall not be acceptable.

i. Type test reports shall contain, as a minimum, the following information:
ii. Name and address of test facility.
iii. Contact details of test facility.
iv. Details and validity of accreditation of test facility.
v. Date of test.
vi. Type of clamp tested.
vii. Description of the test equipment used, including test equipment serial number and last date ofcalibration.

viii. Description of test set-up, including photographs of the set-up.
ix. Description of test procedure.
x. Test results.
xi. Analysis of test results.
xii. A statement that the clamp conforms, or does not conform, to the requirements of this specification.
xiii. Description of the condition of the clamp after testing (include picture of the clamp).
xiv. Names and titles of personnel who conducted the test.

3.4.4.10.10 TESTS AT MANUFACTURER'S WORKS AND TEST CERTIFICATES:

Bidders shall have adequate testing facilities at their works to conduct all acceptance and routine tests as stipulated below as per relevant ANSI in presence of engineers of PGCB.

Acceptance Test for Clamps & Connectors:

i. Tensile test
ii. Resistance test
iii. Dimensional check
iv. Galvanizing test, where applicable.

Routine Test for Clamps & Connectors:

All routine tests at manufacturer's works shall be carried out for each clamp & connectors as per stipulation of relevant IEC and test reports are to be submitted.

All routine tests at manufacturer's works shall be carried out for each equipotential Ring as per stipulation of relevant IS and test reports are to be submitted.

All acceptance tests are to be carried out in presence of representatives of PGCB on equipotential Ring as well as for clamps & connectors at manufacturer's works on every lot offered for inspection.

Three (3) copies of routine and acceptance test results shall be submitted for approval & distribution. The contractor shall give at least 01 (One) months advance notice to PGCB., intimating the actual date of inspection and details of all tests that are to be carried out. The entire cost of acceptance and routine tests that are to be carried out as per relevant ANSI/IEC shall be treated as included in the quoted price of Clamps and Connectors and Equi-potential Ring.

3.4.4.11. Identification Marking

Clamps shall be clearly and indelibly marked with the following minimum information:

i. Manufacturer's identification.
ii. PGCB clamp code number.
iii. Nominal size or range of sizes of conductors with which the clamp is intended to be used.

3.4.4.12. Inspection of Samples

A list of samples of clamps to be submitted during tendering shall be included in the tender enquiry documents.

3.4.4.13. Packaging

All individual clamps shall be packaged in sealed, heavy duty, UV stabilised plastic bag. The clamps/connectors shall be packed in such a manner that they are adequately protected to avoid damage during transportation and storage.

To facilitate inspection and handling, the sealed clamps shall be supplied in strong durable containers.
Wooden crates shall be treated.

A suitable metal label bearing the PGCB's order and item number, the quantity and the delivery address
shall be securely attached to the container. The markings on the label shall not be destroyed during storage and transport.

Each crate shall be clearly marked in order to identify each crate as belonging to a specific clamp. Each
container/crate shall be clearly marked with a durable label using an indelible font indicating the following
information:

- PGCB order number;
- PGCB SAP number (if any);
- PGCB clamp designation/code;
- Manufacturer’s name;
- Contents of the container/crate (i.e. a parts list);
- Overall dimensions of container/crate(in mm); and
- Total mass of each crate (e.g. “TOTAL MASS: 50 KG”);
- Pictograms / symbols showing correct storage and stacking instructions for crates.

3.4.4.14. Off-loading and Storage Procedure

The procedure shall stipulate the maximum recommended period of storage, as well as recommended actions to be taken if a longer storage period is required.

The supplier shall contact the relevant personnel for delivery of clamp consignment at least one (1) week
before delivery.

At the time of off-loading at an PGCB facility, the supplier shall ensure that clamps are off-loaded properly
and safely.

3.4.4.15. Installation

3.4.4.15.1 General

The Installation shall be in accordance with the approved installation instruction of vendors.

The supplier shall submit relevant installation procedures for clamps and spacers to PGCB for approval. It is preferred that; installation shall be by manufacturer personnel. Otherwise, certified personnel shall be performing the work.

Earthing Current carrying parts, conductor groove and conductor, shall be treated in the following way at installation:

Current carrying surfaces shall be brushed thoroughly with a steel brush.

Contact paste shall be applied on the current carrying surfaces.

The current carrying surfaces shall be brushed with a steel brush into the contact Paste

Additional contact past shall be applied

Locally made Connector having type tested is preferred so that after sales technical support is properly achieved.

3.4.4.15.2 Galvanic Action

Although it is best to avoid making connections using different metals like copper and aluminum there are times when this cannot be avoided. There are a few steps that can be taken to minimize potential problems.

The Contractor shall protect all joints between dissimilar metals against corrosion. In particular where a copper earth conductor is supported on galvanised steelwork, contact between the two shall be prevented, in order to avoid galvanic action. Contact shall be avoided by use of insulated conductors for connecting equipment to the earth grid.

The conductors shall be secured to the steelwork by means of suitable clips or saddles. Plastic clips or saddles are not acceptable as they will not survive long term, metal straps are required.

All connectors in contact with galvanised steel shall be tinned. Where possible, connections shall be made to vertical faces only.

3.4.4.16. Inspections

The supplier shall supply inspection information in the form of manuals to PGCB at the tender stage. The manuals shall cover, amongst others, the following aspects:

i. Frequency of inspections
ii. Scope of inspection
iii. Parameters to be inspected
iv. Inspection tools
v. Inspection procedure
vi. Remedial actions

3.4.4.17. Documentation to be Submitted

3.4.4.17.1 Design-Document Approval

Drawings shall comply with the requirements stated in the relevant conditions of contract or order. The following drawings shall be submitted for approval:

i. Outline dimensioned drawing for each type of connector/clamp.
ii. Outline of Hardware & fittings
iii. Outline dimensioned drawings for all compression tools, where applicable.
iv. Technical data of each type of connector/clamp.
v.

01 set of type test Report of each type of clamp -connector to be supplied under the scope of work. Failure to comply with type test requirement will be rejected. The type test shall be within 10 years of bidding date.

Set of GA & Technical datasheet of offered connectors. Details and descriptions of materials to be used e.g. clamp, connectors, washer, nut-bolt, etc. shall be provided. The technical schedule shall not be left blank. Where numerical values (for example, rated values and dimensions) or specific information is required, the actual value/information shall be stated. In such cases, use of words, such as “COMPLY”, “TBA”, is not acceptable

Set of Electromagnetic Field & Expected Corona simulation for 400kV & above voltage level.

Inspection & Test Plan and Manufacturing Quality Plan

Detailed Installation & Construction Procedure. Tools & Machineries required for each type of clamp & connectors shall be indicated clearly. Details of jointing, bolting, crimping, compression, welding methods shall be highlighted.

Qualification required for the welder or installer shall be mentioned and confirmed that, such personnel shall be available. Proof of accreditation of welder shall be provided.

Manual(s) for handling, storage and inspections

3.4.4.17.2 Before test

List of tests to be performed

Procedures of test with circuit or test arrangement diagram

Sampling Plan

Descriptions of tools to be used

Sample Test & Report Format including acceptance criteria.

3.4.4.17.3 After Installation

i. Photographic of installation & testing (if any) QA records.
ii. Test results of Ductor tests and joints.

3.4.4.17.4 Substation Handover

i. Full set of as-built drawings both at site, project office & Design office.
ii. As-built version of earthing model file at Design office.
iii. Final test results site & Design office.
iv. Details of residual hazards and all other information required in the Safety file.

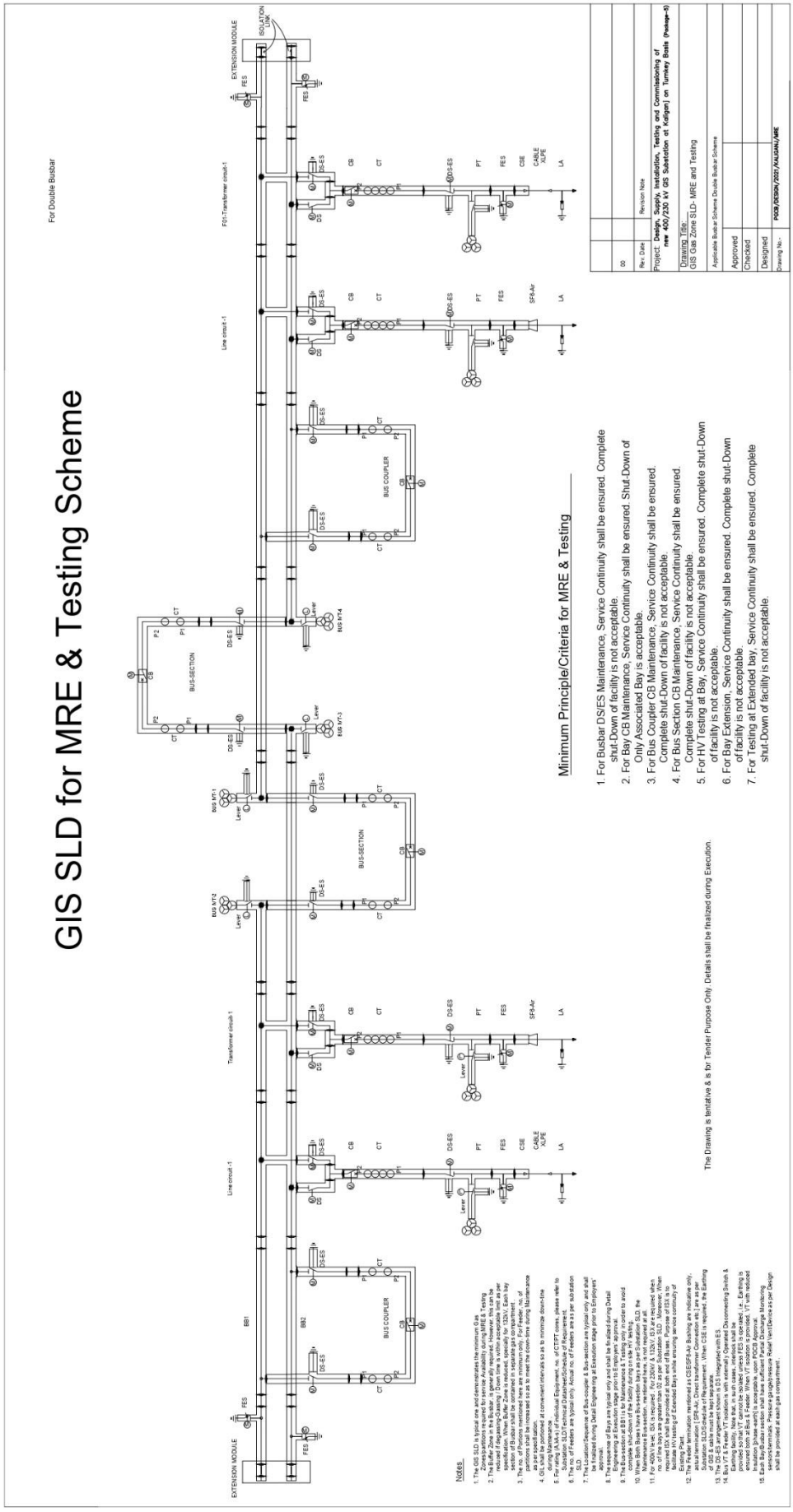
APPENDIX

Appendix : Gas Insulated Switchgear

[GIS SLD for MRE & Testing Scheme]

Hereinafter it is demonstrated about typical GIS SLD for MRE & Testing Scheme.

1. The GIS SLD is typical one and demonstrates the minimum Gas Zones/partitions required for service availability during MRE & Testing.
2. For rating (A, kA-s) of individual Equipment, please refer to Substation SLD.
3. The no. of Feeders are typical only. Actual no. of Feeders are as per substation SLD.
4. The sequence of Bays are typical only and shall be finalized during Detail Engineering at Execution stage prior to Employers' approval.
5. The no. of Portions mentioned here are minimum only.
6. The Feeder termination mentioned as GAB (Gas-to-Air-Bushing)/GOB(Gas-to-Oil-Bushing) are typical only, actual termination [SF6-Air, Direct transformer Connection etc.] are as per Substation SLD.
7. The DS-ES arrangement shown is DS Integrated with ES (145kV).
8. Bus VT isolation is mentioned with DS-ES. For 400kV level, HES may be required as per Manufacturer standard. In that case HES shall be provided within the contract price.
9. Feeder VT isolation is with DS-ES without Motor.
10. When VT isolation is provided, VT with reduced Insulation [phase-earth] is acceptable.
11. When CSE is required as per Substation SLD, the Earthing of GIS & cable must be kept separately.
12. All AIS Connection shown [400kV Line Reactor/Switchgear & 33kV Switchgear] is typical only. All AIS connection shall be as per Substation SLD.
13. For 400kV Level, GIS LA may be required. Such requirement shall be as per Scope of Work.


GIS SLD for MRE & Testing Scheme
For Double Busbar
Minimum Principle/Criteria for MRE & Testing
1. For Busbar DS/ES Maintenance, Service Continuity shall be ensured. Complete shut-Down of facility is not acceptable.
2. For Bay CB Maintenance, Service Continuity shall be ensured. Shut-Down of Only Associated Bay is acceptable.
3. For Bus Coupler CB Maintenance, Service Continuity shall be ensured. Complete shut-Down of facility is not acceptable.
4. For Bus Section CB Maintenance, Service Continuity shall be ensured. Complete shut-Down of facility is not acceptable.
5. For HV Testing at Bay, Service Continuity shall be ensured. Complete shut-Down of facility is not acceptable.
6. For Bay Extension, Service Continuity shall be ensured. Complete shut-Down of facility is not acceptable.
7. For Testing at Extended bay, Service Continuity shall be ensured. Complete shut-Down of facility is not acceptable.
The Drawing is tentative & is for Tender Purpose Only. Details shall be finalized during Execution.
Notes
Project: Design, Supply, Installation, Testing and Commissioning of new 400/230 kV GIS Substation at Kaliganj on Turnkey Basis (Package-5)
Drawing Title: GIS Gas Zone SLD- MRE and Testing
Applicable Busbar Scheme: Double Busbar Scheme
Approved
Checked
Designed
Drawing No.: PGCB/DESIGN/2021/KALIGANJ/MRE
Rev. Date
Revision Note
00

A. 420kV Gas Insulated Switchgear and Associated Equipment

Please refer to volume 03, Schedule E

B. 245kV Gas Insulated Switchgear and Associated Equipment

Please refer to volume 03, Schedule E

C. 145kV Gas Insulated Switchgear and Associated Equipment (Not Applicable)

Please refer to volume 03, Schedule E

D. 420kV Outdoor Switchgear

Please refer to volume 03, Schedule E

E. Outdoor 420kV CVT

Please refer to volume 03, Schedule E

F. 36kV Outdoor Switchgear and Associated Equipment

Please refer to volume 03, Schedule E

G. Gas Insulated Line (GIL)

Sl No	ITEM	SPECIFICATION
1	Enclosure Material	Corrosion-Resistant Aluminum Alloy
2	Inner Post Insulator	Cast-Resin
3	Installation Method	Above Ground
4	Rated Voltage	400kV / 230kV / 132KV
5	Rated Current	4000 / 3150 / 1600A
6	Rated Short Circuit Current	63 / 63 / 40kA 3sec
7	Insulating material for GIB	SF6
8	Outer housing	Composite / Silicon

H. Insulator

Please refer to volume 03, Schedule E

I. Insulator String

1	Rated Voltage	400kV	230kV	132kV
2	Type	Anti FOG	Anti FOG	Anti FOG
3	Size of insulators units (mm)	255 x 145	255 x 145	255 x 145
4	Creepage distance of individual insulator unit(Minimum or as required to obtain total creepage distance, mm)	430	430	430
5	Electromechanical strength (kN)	210	160	120
6	Power frequency withstand voltage of the complete string (kVrms)	630	460	275
7	Lightning impulse withstand voltage of the complete string with C.C. ring(Dry and wet, kVp)	1425	1050	650
8	Switching surge withstand voltage of the complete string with C.C. rings(Dry & wet, kVp)	1050	-	-
9	Power frequency puncture with-stand voltage for a string insulator unit	1.3 times the actual wet flashover voltage of the unit.	1.3 times the actual wet flashover voltage of the unit.	1.3 times the actual wet flashover voltage of the unit.
10	Minimum corona extinction voltage level of the complete string with C.C. ring (Dry, kVrms)	320	156	120
11	R.I.V. Level of the complete string with C.C. ring.(micro V)	1000	1000	1000
12	Total creepage distance (min.) of complete insulator string (mm	>13,020	>7,595	>4,495

4. Power Transformers

4.1 Scope

These clauses describe the general technical requirements for power /auto transformers and shall be read in conjunction with the schedule of requirements.

Installation, testing and commissioning of power transformers shall be done by the Manufacturer(s)' Engineer(s).

4.2 References

4.2.1 IEC Standards

IEC 60076	Power transformers
IEC 60137	Insulated bushings for ac voltages above 1000V
IEC 60044-2	Voltage transformers
IEC 60044-5	- ditto -
IEC 60214-1	On load tap changers
IEC 60228	Conductors of insulated cables
IEC 62155	Tests on hollow insulators for use in electrical equipment
IEC 60289	Reactors and Earthing Transformers
IEC 60296	Specification for unused mineral insulating oils for transformers and switchgear
IEC 60354	Loading guide for oil immersed power transformers
IEC 60422	Supervision and maintenance guide for mineral insulating oils in electrical equipment
IEC 60529	Degrees of protection provided by enclosures
IEC 60551	Determination of transformer and reactor sound levels

4.2.2 British Standards

BS61	Specification for threads for light gauge copper tubes and fittings
BS EN 10220	Specification for dimensions and masses per unit length of welded and seamless steel pipes and tubes for pressure purposes
BS EN 1092	Circular flanges for pipes, valves and fittings (PN designated)
BS 6121	Mechanical cable glands
BS 6346	Specification for PVC insulated cables for electricity supply
BS 6435	Specification for unfilled enclosures for the dry termination of HV cables for transformers and reactors
BS 7354	Code of practice for design of HV open terminal stations
BS EN 10137	Specification for hot rolled quenched and tempered weldable plates

4.2.3 BS European Standards

BS EN 10029	Specification for tolerances on dimensions, shape and mass for hot rolled steel plates 3mm thick and above

4.3 Power Transformers

4.3.1 Types of Transformers

4.3.1.1 The transformers shall be oil immersed and suitable for outdoor installation and shall comply with IEC 60076, Parts 1 to 8 & 10 inclusive.

4.3.1.2 Electrical clearances shall not be less than those in the appropriate sections of BS 7354, or as stated in the System Electrical Parameters of the scope of works in section-1 of volume-2 or 3, whichever is the greater.

4.3.1.3 Following types of transformer is generally available in Transmission system and covered by this specification

SL	Voltage rating	Delta Tertiary winding, kV	Type of transformer	Use
1.	400/235	Yes, 34.5 kV	Auto-Transformer	Power Transmission

4.3.1.4 Both Auto & Power Transformer shall be designed, manufactured & tested in accordance with this specification. Power Transformer shall have separate HV & LV windings & auto transformer will have no electrical isolation between HV & LV windings.

4.3.2 Service Conditions

4.3.2.1 Usual service conditions:

4.3.2.2 The transformer will be installed outdoors and shall be suitable for operation in accordance with the usual service conditions specified in IEC 60076-1.

a) Altitude: Not exceeding 1000m
b) Temperature: ambient -20 to +40 deg C

4.3.2.2 Loading other than rated conditions:

4.3.2.2.1 All transformers specified may be exposed to an emergency loading in excess of nameplate rating, in accordance with IEC 60076-1,2. The transformer may be loaded above nameplate ratings in emergency situations with the knowledge that there will be some sacrifice of life.

4.3.2.2.2 All transformers shall be suitable for operation with an average ambient temperature of 40°C or as specified in Technical Data Sheets or in scope, whichever is higher.

4.3.2.3 Unusual service conditions:

4.3.2.3.1 Additional special service conditions, if any, will be stated in the Specific Transformer Technical Data Sheets. These special service conditions may include: harmonics, environmental hazards, reduced ambient air flow, etc.

4.3.3 Drawings & Documentation

4.3.3.1 All drawings and nameplates shall include measurements in SI Units (millimetres/meters, kilogram, Litres, etc.), unless otherwise specified.

4.3.3.2 Drawings shall have to be provided for each transformer being supplied in accordance with this specification. Each drawing shall contain a Title Block which includes the following information:

- User's name
- Manufacturer's name with country of origin
- Name of substation & project
- Station service voltage (AC and DC)
- Electrical ratings of the transformer
- Manufacturer's shop order number and drawing reference number

A) Electronic File Format – Electronic files of all documents shall have to be submitted on CD or via email in the following formats:

i. AutoCAD drawings in dwg format
ii. Word Documents in PDF format
iii. Photographic files in JPEG format and of appropriate resolution to print an 8"x10" image at 300 dpi with no loss of detail.
iv. SFRA test results in SFRA format

B) Nameplate Drawings – to be submitted as specified in the standard requirements.

C) Outline Drawings - shall include the following information:

i. Rating of Transformer
ii. The following weights:
    a) Core and Coil assembly
    b) Tank and Accessories
    c) Total mass excluding oil
    d) Oil mass in main tank
    e) Oil mass in OLTC
    f) Oil mass in radiator
    g) Oil mass in main conservator
    h) Oil mass in OLTC conservator
    i) Fully assembled transformer including oil (Total)
    j) Shipping (W/O oil)
iii. Overall size & dimensions, shipping dimensions, space requirements (including that for dismantling and maintenance) and the interrelationship of the various components.

iv. Component list with OEM part numbers, voltage ratings and current ratings.
v. The sizes of tubing, cables, and bus bars shall be indicated on this drawing.
vi. Location of the impact recorder, pressure-vacuum relief/gauge.
vii. Location of items to be removed for shipment.
viii. The location of series autotransformers, preventive autotransformers, regulating transformers and core grounds.
ix. Base dimensions and configuration, base and bushing centre lines, location of jacking pads, center of gravity and shall be suitable for designing bus connections, conduit connections and foundations.
x. The number of radiators, and fans utilized on the transformer.
xi. The outline drawing(s) shall include plan view as well as elevation views of all four sides.
xii. Information about additional uses of the tank reinforcing bands. The drawing shall identify if bands are used as a gas expansion space, or filled with sand for sound attenuation.
xiii. Where applicable, details of field erection indicating all field welds, sequence of welding, length of weld, etc. shall have to be provided.
xiv. Torque specification table for all components requiring field assembly.
xv. The outline drawing shall indicate any requirements or restrictions related to shipping. (E.g. shipping direction, whether the transformer may or may not be rail shipped, etc.)

D) Transformer winding layout and configuration diagram. The winding diagram shall be a sectional elevation view of sufficient detail to identify the following basic features of the core/coil construction:

i. Core legs
ii. High-voltage winding
iii. Low-voltage winding
iv. Tertiary-Voltage windings, (if any)
v. Winding taps
vi. On-Load tap changer and lead support structure
vii. Bushing configuration and connections
viii. Shielding (if present)
ix. Pressboard
x. Tank wall surface

E) Certified seismic outline drawings – shall include the following information:

i. All dimensions of each component, break down weights, the center of gravity of the transformer, loads and accelerations used in the design.
ii. Anchoring details including calculation showing bolt sizes, their type, grade and locations on a plan view. Calculations and details of the bracing

system for the radiators. The radiators shall be braced in both the horizontal and vertical directions.

iii. Controlling reactions at the base of the equipment for seismic, wind, and normal operating loads.

iv. Controlling forces used for designing anchors.

F) Schematic Diagrams – shall include the following information:

i. A list of devices with manufacturer and OEM model number shall be included

ii. Where a schematic is continued to another sheet, a transition bubble shall be used with the reference sheet # identified. Reference to separate drawings or sheets shall not be made via terminal board #'s.

iii. Terminal points shall be identified on the schematics.

iv. A typical paralleling diagram shall be provided.

v. The alarm schematic drawing shall show the annunciator with all alarm inputs and associated field contacts on one sheet.

vi. Set-points shall be identified for devices performing alarm or control functions.

vii. Total kVA demand shall be shown for all auxiliary equipment.

viii. Wiring Diagrams – Shall be drawn using the point-to-point wiring method. Connection diagrams using the so-called "Lineless Diagram Method" with separate tabulated wire lists are unacceptable.

ix. Wiring Diagrams for all components shall be provided, including internal wiring of the LTC.

G) Accessory drawings and documentation:

i. Outline drawings and details of bushings, showing stud size, connections, and dimensions.

ii. Bushing stud connector cut sheets shall be provided and shall include ampacity of connectors.

iii. A drawing showing dimensions and quantities of all gaskets.

iv. Outline drawings of arresters, showing connections, height, and mounting details.

v. saturation curves and ratio correction factor curves.

H) Drawings Sizes. Drawings shall conform to standard drawings sizes. (Plus or minus two mm in either dimension)

i. 594 x 841mm(A1 Size)

ii. 420 x 594mm(A2 Size)

iii. 297 x 420mm(A3 Size)

iv. 210 x 297mm(A4 Size)

I) Approval drawing transmittals:

Approval drawings shall have to be submitted by the date stated in the specific transformer datasheet. Prompt receipt of drawings is required to avoid cost of delays to related project activities. Liquidated damages charges will be assessed by the Employer per the General Terms and Conditions. A minimum of 30 days is required by the Employer for review and approval of these drawings.

4.3.4 Design Review

4.3.4.1 A transformer design data review meeting shall be conducted at the transformer manufacturing facility, with representatives of the Contractor, transformer manufacturer, and the user attendance, not later than 60 days after contract award. The User shall be given notification of the date of the transformer design data review meeting, the location, the duration, and the proposed agenda at least 30 calendar days in advance of the meeting.

4.3.4.2 The Employer/User shall have the option of conducting a review of the transformer. The User's Engineers and the Manufacturer's Engineers shall meet for a designreview at such time after the design has been completed but before any materials thatcannot be used by the Manufacturer on other orders have been procured.

4.3.4.3 The purpose of the design data review portion of the meeting is to help assure prior to official submittals that the key elements of thetransformer specification requirements are being met, and to describe thetransformer manufacturing and design data features. The user shall have the right to review, and the Manufacturer shall have available, all mechanical and electrical design aspects, including finite element analyses (FEA) and dielectric calculations at this meeting. Topics to be reviewed are indicated, but not limited to, the items on the checklist included with this specification. As a minimum, Dielectric, Thermal including cooling & Short circuit /Mechanical design of the transformer shall be reviewed in detail.

4.3.4.4 Additionally, the transformer manufacturer shall be prepared todiscuss the following elements as a minimum:

A) Transformer nameplate data and ratings

B) Preliminary transformer layout drawing

C) Winding diagram and dimensions (block or layout format acceptable)

D) Winding information (high- and low-voltage windings), including:

i. Winding type
ii. Conductor type

iii. Insulation type
iv. Turns
v. Stresses
vi. Calculated resistance (@ 85 degrees-C reference)
vii. Drying and clamping methods

E) Core information, including:

i. Core type
ii. Core material type
iii. Joint construction
iv. Banding
v. Acceptable gap/burrs
vi. Cooling ducts
vii. Rated flux density
viii. Calculated exciting current

F) Loss calculations

G) Impedance calculations

H) Accessories, including:

i. Bushings
ii. Cooling equipment
iii. De-energized tap changer
iv. Other proposed accessories

4.3.4.5 Manufacturing schedule shall allow two weeks for Customer evaluation of design review data. Any time and cost associated with redesign if design is not approved shall be borne by the Manufacturer. Any procurement and/or fabrication prior to design approval shall be at the risk of the Manufacturer. This shall apply to the first order of a given transformer or whenever modifications are made to the thermal, electrical, or mechanical of the active or live parts.

4.3.4.6 The Manufacturer shall provide a shop schedule of major milestones to permit the Customer to schedule any in-progress inspections deemed to be necessary or desirable. Schedule shall have to be updated at regular intervals. Core and Coil Assembly and Transformer Testing shall have to be broken down by shift, if possible.

4.3.4.7 The Manufacturer shall provide calculations of GMD withstand to be presented in a design review according to IEC or IEEE, and the calculations shall be verified by an experienced expert on GMD before submission.

4.3.5 Final Documentation

4.3.5.1 Final documentation shall be provided within 2 weeks of shipment, and shall include the following:

- Five (5) sets of AutoCAD drawings, test reports, SFRA data files, and photographs with portable memory.

4.3.5.2 In addition to one Instruction Book provided with the transformer in the control cabinet, four (4) additional Instruction Books per transformer shall be sent to the Engineer within 4 weeks after shipment of the transformer. Each instruction book shall include the followings:

1. Instruction books shall clearly indicate the Customer's name, the substation name and number, Project Name and the Manufacturer's identification number.
2. Certified Test Report for each transformer, including all results of tests required in relevant section of this specification (Routine & Factory Acceptance test) Section 15.
3. 297 x 420 copy of the transformer nameplate drawing, with all data filled in.
4. Assembly instructions
5. 3.5.2.5 Bill of material (identify parts removed for shipment, all parts with manufacturer name/model #, cross reference to applicable drawings by item # or electrical device #)
6. Complete set of “As-Built” drawings (reduced size is acceptable)
7. Arrester and Bushing outline drawings.
8. Instructions for all accessories including Annunciator, relays, counters, Electronic Temperature Monitor (if supplied), and LTC control equipment, etc.
9. Certified test reports for Metering accuracy CT’s.
10. Relay class CT data. For each CT of a different accuracy class or ratio, the following information shall be supplied:
    - Saturation curves
    - Thermal rating factor
    - Secondary resistance in ohms per turn
    - Lead resistance in ohms per lead
    - Ratio correction factor curves
    - Metering accuracy at the full tap ratio

- One (1) set of 8" x 10" colour photographs as follows:

  i. Core and coils viewed from the high voltage side, just prior to tanking
  ii. Core and coils viewed from the low voltage side, just prior to tanking
  iii. Core and coils viewed from the top, just after tanking
  iv. Assembled transformer side-views of the high voltage side and the low voltage side
  v. Tank interior prior to tanking of active part
  vi. Assembled transformer top-view

4.3.6 Short-Circuit Design

4.3.6.1 Requirement

4.3.6.1.1 Notwithstanding the over current limits tabulated in IEC 60076-5, the transformer with the standard minimum percentage impedances given in this specification, shall be capable of withstanding the thermal, mechanical and other effects using the following criteria for calculating the short circuit withstand condition:

i. Pre-fault voltage of 1.1 Um;
ii. Source fault capacity shall be assumed to be infinite (zero impedance).;
iii. Fault duration of 2 s;

4.3.6.1.2 The inner winding shall be designed to withstand the free buckling criteria. However, the specific stress (average) of the inner winding shall not exceed 50 % of the copper conductor yield strength. Whenever a reasonable application of Epoxy Bounded CTC is possible, this would be the preferred solution;

4.3.6.1.3 The yield strength that shall apply to the conductor of the outer winding shall be 80 % of the copper conductor yield strength;

4.3.6.1.4 All material used for winding cylinders shall be pre-dried and pre-impregnated with oil prior to use;

4.3.6.1.5 The blocks which are used to apply the axial compression shall be pinned to the clamping system.

4.3.6.1.6 For transformers with a delta tertiary [brought-out to bushing], the transformer tertiary winding shall be designed to withstand the mechanical & thermal impact due to three phase faults at it's tertiary terminal. Moreover, the tertiary winding shall be sized to provide sufficient mechanical strength & thermal capacity for a single-line-to-ground fault [i.e. short circuit] at its' tertiary terminals.

4.3.6.1.7 When, for three winding transformer, the tertiary is brought out to external bushing, the tertiary winding shall be designed for withstanding three phase terminal fault with HV & LV running simultaneously.

4.3.6.1.8 For Best Short circuit withstand performance, the individual pahses [A,B,C] shall be clamped to theclamping structure. Other arrangement shall be in agreement with Employer or it's Engineer.

4.3.6.1.8 Generally, for three winding transformer upto 520MVA, the tertiary shall not be designed with so called internal current limiting reactor. For higher capacity, actual design shall be finalized during design review process. However, regarding internal current limiting reactor, the Engineer shall have the right to decide the best suitable design in terms of reliability & operational experience.

4.3.6.1.9 When required by schedule of requirement or in the scope of work, the Employer reserves the right to apply a short-circuit test to one transformer of any batch on site or elsewhere where convenient, before taking over the batch, in order to prove the short-circuit strength of the windings. Such tests will follow the guidelines laid down in IEC 60076-5. Should the test fail the Supplier (manufacturer) shall be liable for all costs (redesign is mandatory).

4.3.6.1.10 The calculation of the short circuit design of the offered transformer, shall be verified during the Employer's design review.

4.3.6.2 Calculations and Tests:

1) Evidence shall be submitted with the Bid as to the extent to which the Manufacturer has proved, or is able to prove, by test, or by calculation, the ability of the specified Transformers to withstand short circuit.

2) The test is applicable for a reference transformer of similar design of that of the offered transformer and calculation is for the offered transformer.

3) The Bidder shall provide with his bid a brief description of the transformers, or parts thereof, which have been subjected to short circuit test.

4) The bidder shall submit calculation (both for thermal & dynamic effect of short circuit), with a reference transformer having same MVA, kV, %Z or higher rating which has been subject to short circuit test.

5) The offered transformer must be same or have comparable design to that of the reference transformer.

6) In this regard, bidder shall declare in his bid that, they shall provide the detail short circuit design of the reference transformer & the offered transformer during detail engineering & execution of the project for review and approval of Employer.

7) The contractor must redesign or modify his offered transformer design based on the observation of Employer.

8) Manufacturing shall not commence before clearance & final approval of short circuit force design of the offered transformer from the Employer. The factory location, source of accessories (specially, Core, winding, tank, insulation material, oil, bushing etc.) shall be same for the two transformers: offered one & reference one.

9) Bidder shall demonstrate adequate measures have been taken to overcome the Dynamic force at the following locations:

- ✓ cross overs of turns (inside the winding)
- ✓ transpositions of parallel conductors (inside the winding)
- ✓ exit leads of the windings: fixation to prevent movement and friction (wear of insulation) of exit lead
- ✓ connections to OLTC
- ✓ support of leads to bushings
- ✓ stability of the radial support of windings: for example spacers used during winding the coil (untreated, dried, dried and oil impregnated)

10) In case of the reference transformer, complete type test including complete short circuit performance test shall have to be performed, associated type test certificate & short circuit test certificate shall have to be submitted. The report shall reflect the condition of transformer before & after the Short circuit test. The routine tests performed to the transformer shall have to be available with the type test report.

11) The number of tests for reference transformer shall be preferably fifteen (15); however, minimum nine no.'s of test is also acceptable. Nine (09) tests on a three-phase transformer with tappings are made in different positions of the tap changer, i.e. three (03) tests in the position corresponding to the highest voltage ratio on one of the outer phases, three (03) tests on the principal tapping on the middle phase and three (03) tests in the position corresponding to the lowest voltage ratio on the other outer phase.

12) The sequence shall be highest tap position shall face first three (03) short circuits & lowest tap position shall face last three (03) short circuits for nine/fifteen shots.

13) After completion of the tests, dielectric test at 100% prescribed value as mentioned in this specification shall be performed. Clause 4.2.7.4 of IEC 60076-5 shall be applicable at this stage. However, if the reactance variation is in the range 1 % to 2 %, the acceptance is subject to non-increasing tendency of reactance. Reactance with increasing tendency in sub-sequent routine test shall be rejected.

14) The transformer shall be tested at independent laboratory. A transformer tested for short circuit performance at OEM's premise and witnessed by Independent Inspection Authority shall not be accepted.

15) The short circuit test Laboratory from where the reference transformer has been tested shall have:

- At least 15-20 years of experience in short circuit testing of HV transformer of same or higher voltage class transformer
- Have tested at least transformers from 8-10 nationalities
- Test facility up to next voltage level (i.e. 500kV or 800kV class) and minimum power handling capacity 1000MVA
- Must be a STL or equivalent accreditation member
- Independent Laboratory (the Lab shall not be owned by the OEM or Group that owns the OEM)

4.3.7 Rating

4.3.7.1 General

4.3.7.1.1 Transformers shall have the rating stated in the Schedule of Requirements (Technical Data Sheets) and shall comply with the requirements as regards temperature rise and overloads on all tapings, irrespective of the direction of power flow and with the voltage of the lower voltage winding at the normal voltage stated in the Schedule of Requirements.

4.3.7.1.2 To allow for high atmospheric temperatures, the allowable temperature rises shall be reduced in accordance with IEC 60076-Part 2.

4.3.7.2 Cooling class

4.3.7.2.1 Transformers shall be filled with a dielectric fluid as identified in the specific transformer Technical Data Sheets.

4.3.7.2.2 The circulation mechanism for the internal cooling medium shall be natural convection for all stages of cooling. The external cooling mechanism shall be natural or forced flow of air. The required number of cooling stages will be identified in the specific transformer Technical Data Sheets.

4.3.7.2.3 Where a combination of two methods of cooling is applied to one transformer, as for ONAN/ODAF1/ODAF2 units, the transformer shall be capable of operating under the ONAN condition up to 60 percent load or more as stated in the Schedule

of Requirements or Technical Data Sheets, after which the cooling equipment is to come into operation and the Transformer will operate as an ODAF unit.

4.3.7.2.4 Transformers shall be fitted with at least two coolers or two banks of radiators each capable of dissipating 50 per cent of the losses at continuous maximum rating. They shall be capable of remaining in operation at full load for 20 minutes in the event of failure of blowers associated with one half of coolers or radiators, without the calculated winding hot spot temperature exceeding 140˚C or as stated in the Schedule of Requirement/Technical Data sheets . Such shall be verified by design during design approval stage and taken approval from the Employer.

4.3.7.2.5 Failure of one fan in each group of blowers shall not reduce the continuous maximum rating of the transformer. Design shall confirm this requirement.

4.3.7.2.6 The Continuous capacities of each cooling stage as per voltage level are defined in the Schedule of requirement (Technical Data Sheets) of Volume 3 of 3 of the bidding document.

4.3.7.3 Frequency

4.3.7.3.1 All transformers shall be designed for operation at 50 Hertz.

4.3.7.4 Phases

4.3.7.3.1 All transformers shall be three phase or single phase as mentioned in the schedule of requirement (Technical Data Sheets) of Volume 3 of the bidding document, with three-legged core form design unless otherwise specified in specific transformer Data Sheets. The phase relationship of the winding is identified in the specific transformer Data Sheets.

4.3.7.5 Rated MVA

4.3.7.5.1 The ratings of the transformer shall be given in MVA, unless otherwise specified. With the maximum rated output kilovolt-ampere load at rated frequency and voltage, the average winding temperature and winding hot spot temperature shall conform to IEC 60076 with the exception of 45° ambient temperature. Specific temperature rise ratings are listed in the specific transformer Data Sheets.

4.3.7.5.2 Specific MVA rating requirements are provided in the specific transformer Data Sheets.

4.3.7.5.3 All3 winding transformers shall be designed for simultaneous loading unless otherwise specified. Design shall be such that, when three windingsare loaded simultaneously for the rating specficied in the datasheet, the transformer is not derated; such as for step down case, when TV is loaded for datasheet MVA, with pf as mentioned in this specification, the LV shall not be derated.Same shall be for step up case.

4.3.7.6 Voltage ratings and taps

4.3.7.6.1 Voltage ratings for all windings shall be as specified in the specific transformer Data Sheets.

4.3.7.6.2 Maximum continuous voltage on any tapping (Over flux): Over excitation shall be limited to 5 % at full load and 10% at no-load respectively. The maximum flux density shall be limited to 1.72 T at 50 Hz. Taking the frequency variation as specified in section 01, Network frequency into account the flux density shall not exceed 1.79 T at 48 Hz.

4.3.7.6.3 Maximum temporary over voltage: Under switching conditions, the power frequency line voltage may exceed the highest voltage for equipment (Um as defined in IEC 60076-3). Transformers shall be designed to withstand without damage the system overvoltage profile specified in PGCB's Power's Technical Specification and specifically the following over-voltages.

a) Um for continuous;
b) 1.2 Um for 200 s;
c) 1.5 Um for 0.2 s; and
d) 1.6 Um for 0.02 s

4.3.7.6.4 A On Load Tap Changer shall be provided in accordance with clause 1.7.2 of this specification, and with tap voltages as identified in the specific transformer Data Sheets.

4.3.7.6.5 De-Energized Tap Changer with full capacity taps shall be provided in accordance with clause 4.7.6 of this specification, and with tap voltages as identified in the specific transformer Data Sheets

4.3.7.7 Power Factor

4.3.7.7.1 Permissible range for power factor shall be as per Table 01 unless otherwise specified.

SL	Supply voltage	Power factor range (half-hour average, unless otherwise specified)
	400kV	0.97 lagging to unity
	230 kV	0.96 lagging to unity
	132kV	0.95 lagging to unity
	33/11kV	0.85 lagging to 0.8 leading [same for 3-W case]

4.3.7.8Winding terminal markings and connections

4.3.7.8.1 It shall be in accordance with IEC standard 60076, unless specified otherwise in the specific transformer Data Sheets.

4.3.7.9 Winding configurations and phase relationship

4.3.7.9.1 It shall be as identified in the specific transformer Data Sheets.

4.3.7.10 General Arrangement

4.3.7.10.1 Unless otherwise specified, the physical arrangement shall be such that:

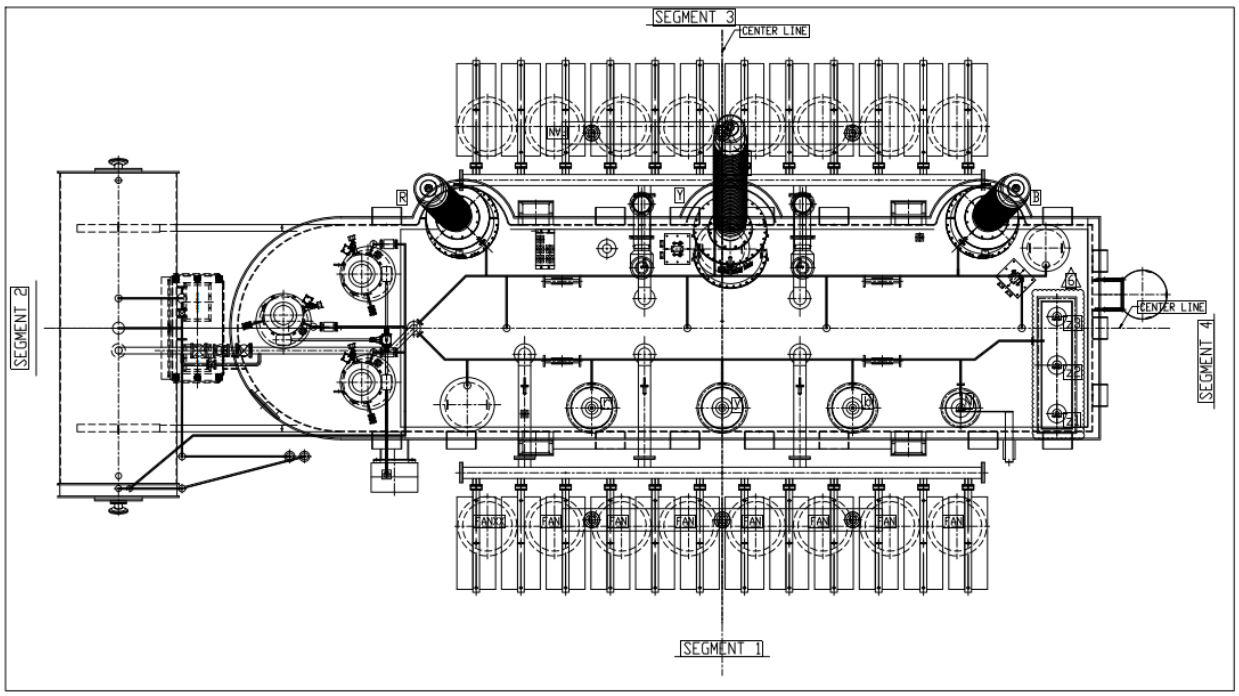


Figure 01: GA & Equipment Layout

Segment 01: LV bushing

Segment 02: OLTC/Conservator

Segment 03: HV bushing

Segment 04: TV bushings

~~**4.3.7.10.2** To suit with the station layout it may be necessary that, segment 01 & 03 are inter-changed and segment 02 & 04 are interchanged.~~

4.3.7.10.3 Those equipment (LA, etc), not mentioned here, are left to the manufacturer for appropriate design.

4.3.7.11 Internal clearance

4.3.7.11.1 The vendors are free to design reduced clearance as per industry practice. Those internal clearance shall be adequate to overcome all abnormal overvoltage condition during impulse testing & the service life period considering the system the transformer will be connected. Special care shall be taken to sufficiently distribute the impulse voltage across the windings, between winding to ground, between turns and inter-winding (& layers).

4.3.7.11.2 For auto transformer, transfer of surges to the low voltage windings shall be given concentration. If it is required to adopt surge limiting techniques, these shall be brough to the attention of Engineer during design review process and appropriate solution shall be adopted based on best industry design practice considering reliability & maintenance of the transformer during the service life.

4.3.7.12 Impedance

4.3.7.12.1 Positive and Zero Sequence Impedance shall be as specified in the Data Sheets.

4.3.7.12.2 For Wye-Wye Transformers or Autotransformers with Delta tertiary, Zero-Sequence Impedance shall be as defined by IEC 60076. A neutral reactor is not an acceptable method for obtaining the required zero sequence impedance.

4.3.7.12.3 The core and coil design shall be such that if the transformer were short circuit tested in accordance with IEC 60076-5, the impedance measured after the test series would not differ from that measured before the test series by more than two percent (2%).

4.3.7.13 Parallel Operation

4.3.7.13.1 Transformers supplied against each item shall be designed to operate satisfactorily, one with the other, when operating on the same tap position. Sufficient information for preparation of a proposal and preliminary engineering are included in the Data Sheets when parallel operation with existing transformer(s) is required.

4.3.7.13.2 The Manufacturer shall obtain necessary detailed information from the manufacturer(s) of the existing transformer(s) after receipt of an order. In addition, the Manufacturer of transformers ordered under this specification agrees to provide such information to other Manufacturers to permit future paralleling of transformers covered by this specification as required for at least 25 years.

4.3.7.14 Insulation Levels

4.3.7.14.1 Insulation levels for line and neutral terminals shall be provided as identified in the Specific Transformer Data Sheets. Refer also to Schedule E for specific dielectric test requirements. Specified insulation levels shall apply to all leads and ancillary equipment associated with each terminal.

4.3.7.14.2 BIL requirements shall be met without the use of internal arresters.

4.3.7.14.3 No internal devices of a linear or nonlinear nature (such as surge arresters) shall be installed for any reason, that would alter, cause abnormal variations or otherwise affect Factory dielectrics testing and/or affect routine maintenance test results such as "Doble".

4.3.7.15 Temperature rise and loading conditions:

4.3.7.15.1 Temperature rise to be as stated in the Data Sheets. The overload capability shall be in accordance with IEC 60354.

4.3.7.16 Nameplate:

4.3.7.16.1 In accordance to the rating plate requirements in IEC 60076, the following (including additional) information shall be shown on the nameplate:

1) Kind of Transformer (Auto, Power…etc.)

2) Number of the standard

3) Type of Core (example type 1, type 2 …)

4) Type of cooling

5) Number of phases

6) Rated power, rated voltages, rated currents, rated frequency

7) Rated BIL, SI Withstand Voltage (if applicable) & PF Withstand Voltage

8) Short circuit (%) impedence

9) Connection symbols

10) Design altitude

11) Design seismic capability

12) Listing of the separate volumes and weights of:

i. Core and Coil assembly
ii. Tank and Accessories
iii. Total mass excluding oil
iv. Oil mass in main tank
v. Oil mass in OLTC
vi. Oil mass in radiator
vii. Oil mass in main conservator
viii. Oil mass in OLTC conservator
ix. Fully assembled transformer including oil (Total)
x. Shipping (W/O oil)

13) BIL rating of neutral terminal(s)

14) Location of the buried tertiary bushing instruction plate (if applicable)

15) Z-winding voltage and capacity ratings, if applicable, whether the terminals are specified to be brought out or buried

16) Accuracy class and thermal rating factor (TRF) of current transformers

17) Location of the core and frame grounding bushing

18) Applicable instructions concerning the special bushings for a buried Y-winding and concerning the core and frame ground bushings

19) Transformer winding and current transformer polarity marks

20) Type, Manufacturer and model number of Tap Changer.

21) Overload rating of OLTC

22) Project Identification number

23) Manufacturer's name, Product's serial number & year of manufacturing

4.3.8 Electrical Connections

4.3.8.1 Transformer windings shall be connected in accordance with the IEC 60076-1 (clause 6) group symbol specified in the Schedule of Requirements (Technical Data Sheets).

4.3.8.2 All electrical connections within windings shall be brazed, subject to approval, mechanically crimped joints may be used for round stranded conductors on tapping, bushing or earthing connections and on bundle conductors where design has been proved by type test and application is subject to rigorous quality control.

4.3.9 Stabilizing Windings

4.3.9.1 Unless otherwise specified in the Schedule of Requirements, the product of the number of turns of the stabilizing windings and the cross- sectional area of one such turn must not be less than 20 percent of the corresponding product for the untapped main winding.

4.3.9.2 When required by the Schedule of Requirements, the stabilizing winding shall be capable of carrying continuously the load specified therein.

4.3.9.3 For Short circuit Design, the winding shall be capable of withstanding the whole short circuit force due to terminal fault. Use of so-called tertiary Reactor (Current Limiting Reactor) inside the tank is not acceptable unless otherwise specified.

4.3.10 Losses and Evaluation of Losses

4.3.10.1 Guaranteed values for component losses of the total loss of the transformers shall be as low as is consistent with transport restrictions, reliability and economic use of materials, shall be as stated in the Schedule B of Particulars and Guarantees. The Loading condition shall be treated as Simultaneous Loading in all windings.

4.3.10.2 For the evaluation of the bid as per section 3 (Evaluation and qualification criteria) capitalization cost (Evaluated price of transformer losses) due to transformer guaranteed losses shall be added with the bid price. The evaluated price of the Power Transformer shall be the sum of the quoted bid price of the transformer plus evaluated price of the transformer losses. The evaluated price of transformer loss shall be:

For each unit of the three-phase/single-phase transformers,

Evaluated price of transformer loss = N * a + L * b + M * c

Where

N= No-load loss (core-loss) at rated voltage in kW

L= Load loss (copper-loss) at 75 °C, 50 Hz maximum continuous rating in kW

M= Total load of transformer cooling fans at transformer maximum continuous rating in kW (when all the cooling fans are in operation)

a= Cost/kW of no load loss (core-loss) valued at Taka 600,000.00

b= Cost/kW of load loss (copper-loss) valued at Taka 300,000.00

c= Cost/kW of auxiliary power valued at Taka 300,000.00

4.3.10.3 The acceptance of transformers (after Factory Acceptance Test) yielding component losses higher than the guaranteed values shall be governed by either of the following:

i. Transformers shall be acceptable subject to full compliance with all technical particulars, including temperature rises at CMR (Continuous Maximum rating) and subject to the Bidder accepting deduction from the contract Price of charges for each kW or part thereof of component losses in excess of the guaranteed values, at the above evaluation rates; where, Component losses in excess of guaranteed values but within the tolerance permitted under IEC 60076 Part 1 or as per technical datasheet or guaranteed by Contractor/Manufacturer.

ii. The acceptance of transformers shall be entirely at the discretion of the Employer and subject to the Bidder accepting the deduction from the contract Price of charges for each kW or part thereof of component losses in excess of the guaranteed values, at the above loss evaluation rates; where, Component losses in excess of guaranteed values but within the tolerance permitted under IEC 60076 Part 1 or as per technical datasheet or guaranteed by Contractor/Manufacturer.

4.3.10.4 In the event of transformers yielding component and total losses that are either equal to or below the guaranteed values, the Bidder will not be entitled to any premium in respect of reduction in losses below the guaranteed values.

4.3.11 Noise

4.3.11.1 The transformer noise levels shall be measured as a type test and in accordance with IEC 60551. The acceptance level of the transformers shall be as stated in the Schedule of Requirements (Technical Data Sheets).

4.3.11.2 Where the bottom plate of the transformer tank will be in direct contact with the surface of the foundation, anti-vibration pads shall be provided under the contract for insertion between the transformer and its foundation.

4.3.11.3 The anti-vibration mountings shall be of an oil and weather resisting rubber or other approved material, capable of operation at temperatures from minus 10°C to plus 80°C. Due regard shall be given to irregularities in the tank under base and the plinth surface. Anti-vibration mountings for separately mounted coolers, pumps, etc. are not required.

4.3.11.4 The total unloaded depth of anti-vibration material (excluding load spreading plates) in the mountings shall not exceed 40mm.

4.3.11.5 When loaded to the same pressure as in service, the anti-vibration mountings shall give, at normal room temperature, a vibration attenuation at 100Hz of not less than 32dB (assuming an infinite ground impedance value).

4.3.11.6 Representative samples of anti-vibration material for the mountings shall be subjected to sample tests.

4.3.12 Harmonic Suppression

4.3.12.1 Transformers shall be designed with particular attention to the suppression of harmonic voltages, especially the third, fifth and seventh harmonics, and to minimise the detrimental effects resulting therefrom.

4.4 Magnetic Circuit and Windings

4.4.1 Magnetic Circuit

4.4.1.1 The design of the magnetic circuit shall be such as to avoid static discharges, development of short circuit paths internally or to the earthed clamping structure, and the production of flux components normal to the plane of the laminations. Each

lamination shall be insulated with a material stable under the action of pressure and hot oil.

4.4.1.2 The winding structure and major insulation shall be designed to permit an unobstructed flow of cooling oil through core cooling ducts to ensure efficient core cooling.

4.4.1.3 With the earthing link removed, the magnetic circuit shall be insulated from all structural parts, and shall be capable of withstanding a test voltage to core bolts and to the frame of 2,000 volts RMS for one minute.

4.4.2 Core: Design & Construction

4.4.2.1 General

4.4.2.1.1 Cores shall be constructed from cold rolled grain oriented steel sheets. Design shall be such that there will be no adverse effects due to core or stray flux heating with the quality of steel employed, and that when operating under the most onerous conditions envisaged in IEC 60076 and IEC 60354.

4.4.2.1.2 Moreover, the Grain-Oriented Silicon Steel with Laser-beam or plasma jet irradiation type shall be used to reduce the transformer's no load loss and the core loss (W/kg). Core loss of core material shall not exceed 0.85 at W17/50 (1.7T, 50Hz).

4.4.2.2 Steel Specification

4.4.2.2.1 All cores including main, series, and preventative auto, shall be constructed using low loss, cold-rolled, grain-oriented, silicon steel. Steel is to be slit to width, annealed and coated with inorganic insulating material. All slits and cuts must be free of burrs.

4.4.2.3 Flux Density

4.4.2.3.1 With the transformer energized at no-load on any tap position, at 100% voltage, the maximum flux density in any part of the core shall not exceed 1.7 Tesla.

4.4.2.3.2 At the maximum forced-cooled rating, the maximum flux density in magnetic shunts shall not exceed 1.2 Tesla.

4.4.2.3.3 The transformer shall be designed to meet the following overvoltage requirements, such that the maximum core flux density shall not exceed 1.9 Tesla at any tap positioning any part of the magnetic circuit:

- 110% secondary voltage at no-load
- 105% secondary voltage with the transformer at maximum rated MVA load condition and at 80% power factor.

4.4.2.3.4 On load tap changing transformers with the tertiary (Z) terminals brought out, the transformer shall be designed such that variation of the voltage output of the tertiary winding is allowed, unless otherwise stated in the Specific Transformer Data Sheets in the Appendix, that the voltage output must be constant.

4.4.2.3.5 The induction level shall be such that the ratio of induction current at 110% and 100%voltages shall not be >3.

4.4.2.4Core design

4.4.2.4.1 The core shall be a three-legged core-form construction using mitred step lap design, unless otherwise specified in specific transformer Data Sheets in the Appendix.

4.4.2.4.2 The edges of the laminations on the core legs and bottom yoke shall be protected against rust with a protective coating. The core legs shall be secured with permanent bands. Bolts through the legs or yokes shall not be used.

4.4.2.4.3 The core internal hot-spot temperature shall be limited to a maximum of 125° C. Material used to form cooling ducts in the core shall not be cellulose.

4.4.2.4.4 Every core step shall be supported at the ends. At the bottom every core step shall be supported from a base bar that connects to the LV and HV core clamps.

4.4.2.4.5 Core frame components shall be welded or bolted using Belleville washers. Self-locking nuts, with stainless steel Belleville washers, or approved self-locking inserts, shall be used where required to secure equipment mounted over the core and coil assembly.

4.4.2.4.6 Split spring lock washers are not acceptable in the assembly of internal transformer components. If flux shield plates and/or non-magnetic steel are used to reduce tank heating and losses, the Seller shall provide detailed drawings of these items for the Employer's approval.

4.4.2.5Core insulation

4.4.2.5.1 The insulation material between tie bars and the core, and the core frames and core, shall be a high-temperature material (tolerant of 150° C minimum) that coordinates with the surface temperatures in the locations where this insulation is to be applied.

4.4.2.5.2 A minimum material thickness of 2 mm shall be provided.

4.4.2.6 Core Grounds

4.4.2.6.1 If the core is constructed with cooling channels separated by insulating material, each core section ground shall be brought up separately through cover mounted bushings.

4.4.2.6.2 The core sections shall be externally bonded and grounded. A bridging strap or other means of internal electrical connection of the core sections is not acceptable.

4.4.2.6.3 An engraved nameplate shall be provided to permanently identify the core ground connections. All core ground connections (main and auxiliary windings) shall be brought up separately and grounded.

4.4.2.6.4 The connections shall be brought out through a bushing mounted on the top of the tank, protected in a metal box. The bushings shall be located on the top of the tank so that a bushing may be replaced without the need to reduce the oil level below the top of the windings.

4.4.2.7Frame Ground

4.4.2.7.1 A frame ground bushing shall be provided.

4.4.2.7.2 When there is more than one (1) frame to clamp separate cores, each frame shall have an insulated cable brought up to a location near the top of the tank and be connected together internally. This connection shall be removable, and shall be designed with captive hardware. The connection location shall be easily accessible from a manhole or handhole on the transformer cover and the location shall be clearly identified on the transformer nameplate and marked on the appropriate manhole or handhole cover.

4.4.2.7.3 Frame ground bushings shall be separately grounded outside the main tank. Audible Sound Level:

4.4.2.7.4 The guaranteed sound level for operation at the rated voltage shall be described in the Specific Transformer Data Sheets.

4.4.3 Winding Design & Construction

4.4.3.1Arrangement

4.4.3.1.1 For all separate winding transformers the winding arrangement (reference from the transformer core) shall be MV winding, HV winding and Regulating winding.

4.4.3.1.2 For auto-transformers the winding arrangement (reference from the transformer core) shall be Tertiary winding, Common winding, Regulating winding & Series winding.

4.4.3.1.3 Other arrangement shall be in agreement with PGCB.

4.4.3.2 Design

4.4.3.2.1 Self-supporting coil design is encouraged, but windings must still be fully supported back to the core. Circular disc and/or helical type windings shall be provided for all windings, including series transformer if provided. Rectangular winding design will only be accepted for preventive autotransformers for a reactance-type LTC.

4.4.3.2.2 Layer type windings will be accepted only for regulating windings. When layer windings are used, the radial build shall be a minimum of 12 mm. Only one conductor in the radial direction is allowed unless CTC conductor is used.

4.4.3.2.3 Spring or isostatic pressure (preferred) shall be applied during the winding sizing process.

4.4.3.2.4 If CTC (continuously transposed conductor) is used, the following requirements shall be:

- When conductor insulation on CTC is cellulose, it shall be Weidmann (Dennison) paper. On strap conductor, at least the outside 2 layers of conductor insulation shall be Weidmann paper. The insulating paper shall be applied in either single or multiple strands in such a manner that 30% overlaps.
- Brazes in CTC shall not be used unless the required conductor length exceeds the maximum available reel capacity. When required due to conductor length limitations, brazes shall be strand-to-strand, i.e. each strand shall be individually brazed and insulated separately.

- Epoxy-bonded CTC shall not soften during any type of fault based on the short-circuit temperature rise calculation in IEC 60076-5. The allowable temperature for this condition is less than 140 °C.
- When using CTC that is insulated with paper, the radial cooling duct shall be a minimum of 4.5 mm.
- Formvar insulated conductors are not acceptable except with CTC.

4.4.3.2.5 The dielectric stress at any location in the core-and-coil assembly shall not exceed 2.65kV RMS/mm with the transformer energized at 100% voltage on the maximum stress tap position. Applicable stresses include but are not limited to turn-to-turn, winding-to-winding, winding-to-ground, phase-to-phase and lead-to-lead.

4.4.3.2.6 Windings subject to inward radial buckling shall be designed to withstand "free" (unsupported) buckling in addition to "forced" (supported) buckling. The control of inward radial forces shall not depend on bracing to the core. The use of epoxy bonded CTC is required for windings subject to inward radial buckling. Short circuit calculations shall be based on an infinite bus. When layer windings are used, each layer shall be designed for "free" buckling independent of the other layers.

4.4.3.2.7 Where needed for pack-out, solid tapered insulating material shall be used in a disk or turn instead of duct-strip.

4.4.3.3 Winding and lead insulation

4.4.3.3.1 The winding insulation system shall be of the thermally upgraded type to meet the operating conditions for 65°C/55°C rise as per datasheet. The axial spacers for disk windings shall be at least 3 mm.

4.4.3.3.2 All cellulose winding insulation shall be Dennison paper insulation. All insulating materials that could come in contact with the winding conductors or leads shall have rounded edges.

4.4.3.3.3 Excluding lead supports and clamping rings, all insulation material shall be thermally upgraded (suitable for continuous operation at 110°C).

4.4.3.3.4 One-piece top and bottom clamping rings shall be used. There shall be no reduction in the thickness of the top clamping ring in the core window.

4.4.3.3.5 All lead support distances shall be less than 610 mm. All leads shall be clamped to blocks secured by non-metallic bolts. Ties and tie-wraps shall not be used. All

connections shall be firmly supported with reasonable clearances between connections of unlike voltages. Sharp bends shall not be used in interties or terminal leads. Supports for insulated transformer leads shall have rounded edges, either from machining or cardboard angles, to prevent damage to cable insulation during normal movement in transportation or operation. Openings in insulated tubing shall be flared or rounded smooth when used for entrances or exits of insulated leads run inside the tubing.

4.4.3.3.6 Internal non-metallic support structures provided for support of leads and other internal devices shall be bolted together using non-metallic threaded rods with nuts at each end. Nuts shall be locked in place, either by disrupting threads, tying off threads or epoxying threads, so that nuts cannot come loose due to any amount of vibration or any amount of thermal expansion and contraction while still allowing for disassembly by the application of deliberate force on the nut.

4.4.3.4 Windings and internal leads

4.4.3.4.1 All conductors of transformer shall be copper unless otherwise specified in the Requirement. Transformer HV and MV auto & star connected windings shall have graded insulation as defined in IEC 60076. For 33kV and below they shall have uniform insulation as defined in IEC 60076. All neutral points shall be insulated to withstand the applied test voltage specified in the Schedule of Requirements.

4.4.3.4.2 The windings shall be located in a manner that will ensure that they remain electromagnetically balanced and that their magnetic centres remain coincident under all conditions of operation.

4.4.3.4.3 The windings shall also be thoroughly dried and shrunk by the application of axial pressure for such length of time as will ensure that further shrinkage will not occur in service.

4.4.3.4.4 The windings and leads of all transformers shall be braced to withstand the shocks that may occur through rough handling and vibration during transport, switching and other transient service conditions including external short circuit.

4.4.3.4.5 If the winding is built up of sections or of disc coils separated by spacers, the clamping arrangements shall ensure that equal pressures are applied to all columns of spacers.

4.4.3.5 Bracing of Windings

4.4.3.5.1 All winding insulation shall be processed to ensure that there will be nodetrimental shrinkage after assembly.

4.4.3.5.2 Windings shall be provided with clamping arrangements that will distribute theclamping forces evenly over the ends of the winding. Unless otherwise approved,winding clamping arrangements shall permit adjustment of the pressure and thetaking up of shrinkage that may occur in service.

4.4.3.5.3 The bracing of the windings and connections shall be such that these parts shallsafely withstand the cumulative effects of stresses that may occur duringhandling, transportation, installation and service, including line-to-line and line-to-ground faults.

4.4.3.5.4 Full details of the winding clamping arrangements, and their adjustment in or outof the tank, together with relevant drawings and values, shall be submitted forapproval and shall form part of the transformer manual. The Supplier shall informthe purchaser of any changes to this design prior to construction.

4.4.3.6 Method of Winding Connections

4.4.3.6.1 Soft solder shall not be used in making winding connections. If brazed connections are used all traces of acidity shall be eliminated on completion of the process.

4.4.3.6.2 Welded connections and joints in winding body shall be welded copper connections made by the metal-inert gas method or other specifically approved method. This applies particularly to conductor joints in the body of windings. All such joints shall be properly controlled by an approved quality control procedure.

4.4.3.6.3 For Bolted connections , the mating faces of bolted connections shall be appropriately finished and prepared for achieving good, long lasting, electrically stable and remake able contacts. Each internal bolted electrical connection shall use two bolts with Belleville washers. Split spring lock washers are not acceptable in the assembly of internal transformer components. All nuts shall be locked by standard machined lock nuts, or by using approved locking plates.

4.4.3.6.4 Crimped connections and other methods Connections made by “compression” and “cold-welding” techniques may be used where the particular method has been approved by PGCB. All compression fittings shall be the correct size for the conductors and the correctly sized compression dies shall be used.

4.4.3.7 Winding terminations onto bushings

4.4.3.7.1 Winding termination interfaces with bushings shall be designed to allow for repeatable and safe connection under site conditions without jeopardising the in service integrity of the transformer.

4.4.3.7.2 The winding-end termination, insulation system and transport fixings shall be so designed that the integrity of the insulation system is not easily compromised during repeated work in this area.

4.4.3.7.3 Allowances shall be made for accommodating up to 100 mm tolerances on bushing axial dimensions and the fact that bushings may have to be rotated to get oil level inspection gauges to face in a direction that allow easy inspection from ground level.

4.4.3.7.4 In particular, rotation or straining of insulated connections shall be avoided during the fastening of conductor pads from the winding onto the termination surfaces of the bushing. Suitable inspection and access facilities into the tank shall be provided to minimise the possibility of creating faults during the installation of bushings.

4.4.4 Internal & External Earthing

4.4.4.1 Internal

4.4.4.1.1 All metal parts of the transformer, with the exception of the individual core laminations, core bolts and associated individual clamping plates, shall be maintained at some fixed potential.

4.4.4.2 Earthing of Core Clamping Structure

4.4.4.2.1 The top main core clamping structure shall be connected to the tank body by a copper strap. The bottom main core clamping structure shall be earthed by one or more of the following methods:

i. by connection through vertical tie rods to the top structure;
ii. by direct metal-to-metal contact with the tank base maintained by the weight of the ore and windings;
iii. by connection to the top structure on the same side of the core as the main earth connection to the tank.

4.4.4.3 Earthing of Magnetic Circuits

4.4.4.3.1 The magnetic circuit shall be earthed to the clamping structure at one point only through a removable link placed in an accessible position just beneath an inspection opening in the tank cover and which, by disconnection, will enable the insulation between the core and clamping plates, etc., to be tested at voltages up to 2 kV.

4.4.4.3.2 The link shall have no detachable components and the connection to the link shall be on the same side of the core as the main earth connection. These requirements are compulsory.

4.4.4.3.3 All insulating barriers within magnetic circuits shall be bridged by means of aluminium or tinned copper strips, so inserted as to maintain electrical continuity.

4.4.4.4 Earthing of Coil Clamping Rings

4.4.4.4.1 Where coil clamping rings are of metal at earth potential, each ring shall be connected to the adjacent core clamping structure on the same side of the Transformer as the main earth connection.

4.4.4.5 External Earthing

4.4.4.5.1 The neutral shall be solidly grounded with insulated copper or insulator supported bare copper with double connection. These connections shall not be looped.

4.4.4.5.2 The Transformer tank shall be earthed with single connection at least at two different points.

4.4.4.5.3 Radiator, cubicle etc. those may have electrical dis-continuation shall be earthed.

4.4.4.5.4 As appropriate, Manufacturer shall provide earthing or suitable terminals for the above mentioned earthing.

4.4.4.6 Size of Earthing Connections

4.4.4.6.1 Main earthing connections shall have a cross-sectional area of not less than 80 sq.mm but connections inserted between laminations may have cross-sectional areas reduced to 20 sq.mm when in close thermal contact with the core.

4.5 Tanks and Ancillary Equipment

4.5.1 Transformer Tanks

4.5.1.1 Each transformer shall be enclosed in a suitably stiffened welded steel tank such that the transformer can be lifted and transported without permanent deformation or oil leakage.

4.5.1.2 The construction shall employ weldable structural steel of an approved grade to BS 7613 and BS EN 10029. The final coat colour of transformers shall be to Munsell notation N5Y-7/1. Temporary internal shipping braces shall not be used. The exterior painting and corrosion protection shall be in accordance with the Manufacturer's standard practice and must be submitted for approval.

4.5.2 Structural Loading & Other Requirements

4.5.2.1 Equipment provided under this specification shall be analyzed and found to be functional for the physical loading conditions described below. The equipment shall be designed so that there will be neither damage nor loss of function during and after the loading conditions delineated below. In addition, equipment shall maintain correct operational state during these conditions.

4.5.2.2 The manufacturer/supplier is responsible for assuring that their analytical methodologyis consistent with industry standards and guidelines listed below and that the results are reported accurately to the Employer.

4.5.2.3 The manufacturer's analysis shall consider the higher of seismic load or wind load to act concurrently with the other applicable loading conditions as follows. Design criteria shall be clearly noted on the outline drawing.

i) **Wind Load**: The equipment shall be analyzed to the appropriate state building code for a wind load 120 mph applied to the component's entire projected are abnormal to the wind.

ii) **Seismic Load**: Seismic analysis of equipment shall be performed utilizing the Static Analysis Method as described in IEC60068-3 . A horizontal seismic coefficient of 0.2g and a vertical seismic coefficient of 0.2g shall be applied to the component's center of gravity and the resulting forces determined. Appendages such as electrical bushings, radiators, and pipes shall be designed for twice the horizontal and vertical seismic loads.

iii) **Dead Load**: Consider the weight effects of the equipment including all ancillary equipment and fluids.

iv) **Operating Load**: Equipment mechanical operating loads shall be evaluated for impact on anchorage and other support points. If operating loads are negligible, then a statement shall be clearly noted on the drawings.

v) **Terminal Connections**: Allowable loads for terminal connections shall be determined by the manufacturer for the lug design shown on their equipment drawing. Allowable loads shall be noted on the drawings.

4.5.2.4 The core clamp shall be isolated from the tank. Bolted joints are not preferred. It is preferred that the tank be fabricated in one piece for each side of the main tank. Tank corners shall be bent with seams welded inside and outside at least 6 inches/ 150mm from the corner. The top shall be welded, not bolted to the tank. The tank and cover shall be designed in such a manner as to leave no external pockets in which water can lodge, no internal pockets in which oil can remain when draining the tank or in which air can be trapped when filling the tank, and to provide easy access to all external surfaces for painting. Each tank cover shall be of adequate strength, must not distort when lifted.

4.5.2.5 A leak test of the welded joints at the factory is required before the transformer is accepted for shipment.

4.5.2.6 Both the tank and cover shall be provided with lifting lugs. Lifting lugs shall be provided, suitable for the weight of the transformer, including core and windings, fittings, and with the tank filled with oil.

4.5.2.7 Each tank shall be provided with at least four jacking lugs, and where required, with lugs suitably positioned for transport on a beam transporter. Haulage lugs should also be provided to enable a cable to be used safely for haulage in any direction.

4.5.2.8 The tank shall be provided with jacking lugs with stencilled identification. Minimum height of jacking lugs shall be 12”/300mm above base. Minimum projection of the jacking lugs shall be 10”/250mm from the tank wall.

4.5.2.9 The base of each tank shall be so designed that it is possible to move the complete transformer unit in any direction without injury when using rollers, plates, or rails. Transformers shall have wheel bases, unless otherwise specifically approved by the Engineer.

4.5.2.10 All joints, other than those that may have to be broken, shall be welded.

4.5.2.11 Where cooling tubes are used, each tube shall be of heavy gauge steel welded into the tank sides, top and bottom.

4.5.2.12 The tank and cover shall be designed in such a manner as to leave no external pockets in which water can lodge, no internal pockets in which oil can remain when draining the tank or in which air can be trapped when filling the tank, and to provide easy access to all external surfaces for painting.

4.5.2.13 Each tank cover shall be of adequate strength, must not distort when lifted and shall be provided with suitable flanges having sufficient and properly welded with Tank Body. Inspection openings shall be provided to give access to the internal connections of bushings, winding connections and earthing links. Each opening shall

be correctly located and must be of ample size for the purpose for which it is intended. All inspection covers shall be provided with lifting handles.

4.5.2.14 All manhole, bushing, and pressure relief device openings in the tank cover shall utilize raised flanges with thru-bolts or blind tapped holes. Studs welded to the tank cover will not be accepted. All bushing adapters shall be equipped with air bleeder valves when a conservator-type oil preservation system is specified. These valves shall be used to purge air from the main tank during oil filling.

4.5.3 Manholes

4.5.3.1 There shall be two or more 24-inch/600mm manholes in the top of the transformer to facilitate the removal and installation of bushings and current transformers (CTs) and to provide access to terminal boards (when used) without disturbing the leads, un-tanking the transformer, removing the cover, or removing radiators.

4.5.3.2 Manhole covers shall include lifting handles. Covers and flanges shall be sufficiently stiff to prevent gas or oil leakages after bolts are tightened. Sufficient manholes shall be provided on the tank cover of core form transformers to permit access to each side of the core and coil assembly, with at least one on each side of the core and coil.

4.5.3.3 Manhole locations shall permit the proper use of confined space retrieval equipment for personnel inside the tank.

4.5.3.4 All manhole covers, whether on top or walls, shall be on raised flanges. Covers for maintenance or field assembly access shall be secured with nuts, bolts and gaskets, with those on walls having two concentric gaskets in separate grooves. Any and all wall access provisions are subject to specific approval by the Engineer during the bid evaluation process, regardless of past history of acceptance.

4.5.3.5 Covers for wall mounted access points shall be equipped with hinges and handles regardless of weight. Covers of access points used solely for factory assembly and testing shall be sealed using at least two full passes with no oil in the tank during welding.

4.5.3.6 The tank shall be mechanically strong and designed for both full vacuum filling and 10 psi (1.7 bar relative to Vacuum) positive pressure (or 25% above maximum operating pressure, whichever is greater), with all joints and connections full seam welded externally to eliminate possible oil leaks.

4.5.3.7 At no time during normal operation of the transformer, up to and including full loading above nameplate capabilities, shall the:

a) Exterior surface of the tank, or any appurtenances, become hot enough to cause injury to personnel upon momentary contact or to cause personnel to react in an unsafe manner upon such contact.

b) Interior surface of the tank, or any interior metallic members, become hot enough to generate gas in the insulating oil.

4.5.3.8 Sufficient clearances shall be provided between the core and coil assembly and the tank wall sand cover of core form transformers to permit comfortable internal inspection of the transformer by an average sized individual.

4.5.3.9 Lifting, moving and jacking facilities shall be provided in accordance with IEC60076 and for any covers over 20 kg. Covers under 20 kgshall be equipped with handles to facilitate controlled removal. All vents on top of transformer tanks shall be sealed using pipe caps. Pipe plugs are not acceptable.

4.5.3.10 Fall protection shall include two Lifting Lug weld-on base plates. The top of the main tank shall be painted with non-slip coarse grit paint compatible with the Manufacturers normal finish. Grit paint shall be on the tank top only and not on raised flanges or covers.

4.5.3.11 All valves, pipes or other extensions shall be strong enough to support a 100kg person or shall be provided with a guard that can support a 100kg person. Guards shall not restrict maintenance or operating access to the equipment being guarded.

4.5.3.12 Bolts, nuts, screws, etc., shall meet ANSI Standard B1.1/ISO 898-2 and shall be corrosion proof. Bolt heads and nuts shall be hexagonal. All hardware exposed to the weather shall be stainless steel (nuts, bolts, hinges, etc.).

4.5.3.13 Inspection openings shall be provided to give access to the internal connections of bushings, winding connections and earthing links. Each opening shall be correctly located and must be of ample size for the purpose for which it is intended. All inspection covers shall be provided with lifting handles.

4.5.3.14 It must be possible to remove any bushing without removing the tank cover.

4.5.3.15 Pockets shall be provided for a stem type thermometer and for the bulbs of temperature indicators where specified. These pockets shall be located in the position of maximum oil temperature and it must be possible to remove any bulb without lowering the oil level in the tank. Captive screwed caps shall be provided to prevent the ingress of water to the thermometer pockets when they are not in use.

4.5.3.16 Where called for in the Schedule of Requirements, accommodation shall be provided for outdoor weather proof neutral current transformers.

4.5.3.17 A ladder shall be provided on one side of the tank as a means for inspection and access to the top of the transformer. The lower section of the ladder shall be equipped with a barrier complete with provision for locking with a padlock.

4.5.4 Conservator Tanks and Air Dryers

4.5.4.1 Each transformer shall be provided with an overhead conservator tank formed of substantial steel plates and arranged above the highest point of the oil circulating system (see also Clause 4.6. 1). Connections into the main tank shall be at the highest point to prevent the trapping of air or gas under the main tank cover.

4.5.4.2 The capacity of each conservator tank shall be adequate for the expansion and contraction of oil in the whole system under the specified operating conditions. Conservator tanks shall also be provided with a cleaning door, filling cap, drain valve with captive cap and an oil level indicator with minimum and maximum levels indicated. The normal level at an oil temperature of 25˚C shall be indicated and the minimum and maximum levels shall also be correlated with oil temperature markings. The temperature markings shall preferably be integral with the level indicating device.

4.5.4.3 The location of the conservator tank shall be so arranged that it does not obstruct the passage of high voltage conductors immediately above the transformer.

4.5.4.4 The pipework between the conservator and the transformer tank shall comply with the requirements of Clause 4.6.1 and a valve shall be provided at the conservator to cut off the oil supply to the tank.

4.5.4.5 Appropriate membrane has to be provided inside the conservator for “breathing” of the transformer.

4.5.4.6 Schedules for Outdoor Surfaces Finishes

Treatment at Factory	Treatment at Site after Completion of Erection
General	
(a) Structural and supporting steelwork, plant items above ground, tank external surfaces. All not above 95°C (or 65°C for chlorinated rubber finishes).	
Blast-clean to BS 7079 2nd quality (SA2.5) profile amplitude 40-75 microns.	Thoroughly clean to remove oil, grease and dirt. Paint coats to be touched up where necessary.

Treatment at Factory	Treatment at Site after Completion of Erection
Then apply within 4 hours one coat (13 microns) weld able holding primer for 6 months protection or (25 microns) weldable holding primer for 12 months protection. After the protection period, thoroughly clean to remove oil, grease and dirt and apply one coat (50 microns) of two pack epoxy zinc phosphate primer followed by two coats two pack epoxy micaceous iron oxide (250 microns total).	Then apply one tie coat to match finish (30 microns) and one coat alkyd gloss (25 microns)
(b) Steel floors, chequer plates, galleries, stairways, treads, kick stops	
Galvanised to BS 729	Thoroughly clean to remove oil, grease and dirt. Where galvanising is damaged, wire brush to BS 7079 3rd quality (SA2) and apply one coat zinc rich epoxy primer (50 microns). Then apply: 1st coat epoxy etch primer 2nd coat epoxy zinc chromate (30microns) 3rd coat two pack epoxy micaceous iron oxide (100 microns) On galleries and stairways top surfaces apply: 4th coat non-skid epoxy deck paint (30 microns).
(c) Galvanised iron and steel requiring paint finish	
Galvanised to BS 729	Thoroughly clean to remove oil, grease and dirt. Then apply: 1st coat etch primer 2nd coatzinc chromate primer (30microns) 3rd coat alkyd undercoat (30 microns) 4th coat alkyd gloss (25 microns).
(d) Stainless steel, aluminium alloys and non-ferrous alloys requiring paint finish	
Not applicable.	Thoroughly clean to remove oil, grease and dirt. Then apply: 1st coat alkyd undercoat (30 microns) 2nd coat alkyd gloss (25 microns).

4.5.5Breather

4.5.5.1 Each conservator shall be fitted with an air cell that shall be connected to a silica gel regenerative dehydrating breather.

4.5.5.2 The dehydrating breather of a maintenance-free and self-supervision type shall be mounted on the conservator of the transformer and the tap changers. Silica gel shall be used as a drying agent. It is automatically regenerated by the internal heater element controlled by a microprocessor control unit. The relative humidity of the air flow must be controlled by a humidity sensor. The device should have a service-friendly design: The humidity and temperature sensor, the silica gel and the PCB shall be replaceable in the field.

4.5.5.3 Alpha-control: The maintenance-free breather shall be equipped with a state-dependent control of the heating process by monitoring the humidity

4.5.5.4 Beta-control: The maintenance-free breather shall be equipped with a self-learning algorithm that enables the regeneration process only when the conservator is exhaling. This algorithm is based on humidity monitoring and the temperature-dependent determination of the most advantageous time to perform heating.

4.5.5.5 There shall be no moving parts to restrict or redirect the air flow from the desiccant chamber. The use of fans to expel condensed water out of the desiccant chamber is also not permitted. Weight cells are not accepted, as well. The flange of the breather (Conservator piping) must be with rigid metal flanges (Hose/flexible connection won't be accepted). The flanges shall be in accordance with the norm DIN 42562-3. The grade of protection of the device shall be IP66/67. The device shall be of MESSKO – MtraB or equivalent.

4.5.5.6 All breathers shall be mounted at a height of approximately 1400 mm above ground level.

4.5.6Valves

Each transformer shall be fitted with the following valves as a minimum requirement:

4.5.6.1 Main Tank

A) One 50mm bore filter valve located near to the top of the tank.

B) One 50 mm bore filter valve located near to the bottom of the tank and diagonally opposite to the filter valve required against (A). Where design permits, this valve may be combined with item (C).

C) One 50mm drain valve with such arrangements as may be necessary inside the tank to ensure that the tank can be completely drained of oil as far as practicable. This valve shall also be provided with an approved oil sampling device.

D) One valve between the main tank and gas actuated relay, complete with bypass facility to facilitate removal of relay and maintain oil flow.

4.5.6.2 Conservator

A) One valve between the conservator and gas actuated relay for the main tank and, where appropriate, for the tap change diverter switch tank complete with bypass pipework for Buchholz relay to facilitate maintenance of the relay.

B) One drain valve for oil conservator tank so arranged that the tank can be completely drained of all oil.

4.5.6.3Tap Changer

A) 50mm filter and 50mm drain valve where selector switches are contained in a separate tank.

4.5.6.4 Diverter Switch

A) One drain valve to be fitted to each tank.

4.5.6.5 Radiators and Cooler Banks

A) Valves at each point of connection to the tank

i. A valve at each point of connection to the tank.
ii. A valve at each point of connection of radiators.
iii. Loose blanking plates for blanking off the main oil connections.
iv. A 50mm filter valve at the top of each cooler bank.
v. A 50mm drain valve at the lowest point of each interconnecting oil pipe.
vi. A thermometer pocket, fitted with captive screw cap, in the inlet and in the outlet oil pipes.
vii. Air release and drain plugs on each radiator.

4.5.6.6 The two valves (D) and (E) arrangement across the gas-actuated relay are to be connected with an oil pipework bypass facility to facilitate removal of the relay, due

to failure etc., and still maintain the oil flow system between the conservator and main tank.

4.5.6.7 Blank flanges, plates or captive screw caps shall be fitted to all valves and pipe ends not normally connected in service.

4.5.6.8 The omission of any, or the provision of alternative arrangements to the above requirements, will not be accepted unless approved in writing by the Engineer before manufacture.

4.5.7 Joints and Gaskets

4.5.7.1 All joint faces shall be arranged to prevent the ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of oil or air.

4.5.7.2 Gaskets shall be of nitrile rubber. Oil resisting synthetic rubber gaskets are not permissible.

4.5.7.3 Gaskets shall be as thin as possible consistent with the provision of a good seal and full details of all gasket sealing arrangements shall be shown on the Plant drawings. Gaskets shall be of nitrile rubber.

4.5.7.4 All gaskets shall be of closed design (without open ends) and shall be of one piece only. Gaskets are not allowed to be re-used and needs to be replaced on all locations where the connection has been opened.

4.5.7.5 Metal surfaces to which gaskets are applied shall be finished smooth, seamless, and shall be designed with sufficient rigidity to assure proper compression of the gaskets.

4.5.7.6 Machine grooves shall be provided so that over-compression of the gaskets cannot occur, unless it is demonstrated to the Purchaser's satisfaction that the manufacturer is using another gasketing system of high quality and reliability.

4.5.7.7 Final drawings shall include a gasket dimension sheet which identifies quantities and dimensions of all gaskets associated with the tank pressure boundary.

4.5.7.8 One full set of gaskets shall be provided, along with drawings identifying all gasket dimensions and quantities.

4.5.8 Pressure Relief Device

4.5.8.1 An approved pressure relief device of sufficient size for the rapid release of over pressure that may be generated in the tank, and designed to operate at a static pressure lower than the hydraulic test pressure called for in Section 15, shall be provided. It shall be of the spring operated valve type (Qualitrol/ Messko or equivalent) and shall be provided with one set of normally open signalling contacts that will be used for trip alarm purposes.

4.5.8.2 The relief device is to be mounted on the tank cover and is to be provided with a skirt to project at least 25mm into the tank to prevent gas accumulation. Discharge of oil shall be directed away from the transformer top cover and clear of any operating position. Means shall be provided to direct the oil discharge to the oil collecting pit.

4.5.8.3 The Pressure Relief Device (PRD) for main tank shall consist of double synthetic coated and cathode corrosion protected springs made of spring steel acc. to Class 1 European Standard EN10270-1-SH to make sure that the springs transmit the pressure equally to the entire opening plate and neither lose their tension nor corrode.

4.5.8.4 The contacts shall have the protection class IP65 according to IEC 60529 and must be directly activated by a self-locking pin.

4.5.8.5 The release time of the device shall not be more than 2 ms. A semaphore for clear indication of a signalling event shall be provided. A routine leak test with Helium Gas shall be performed, the device shall pass a leakage test at 1.50E-05 mbar I/sec or below and test report of each device shall be submitted.

4.5.8.6 To protect the device against environmental influences such as water and UV exposure, all important parts such as springs, valve disc, switching contacts and gaskets shall be mounted under the aluminum cover.

4.5.9 Earthing Terminals

Two substantial steel flag type terminals each having two 14mm diameter holes on 55mm centres shall be located one on either side and near to the bottom of the transformer to facilitate connection to the local earthing system.

4.5.10 Rating, Diagram and Valve Plates

4.5.10.1 The following plates, or an approved combined plate, shall be fixed to each transformer tank at an average height of 1500mm above the ground level:-

A) A rating plate bearing the data specified in IEC 60076 Part 1. This plate shall also include the short-circuit current rating and time-factor for each winding & the data mentioned in clause no.1.3.7.11

B) A diagram plate showing in an approved manner the internal connections and the voltage vector relationship of the several windings, in accordance with IEC 60076 Part I with the transformer voltage ratio for each tap and, in addition, a plan view of the transformer giving the correct physical relationship of the terminals.

C) A plate showing the location and function of all valves and air release cocks or plugs. This plate shall also if necessary warn operators to refer to the Maintenance Instructions before applying vacuum.

4.5.10.2 Plates are to be of stainless steel or other approved material capable of withstanding the rigours; of continuous outdoor service at site.

4.6 Cooling Plant

4.6.1 Cooling Plant General

4.6.1.1 Radiators and coolers shall be hot-dip galvanised, designed so that all painted surfaces can be thoroughly cleaned and easily painted in situ with brush or spray gun. The design shall also avoid pockets in which water can collect and shall be capable of withstanding the pressure tests specified in Section 15 for the transformer main tank.

4.6.1.2 The transformer cooling equipment shall be arranged to provide a uniform distribution of cooling within the transformer with either or both stages in operation. The clearance between any oil or other pipework and live parts shall be not less than the minimum clearances stated in the Schedule of Requirements.

4.6.2 Radiators

4.6.2.1 The design and construction of the radiators shall be such as to eliminate pockets where moisture can accumulate or which can prevent application of a continuous film of paint. Radiators shall have the necessary piping, fittings, valves, drains, and bleeder connections so that individual radiators may be removed and replaced with the transformer in service.

4.6.2.2 Where built-on radiators are used, each radiator shall be connected to the main tank through flanged valves. Plugs shall be fitted at the top of each radiator for air release and at the bottom for draining.

4.6.2.3 A valve shall be provided on the tank at each point of connection to the tank.

4.6.2.4 Radiators shall be connected to the main tank through flange mountings with shut off valves at the top and bottom to permit shut-off of oil from the main tank for removal or installation of the coolers. Valves shall be designed to withstand maximum differential forces that can be applied during normal vacuum type oil filling operations.

4.6.2.5 The radiators shall have solid steel plugs provided at the top and ball type drain valves at the bottom shipped with solid steel plugs. All radiators shall be galvanized and shall use plate type radiators. All radiators shall be flushed out prior to shipment. Pipe caps shall be provided at the top and pipe plugs at the bottom of each cooler to permit field flushing when desired.

4.6.2.6 The oil flow pattern to and from the coolers and through the transformer coils shall be designed to be free of turbulence and shall not cause impinging of oil on any part of the solid insulation system.

4.6.2.7 Radiators shall be designed to permit removal and installation without additional special bracing.

4.6.2.8 Refer to the Data Sheets for unusual service conditions that can affect radiator efficiency during the life of the transformer.

4.6.3 Cooler Banks

4.6.3.1 Each cooler bank shall be provided with:

4.6.3.2 The omission of any, or the provision of alternative, arrangements to the above requirements will not be accepted unless approved in writing by the Engineer before manufacture.

4.6.4 Oil Pipes and Flanges

4.6.4.1 All oil piping necessary for the connecting of each transformer to its conservator, cooler banks etc. shall be supplied and erected under this contract.

4.6.4.2 The oil piping shall be of approved material with machined flanged joints. Copper pipework is to comply with BS 61.

4.6.4.3 Dimensions of steel pipes shall be in accordance with BS 3600 and the drilling of all pipe flanges shall comply with BS EN 1092.

4.6.4.4 An approved expansion piece shall be provided in each oil pipe connection between the transformer and each oil cooler bank.

4.6.4.5 All necessary pipe supports, foundation bolts and other attachments are to be provided.

4.6.4.6 It shall be possible to drain any section of pipework independently of the rest and drain valves or plugs shall be provided as necessary to meet this requirement.

4.6.5Forced Cooling

4.6.5.1 The type of forced cooling shall be as stated in the Schedule of Requirements.

4.6.5.2 Forced cooling equipment for transformers of similar rating and design shall be completely interchangeable, one with the other, without modification on site.

4.6.6Air Blowers

4.6.6.1 Air blowers for forced air cooling shall be of approved make and design and be suitable for continuous operation out-of-doors. They shall also be capable of withstanding the stresses imposed when brought up to speed by the direct application of full line voltage to the motor.

4.6.6.2 It shall be possible to remove the blower, complete with motor, without disturbing or dismantling the cooler structure framework.

4.6.6.3 Blades shall be of material subject to approval. Fan blades and fan ducting shall be of aluminium alloy, stainless steel, galvanized steel or other corrosion- resistant material and shall be designed to keep noise and vibration to a minimum. All fans shall be provided with galvanized wire-mesh guards.

4.6.6.4 Blower casings shall be made of galvanised steel of thickness not less than 2.6mm (14 S.W.G.) and shall be suitably stiffened by angles or tees.

4.6.6.5 Galvanised wire guards with mesh not exceeding 12.5mm shall be provided to prevent accidental contact with the blades. Mesh guards shall be provided on all fans to

prevent accidental contact with moving parts. Guards shall be designed such that blades and other moving parts cannot be touched by test fingers to IEC 60529.

4.6.6.6 The rotation and air flow directions shall be clearly and indelibly indicated by appropriate
arrows.

4.6.6.7 To reduce noise to the practical minimum, motors shall be mounted independently from the coolers or, alternatively, an approved form of anti-vibration dampers shall be provided.

4.6.6.8 Fan motors shall comply with IEC 60034 and shall be 3 phase induction motors suitable for D.O.L. starting and continuously rated at 415 volts ± 10% 3 phase, 50 Hertz at an ambient temperature of 45°C. The motor rating and frame size shall be selected from IEC 60034.

4.6.7 Motors

4.6.7.1 All motors shall be suitable for direct starting and continuous running from the415 V supply voltage. Three-phase motors are preferred but single-phase motors of 0.5 kW and less will be acceptable.

4.6.7.2 All motors shall comply at least with IEC 60034 and shall be of the totally enclosed weather-proof type.

4.6.7.3 Three-phase motors shall be of the single-cage squirrel cage type. Bearings of allmotors shall be of the ball or roller bearing type. With the exception of oil-pumpmotors, the bearings shall be grease lubricated.

4.6.7.4 Each motor shall be equipped with a terminal box arranged to accommodate theincoming cable provided by the manufacturer (see clause 4.7). If necessary, asuitable cable box shall be provided to terminate the cable.Motors shall be provided with starters, overload protection (three-phase whereapplicable) and, in the case of three-phase motors, single-phasing protection.All motors shall be labelled indicating kW and A ratings.

4.6.8 Cooler Control-Settings

4.6.8.1 Forced cooling equipment for system transformers shall be designed forautomatic operation by a winding temperature thermometer or current levelcontacts set at predetermined temperatures/currents.

4.6.8.2 Generally the manufacturer's standard settings for the starting of fans and pumps shall be used, otherwise a setting of 65 °C or 0.6 pu current shall apply. The cooler switches shall be suitably labelled.

4.6.9 Cooler Control-Equipment & Principle

4.6.9.1 All the necessary automatic control, motor contactors, protective devices, and switches for the forced cooling equipment shall be housed in an IP55W rated cabinet. This cabinet shall be mounted separately from Transformer tank or on the transformer tank using approved anti-vibration mountings. Hinged door(s), handle(s), locking facilities, a separately fused 230 V single-phase heater and switch, and a separately fused lamp with door switch shall be provided.

4.6.9.2 The heater shall be rated and located so that none of the apparatus in the cabinet will suffer damage due to prolonged operation of the heater at high ambient temperatures.

4.6.9.3 Tap-changer control equipment may also be housed in this cooling cabinet.

4.6.9.4 The cooler control equipment shall include following accessories as a minimum

i. an isolating switch rated to carry and break full-load current for each group of fan and pump motors;

ii. a "manual"/"auto" change-over switch;

iii. a magnetic contactor for each group of fan and pump motors. Contactor coil leads shall be wired to the terminal board. A set of normally open contacts shall be provided to initiate an alarm circuit if the contactor is tripped by its overload element. All such contacts of the various groups shall be paralleled and wired to a pair of terminals in the control cabinet.
Magnetic contactors shall maintain supply to motors at supply voltage down to 0.85 pu of the rated supply voltage at their terminals. Tripping shall only occur on a controlled basis and there shall be automatic restarting in the staggered mode if the voltage recovers while the transformer is in service; and

iv. provision for disconnection of all cooling pumps and fans on the closure of a pair of contacts provided by the contractor on the master tripping relay controlling the isolation of the transformer on the occurrence of a fault.

4.6.9.5 The ratings of these contacts will be:

i. Make and carry continuously: 1250 W at maxima of 5 A and 660 V.

ii. Make and carry for 0.5 s: 7500 W at maxima of 30 A and 660 V.

iii. Break: 100 W resistive

iv. 50 W inductive as defined in BS EN 60255-22-4: i.e. L/R = 40 ms.

4.6.9.6 The arrangement for disconnection of the oil pumps and fans shall not be self-resetting.

4.6.9.7 The cooler failure relay is to monitor all three phases and the cooler supply failure alarm to have a 4 s to 10 s timer fitted to prevent unnecessary signalling.

4.6.9.8 A change-over relay shall be provided in the control scheme. A contact of the trip relay, on the user's protection panels will energise the operating coil of this change-over relay which in turn shall isolate the contactor control circuits.

4.6.9.9 A reset push button shall be provided in the marshalling kiosk for resetting the changeover relay. The operating coil of the relay shall be continuously rated, or a make contact of it shall be wired in series with the operating coil and a break contact in series with the reset coil (see Figure 02 – Preferred cooler stop circuit Figure 02).

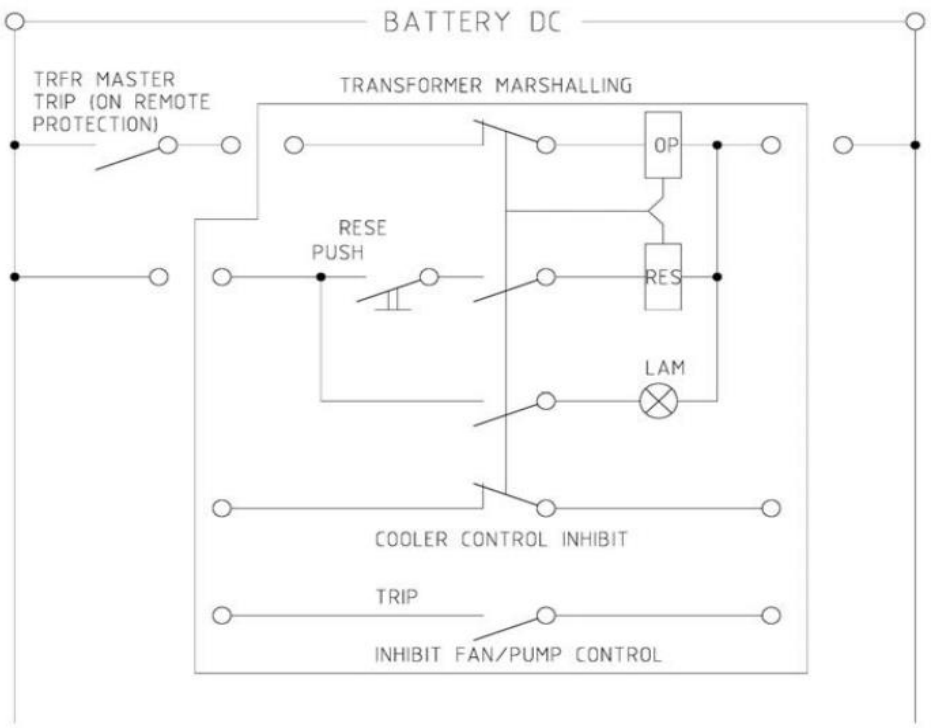


Figure 02 – Preferred cooler stop circuit

4.6.9.10 Where a contactor is supplied for this purpose, the operating coil shall be suitable for operation by way of the above-mentioned contacts and shall operate and reset correctly between 80 % and 120 % of the DC auxiliary supply voltage specified in Schedule A of an enquiry document. The contactor shall have one set of normally closed contacts, which shall isolate the fan and/or oil pump motor control circuit(s). A N/O contact is to be provided for alarming purposes.

4.6.9.11 Contactors shall comply with the provisions of IEC 60947:

i. for staggering the starting times of oil pumps and fans or of individual groups of fans as required;

ii. or overload and single-phasing relays;

iii. for winding temperature and oil-temperature indicators, that shall be visible through a window in the door of the cabinet if installed in the same cabinet;

iv. for links for testing winding temperature relay, and interposing currenttransformer;

v. for fuses, links and terminal boards (see clause 4.7) to make a completeassembly; and

vi. for labelling of all apparatus, that shall be inscribed indelibly in blacklettering on a white background and that will not discolour in long termservice.

4.6.9.12 Where forced cooling using multiple small single-phase motors is employed, the motors in each cooling bank shall be grouped so as to form a balanced three-phase load.

4.6.9.13 Each motor or group of motors shall be provided with a three-pole electrically operated contactor and with control gear of approved design for starting and stopping manually.

4.6.9.14 Where forced cooling is used on transformers, provision shall be included under this contract for automatic starting and stopping from contacts on the winding temperature indicating devices as specified. The control equipment shall be provided with a short time delay device to prevent the starting of more than one motor, or group of motors in the case of multiple cooling, at a time.

4.6.9.15 Where motors are operated in groups, the group protection shall be arranged so that it will operate satisfactorily in the event of a fault occurring in a single motor.

4.6.9.16 The control arrangements are to be designed to prevent the starting of motors totalling more than 15kW simultaneously, either manually or automatically. Phase failure relays are to be provided in the main cooler supply circuit.

4.6.9.17 All contacts and other parts that may require periodic renewal, adjustment or inspection shall be readily accessible.

4.6.9.18 All wiring for the control gear accommodated in the marshalling kiosk, together with all necessary cable boxes and terminations and all wiring between the marshalling kiosk and the motors, shall be included in the contract.

4.6.9.19 PLC type cooler control design which are prone to frequent fault, shall not be acceptable, unless agreed in writing.

4.6.9.20 Provision shall be provided for all signalling to Remote panels in the Panel rooms as well as to station automation.

4.6.9.21 An alarm of indicating "Transformer Cooling Fault" is to be provided and initiated in the event of any ventilation/cooling motor trip, or failure of either main or control supplies.

4.6.9.22 Fans/pumps/motors shall be installed to facilitate their easy removal in the eventof failure. Although very low maintenance is desired, lubrication and servicinginstructions, if required, shall be clearly stated in the transformer manual. Ifdeemed necessary by the purchaser, labelling shall be provided at each pump orfan.

4.7Voltage Control

4.7.1General

4.7.1.1 Transformers shall be provided with tap changers for varying the effective transformation ratio. Control schemes shall utilise voltage derived from the 400V, 3 phase, 4 wire system. Phase failure relays shall be provided to ensure a secure supply.

4.7.1.2 Winding taps as called for in the Schedule A of Requirements shall be provided on the high voltage winding.

4.7.1.3 All terminals shall be clearly and permanently marked with numbers corresponding to the cables connected thereto.

4.7.1.4 Tap positions shall be numbered consecutively, ranging from one upwards. The tap positions shall be numbered so that by raising the tap position the LV voltage is increased.

4.7.2 On-Load Tap Changers

4.7.2.1 General

4.7.2.1.1 For quality, reliability and maintenance requiements the On-load tap changers shall be suppliedfrom MR Germany or ABB Sweden make or equivalent, and comply with IEC 60214-1 and shall be suitable for power flow in both directions. OLTC shall be of sufficient capacity to satisfy the requirements in this specification. The OLTC shall be of Vacuum type.

4.7.2.1.2 Only designs that have been type-tested in accordance with the relevant IEC standards will be accepted. Tap changers in auto-transformers shall be located at auto point between the HV and LV windings. Then tap changer shall be placed in primary winding side of the Power transformer in order to regulate the secondary winding side operating voltage. It shall operate in Constant Flux & Variable Voltage (C.F.V.V.) mode. The Variable Flux & Variable Voltage (V.F.V.V.) design for OLTC is generally not acceptable.

4.7.2.1.3 The OLTC shall be installed inside the main tank.

4.7.2.1.4 Current making and breaking switches [i.e., diverter switches] associated with the tap selectors or otherwise where combined with tap selectors shall be contained in a tank in which the head of oil is maintained by means of completely independent of that on the transformer itself for Oil type OLTC and the same [i.e., diverter switches] shall be in vacuum for Vacuum type OLTC. Details of maintaining oil separation, oil levels, detection of oil surges and provision of alarm or trip contacts will be dependent on the design of tap-changer and be to the approval of the Engineer.

4.7.2.1.5 Some of the above mentioned make, viz., MR Germany and ABB Sweden make OLTCs are already existed in PGCB's System and their performance is proven. Hence, if the bidder choose to propose OLTCs from other manufacturers, the proposed manufacturer shall have at least thirty (30) years of manufacturing experience of OLTC prior to the date of bid submission with minimum delivery of at least one hundred (100) nos. of similar or higher rating Vacuum type OLTCs over the last ten years outside the manufacturer's own country and the OLTCs similar to or higher rating of the proposed type shall have complete type test report

as per relevant IEC standard (IEC 60214-1) from any independent/STL testing laboratory. The bidders shall have to submit relevant documents with their bids.

4.7.2.2Capabilities and Ratings

4.7.2.2.1 Load-tap changing equipment shall provide plus and minus 10% in-phase regulation of the high voltage winding in 17 steps of approximately 5/8% each. For other design, refer to datasheet. All voltages listed on the nameplate shall reflect the actual design voltages, rounded to the nearest 10 volts.

4.7.2.2.2 All taps shall be full capacity taps.

4.7.2.2.3 The tap changer is required to regulate the secondary voltage for a varying primary voltage on the transformer as well as for the increased voltage drop due to increased load on the transformer.

4.7.2.2.4 The transformer shall be capable of full MVA output should the LTC stall in any off-tap position. The tap changer shall be capable of completing a tap change if a thru-fault occurs after a tap change has begun.

4.7.2.2.5 LTC's shall be capable of parallel operation with circulating currents not to exceed 20% of rated current.

4.7.2.2.6 All components of the transformer shall be capable of carrying maximum rated current at all tap positions.

4.7.2.2.7 Series load tap changer windings, if any, shall be so sized and arranged that they, or any of their associated leads, do not become the transformer hot spot or generate gasses if the transformer is operating at full buck at maximum current above nameplate capacity.

4.7.2.3Tap changer operation mechanism

4.7.2.3.1 A mechanism for hand operation shall be provided. A permanently legible lubrication chart shall be provided and fitted inside the tap change mechanism chamber.

4.7.2.3.2 The tap change mechanism shall be designed such that when a tap change has been initiated, it will be completed independently of the operation of the control relays and switches. If a failure of the auxiliary supply during tap change or any other contingency would result in that movement not being completed, an approved means shall be provided to safeguard the transformer and its auxiliary equipment.

4.7.2.3.3 LTC drive motor shall include the following:

i) A driving motor suitable for operation from the station service source described in the Appendix. 230 VAC motor is preferred. Motors rated 240 VAC or 415 VAC shall be capable of operating at either voltage. Proper working of the drive motor shall be ensured up to 25% below the rated voltage.

ii) Suitable thermal & overload protection and motor starting contactors for the driving motor control.

iii) An ammeter to monitor the drive motor.

iv) Under-voltage relays sensing loss of power to the LTC motor and controls.

4.7.2.3.4 Thermal devices or other approved means shall be provided to protect the motor and control circuit. Mechanical position indicator with provisions to show maximum raise and lower positions of the mechanism by means of manual reset indicators. The drag-hand reset device shall be located less than five feet above the base of the transformer. The dial-type indicator shall be configured so that the dial moves in the clockwise direction for tap changes in the raise direction (increasing LV voltage).

4.7.2.3.5 Two operation counters; one will display total operations and the other will be resettable and will have an alarm contact for excessive operations. The number of operations for which the alarm contact closes shall be user-adjustable.

4.7.2.4 Tap changer controls

4.7.2.4.1 LTC controls equipment shall be provided as follows:

- Tap Changer Control with Vacuum Fluorescent Display
- Adapter Panel
- Parallel Balancing Module
- Over current Relay (circulating current), with auxiliary contacts for alarm indication.
- (5/8.66 – 0.2 Amp) Auxiliary CT

4.7.2.4.2 Mode Selector Switch to select sequential or non-sequential mode of operation (Operable from ground with doors open):

- Sequential -Tap changer will continue changing taps as long as Raise-off-Lower switch is held in either position.

- Non-Sequential -Tap changer will move only one step regardless how long Raise off-Lower switch is held in position. Control Switch must be returned to OFF position before OLTC will move to another tap.

4.7.2.4.3 Manual, Automatic and provisions for Remote control shall be provided as follows:

- "Raise-Lower" manual control switch shall be provided in the control cabinet for local control.
- "Remote-Automatic-Manual" switch shall have to be provided.
- There shall be provisions made for future remote control of load tap changing equipment.

4.7.2.4.4 Voltage Reduction Provisions All transformers shall include provisions for two steps of voltage reduction (2-1/2% and 5%).

- 230 VAC power supply provision for the Customer's radio receiver which will contain contacts for 2-1/2% and 5% voltage reduction.
- A three-position 43VR switch shall be provided for local initiation of voltage reduction. (The switch shall be labeled "2-1/2% -Normal -5 %.")

- VR2.5 and VR5.0 Auxiliary Relays which will be picked up by appropriate contacts in either the radio receiver or the 43VR switch. The VR2.5 and VR5.0 Auxiliary Relays will have contacts connected to appropriate terminals of the "90" relay.

4.7.2.4.5 The LTC control shall include Line Drop Compensation. LTC current circuit grounds are to be grounded directly at the short-circuiting block of the current transformer only.

4.7.2.4.6 Suitable test terminals for measuring regulated voltage shall be provided.

4.7.2.4.7 Test switches shall be provided for isolating voltage and current to the LTC controls. Current test switches shall be shorting type with test jack. Voltage test switches shall include test jacks.

4.7.2.4.8 Three limit switches, SPDT suitable for 0.5A at 110VDC as follows:

- One switch with the normally open (N.O.) contact closed only when OLTC is in ON TAP in the full raise position and the normally closed (N.C.) contact closed in all other positions.
- One switch with the normally open (N.O.) contact closed only when OLTC is ON TAP in the full lower position and the normally closed (N.C.) contact closed in all other positions.

- One switch with the normally open (N.O.) contact only closed when OLTC is ON TAP in the neutral position and the normally closed (N.C.) contact closed in all other positions. The NO contact shall be wired to the LTC control relay for use with the neutral position detection feature.

- All contacts shall be wired out to terminal block in the control cabinet.

4.7.2.4.9 The following operating conditions are to apply to the on-load tap changer controls:

A) It must not be possible to operate the electric drive when the manual operating gear is in use.

B) It must not be possible for two electric control points to be in operation at the same time.

C) Operation from the local or remote control switch shall cause one tap movement only, unless the Control switch is returned to the off position between successive operations.

D) It must not be possible for any transformer operating in parallel with one or more transformers in a group to be out of step with the other transformers in the group. Any deviation in the position of tap changers has to stop further function of the AVR. (Out of step protection)

E) All electrical control switches and local manual operating gear shall be clearly labelled in an approved manner to indicate the direction of tap changing, i.e. raise and lower tap number.

F) Emergency stop push-button at local and remote control positions.

4.7.2.5 Indications

4.7.2.5.1 Apparatus of an approved type shall be provided on each transformer:

A) To give indication mechanically at the transformer and electrically at the remote control point of the number of the tapping in use.

B) To give electrical indication, separate from that specified above, of tap position at the remote supervisory point.

C) To give indication at the remote control point and at the supervisory control point that a tap change is in progress; this indication to continue until the tap change is completed.

D) To give indication at the remote control point and at the supervisory control point when the transformers operating in parallel are operating out of step.

E) To indicate at the tap change mechanism the number of operations completed by the equipment.

4.7.2.5.2 Tap position indicator providing exact position, complete with an electrically operated synchro transmitter for remote exact position indication. Indicator shall not be mounted on cabinet cover but shall be visible through a weatherproof view port by a person of average height standing erect. The vendor shall also supply a tap position receiver with the appropriate programming and scaling to function properly with the supplied tap position transmitter. The receiver shall be suitable for panel mounting and contain an integral transducer providing 0-1mA or 4-20 mA analog output and RS232 serial output for remote tap position indication to SCADA center. The vendor shall supply documentation showing the value of the analog output signal of the transducer and the corresponding tap position of the transformer.

4.7.2.6OLTC alarms

4.7.2.6.1 One common annunciator point on the transformer annunciator shall be provided to indicate any of the following:

A) OLTC "OFF-TAP".

B) Vacuum problem, if applicable

C) Excessive operations

D) LTC fault pressure relay alarm

E) LTC control relay “Self-Test” alarm

F) LTC control relay actuation of Block Raise/Lower (user programmable alarm)

4.7.2.6.2 Provisions shall be made to block OLTC operation by a normally closed contact of the Employer's transformer lockout relay.

4.7.2.7Paralleling facilities

4.7.2.7.1 Transformers supplied against each item shall be designed to operate satisfactorily, one with the other, when operating on the same tap position.

4.7.2.7.2 A circulating current paralleling scheme shall be used for parallel operation of the transformer's regulating equipment with a similar unit as described in the Specific Transformer Data Sheets. This scheme shall insure that the transformers are within two steps of each other while they are operating in parallel.

4.7.2.7.3 Equipment shall be installed to block operation of the load tap changing equipment in a direction which would increase circulating current for an abnormal condition.

4.7.2.7.4 Suitable current transformers shall be provided for line drop compensator operation and/or for input to a circulating current paralleling scheme. Phase(s) to be used for LDC CT's are identified on the Specific Transformer Data Sheet. Secondary leads shall be connected to terminal blocks in the CT cabinet. Auxiliary CT's (1:0.2 amp) shall be provided as necessary.

4.7.2.7.5 A 52Y (Interposing relay) with (2 NO and 2NC) contacts shall be provided for use by the Customer in the paralleling scheme.

4.7.2.7.6 Provisions shall be made to permit either phase-to-neutral or phase-to-phase voltage input along with corresponding CT connections.

4.7.2.7.7 A 17 step resistor (25 ohm, 3 watt resistor per step, 800 ohms total) shall be provided for use by the Employer to indicate tap position as per standard practice.

4.7.2.8OLTC Accessories:

4.7.2.8.1 Local ControlSwitch with pistol grip handle, spring return to OFF, for LTC controls. Switch shall be labeled Lower-OFF-Raise (Operable from ground with doors open).

4.7.2.8.2 Necessary equipment to permit parallel operation with the transformers specified. This equipment shall include:

A) An adjustable time delay relay, to start timing on operation of the circulating current relay.

B) Current test facilities, testing LDC current transformer and circulating current relay.

C) An auxiliary relay used in conjunction with the LTC control relay, to block tap changer operation and transmit remote alarm on time out of the time delay relay. Alarm contact(s) shall be connected as required to the HIGH CIRCULATING CURRENT ALARM point on the local annunciator. Auxiliary relay shall have contacts rated for 125VDC.

4.7.2.8.3 Pressure relief device, temperature indication equipment, and fault pressure relay (i. e.,oil Surge relay) as per relevant Section below:

A) Pressure relief device shall be screened to prevent entrance of foreign objects and moisture into the compartment. Setting of the relief devices shall be as determined by the load tap changer manufacturer.

B) The LTC pressure relief alarm will be connected to an LTC PRESSURE RELIEF alarm point on the local annunciator.

C) Semaphore for LTC compartment shall be visible from the ground.

D) Discharge of pressure relief device(s) shall be baffled to control direction and extent of spray and to facilitate clean-up.

4.7.2.8.4 Limit switches shall be provided to prevent over-running of the tap changing mechanism. These shall be directly connected in the operating motor circuit. In addition, mechanical stops shall be fitted to prevent over-running of the mechanism under any conditions. For on-load tap change equipment these stops shall withstand the full torque of the driving mechanism without damage to the tap change equipment.

4.7.2.8.5 Lamp receptacle controlled by a door switch and located remote from control wires. Receptacle shall be for IEC standard medium base lamps. IEC grounded convenience receptacle with GFI protection in the control cabinet.

4.7.2.8.6 Parts or components of the tap changer that will require periodic adjustment or replacement shall be built to IEC Standards permitting the use of standard tools.

4.7.2.8.7 Space heater(s) with protective guard(s), located to prevent overheating wiring or equipment or accidental contact by personnel checking wiring.

4.7.2.8.8 Space heaters shall be uncontrolled and sized to maintain internal cabinet temperature at least 5°C above external ambient, with external ambient temperature as per Section 4.4, Service Conditions.

4.7.2.8.9 Multiple heaters safely distributed over bottom of control cabinet shall be provided if more than 350 watts (net) is required. To be controlled by 20A circuit breaker.

4.7.2.8.10 Rated voltage of space heaters shall be at least 67% higher than the applied voltage.

4.7.2.8.11 All LTC control wiring shall be stranded copper, with thermosetting 600V insulation, 90oC or higher, electrically, thermally and mechanically suitable for its environment and application. Flame, oil and heat resistant wiring with higher voltage thermosetting insulation or higher operating temperatures are acceptable without prior approval.

4.7.2.8.12 A Non-GGCI outlet (refer to section below for rating) to be provided.

4.7.2.8.13 LTC compartments shall meet the following requirements:

A) The oil system for OLTC shall be independent of and isolated from the main tank oil system. All barriers between OLTC compartment and main tank shall permit full vacuum filling of the main tank regardless of the status of the tap changer compartment.

B) Tap changer shall be free-breathing with a suitable desiccant breather located approximately 5 feet from the transformer base for ease of replacement.

4.7.2.8.14 Each separate LTC oil-filled compartment shall have the following minimum accessories:

A) One -Upper vent connection with pipe cap.

B) One -Lower fill and drain valve with pipe plug.

C) Valve to have sampling valve located outside the disk of the main valve.

D) The valve shall be on the bottom of the compartment.

E) One -Oil level indicator with high and low level alarm contacts.

F) All LTC level alarms will be connected to a single LTC OIL LEVEL alarm point on the local annunciator.

G) Indicators for all compartments shall be readily visible from a single location.

H) Each compartment of the tap changer shall have an RTD temperature sensing device mounted in a well. Extension leads shall be run in a weatherproof raceway system to the electronic temperature monitoring device in the cooling control cabinet.

I) One -Pressure relief device shall be provided for the common LTC compartment, with alarm contacts and readily visible semaphore. And baffle and discharge pipe.

4.7.2.8.15 The power supply for the LTC motor shall be as specified in the Data Sheets in the Appendix. AC and DC auxiliary power for LTC motor and controls shall be routed from the cooling equipment control cabinet as separate branches.

4.7.2.8.16 A hand crank shall be provided for operating the LTC for maintenance or due to a defective motor. It shall not be necessary to take the transformer out of service to manually operate the LTC. Interlocks shall be provided to de-energize motor while hand crank is in place for manual operation. Heavy duty limit switches shall be provided to cut off the LTC motor circuit and control circuit at the end of the desired travel. Separate contacts shall be provided for the motor circuit and the control circuit. Limit switches shall not be located in any oil filled compartments.

4.7.2.8.17 Torque switches for motor and/or control circuit shutoff are not acceptable. LTC drive motor and controls may be in a common control cabinet. The control cabinet for OLTC drive motor and controls shall be separate from the control cabinet for transformer cooling controls, miscellaneous controls, alarms and CT lead terminations unless otherwise specified.

4.7.2.8.18 Each LTC control cabinet shall be weather proof, with hinged access doors as follows:

A) Locking facilities, suitable for padlocks with shanks

B) Doors shall have suitable gaskets completely around each opening and a weather shield on the top horizontal surface.

C) Each door shall be equipped with a holding bar or other mechanism to securely hold the door open at least 110o from the cabinet against winds gusting to 40 kph.

4.7.2.8.19 The top of the LTC control cabinet shall not be more than six feet above the base of the transformer. Exposed operating shafts between the LTC and the control cabinet shall be equipped with removable shrouds for personnel safety.

4.7.2.8.20 The following equipment shall be housed in all LTC control cabinets. No control or indicating devices shall be mounted on the outer cabinet doors.

4.7.2.8.21 Voltage test terminals to permit monitoring voltage regulating relay input voltage and to permit impressing external voltages for calibration and setting of voltage regulating relay. (Accessible from ground with doors open)

4.7.2.8.22 All control wiring shall terminate with insulated full ring lugs on one side of 600V, 25A (or higher), double row barrier type terminal blocks with screw terminals and captive links. Barrier spacing shall be sufficient to permit termination of wiring using Insulated Full Ring Terminal with Seamless Barrel or Braised Barre

4.7.2.8.23 No more than two wires shall be terminated under any given screw terminal. Manufacturer's wiring to terminal blocks intended for extension by Employer shall terminate on one row, with the other row kept clear of Manufacturer's wiring. The row used for Manufacturer's wiring and Customer's wiring shall be consistent on all terminal blocks in a vertical column, with rows arranged so Customer's cables may rise between two adjacent rows and fan out in each direction. There shall be a wiring extension to a connection box where plug/ receptacle type connectors shall be used for quick connection of wiring into modular substation.

4.7.2.8.24 All wiring associated with tripping, including lockout relays and initiating devices, shall be unfused.

4.7.2.8.25 All Manufacturer's LTC control wires shall be provided with indelible marker sleeves at each termination designating the location of the opposite end termination.

4.7.2.8.26 All wiring inside the LTC control cabinet shall be run in wire duct with snap on covers to permit easy tracing of circuits. Open wiring bundles with wraps are not acceptable.

4.7.2.8.27 All components in the LTC control cabinet shall be capable of continuous operation with an air temperature inside the cabinet that is 10°C above the outdoor ambient temperature as specified in Section 4, Service Conditions. Any load tap changer shall be capable of successfully completing a tap changing operation without damage if an external short circuit occurs while the load tap changer is changing taps.

4.7.2.8.28 Line drop compensator, control relays, time delay relays and facilities for readily reversing polarity of reactance compensation. See Data Sheets for specific transformer.

4.7.2.9 Local and Remote Control

Equipment for local manual and electrical operation shall be provided in an outdoor cubicle complying with Section 2. A thermostat controlled anti-condensation heater is to be provided in the cubicle. Electrical remote control equipment shall also be supplied as specified in the Schedule A - Schedule of Requirements.

The following operating conditions are to apply to the on-load tap changer controls:

(A) It must not be possible to operate the electric drive when the manual operating gear is in use.

(B) It must not be possible for two electric control points to be in operation at the same time.

(C) Operation from the local or remote control switch shall cause one tap movement only, unless the control switch is returned to the off position between successive operations.

(D) It must not be possible for any transformer operating in parallel with one or more transformers in a group to be out of step with the other transformers in the group. Any deviation in the position of tap changers has to stop further function of the AVR. (Out of step protection)

(E) All electrical control switches and local manual operating gear shall be clearly labelled in an approved manner to indicate the direction of tap changing, i.e. raise and lower tap number.

(F) Emergency stop push-button at local and remote control positions.

4.7.2.10 Oil Filter

4.7.2.10.1 Each oil type tap changer is to be equipped with a stationary on-line oil filter facility, complete with time switch control.

4.7.3 Automatic Voltage Control

4.7.3.1 Automatic control shall be suitable for control of transformers in parallel. In addition to the methods of control covered by Clause 4.7.2, the following methods shall also be provided.

A) Automatic Independent - It shall be possible to select automatic independent control for each transformer irrespective of the method of control selected for any other of the associated transformers.

B) Automatic parallel - It shall be possible to select any transformer for master or follower control.

4.7.3.2 It must not be possible to operate any tap changer by supervisory, remote or local electrical hand control while the equipment is switched for automatic operation.

4.7.4 Voltage Regulating Relays

4.7.4.1 Automatic voltage control shall be initiated by a voltage regulating relay of an approved type and suitable for flush mounting. The Relay shall be from the offered OLTC Vendor[i.e., from MR, Germany or ABB, Sweden or equivalent]being the latest Model &version available for specific application of this project. The relay shall operate from the nominal reference voltage stated in the Schedule of Requirements derived from a circuit mounted LV voltage transformer having Class 1.0 or 0.5 accuracy to IEC 60044-5 (for capacitive) IEC 60044-2 (for inductive) and the relay voltage reference balance point shall be adjustable.

4.7.4.2 The relay bandwidth shall preferably be adjustable to any value between 1.5 times and 2.5 times the transformer tap step percentage, the nominal setting being twice the transformer tap step percentage.

4.7.4.3 The relay shall be insensitive to frequency variation between the limits of 47Hz and 51Hz. The relay shall be complete with a time delay element adjustable between 10 and 120 seconds. The relay shall also incorporate an under voltage blocking facility which renders the control inoperative if the reference voltage falls below 80 percent of the nominal value with automatic restoration of control when the reference voltage rises to 85 percent of nominal value.

4.7.4.4 On each transformer the voltage transformer supply to the voltage regulating relay shall be monitored for partial or complete failure. The specified indicating lamp and alarm will be inoperative when the circuit breaker controlling the lower voltage side of the transformer is open and also that when the tap changer is on control other than automatic control.

4.7.5 Remote Control Panels for Tranformer

4.7.5.1 The remote control panels specified in the Schedule of Requirements shall be floor mounted sheet steel cubicles of approved type, layout and colour to Munsell

notation 5Y-7/1 and shall be provided for each transformer. The control cabinet shall be of weather-proof construction with dip edge over hangingcabinet doors. Cabinet door to have provisions for a padlock. Each door shall be equipped with a holding bar or other mechanism to securely hold the door open at least 120° from the cabinet against winds gusting to 25 miles per hour. Lamp receptacle controlled by a door switch and located remote from control wires. Receptacle shall be for IEC standard medium base lamps. 100W equivalent LED bulb to be supplied.

4.7.5.2 One (1) 20 Amp, 230 VAC, single phase, wire grounded duplex convenience receptacle(GFI protected) shall be provided in the control cabinet.

4.7.5.3 Weather-shielded, screened breather holes shall be furnished at the top and bottom ofthe cabinet.

4.7.5.4 The bottom of the control cabinet shall have a removable plate suitable for the Customer's conduit connections. The removable plate shall be 8" x 20" or larger. The dimensions and centerline location of this plate shall be clearly shown on the outline drawing.

4.7.5.5 Each shall form a complete enclosure with lockable rear doors and shall be fitted with interior lamp, door switch, heaters, cable gland plates for bottom entry of cables and all other equipment to provide the features specified, the standard requirements (which may be varied to suit Manufacturer's design) being as follows:

- Instruments:
  - Voltmeter (voltage at the low voltage terminals of the transformer)
  - Tap position indicator with integral or separate scale to indicate the no-load (LV) Voltage in kV appropriate to each winding tap.
- Relays:
  - Automatic voltage control
- Controls:
  - Automatic/Non-automatic voltage control selector switch
  - Remote/Supervisory tap change control selector switch
  - Pistol grip selector switch with centre zero
  - Independent/Master/Follower selector switch
  - AVR voltage reference adjuster
- Indications and Alarms:
  - Continuous Oil & Winding temperature [Digital type]

- Tap change in progress - white lamp
- Tap change out of step - amber lamp
- Tap change incomplete - amber
- Tap change control on "local"
- Tap change control on auto/manual
- Group 1 Air forced cooling equipment running - white
- Group 1 Air forced cooling overcurrent alarm - amber
- Group 2 Air forced cooling equipment running - white
- Group 2 Air forced cooling overcurrent alarm - amber
- Forced cooling failure-amber lamp
- VT Fail alarm - amber
- Supply voltage to OLTC failure - amber lamp

Remote control schemes shall be entirely suitable for operation with the distance between the transformer and remote control panels as shown on the Specification drawings.

4.7.6 Off-Load Tap Changers

4.7.6.1 When specified in the schedule of requirement, An externally operated DETC [typically for station power supply transformer] shall be provided for the high voltage winding taps in accordance with this clause. The off-circuit tappings as specified in the Schedule of Requirements shall be provided on the higher voltage windings for a variation of no-load primary voltage as specified. The DETC shall include tap positions as described in the Appendix section. All taps shall be full capacity taps.

4.7.6.2 A positive type position indicator shall be furnished, complete with provisions for padlocking the DETC in any on-tap position with padlocks having 3/8" shanks and 2" x 2" x 7/8" bodies. A suitable weather shield shall be provided over the padlock and positioning pin and shall be designed to eliminate the need for tools for access. Any exposed portion of the mechanism, such as a position indicator or geneva gear, shall also be furnished with a weather shield. Off-load tap-changing shall be carried out by means of an external hand-operated tapping switch mounted on the side of the tank. All phases of the tapping switch must be operated by one hand wheel.

4.7.6.3 All DETCs on a transformer shall be operated by a suitable single external manual handle device, conveniently and safely operable from the ground, with the handle no more than 3 to 5 feet above the tank base. Multiple DETC operating handles are not acceptable.

4.7.6.4 The DETC operating handle is to be readily accessible for operation without interference from adjacent parts. All taps shall be rated for loading above maximum nameplate capabilities of the transformer as specified in Data Sheets.

4.7.6.5 Any shaft penetration designs directly through the tank wall at a location below the top of the core/coil assembly shall have double sealing on the rotating shaft and on the mounting flange.

4.7.6.6 Under no conditions shall a sprocket and chain drive arrangement be acceptable for connecting the DETC assemblies on each phase to the common operating shaft.

4.7.6.7 The tapping switch shall have a spring-loaded captive bolt or other approved means on the moving part that positively locates the switch correctly at each tapping position. This bolt must be lockable at each tapping position and shall be provided with a suitable padlock and keys. Moving the switch from one tapping position to another shall require that the bolt be withdrawn by hand from its locating socket on the transformer tank against the spring pressure.

4.7.6.8 Tap-position numbers corresponding to the tapping switch bolt-locating sockets shall be cast or engraved in a metal indication plate fixed to the tank and a keyed metal pointer on the tapping switch operating handle shall show clearly at which tapping number the transformer is operating.

4.7.6.9 All tap-position indicators shall be marked with one integer for each tap position, beginning at number 1. Adjacent taps shall be numbered consecutively in such a manner that when moving a tap to a new tapping position that has a higher number, the no-load output voltage of the untapped winding increases.

4.7.6.10 DETCs shall be prevented from being left between taps and shall be prevented from moving off tap due to vibrations or bumping.

4.7.6.11 All tapered pins used in DETC assemblies shall be fully driven into the holes, slightly below the surface of the entrance side of the holes, and the entrance side of the holes deformed.

4.8 Supervisory Control

4.8.1 Requirements

4.8.1.1 Transformer tap change control will be affected from the substation control room with facilities for remote control from the Load Despatch Centre. All necessary connections, indications, auxiliary switches, relays and changeover switches to meet

supervisory control requirements shall be provided and connected under this contract to terminal blocks in the remote control panels. The supply and installation of the multicore control cables between the remote control panels and the plant/telecontrol interface cubicle shall be provided under the contract.

4.8.2 Required Supervisory Facilities

4.8.2.1 Controls

i) Supervisory selection of auto/non-auto voltage control.

ii) Tap change raise/lower by direct operation of tap changer.

iii) Tap change blocking on/off.

iv) Remote/supervisory selection "override".

v) Parallel/independent control.

4.8.2.2 Indications and Alarms

i) Tap position indication by means of transducer with 4-20 mA d.c. output range proportional to step increment.

ii) Tap change out of step alarm.

iii) Buchholz and winding temperature non-trip alarm.

iv) Continuous OTI & WTI

v) Tap change control on Local/Supervisory.

vi) Parallel/independent, master/follower.

vii) Tap change blocking on/off.

viii) Tap change control on automatic/manual.

4.8.2.3 All contacts for supervisory alarms and indications shall be potential free

4.9Terminal Bushings and Connections

4.9.1General

4.9.1.1 Where stated in the Schedule of Requirements, transformers are to be provided with outdoor type bushing insulators.

4.9.1.2 All bushings shall comply with IEC 60815& IEC 62217. The minimum creepage distance for outdoor bushings shall not be less than 25mm per kV of rated voltage between phases.

4.9.1.3 Outdoor bushing insulators shall be provided with adjustable arcing horns where applicable and for rated voltages of 33kV and lower these shall be of the duplex gap type.

4.9.1.4 Bushings shall be of sealed construction suitable for service under the very humid conditions at Site and, addition, for the very rapid cooling of equipment exposed to direct sunlight when this is followed by sudden heavy rainstorms.

4.9.1.5 Typical sections of bushing insulators showing the internal construction, method of securing the top cap and methods of sealing shall be included in the Bid.

4.9.1.6 The bushings shall be located on the top of the tank so that a bushing may be replaced without the need to reduce the oil level below the top of the windings.

4.9.1.7 n all bushings a tapping shall be brought out to a separate terminal for testing purposes on site.

4.9.1.8 Special precautions shall be taken to exclude moisture from paper insulation during manufacture, assembly, transport and erection.

4.9.2Type, rating & Construction of Bushings

4.9.2.1 All bushings shall be Resin Impregnated Paper (RIP) bushings oil-free dry and clean technology. All terminal bushings (unless otherwise noted on the Specific Transformer Data Sheet) shall be located on the tank cover and shall be in accordance with IEC Standards where applicable.

4.9.2.2 The current rating of each bushing shall be equal to or greater than the current it will carry at the maximum forced-cooled rating and overload rating. Additionally, the current rating of each neutral bushing shall not be less than the current rating of the

associated line bushings. The H0X0 bushing, when required, shall be rated to sustain the maximum operating current of the common winding.

4.9.2.3 Bushing leads shall be accessible from the bushing cover. Accessibility to leads shall not require personnel to enter the transformer tank. draw-lead connection is required for all bushings whenever possible. In cases where the transformer winding leads are bolted to the bottom of the bushings, two-bolt connections shall be used; single-bolt connections are not acceptable.

4.9.2.4 For quality, reliability and maintenance requirements the bushings shall be supplied fromABB (Sweden/Switzerland), Trench (France/USA), HSP (Germany), GE (Italy) (and as specified in Technical data sheets) or equivalent.

4.9.2.5 Bushing outline drawings with stud sizes identified shall be submitted with transformer approval drawings.4-hole IEC bushing terminal connectors shall be supplied for each bushing. Connectors shall be tinned copper-bronze, and finished on both sides. Cut sheets shall be provided showing materials, dimensions and current rating of terminal connectors. Type test of the Busing for Short circuit force withstand capability shall be submitted with the Bid and the same shall be submitted during execution for approval.

4.9.2.6 Some of the above mentioned make, viz., ABB (Sweden/Switzerland), Trench (France/USA), HSP (Germany) & GE (Italy) make bushings are already existed in PGCB's System and their performance is proven. Hence, if the bidder choose to propose bushings from other manufacturers, the proposed manufacturer shall have at least thirty (30) years of manufacturing experience of Resin Impregnated Paper (RIP) bushings prior to the date of bid submission with minimum delivery of at least three hundred (300) nos. of similar or higher rating Resin Impregnated Paper (RIP) bushings with silicon composite housing over the last ten years outside the manufacturer's own country and the bushings similar to or higher rating of the proposed type shall have complete type test report as per relevant IEC standard (IEC 60137) from any independent/STL testing laboratory. The bidders shall have to submit relevant documents with their bids.

4.9.3Bushings for Buried Z-Terminals

4.9.3.1 Where a buried delta tertiary is specified, the corner of the delta shall be brought out through bushings. The corner of the delta shall be completed externally and grounded through an external connection. The two winding terminals at one corner of the tertiary delta shall be separately brought through 15/36 kV bushings mounted on the tank cover. Removable straps shall be furnished to connect the external bushing terminals together and to the tank. The bushings shall be located and labeled

to avoid confusion with other bushings, and shall be protected with a removable, weatherproof metal cover.

4.9.3.2 An instruction plate shall be furnished and mounted near these bushings, specifying that the external bushing terminals must be connected together, and to the tank, whenever the transformer is energized. The same instructions shall be shown on the main transformer nameplate.

4.9.4Porcelain

4.9.4.1 Hollow porcelain shall meet the test requirements of IEC 60233 and shall be sound, free from defects and thoroughly verified. Designs based on jointed porcelains will not be acceptable. The glaze must not be depended upon for insulation. The glaze shall be smooth, hard, of a uniform shade of brown and shall cover completely all exposed parts of the insulator. Outdoor insulators and fittings shall be unaffected by atmospheric conditions producing weathering, acids, alkalis, dust and rapid changes in temperature that may be experienced under working conditions.

4.9.4.2 The porcelain must not engage directly with hard metal and, where necessary, gaskets shall be interposed between the porcelain and the fittings. All porcelain clamping surfaces in contact with gaskets shall be accurately ground and free from glaze.

4.9.4.3 All fixing material used shall be of suitable quality and properly applied and must not enter into chemical action with the metal parts or cause fracture by expansion in service. Cement thicknesses are to be as small and even as possible and proper care is to be taken to centre and locate the individual parts correctly during cementing.

4.9.4.4 The bushing shall be provided with tap for capacitance and tan delta test. Test taps relying on pressure contacts against the outer earth layer of the bushing is not acceptable.

4.9.4.5 All porcelain insulators shall be designed to facilitate cleaning.

4.9.5Polymer / Composite Insulator

4.9.5.1 Resin Impregnated Paper (RIP) Condenser Bushing shall use Silicone Rubber composite insulator as housing of the bushing.

4.9.5.2 Different composite insulating materials are available like EP, PTFE, EPDM or silicone for use as Composite Insulator. For Bushing application under this specification, silicone rubber (SiR/SR) shall be used.

4.9.5.3 Bushings shall be robust and designed for adequate cantilever strength to meet the requirement of seismic condition, substation layout and movement along with the spare Transformer/ Reactor with bushing erected and provided with proper support from one foundation to another foundation within the substation area. It shall have Low dielectric losses.

4.9.5.4 The hollow silicone composite insulators shall comply with the requirements of the IEC publications IEC 61462 and the relevant parts of IEC 62217.

4.9.5.5 The electrical and mechanical characteristics of bushings shall be in accordance with IEC: /60137DIN .42530All details of the bushing shall be submitted for approval and design review during contract stage.

4.9.5.6 The bushing shall be provided with tap for capacitance and tan delta test. Test taps relying on pressure contacts against the outer earth layer of the bushing is not acceptable.

4.9.5.7 Where current transformers are provided, the bushings shall be removable without disturbing the current transformers.

4.9.5.8 Bushings of identical rating shall be interchangeable to optimise the requirement of spares.

4.9.5.9 The material shall be non-inflammable, have no partial discharge during whole lifetime, Secondary insulation shall be Dry material filler,i.e., no oil or gas shall be used inside the bushing and maximum operating temperature shall be 120°C or more.

4.9.5.10 The SiR generally have the following component –

- Basic polymer
- Filler, normally AluminiumTriHydrate, ATH
- Catalyst
- Other additives, for instance mould release agent

4.9.5.11 Proper combination shall be made to meet specific requirement of this specification. Silicone rubber shall withstand ozone and UV light. The Material shall be suitable for outdoor use, i.e. temperature range, as mentioned in the bidding document.

4.9.5.12 The design of the composite insulators shall be tested and verified according to IEC 61462 (Type & Routine test).

4.9.5.13 The insulator shall have Epoxy resin tube supported with fiber glass as mechanical reinforcement. On each end of the tube there shall be a flange made of cast aluminum alloy.

4.9.5.14 Polymer / composite insulator shall be seamless sheath of a silicone rubber compound. The housing & weather sheds should have silicon content of minimum 30% by weight. It should protect the bushing against environmental influences, external pollution and humidity.

4.9.5.15 It shall be extruded or directly moulded on the core. The interface between the housing and the core must be uniform and without voids. The strength of the bond shall be greater than the tearing strength of the polymer. The manufacturer shall follow non-destructive technique (N.D.T.) to check the quality of jointing of the housing interface with the core.

4.9.5.16 The weather sheds of the insulators shall be of alternate shed profile as per IEC 60815 The weather sheds shall be vulcanized to the sheath (extrusion process) or moulded as part of the sheath (injection moulding process) and free from imperfections.

4.9.5.17 Different formulations of silicone rubber require different processing when producing high voltage insulators. For example –

4.9.5.18 Low pressure moulding (up to 10 bar) with relatively low curing temperatures (50–80 °C) is used with low viscosity RTV (Room Temperature Vulcanised) or LSR (Liquid Silicone Rubber) rubber.

4.9.5.19 High pressure injection moulding (up to 250 bar) with high curing temperatures (130–180 °C) is used with HTV (High Temperature Vulcanising) rubber. Helical winding of an extruded profile to give an insulator with a thread shaped shed is used with HTV when a high degree of production flexibility is desired.

4.9.5.20 HTV rubber shall be used for silicone rubber housing of RIP bushing under this specification. That is, the vulcanization for extrusion process shall be at high temperature and for injection moulding shall be at high temperature & high pressure. Any seams / burrs protruding axially along the insulator, resulting from the injection moulding process shall be removed completely without causing any damage to the housing. The track resistance of housing and shed material shall be class 1A4.5 according to IEC .60587

4.9.5.21 The strength of the weather shed to sheath interface shall be greater than the tearing strength of the polymer. The composite insulator shall be capable of high pressure washing.

4.9.5.22 End fittings shall be free from cracks, seams, shrinks, air holes and rough edges. End fittings should be effectively sealed to prevent moisture ingress, effectiveness of sealing system must be supported by test documents.

4.9.5.23 The surface shall be Water repellent & self-cleaning, High hydrophobicity over the whole life time. All surfaces of the metal parts shall be perfectly smooth with the projecting points or irregularities which may cause corona. All load bearing surfaces shall be smooth and uniform so as to distribute the loading stresses uniformly. It must be confirmed that, the surface colour shall not degrade over it's lifetime.

4.9.5.24 Clamps and fittings shall be of stainless steel. Bushing turrets shall be provided with vent pipes, to route any gas collection through the Buchholz relay. No arcing horns shall be provided on the bushings. The terminal marking and their physical position shall be as per IEC: .60076

4.9.5.25 Bushing handling and lifting tools with nylon rope / belt, chain block (2 nos.) and D- Shackle shall be supplied for which cost shall be deemed included. Valid type test report conducted at third party lab or witnessed by third party shall be submitted.

4.9.5.26 Lifetime : The bushings shall be designed to withstand service for the life of the equipment it serves, normally at least 30 years.

4.9.5.27 Plug-In Type Bushing : Where possible, Tertiary Bushing shall be Plug-In type.

4.9.6Marking

4.9.6.1 Each porcelain or Silicone insulator shall have marked upon it the Manufacturer's name or identification mark and year of manufacture. These marks shall be clearly legible after assembly of fittings and shall be imprinted before firing, not impressed.

4.9.6.2 When a batch of insulators bearing a certain identification mark has been rejected, no further insulators bearing this mark shall be submitted and the Contractor shall satisfy the Engineer that adequate steps will be taken to mark or segregate the insulators constituting the rejected batch in such a way that there can be no possibility of the insulators being re-submitted for the test or supplied for the use of the Employer.

4.9.6.3 Each complete bushing shall be marked with the Manufacturer's name or identification mark, year of manufacture, serial number, electrical and mechanical characteristics in accordance with IEC 60137.

4.9.7Mounting of Bushings

4.9.7.1 Bushing insulators shall be mounted on the tank in a manner such that the external connections can be taken away clear of all obstacles. Neutral bushings shall be mounted in a position from which a connection can be taken to a neutral current transformer mounted on a bracket secured to the transformer tank. The current transformer will be supplied by the switchgear Manufacturer but provision shall be made on the tank for mounting to the Engineer's requirements.

4.9.7.2 The clearances from phase to earth must not be less than those stated in the Schedule of Requirements.

4.9.7.3 A flexible pull-through lead suitably sweated to the end of the winding copper shall be provided for the bushings and is to be continuous to the connector that is housed in the helmet of the bushings.

4.9.7.4 When bushings with an under-oil end of a re-entrant type are used the associated flexible pull-through lead is to be fitted with a suitably designed gas bubble deflector.

4.9.7.5 The bushing flanges must not be of re-entrant shape that may trap air.

4.9.7.6 Clamps and fittings made of steel or malleable iron shall be galvanised and all bolt threads are to be greased before erection.

4.10Bushing Current Transformer

4.10.1General

4.10.1.1 Except where otherwise specified, each terminal bushing, including neutral, shall be equipped with bushing-type current transformers that meet the following requirements:

4.10.1.2 All CT's shall have a continuous thermal current rating factor (RF) of 2 or higher. The thermal factor requirement shall be met during all loading requirements including planned overload. Multi-ratio (MR) CT's shall have 5 leads and fully

distributed windings. All CT secondaries shall be rated 1 ampere with a continuous thermal rating of 5 amperes on all taps.

4.10.1.3 CTs shall conform to the latest IEC Standard for 5-lead, multi-ratio current transformers. Multi-ratio CTs supplied with the transformer for relay purposes shall have a metering accuracy of 0.3% up to B2.0 when at the full tap winding. Single-ratio (SR) CTs supplied with the transformer for metering purposes shall have an accuracy of 0.3% up to B2.0. See the Appendix for the number of CTs on each bushing and their ratios.

4.10.2CT Wiring

4.10.2.1 All secondary wiring for CTs shall be at least 2.5 mm2 stranded copper with oil resistant, thermosetting 600V insulation, 90°C or higher, electrically, thermally and mechanically suitable for its application. Flame, oil and heat resistant wiring with higher voltage insulation or higher operating temperatures are acceptable. The five leads of each CT shall be wired to their own 6-point short-circuiting type terminal block, General Electric Type EB-27.

4.10.2.2 All CT secondary leads shall be brought out to an external junction box with stud, nut and lock washer connections. All CT secondary leads shall be continuous except at the external junction box. No internal or external splices shall be allowed. Split lock washers are not acceptable. Moulded type junction blocks using splices are not acceptable. Note that this applies to all CT wiring termination, including connections at Electronic Temperature Monitoring devices where provided. CT connections via "set-screw" type connectors or wire wrapped around screw terminals is not acceptable. Wiring shall be installed in a weather proof metal conduit system which shall be effectively sealed. Wire fill in conduit shall meet IEC/NEC requirements for both # of wires per conduit and % fill.

4.10.2.3 All CT leads longer than 12 inches inside the tank shall be run in non-metallic tubes instead of being tied directly to supports. All wiring entrances and exits from the tube shall be flared round to prevent sharp edges that could damage wiring during shipment or other movement. Leads shall be tied off with cotton tape where they enter and exit the tubing to prevent unnecessary movement.

4.10.2.4 If CT turrets require removal for transformer shipment, CT lead junction boxes shall be installed on the removable turret with the CT's factory installed in the turrets and wired out to the junction boxes. Prefabricated and pre terminated extension cable pigtails and short sections of liquid tight flexible conduits shall be used for reconnecting the CT's during field assembly. The cabinet containing the CT terminal blocks shall also be equipped with one States type MTS test switch with 2 current

shorting poles and sufficient, properly braced, space for future field installation of a 5/5A single ratio auxiliary current transformer.

4.10.2.5 The short-circuiting strips of the blocks shall be grounded. Terminal Blocks shall be located in a separate cabinet or, if located in the main control cabinet, they shall be positioned so as to minimize the possibility of personnel making inadvertent contact. If a separate CT Cabinet is provided, it shall meet the following requirements:

4.10.2.6 The CT Cabinet shall be weather proof and shall be large enough to provide sufficient room to pull in and terminate the user's 4/C 2.5mm2 cables. The bottom of the CT cabinet shall have a removable plate, at least 8" x12", suitable for the Customer's connections. The dimensions and centreline location of this cabinet shall be clearly shown on the outline drawing. Wire-ways shall be provided for customer wiring.

4.10.2.7 Stainless steel hinges and latching door handle shall be provided. Winding temperature (hot-spot) current transformer leads shall be brought to a short-circuiting type terminal block (EB-27 or Employer approved equivalent) in the CT cabinet so that the temperature indicators can be field calibrated. Calibration information shall be included in the test report (CT current correlation to hot spot adder; and heater calibration data).

4.10.2.8 A current transformer nameplate shall be mounted adjacent to the respective terminal block and shall contain the following information. (If space adjacent to the terminal blocks is limited, a single data plate may be mounted on the inside of the door which includes the below information.)

- Manufacturer's name
- Manufacturer's type designation
- Rated frequency
- IEC accuracy class
- Connection chart showing winding development, taps, and ratio in terms of primary and secondary current, polarity, pole and pocket location.
- Curve sheet numbers
- Thermal Rating Factor

4.11 Auxiliary Power and Control Cables

4.11.1 This Contract includes the supply, installation and termination of the necessary auxiliary power and control cables within items of plant supplied under the contract.

4.11.2 The Contractor shall produce, during the currency of the contract and in any case, before shipment of plant commences, detailed cable core schedules for each transformer.

4.11.3 All the control wiring for the control equipment on the transformer must run through rigid conduit piping in order to prevent it from environmental influences. The last 50 cm can be done with flexible conduit in order to make the connections to the devices and the control cabinet.

4.11.4 Cabinet bottoms shall have ample space for the entrance of the Customer's conduits. In general, two 3 inch IPS conduits will enter the OLTC control cabinet and three 3 inch IPS conduits will enter the cooling equipment control cabinet.

4.11.5 All external control wiring to accessories, current transformer junction boxes, etc., shall be run in weather proof raceway systems to either control cabinet as required for local control connections and the Customer's connections. Raceway systems that fill with water during normal use will be remedied at the Manufacturer’s expense.

4.11.6 Tank bracing is not to be used as a raceway for any control wiring. Flexible conduits or armoured cables between devices and rigid conduits or tank bracing shall be weather proof and their lengths as short as possible and no longer than 3 feet. Loose ends of flexible connections ending in tank bracing shall be sealed against entry of moisture until field connections are made.

4.11.7 Intermediate terminal blocks between external devices and the control cabinets shall be barrier type. No splices shall be used.

4.11.8 Terminal blocks shall be made of phenolic plastic with captive screws. All control wiring, with the exception of CT and VT secondary leads and sudden pressure trip leads, shall be stranded copper, #12 AWG minimum, with oil resistant thermosetting 600V insulation, 90°C or higher, electrically, thermally and mechanically suitable for its application. Flame, oil and heat resistant wiring with higher voltage insulation or higher operating temperatures are acceptable.

4.11.9 All wiring inside control cabinet shall be run in wire duct with snap on covers topermit easy tracing of circuits.

4.11.10 All control wiring shall terminate with insulated full ring lugs on one side of 600V,25A (or higher), double row barrier type terminal blocks with screw terminals and captive links, GE type EB-25 or equivalent. Barrier spacing shall be sufficient to permit termination of #10 AWG wiring using Insulated Full Ring Terminal with Seamless Barrel or Braised Barrel. No more than two wires shall be terminated under any given screw terminal.

4.11.11 Manufacturer's wiring to terminal blocks intended for extension by Customer shall terminate on one row, with the other row kept clear of Manufacturer's wiring. The row used for Manufacturer's wiring and Customer's wiring shall be consistent on all terminal blocks in a vertical column, with rows alternating every other vertical column so Customer's cables may rise between two adjacent rows and fan in each direction.

4.11.12 All Manufacturer's wires shall be provided with indelible marker sleeves at each termination designating the location of the opposite end termination. All wiring in the control cabinet shall be run in wire duct with snap on covers to permit easy tracing of circuits.

4.11.13 External wiring that is not in conduit shall be type SOW. All relays, relay terminals, and terminal blocks shall be easily accessible even if the installation of a hinged door or a hinged panel is required. Control devices shall not be more than five (5) feet above the transformer base.

4.11.14 All unused relay contacts provided for the Customer shall be wired to terminal blocks and clearly identified in the control cabinet. At least 20% of the terminal points shall be provided as spares and evenly distributed among the occupied terminal points.

4.11.15 All relay and control devices shall be identified by engraved nameplates.

4.11.16 Auxiliary power and control cables shall have copper conductors, PVC insulated, armoured and PVC sheathed overall. The cable design shall generally be in accordance with BS 6346 and Section 6 of this Specification.

4.11.17 All cables installed under the contract shall utilise compression glands of type El to BS.6121 or otherwise designed to secure armour wires and bond them to earthed metal and to provide seals between sheath and gland and between inner sheath and threaded fixing component.

4.11.18 The Contractor shall supply and fit the compression gland and make off individual cores on to the terminal boards, including the supply and fitting of numbered markers on each core.

4.12 Temperature-Indicating Devices and Alarms

4.12.1 The transformers shall be provided with approved devices of Kihlstrom or equivalent for indicating the top oil temperature and hottest spot winding temperatures. The devices shall have a dial type indicator and, in addition, a pointer to register the

highest temperature reached. Each winding temperature device shall have four separate contacts fitted, two of which shall be used to control the two groups of cooling plant motors (i.e. AF1 and AF2), one to give an alarm and one to trip the associated circuit breakers.

4.12.2 To simulate indication of the hottest spot temperature of the winding the device shall comprise a current transformer associated with one phase only and a heating device designed to operate continuously at 130 percent of transformer CMR current and for 30 minutes at 150 percent of CMR current, associated with a sensing bulb installed in an oil tight pocket in the transformer top oil.

4.12.3 The winding temperature indicators (WTI) shall be housed in the marshalling cubicle. The tripping contacts of the winding temperature indicators shall be adjustable to close between 80˚C and 150˚C and to re-open when the temperature has fallen by not more than 5˚C.

WTI/OTI of Transformer shall be connected to SAS for continuous monitoring by operator.

4.12.4 The alarm contacts and the contacts used to control the cooling plant motors on the above devices shall be adjustable to close between 50˚C and 100˚C and to re-open when the temperature has fallen by a desired amount between 5˚C and 10˚C.

4.12.5 All contacts shall be adjustable to a scale and must be accessible on removal of the relay cover. Alarm and trip circuit contacts shall be suitable for making or breaking 150 VA between the limits of 30 volts and 250 volts AC or DC and of making 500 VA between the limits of 110 and 250V DC. Cooler motor control contacts shall be suitable for operating the cooler contactors direct or, if necessary, through an interposing relay.

4.12.6 The temperature indicators in the marshalling kiosk shall be so designed that it is possible to move the pointers by hand for the purpose of checking the operation of the contacts and associated equipment.

4.12.7 The working parts of the instrument shall be made visible by the provision of cut-away dials and glass-fronted covers and all setting and error adjustment devices shall be easily accessible.

4.12.8 Connections shall be brought from the device to terminal boards placed inside the marshalling cubicle.

4.12.9 Terminals, links and a moving iron ammeter shall be provided in the marshalling kiosk for each WTI for:

(A) Checking the output of the current transformer.

(B) Testing the current transformer and thermal image characteristics.

(C) Disconnecting the bulb heaters from the current transformer secondary circuit to enable the instrument to be used as an oil temperature indicator. Links shall be provided as shown on the drawing enclosed with this Specification.

4.13Fiber Optic Based Temperature Sensing System

4.13.1 Fiber optic based direct temperature sensing shall be provided for power transformer winding. The purpose is to provide for faster and more appropriate response to sudden load increases. Hot spot temperature shall also be measured with the help of fiber optic sensors. Instead of one point of measurement, multiple point of measurement shall be used for more accurate result. The probe shall be distributed evenly & suitably to have comprehensive results. Probes shall be such designed and inserted so that winding insulation is not compromised. Typically, 2 probes will be mounted at the hot spot location in each phase. The Fiber Optic Based Temperature Sensing System will be incorporated mainly for the voltage levels of 230 kV & above.

4.13.2 The winding sensors are typically located at:

- Near top of upper primary oil duct, X-winding -- 2/ph
- Near bottom of lower primary oil duct, Y-winding--- 2/ph
- Near bottom of lower primary oil duct, Z-winding--- 2/ph when applicable
- One (Total 03) more on each core legs

4.13.3 Sensors located other than specified locations which are well adopted in the industry shall be deemed to finalized during detail design prior to Employers approval.

4.13.4 Design having one probe in the lateral phases (A/C) is acceptable subject to justification that, such design is reliable and does not affect the performance considering the sensors life-time.

4.13.5 Design of Fiber optic probe must be robust. Ideally, long-life probes should have the following characteristics:

- The sensing technology must be absolutely stable with time, immersed in harsh chemical environments, and at elevated temperatures
- The probes must be designed so they can mechanically survive steady vibrations and frequent thermal cycles inside the power transformer.
- The technology that converts the light signal into temperature information must be insensitive to light intensity variations. This is required to avoid problematic compensation for any aging effects in the optical fiber link and any interconnections

- Fiber connectors must be leak-proof, reliable and maintenance-free. Oil in optical path should not interfere with signal.

4.13.6 Although it may seem more accurate to mount fiber optic probes directly on the conductors, however, it can also be mounted in radial spacers. Also, it appears that the temperature under the spacer is higher by 1 or 2°C than the surrounding conductor. Hence, the manufacturer must take approval from the employer during design approval about the place of mounting of fiber optic probes.

4.13.7 The HMI for temperature monitoring shall be of modular type and shall be mounted in the RTCC panel of transformer with IP54. However, transformer body mounted module is also acceptable with higher IP (i.e. IP66) & EMC rating. Operating temperature shall be -200C to +550C. All accessories like Fiber optic cables, couplers, RS-485 port etc. shall be provided. Approved communication protocols are IEC 61850, shall be used in the system. Serial or TCP/IP communication shall also be available. SCADA integration option shall be made available. Any software (if required) shall be furnished. Spare items like light source, probes etc. vulnerable parts shall be supplied with sufficient numbers along with the system. Light source shall have a minimum MTBF of 300 years. Calibrated accuracy shall be of ± 01°C

4.14Gas and Oil-Actuated Relays

4.14.1 Each transformer shall be fitted with gas and oil-actuated relay equipment having alarm contacts that close on collection of gas or low oil level, and tripping contacts which close following oil surge conditions.

4.14.2 Each gas and oil-actuated relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay.

4.14.3 Each relay shall be fitted with a calibrated glass window for indication of gas volume.

4.14.4 To allow gas to be collected at ground level, a small bore pipe shall be connected to the gas release cock of the gas and oil-actuated relay and brought down to a point approximately 1400MM above ground level, where it shall be terminated by a cock which shall have provision for locking to prevent unauthorised operation.

4.14.5 The design of the relay mounting arrangements, the associated pipework and the cooling plant shall be such that mal-operation of the relay will not take place under normal service conditions, including starting or stopping of oil circulating pumps, whether by manual or automatic control under all operating temperatures.

4.14.6 The pipework shall be so arranged that all gas arising from the transformer will pass into the gas and oil-actuated relay. The oil circuit through the relay must not form a delivery path in parallel with any circulating oil pipe, nor is it to be teed into or connected through the pressure relief vent. Sharp bends in the pipework shall be avoided.

4.14.7 When a transformer is provided with two conservators, the gas and oil-actuated relays shall be arranged as follows:

(A) If the two conservators are connected to the transformer by a common oil pipe, one relay shall be installed in the common pipe.

(B) If the two conservators are piped separately to the transformer, two relays shall be installed, one in each pipe connection.

4.14.8 The clearance between oil pipework and live metal shall be not less than the minimum clearances stated in the Project Requirements of Section 1.

4.15Fire Protection System

4.15.1 General

4.15.1.1 The new power (auto) transformers shall be provided with Fire Protection and/or Fire Prevention system as per schedule of requirement for each of 230kV & above voltage rating transformers. General description, design and performance requirements of the systems are given below. It is not intended to completely specify all details of design and construction. Nevertheless, the system design and equipment shall conform in all respects to high standard of engineering, design and workmanship.

4.15.1.2 The system design shall also conform to TAC/ NFPA norms (NFPA 850). The offered system shall comply with the relevant international standards. Reference standards are listed below. Relevant international standards other than BS standards shall be subject to approval by the Employer:

4.15.2 Applicable Standard

- IEEE National Electrical Safety Code

- IEEE 979 Guide for Substation Fire Protection
- IEEE 980 Guide for Containment and Control of Oil Spills in Substations
- NFPA 13 Standard for the Installation of Sprinkler Systems.
- NFPA 15 Standard for Water Spray Fixed Systems for Fire Protection
- NFPA 25 Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems
- NFPA 70 National Electric Code
- NFPA 72 National Fire Alarm Code.
- NFPA 750 Standard on Water Mist Fire Protection Systems
- NFPA 850 Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations
- DIN 2391, 3861, 3865, 20078, 17457, 17458
- FM Approval Standard for Water Mist Systems Class Number 5560.
- BS 381 C Colours for Identification, Coding & Special Purpose
- BS 7629-1 Specification for 300/500 V fire resistant electric cables having low emission of smoke and corrosive gases when affected by fire.
- BS 8434-1 Methods of test for assessment for power integrity of electric cables
- BS 5839-1 Code of practice system design, installation, commissioning and maintenance for fire detection and fire alarm system
- BS EN50267-2-1 Common Test Methods for Cables Under Fire Conditions

4.15.2.1 The fire prevention & protection system shall have been in successful operation in for at least last three years for protection of transformers of offered type or higher voltage class. The reference list along with performance certificate from end users of the system shall be submitted with the bid and/or during detail Engineering.

4.15.2.2 The system shall be reliable without making any mal operation.

4.15.3WATER SPRAY SYSTEM (WSS)

4.15.3.1 When required by schedule of requirement, the Contractor shall provide the water spray system arrangements specified below for each of the transformer:

4.15.3.2 The water spray system shall be provided with a valve station including the necessary control and monitoring cabinet to be capable of extension to serve in total four transformer units.

4.15.3.3 The water spray system is to be designed for manual, automatic and electrical remote operation and must be provided in free-standing and self-supporting design, with the following basic equipment:

- The required number of triggering and fire extinguishing nozzles with galvanized pipes and mountings
- The necessary galvanized connecting lines from the appropriate valve station to the nozzle pipe network
- The necessary drainage valves, struts, diaphragm sleeve valves, single chamber valve stations with all fittings and connections, pressure-sensitive switches for signalling and air pressure drop, with the possibility of extension by four transformers
- The necessary tank feed pump
- Pressurizing air vessel for maintaining a reserve of fire-fighting water

4.15.3.4 The required water discharge rate shall be 10litter / m2 / min. Design wind velocity shall be 10m / sec. The required water volume shall be considered for spraying for any one unit of the power transformers.

4.15.3.5 The pressurizing air vessel is to be designed for a minimum spraying time of 20 minutes and is to be fully equipped with all necessary fittings and connecting pipes, pressure controllers, low water level alarm, reducing valves and all other equipment essential for trouble-free operation.

4.15.3.6 The pressurizing air vessel is to be installed above ground.

4.15.3.7 Two air pressure units, rated pressure 10 bar, each provided with the following main equipment:

- air compressor
- 415/240V three-phase motor
- flexible coupling
- oil and water separator
- non-return valve
- vent and drain valve
- pressure gauge

4.15.3.8 Installed completely on a sturdy base frame with all necessary anti-vibration mounts and fixing material.

4.15.3.9 One compressed air container, vertical type, welded with manhole, rated pressure matched to the water spray system, including the following main fittings:

- contact type pressure gauge
- relief valve
- pressure switch
- drain valve

4.15.3.10 Assembled completely and ready for operation, the volume of air being matched to the time sequence of the transformer extinguishing operation.

4.15.3.11 The necessary control cabinet, enclosure type IP55, completely equipped with the following main items:

- 2motor protection switches, 415/240V, 50Hz, coil voltage 240V 50Hz / 110Vdc, auxiliary contactors and relays for optional operation of compressors 1 and 2 with switch controlling operation

4.15.3.12 With terminal board and cable entry glands as well as the necessary local fault and indicator lamps and spare contacts for remote monitoring and the necessary interlock criteria.

4.15.3.13 One complete compressed air distribution system with the necessary signalling pressure gauges, contact pressure gauges, pressure relief valves, pressure gauge valves, drain valves, pressure reducing valves, hand-operated shut-off valves and copper piping in the diameters shall be provided for the compressed air distribution.

4.15.3.14 For quality and maintenance requirement, the Watery Spray System (WSS) shall be from Europe/USA/Canada/Japan originor other eligible countries with equivalent quality.

4.15.3.15 Automation Requirement

The WSS must be integrated with the SAS to check the functional status of the system. Necessary works to facilitate the monitoring of major component and/or activation status shall be performed at site.

4.15.4 Water Mist System

When required by BPS, complete Water Mist system shall be provided. For operation & maintenance requirement, the complete system shall be of USA/Canada/Europe/Japan originor other eligible countries with equivalent quality.

4.15.4.1 General

4.15.4.1.1 A water mist system is a fire protection system which uses very fine water sprays (i.e. water mist). The small water droplets allow the water mist to control, suppress or extinguish fires by:

- cooling both the flame and surrounding gases by evaporation
- displacing oxygen by evaporation
- attenuating radiant heat by the small droplets themselves

4.15.4.1.2 The effectiveness of a water mist system in fire suppression depends on its spray characteristics, which include the droplet size distribution, flux density and spray dynamics, with respect to the fire scenario, such as the shielding of the fuel, fire size and ventilation conditions.

4.15.4.1.3 The use of water mist fire suppression, shall have following characteristics:

- Proven performance
- Immediate activation
- High efficiency in the suppression of a wide variety of fires
- Minimized water damage
- No toxic problems
- Quick control and suppression of fire
- Efficient cooling preventing the fire from spreading
- Low water usage, minimal damage and downtime
- Safe for people and Environmentally sound characteristics
- Small stainless-steel piping and water supply to spray heads
- Easy installation
- Fully scalable to cover new protection needs

4.15.4.1.4 The NFPA 750 defines three pressure regions for water mist-generating technologies: low, intermediate and high pressure systems. Among different types, High pressure HI-FOG technology shall be used for transformer Fire detection & suppression agent. HP-HIF has the following benefits:

- Better penetration into the seat of the fire
- Superior coverage of the protected volume
- An improved cooling effect from better mixing of gases and high evaporation rate

- Lower overall system weight
- Less water consumption

4.15.4.1.5 Since oil is a combustible liquid, when a transformer fault or failure occurs, the transformer itself can provide both the ignition source, and fuel for a fire. Once ignition occurs, the oil will sustain combustion until thoroughly consumed, unless oxygen is depleted or significant cooling is applied to limit the fire from propagating. The technical characterization of a flammable liquid fire is a Class B Fire. Class B fires have hazards primarily associated to the fuel loading, fuel configuration, flashpoint, and burning rate of the fuel.

4.15.4.1.6 Note that, the fine (that is smaller than 400 microns) droplets are essential for extinguishment of Class B (flammable liquid) fires.

- FM Approval Standard for Water Mist Systems Class Number 5560.

4.15.4.2 System Operation

4.15.4.2.1 Upon fire detection, the fire detection and control panel shall provide a signal to the control system for the water mist system activation. The water mist control signal shall remain energized for 15 seconds (the system control valve is a self-latching/self-resetting valve).

4.15.4.2.2 A single unit of water mist system shall protect a single transformer. For more than one unit of transformer placed side by side, the second unit shall not be activated until fire is caught in the second unit.

4.15.4.2.3 The system shall discharge completely over a period of minimum 10 minutes. However, when design requires longer time (i.e., for larger transformer) , the same shall be provided.

4.15.4.3 Principle of Extinguishment

4.15.4.3.1 The extinguishment of fire by water mist is based on the principles of cooling and oxygen depletion. Based on the triangle of fire, i.e., fuel, oxygen and heat, if any of the three elements is removed, the fire should in principle extinguish itself. It is necessary however that the cooling be not only of the fuel, thus the evaporating combustible fumes, but that also of the radiant heat which will prevent re-ignition from taking place.

4.15.4.3.2 Fire shall be detected at the very initial stage using fire detection system. Immediately after detection, stored water mist shall be sprayed over the transformer body.

4.15.4.3.3 The water mist shall be drawn into the fire by the air, where due to the high heat, it quickly evaporates. Actually, after spraying, when the water droplets come into contact with the fire, they extract the heat until they evaporate. As the water droplets evaporate, there is enormous increase in the volume of the water droplets & sub-sequently, the oxygen is displaced at the source of the fire. The large water surface formed by the small droplets creates the conditions for an optimal exchange of energy between the water mist and the surrounding area. Of all known extinguishing materials, water has the highest evaporation enthalpy (2442 J / g). A complete void shall be created to evacuate oxygen from transformer fuel so that fire is self-extinguished.

4.15.4.3.4 Water mist shall be sprayed at high pressure (500-4000 psi) & water mist (droplet size 10-100µm) shall be created before spraying.

4.15.4.3.5 The water droplet shall have a volumetric diameter where Dv0.99 shall be less than 100 µm at the beginning of the discharge and it shall not be more than 50 µm after eight minutes of discharge.

4.15.4.3.6 Three major characteristics establish the uniqueness of every water mist system: droplet size, flux density and spray momentum. A high pressure system offers the advantage of a finer and more efficient water droplet combined with the high pressure discharge which translates into higher momentum and more efficient fire plume penetration.

4.15.4.3.7 The relativistic aspects of the drop size are also very important. Therefore for larger fires, larger droplets (100 µm) are essential while for smaller fires it is very important to have a large fraction of smaller droplets than can easily be entrained by small, less dynamic flamelet type or residual fires (these flamelets can be the source of re-ignition if not completely extinguished).

4.15.4.3.8 The water mist shall effectively suppress the fire and avoid spreading of fire to next transformer or further area of substation even under turbulent air flow that typically occur during typical transformer fire.

4.15.4.4System design

a) <u>Fire detection system</u>

Ensuring high sensitivity to fire, the system shall use different types of detectors such as smoke

detectors, linear heat detectors, flame detectors and air sampling devices.

b) Smoke detector

Smoke detector shall be provided to detect even the minutest particle of smoke, they instantly raise the alarm in the event of a fire by alerting the control panel.

c) Heat detector

In a fire situation, the increase in temperature triggers heat detectors in seconds. Heat detectors are of two kinds, rate-of-rise and fixed temperature detectors.

d) Linear Heat Detector

A line-type form of fixed temperature heat detection. Fiber optic type heat detector shall be used for effective heat detection.

e) Air Sampling Device

Suitable sampling device shall be provided or fine operation of the detection system.

These detection devices shall communicate with the control panel, sending a signal that activates the system the very second a fire is detected.

f) Fire suppression Water Mist Extinguishing Agent

This mist is thrown at the transformer fire with a great kinetic force, covering a large surface area. As soon as the mist comes in contact with the fire, it instantly turns into steam. Enveloping the flames, cutting down the oxygen supply and reducing the temperature to below combustion levels. Ensuring that even the largest transformer fire succumbs to Water mist technology in minutes

The system shall be fitted with water reservoirs designed for high pressure operation (up to 4000 psi). The maximum volume of water, for every 10 minutes of protection required.

The system shall use water which meets the manufactures requirements. As a minimum the water shall meet the following requirements:

- Equivalent of a potable water supply
- Colorless and odorless
- Non corrosive
- Chloride concentration < 50ppm (=50mg/l)
- pH value 7.0 – 9.0
- Iron (Fe) and Manganese (mN); sum < 0.3mg/l
- No free chlorine

g) Nozzle

Nozzle/Spray Heads shall be listed or tested for the intended application, or Approved by the Authority Having Jurisdiction (AHJ). Each spray head shall be fitted with a screen to prevent particles from interfering with the normal operation of the spray head. The water mist spray heads shall produce a droplet size in the range of 100 µm at the maximum operating pressure of i.e., spray head pressure and a droplet size of approximately 50 µm at the nominal operating pressure of 40 bar/manufacturers' designed value.

h) Pipes & Fitting

Galvanized pipe shall not be used for any part of the water mist system. Metric Stainless Steel Tubing shall be used for all system piping. Use only metric size tubing meeting European DIN standards, in order to permit connection to European manufactured water mist system fittings including distribution blocks, sectional control valves, ball valves, and nozzle mounting adapters. Maximum hardness of stainless steel tubing shall be HRB 90.

i) Pipe and Tubing Supports

Pipe supports for welded stainless steel piping shall conform to the hanging requirements of NFPA 13 and ASME B31.1. Construct stanchions, straddle supports, and trapeze supports based on hanger spacing, span and minimum load capacities in NFPA 13.

Supports for stainless steel tubing shall comply with ASME B31.1 and the manufacturer's recommendations with respect to spacing. Where obstructions make it impossible to comply with spacing limits for tube supports, the distance between supports may be increased by 75 percent, provided that there are no fittings or changes in direction between the two supports.

Tube clamps shall be non-combustible Ermeto Original series A components for normal mechanical stress, or equivalent. Utilize compatible mounting rail attachments with lock nut and locking plate where necessary.

j) Valves

Valve type and size shall be in accordance with the design drawings. Drain valves are located at the base of each system riser and at the extreme end of each water mist piping system. The discharge control valve shall be designed to fit directly to the outlet port of the nitrogen cylinder hand wheel valve (an adaptor may be required or used) and it shall be of the latching/self-resetting type.

k) STRAINERS AND FILTERS

Comply with the requirements in NFPA 750 for filters and strainers on the water supply connection.

l) Alarm

The water mist system installer shall provide and install all monitoring, supervisory and alarm devices that attach to the MAU, control valves, or water mist piping system. The contractor responsible for work shall connect the devices to the fire alarm system.

m) Control Panel

At the very heart of the system is a control panel. On being alerted by the detectors, this state-of-the-art control panel instantly sends a signal to activate the system and release the extinguishing agent.

n) Water management Pump driven system

The Pump Driven System shall be provided, Cylinder systems is not acceptable. Water, the principal component of this extinguishing agent is stored in a reservoir/tank that is connected to a pump. high-pressure water mist pump system has a modular design and consists of one or more robust triplex plunger pumps, a break tank and a control cabinet. If necessary, the system is supplemented by a jockey pump and compressor.

On receiving a signal from the control panel a high-powered pump propels water from the water reservoir/tank quickly and efficiently to the pipes and nozzles. This system generates high volumes of Water mist, ensuring higher firefighting effectiveness without using much water.

o) Storage

Water may be stored underground or over-ground as per standard design & Engineers approval.

High pressure water tank inside surface shall be plastic coated. The capacity shall be designed & suitable for complete fire suppression of transformer fire. When required by the design higher capacity shall be provided.

The discharge manifold shall be fitted with a pressure switch rated for 50 bar (750psi)/manufacturers' designed value to close upon system discharge and pressurization.

The water cylinders shall be maintained under normal atmospheric pressure until such time as the system is activated and the nitrogen is released.

The sprayed water mist shall be stored beneath the transformer and accumulator tank/area shall be provided so that after spraying water will be collected here. From the accumulator, the water shall be drained out to the substation drainage system.

4.15.4.5Drawings and Manuals

All Design drawings shall be submitted for Employers approval during detail design stage. Typical design-drawings are as follows;

- System Layout
- Component specification
- Bill of Material (BoM)
- Control Panel Drawings
- Calculation for storage tank & pump capacity, pressure selection
- Pipe-fittings selection
- Control logic/electrical schematic diagram etc.

Moreover, Shop drawings shall be submitted and shall include but not limited to: space layout, piping layout and nozzle location.

The system layout, specification of the system & Bill of Material (BoM) shall be provided with the bid.

4.15.4.6 Operation and Maintenance Manual

1. Submit written instructions on how to operate and maintain the system

2. Provide a Matrix of Scheduled Maintenance Actions for inspection and maintenance requirements in conformance with NFPA 750, NFPA 25, and the Manufacturer's recommendations. Identify actions for weekly, monthly, semi-annual and/or annual intervals.

A CD containing the design drawing & instruction manual shall be provided.

4.15.4.7 Qualifications

1) **Manufacturer**shall have the following background:

- Specialist in manufacturing water mist nozzles and high-pressure pumping equipment and valves for water mist fire protection systems.
- Demonstrated evidence of fire tests of their equipment conducted to FM Approval Standard 5560 fire test or other international protocols for applicable fire hazards.
- Full-scale test shall be available to show that the system provides effective suppression of transformer fire.

2) **Sub-vendor**

The company carrying out the installation must be experienced in the installation of high-pressure water mist systems and be authorised by the manufacturer of the offered system. Corresponding certificates of training in theory and practice, as well as proof of successfully performed reference projects which are comparable to the offered application are required.

Moreover, membership of professional associations such as the IWMA (International Water Mist Association) and FIA (Fire Industry Association UK) is required.

The installation company and any significant subcontractors and supplier must be certified for all of the offered scopes of services according to ISO 9001. Insofar as design and/or installation work is carried out by subcontractors, references relating to comparable risks with high-pressure water mist systems are to be requested from the subcontractor.

Moreover, the quality of the project design/installation documents and drawings, as well as hydraulic calculations, shall be verified.

4.15.4.8Automation

The HFWM must be integrated with the SAS to check the functional status of the system. Necessary works to facilitate the monitoring of major component and activation status to the SAS shall be performed at site.

4.15.4.9 INSPECTION AND TESTING

System acceptance tests shall comply with NFPA 750, NFPA 25, manufacturer's acceptance test recommendations and the requirements of this section.

The test procedures may include the following (as applicable):

1. Visual quality check of installation of nozzles, pipes, tubing and hangers,
2. Pneumatic and Hydrostatic Tests,
3. Review of Mechanical Components,
4. Review of Electrical Components,
5. Preliminary Functional Tests, and
6. System Operational (Discharge) Tests.

4.15.4.10Tubing and Supports

1) Visual Inspection

1. Hanger details including support fastening to walls, ceilings, ceiling structure, tube clamp spacing and nozzle supports shall be inspected for conformance to recommended practice and the details of this specification.
2. Repair or replace all hangers and tube supports that do not meet the requirements of this specification.
3.

2) Hydrostatic Testing

1. Test all piping and tubing hydrostatically in accordance with the requirements of NFPA 750.
2. Vent air from the system piping and tubing as it is filling with water.
3. Repair all leaks revealed through the hydrostatic test and retest until the test pressure remains stable for the duration of the test.

4.15.4.11System Commissioning

A representative of the manufacturer or trained authorized Distributor shall be present for the commissioning of the system. The commissioning of the system shall be coordinated with the contractor responsible for the work and the AHJ.

Commissioning shall be performed in accordance with a written procedure which has been reviewed and approved by the system manufacturer.

4.15.5Compressed Air Foam System (CAFS)

When required by the schedule of requirement, the Contractor shall provide the CAFS (Compressed Air Foam System) arrangements specified below:

The Compressed Air Foam System design shall also conform to NFPA 11.

The compressed air foam system shall be provided with selection valve station including the necessary control and monitoring cabinet to be capable of extension to serve in total of transformer units in each substation.

The compressed air foam system is to be designed for manual, automatic and electrical remote operation and must be provided in the package type and equipped inside house (with temperature control system to protect itself from the external environment), with the following basic equipment:

Water tank and Foam concentrate tank shall be installed and pre-mixed foam system is not accepted. Fire water and Foam concentrate is stored separately, and water driven type foam proportioning unit shall be installed.

4.15.4.1 CAFS Package includes:

- PLC based CAFS Control Panel
- Foam Proportioning unit : water turbine drives a positive displacement foam concentrate pump. Ratio 3%
- CAF Mixing Chamber Unit : Foam Solution to Air Ratio = 1:7
- Compressed Air Cylinder Unit : Compressed air cylinders pressurized to 200 bar. Each cylinder is supplied with a cylinder valve equipped with a safety relief disc which provides relief at 300 bar.
- And cylinder valve should be closed normally. The method of open the cylinder valve should be electromagnetic two actuators (main and stand-by), not CO2/N2 actuating unit. (for reliable, open operation)
- Air pressure regulators are used to reduce the air pressure to a working pressure for the CAF system operation. The cylinders unit is factory assembled on a painted steel skid and includes regulator box with stainless steel for safety protection.
- Water Storage Tank : Water storage tank stored inside a normally non-pressurized stainless steel pressure vessel type tank stamped according to ASME Section VIII Div. 1.
- Storage tank maximum working pressure is 10 bar. The tank is supplied with a safety relief valve for protection against over-pressurization and also with a two-points level switch. (1st point : Low-level alarm when water less than required, 2nd point : A spraying CAF is stopped automatically when running out of water)
- Foam Concentrate Storage Tank : Stainless steel atmospheric pressure tank
- No Pre-mixed type : Foam solution should be made with Foam Proportioning unit.
- Internal stainless steel pipe & valves, instruments shall be double-structured.
- CAFS control panel : for manual, automatic and electrical remote operation.
- The UPS shall be built in CAFS control panel.

<Other components>

The required number of CAF nozzles

The required number of selection valves

The required amount of foam concentrate (AFFF 3%)

The required CAF discharge rate shall be 1.63 lpm / m2 (foam solution). The required CAF volume shall be considered for spraying for any one unit of the power transformers.

The compressed air foam system is to be designed for a minimum spraying time of 10 minutes and is to be fully equipped with all equipment essential for trouble-free operation.

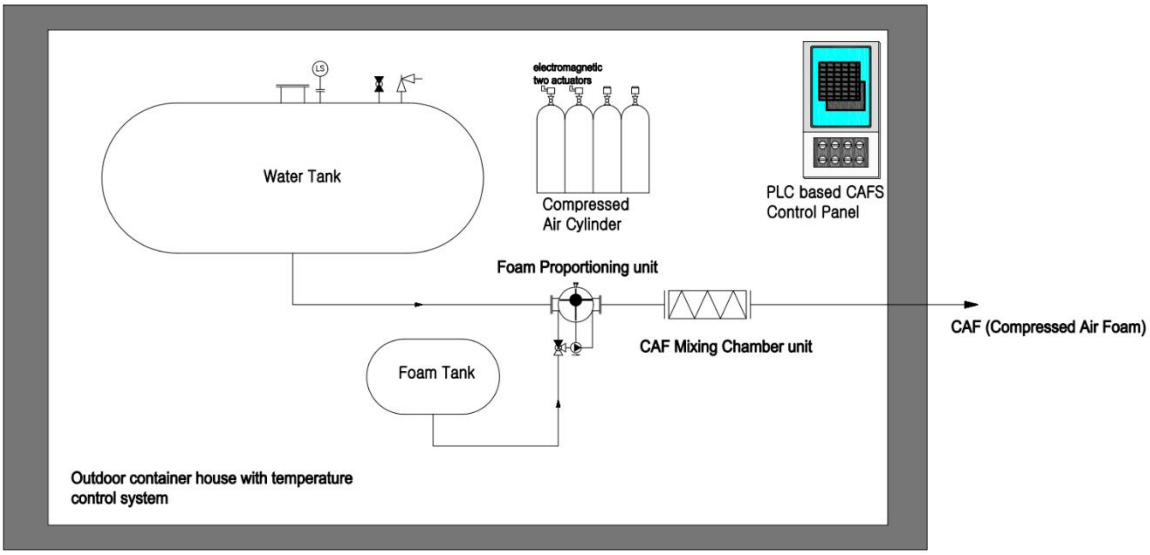
In the event of a fire by external causes such as bushing fire, OLTC fires, fire from surrounding equipment etc., it shall act as a fast and effectively.

For quality and maintenance requirements, the Compressed Air Foam Systems (CAFS) shall be from Europe/USA/Canada/Korea/Japan origin or other eligible countries with equivalent quality. And the supplier of CAFS must have a delivery record (including installation) of CAFS for more than ten (10) power transformers (over 50MVA each) within the last three (3) years.

4.15.4.2 Automation Requirement

The CAFS must be integrated with the SAS to check the functional status of the system. Necessary works to facilitate the monitoring of major component and/or activation status shall be performed at the site.

<Reference Drawing>



4.15.6 Fire Wall

A firewall of suitable height shall be installed between the transformers to prevent transformers from the spreading fire. The wall shall be made of reinforced concrete.

The fire wall design shall conform to NFPA 851.

4.16Oil for transformer and tap-changer

4.16.1Type and quality

4.16.1.1 Only new naphthenic-based mineral oils, which must be certified as such prior to filling, shall be used.

4.16.1.2 Where the first filling of virgin oil is to be supplied by the contractor, the oil shall at least be as specified in IEC 60296-class II, without any additives such as corrosive sulphur and PCB. It shall be acid-refined and pre-treated and shall have properties complying with IEC 60296-class II.

4.16.1.3 Under no circumstances shall poor quality oil be filled into the transformer and subsequently bringing up to specification by circulation within the transformer.

4.16.1.4 The transformer oil shall be power grade and shall be from approved manufacturer. Acceptable manufacturer are Nynas AB, Midel, Cargil, Eargon Inc. or equivalent.

4.16.2 Dielectric strength

4.16.2.1 The power frequency dielectric breakdown strength of the oil in any part of the transformer and on-load tap-changer shall not be less than 60 kV / 2.5 mm for virgin oil prior to filling, and not be less than 50 kV/2.5 mm at time of take over.

4.16.2.2 Dielectric strength shall be determined in accordance with the method prescribed in IEC 60156.

4.16.3 Moisture content

4.16.3.1 The moisture content of the oil before filling the transformer and on-load tap-changer shall not exceed 10 ppm. At time of takeover, the moisture content of the insulating oil shall not exceed 20 ppm in the main tank and the on-load tap-changer compartment. The requirements of Oil sampling and testing shall be met and if not achieved, drying / filtering of oil needs to be undertaken.

4.16.3.2 It shall be demonstrated that the moisture content in the paper insulation body of the transformer is less than 1 %. The test to verify the moisture content must be to internationally accepted standard methods for determining the moisture in paper.

4.16.4Degree of polymerisation

4.16.4.1 After dry out, the manufacturer is to provide the degree of polymerisation (DP) value of the paper. Minimum value is 950 DP. The paper used shall be thermally upgraded paper.

4.16.5Oil sampling and testing

4.16.5.1 Units with a highest voltage of 132 kV and above One sample is required in each of the following cases:

i. during testing in the factory:

a particle test shall be performed before and after each filling of the transformer for factory testing. The particle count in oil shall be less than 1000/10 ml for particles less than 2 µm.

ii. **at time of take over:**

all units delivered to site without oil, at least 7 days after in-situ oil processing has been completed, to test for dielectric strength, dissolved gas analysis (DGA), and acidity (A), but with the main emphasis on water content. Samples taken sooner will not necessarily reflect the correct water content (WC).

4.16.5.2 Units with highest voltages below 132 kV

Routine oil sampling and DGA of transformers in this group is normally not required, but this will be done at the discretion of the user (i.e. sampled on a "need only" basis). However, one sample to test for DS and WC, is required for acceptance purposes; before despatch from the manufacturer, or before commissioning on site. Records of the oil sample results shall be kept for future reference purposes.

4.16.5.3 On-load tap-changer diverter switches (all voltage categories)

A sample, to test for WC and DP only, shall be taken before commissioning and thereafter annually. This sample shall be taken from the tap-changer diverter conservator or diverter drain valve.

4.16.6 Oil-filling/impregnation under vacuum

4.16.6.1 When a transformer is designed to be oil-filled under vacuum, an instruction to this effect shall feature prominently on the rating-and-diagram plate or on a separate plate mounted adjacent to it.

4.16.6.2 All transformers installed in vacuum-proof tanks shall be oil impregnated and filled under vacuum.

4.16.6.3 Oil impregnation or drying under vacuum shall be done with the transformer and oil at a temperature of at least 60°C.

4.16.6.4 The duration of the treatment shall be such that is results of the in moisture content is as specified in clause 4.3.3 – Moisture content.

4.16.6.5 Procedures shall be submitted for approval and full instructions shall be includedin the transformer manual.

4.16.7 Preservation system

4.16.7.1 See clause for the detail requirements of the conservator systems.

4.16.8 Poly Chloride Biphenyls (PCB) content

4.16.8.1 All oils used in the transformer and its accessories shall be free of PCBs (zero ppm). A formal test certificate to this effect shall be included in the transformer manual.

4.16.9 Contact with bare copper

4.16.9.1 Bare copper in contact with transformer oil shall be minimised by using appropriate paper covering or painting.

4.16.10 OilTreatment Plant

The Contractor shall supply oil treatment plant for the treatment of insulating oil for the initial filling of transformers at Site and handed over the same to Employer at the end of work. The oil treatment plant is to be mounted on a steerable trailer equipped with pneumatic types, over-run and parking brakes and weatherproof canopy. The plant shall be capable of treatment of oil to IEC 60296 and IEC 60422, shall be of the replaceable paper filter type and shall have the following facilities:

(A) Oil treatment rate not less than 10,000 litres per hour.

(B) Water extraction capability down to 5 ppm.

(C) Reduction of dissolved gas content to 1% by volume or less.

(D) Filtration level less than 1 micron.

(E) Oil transfer, vacuum pumps and heaters suitable for 400V, 3Φ 4w 50Hz supply.

(F) Vacuum capability approximately below 1 Torr.

(G) Facility to apply vacuum to transformer tank during oil filling.

(H) Two 15m lengths of wire reinforced hose coloured differently for clean and dirty oil.

(I) Facility for "closed loop" operation.

(J) One 20m length of power supply cable with plug and socket at the filter end only.

4.16.11 Oil Storage (Tanks and Bags)

As required by Clause 4.16.1, the Contractor shall supply the first filling of transformer oil. It is envisaged that the oil will be supplied to site in 200kg drums and filtered by use of the plant described in the preceding paragraph into a storage tank prior to transfer again via filter plant into the transformer. Storage tanks shall be painted internally and externally and shall be equipped with:

- 50mm top inlet and bottom outlets with blank flanges.
- 50mm drain valve.
- Oil level indicator.
- Manhole.
- Silica gel breather.

Contractor shall also provide a rubber oil bag (pillow type) for MRE at Kaliganj substation, which shall be able to contain the oil capacity more than the oil quantity of the biggest transformer.

- Made with special high strength PVC or Urethane coated fbrics, such as polyester, nylon, and Kevla.
- Collapsible and can be folded for easy storage and transportation
- All fittings are made from cast anodized marine grade aluminum and stainless steel fasteners.
- Hose connections are generally camlock type and the connection sizes may vary depending on the end-user application for load and offload operations.

4.16.12 Oil Insulation Tester (Oil breakdown test)

Portable Oil Insulation Testers shall be provided to check for determining the dielectric strength of mineral and synthetic insulating oils. The testers determine the oil breakdown voltage (BDV) in a fully automatic mode and feature a built-in printer for printing out test results. The testers are also equipped with the means of stirring and determining the temperature of the oil sample (up to 125℃) which ensures compliance with the requirements of the majority of the national and international oil testing standards.

- Test voltage up to 20~80 kV

- Automatic test cycle
- Support of wide selection of standards (IEC 60156:2019, GOST 6581-75, etc.)
- Highly accurate results
- Integrated printer, stirrer and temperature sensor
- Test report storage and exporting to PC
- Portability and low weight (<25kg)

4.17 Inspection and Testing

Tests shall be carried out in order to determine whether the material and equipment complies with the required properties. All tests on materials and equipment shall be made in accordance with IEC standards 60076. Testing shall not impair the properties and reliability of a test object or reduce its lifetime. Test shall be performed at all power transformers.

4.17.1 Factory Acceptance Tests

Factory acceptance tests shall be carried out at the Manufacturer's laboratory, following a mutually agreed programme, in presence of Employer's authorized Engineer.

4.17.1.1 Type Tests

The following type tests shall be conducted on the first power transformer of in a single FAT schedule:

- Temperature rise test.

  The temperature rise test must be carried out in a manner that the highest losses are generated (tap changer in the highest loss position) and the reserve cooling unit is not in operation.

- Sound level measurement test

4.17.1.2 Routine Tests

Routine tests will be performed to detect defects in material or construction. They shall not impair the properties and reliability of any part being tested or reduce its lifetime. The following routine tests shall be performed:

1) Visual inspection and dimension verification
2) Power transformer tank oil leakage test
3) Corrosion protection check
4) Autotransformer tank vibration test
5) Jacking pad test - checking of tank by lifting of power transformer

6) Welding check after jacking pad test
7) Oil dielectric strength
8) Winding resistance measurement
9) Transformation ratio measurements and winding connection verification
10) Measurement of winding insulation resistance (before and after dielectric tests)
11) Core insulation measurement (before and after dielectric tests)
12) Switching impulse withstand voltage (SI)
13) Impulse voltage test; primary voltage, secondary voltage, tertiary, including neutral point (LI)
14) Impulse chopped voltage (LIC)
15) Power frequency withstand voltage test, 50 Hz , 1 min (winding, core and secondary equipment)
16) Short-duration induced AC withstand voltage test (ACSD) with monitoring of partial discharges.
17) Long-duration induced AC withstand voltage test (ACLD) with measurement of partial discharges.
18) Measurement of no load losses and no-load current at rated frequency before and after impulse test.
19) Dissolved gas-in-oil analysis by chromatography prior to dielectric tests, after completion of dielectric tests and prior and after the temperature rise tests.
20) Tap changer test for no load and short circuit conditions.
21) Functional tests of protection devices and related equipment.

4.17.1.3 Special Tests

Within the factory acceptance test, the following special tests shall be performed:

1) Measurement of zero-sequence impedance.
2) Measurement of no-load current harmonics.
3) Measurement of magnetizing current.
4) Measurement of power consumption for cooling system.
5) Measurement of capacitance (C), factor of dielectric losses (tgδ), (before and after dielectric testing).
6) Measurement of the mutual inductance of the winding.
7) Sweep frequency response analysis (SFRA).
8) Measurement of transferred overvoltages.

Note: The transformer's capability to withstand thermal and dynamic effects of short circuit without any damage should be presented by design analysis and calculation.

4.17.2 Detailed Testing Requirements

4.17.2.1 All applicable standard and special test requirements shall apply to each transformer, whether manufactured separately or at the same time as other identical units. Data from identical or similar transformers is not acceptable.

4.17.2.2 Transformers shall be fully assembled including all auxiliary devices, surge arresters, DGA monitoring equipment, conduits and the wiring of the control cabinet, (the transformer shall be completely assembled and ready for energization) before testing.

4.17.2.3 All test results, measurements, and calculated values shall be recorded on the supplier's certified test report.

4.17.2.4 The Employer shall have the option of witnessing all tests. The Seller shall advise the Employer at least two weeks in advance of test dates so travel arrangements may be made.

4.17.2.5 In the event of a test failure, no corrective action shall be taken until authorized by the Employer.

4.17.2.6 In no case shall a transformer be shipped without clearance from the Employer if test values do not meet the requirements of this specification or other requirements stated in the purchase order.

4.17.2.7 If a Z-winding is specified, whether the terminals are specified to be brought out or buried, the Z-winding voltage and capacity ratings shall be shown on the test report.

4.17.2.8 The following tests shall be performed on each unit in accordance with IEC Standards 60076-1

1) Transformer winding resistance measurements of all windings at all winding tap positions shall be taken for each phase of each winding and included in the test report.

2) Transformer turns ratio tests shall be performed at all tap positions listed in IEC Standard 60076-1. The applied voltage, the calculated ratios for each tap position and the measured ratios for each phase of each connection shall all be included in the test report.

3) Polarity and phase relation tests shall be performed, and the phasor diagram shall be included in the test report.

4) Excitation (no-load) loss tests shall be performed at the rated voltage tap by the "Three Wattmeter Method" as in IEEE C57.12.90-2015 or as per IEC 60076-1.

- No-load losses shall be recorded prior to dielectric testing and then again after dielectric testing has been completed. Both test readings shall be included in the test report. Temperature corrections shall be reported as per IEC standards 60076-2.
- No-Load Loss measurements shall be taken at rated voltage of the tap position which results in maximum excitation of all cores. (At an LTC position that results in the series transformer and/or preventive autotransformer being excited at 100% rated voltage. i.e. at 16R when only a series transformer is provided, at 15R when both series and PA transformers are provided, or 1R when only a PA is provided.)
- Excitation current measurements shall be taken at 100% and 110% of the rated voltage.
- Current readings for each phase at both voltage levels shall be included in the test report. These current values shall be recorded prior to dielectric testing and then again after dielectric testing has been completed.
- A one-hour core excitation test shall be performed after the completion of all dielectric tests at rated frequency and 110% of the rated voltage. All cores shall be excited to 110%. Therefore, the test shall be performed at an LTC position that results in series transformer and/or preventive autotransformer being excited at 110% rated voltage.
- The one-hour core excitation test shall be followed by the No-load loss test after dielectric.

5) Cooling system loss measurements shall be taken at all stages and shall be included in the test report.

6) Impedance and load loss measurements shall be taken using the three-watt meter method (IEEE C57.12.90) at all tap positions listed in IEC 60076-1.

   All measurements shall be performed at the base nameplate and maximum 65°C rating for that tap position and recorded in the test report.

   Impedance and Load Loss data shall be included in the test report for the following tap positions:

   - HV at Tap “1” or “A” – LV at Neutral
   - HV at Tap “2” or “B” – LV at Neutral
   - HV at Tap “3” or “C” – LV at Neutral
   - HV at Tap “3” or “C” – LV at 9a (If LTC provided)
   - HV at Tap “3” or “C” – LV at 9c (If LTC provided)
   - HV at Tap “4” or “D” – LV at Neutral
   - HV at Tap “5” or “E” – LV at Neutral

The transformer's actual impedances for each OLTC tap shall not differ from the quoted impedances by more than IEC tolerances.

7) Zero Sequence impedance measurements shall be taken and shall be included int he test report.

For Wye-Wye transformers, zero sequence impedance measurements shall be taken in accordance with IEC60076-1. A "T" network diagram shall be included in the test report and shall include complex values for Z1, Z2, and Z3. Complex values shall be shown as %R and %jX at base MVA.

8) Temperature tests shall be performed on each transformer.

- Each transformer shall be tested in accordance with this spec. Test data from a "thermal duplicate transformer" is unacceptable
- Tests shall be performed at the HV and LV tap positions that produce the highest losses.
- A standard liquid temperature rise test shall be performed per IEC 60076-2 at the current required to produce total losses. The test report shall include the top oil temperature and the bottom oil temperature rise above ambient temperature. The test report shall also include the ambient temperature during the test.
- A standard temperature rise test shall be performed per IEC 60076-2, using constant rated current. The average winding temperature rise shall be reported for both ONAN rating as well as top nameplate rating (ONAF/ODAF), and shall not exceed 55°C by resistance measurement and 95°C for hot spot winding temperature. The test report shall include the calculated hottest spot temperature for maximum rating. The test report shall also include the ambient temperature during the test.
- During factory testing, the radiators that will be supplied with the transformer shall be completely assembled and installed and used for cooling during tests.
- Calibration information for the winding temperature devices shall also be included in the test report. The test report shall include the set-points of the devices used to initiate auxiliary cooling equipment.
- Thermovision (infrared) photographs shall be taken during the heat run, and shall be included in the test report.

9) Sound level tests shall be performed on each transformer and shall be in accordance with NEMA Publication TR1 and IEC Std 60076-10.

- Guaranteed sound levels shall be at 100% rated voltage, at rated HV tap and at the LV tap position that produces the highest noise level.
- Transformers with reactance LTC's shall have their sound level measured at an LTC position that results in the Preventive Autotransformer being excited.

- Where a "Booster" or "Series" transformer is provided, the sound level shall be measured at an LTC position that results in the "Booster" or "Series" transformers being fully excited (LTC position at an extreme).
- Test data from a duplicate unit is unacceptable.
- All values recorded for the sound level shall be included in the test report.
- The test report shall include the type of meter used, and a diagram of the test point locations.

10) Switching Impulse testing.

- Switching surge tests shall be performed on each transformer with windings rated 110 kV or higher.
- Switching surge tests shall be applied to each high voltage terminal in accordance with IEC Standard 60076-3.
- Transformers with multiple voltage connections (series-parallel) shall be impulse tested in the parallel configuration.
- DETC/OLTC shall be set at the minimum voltage tap position.
- The switching surge voltage transient shall be a relatively smooth uni-directional wave of negative polarity.
- The test report shall include test wave characteristics and copies of oscillographs captured during the testing of each phase.
- Oscillographs shall include timescales and data showing Time to Peak, Time Above 90%, and Time to Zero.

11) Lightning Impulse testing.

- Lightning impulse tests shall be performed on each transformer.
- Impulse tests shall be performed on each and every line terminal individually.
- Impulse tests on all line terminals and neutral terminals (X0 and H0 where provided) shall be performed in accordance with IEC Standards 60076-1&3
- Windings with multiple voltage connections (series-parallel) shall be impulse tested in both series and parallel configuration, regardless of voltage class.
- Windings with connections for either Delta or Wye configuration shall be impulse tested in both Delta and Wye configuration.
- For HV winding impulse tests, the DETC shall be set at the minimum voltage tap position.
- For LV winding impulse tests, the LTC (where provided) shall be set at the minimum voltage tap position.
- Tests shall include reduced full-wave 50%, chopped wave, and full-wave tests. The test report shall include wave characteristics and copies of oscillogram films taken during each test. The test report shall also include a copy of the wave comparisons or overlays for the reduced full wave and full wave traces for each terminal tested.

12) Low-frequency dielectric tests

- Applied potential test shall be performed in accordance with IEC 60076
- Induced potential testing accompanied by partial discharge (corona) monitoring shall be performed in accordance with 60076 , with the following additional criteria:
    a. The de-energized tap-changer shall be set on the full winding tap for these tests and actual readings taken shall be included in the test report.
    b. The Test Report shall show the RIV and PD results as well as the actual test voltages.

13) Doble single phase excitation test.

- Excitation current measurements of the high-voltage windings at their full winding tap shall be taken for each phase. Tests shall be performed for LTC transformer as follows:
- HV at full winding tap, LV at neutral.
- HV at full winding tap, LV at maximum raise position.
- HV at full winding tap, LV at maximum lower position.
- HV at full winding tap, LV at 9a or 9c position (reactance type LTCs only).
- The high- voltage side shall be excited to a potential (approximately ten kilovolts) which will produce an exciting current that is not to exceed 200 milli amperes.
- The test report shall include the excitation current value for each phase.

14) Insulation power factor and capacitance tests shall be performed in accordance with IEEE Standard C57.12.90, Method II (Test with Guard Circuit)/ IEC 60076.

- Transformers with delta tertiary stabilizing windings shall be tested as “three-winding transformers.”
- Test results for “Two-Winding Transformers” or “Three-Winding Transformers” as appropriate shall be included in the test report.

15) Winding insulation resistance tests shall be performed.

- Transformers with delta tertiary stabilizing windings shall be tested as “three-winding transformers.”
- Test results for “Two-Winding Transformers” or “Three-Winding Transformers” as appropriate shall be included in the test report.

16) Doble SFRA Testing:

Doble SFRA tests shall be performed on every transformer as follows:

- Tests shall be performed with a Doble M5000 series test set. SFRA tests using othe rmanufacturer’s equipment are not acceptable.
- Tests shall be performed in accordance with Doble’s SFRA Power Transformer Test Specification.

- A CD ROM shall be provided which includes all test files for electronic comparison with future test results.
- Sketches shall be provided showing test set-up with all equipment identified.
- Both open-circuit tests and short-circuit tests shall be performed for the following winding connections for each phase (9 tests per tap configuration):
- HV Winding at maximum tap and LV winding at maximum tap (LTC at maximum boost position)
- HV Winding, at maximum tap and LV Winding at LTC Neutral position.
- For transformers with a reactance-type LTC, an additional set of tests shall be done with the LTC in a bridging position (with preventive autotransformer excited). Position 15R is suggested, but the manufacturer may select an alternate bridging position if it would provide more informative results.
- For Wye-Wye transformers with the corner of the buried delta tertiary brought out and completed externally, one test shall be done on the tertiary winding (Ya-Yb, with all other bushings floating.)

17) Controls and wiring check, including but not limited to the following:

- Point-to-point wiring check.
- CT tests: Ratio, Polarity, Resistance and Hi-Pot. Also verify wiring to the shorting block in the control cabinet.
- Functional check of LTC operation and voltage control including applying voltage to the LTC control relay.
- Functional check of all alarms.
- Functional check of all other ancillary devices.
- Hi-pot test of control circuits.

18) Other tests to be performed and results included in the Test Report as follows:

a) Tank welds shall be given a pressure test by filling the tank with oil and holding 10 psifor six hours, after which all welded seams shall be inspected for leaks.

b) Certified tests shall be provided for metering accuracy current transformers (when used)at burdens 5P20, 0.5, and 0.2 (as applicable) at secondary currents of 0.1, 0.2, 0.5, 0.75, 0.9, 1.0, and 1.2 amperes Included as part of the test report, CT's shall be identified by correlating each CT serial number with its respective bushing location (e.g., X1, X2, and X3).Metering CT's are to be capable of overloads consistent with transformer overloading.

c) The De-Energized Tap Changer operating mechanism shall be operated through its full range periodically during the 10 psi pressure test and during de-energized periods in test program and the shaft seals shall be checked for leaks, with each such operation logged on the test report.

d) Documentation shall be provided for the metering accuracy of relay-class CT's at burdens of 5P20, 0.5, and 0.2 (as applicable) at secondary currents of 0.1, 0.2, 0.5, 0.75, 0.9, 1.0, and 1.2 amps.

e) A core-to-ground megger measurement shall be made after completion of all tests and shall also be included in the test report. Insulation resistance values shall be included in the test report for each core or core section. (Main core, series core, PA core, etc.)

f) Each bushing shall have its C1 and C2 power factor test performed.

g) Calculated peak inrush current shall be provided with the test report.

h) A minimum of three oil samples shall be taken from the transformer main tank and dissolved gas analysis shall be performed per C57.130. DGA results shall be submitted with the test report. If oil is removed before completion of last test, then gas-in-oil tests shall be made before oil is removed and again after oil is replenished.

i) Samples shall be taken as follows:

i After the unit is filled and before any tests are performed. (All gas levels should be negligible).

ii Immediately after the temperature tests at the maximum force-cooled rating.

iii After all preliminary and Dielectrics testing.

4.17.3 Acceptance Criteria

1) Winding and Bushing power factor:

a) Maximum acceptable power factor is 0.5% or manufacturer's criteria, whichever is lower.

b) For Class I and Class II transformers, the measured partial discharge shall not exceed200 microvolts and 500 picocoulombs during the enhancement level, and shall not exceed 100 microvolts and 300 picocoulombs during the one-hour level.

c) The measured levels of gasses generated during the preliminary and dielectrics tests shall not exceed the limits specified below

Dissolved Gas Limits	
Gas	Maximum Generation Rate (ppm per hour while at rated current)
Hydrogen (H2)	2
Carbon Monoxide (CO)	5
Carbon Dioxide (CO2)	20
Methane (CH4)	1

Ethylene (C2H4)	Non-Detectable
Ethane (C2H6)	Non-Detectable
Acetylene (C2H2)	Non-Detectable

2) The measured levels of gasses generated during the temperature rise tests shall not exceed the limits specified below.

Dissolved Gas Limits	
Gas	Maximum Generation Rate (ppm per hour while at rated current)
Hydrogen (H2)	10
Carbon Monoxide (CO)	30
Carbon Dioxide (CO2)	300
Methane (CH4)	2
Ethylene (C2H4)	Non-Detectable
Ethane (C2H6)	1
Acetylene (C2H2)	Non-Detectable

4.18Shipment , Receiving &Site Testing

4.18.1Shipment

4.18.1.1 Each transformer, when prepared for shipment, shall be fitted with a shock indicator or recorder which shall remain in situ until the transformer is delivered to site. In the event that the transformer is found to have been subjected to excessive shock in transit, such examination as is necessary shall be made in the presence of the Engineer.

4.18.1.2 The transformer shall be shipped with the standard shipping connections as per IEC 60076, unless otherwise specified in the “special requirements” on the data sheet.

4.18.1.3 Factory test data in accordance with this specification shall be provided to the Employer for review and approval prior to shipment:

1) All Dielectric testing results including waveforms and test values.

2) All temperature test results.

3) All Doble test results (single phase excitation test, power factor and capacitance)

4) Impedance, load loss and no-load loss.

5) DGA results.

4.18.1.4 The transformer shall be designed to withstand a minimum shipping force of 2G in the lateral direction, 5G in the longitudinal direction, and 3G in the vertical direction. Shipping terms are delivery to the pad at the location specified in the Data Sheets and as per section above with the Seller to bear all risk of loss or damage while in transit.

4.18.1.5 Bidders shall verify their ability to ship to Purchaser's specified shipping destination and shall submit written confirmation of this with the submission of bids. Shipment of the transformer via truck is preferred.

4.18.1.6 Transformers shall be shipped under at least 3 pounds (at 30°C) positive pressure of breathable quality dry air. A gauge with valves and fittings to permit sampling or adding air shall be provided to monitor air pressure until transformer is filled with oil. Shipping accessories shall include appropriate pipe plug or pipe cap to replace shipping gauge.

4.18.1.7 A recording impact meter with two horizontal and one vertical axis indicator shall be mounted on each vehicle used for shipping the core and coil to its destination. The recording shall be made available to the Customer for review. If meter is not tamper proof then it shall be sealed to show evidence of tampering. Impact meter shall only be opened by the Manufacturer’s representative in the presence of a Customer representative. The recorder shall be capable of recording the entire transport plus 30 days.

4.18.1.8 Shipment shall include one complete set of fresh gaskets to replace all those used on equipment removed after factory testing and two sets of fresh gaskets for all access covers on the tank and tap changer compartments. Gaskets used during factory test and shipping shall not be reused once disturbed. Gaskets shall be packed in plastic bags for protection and identified as to intended location on the transformer.

4.18.1.9 All radiators and associated piping that are disassembled for shipment shall be kept water-tight by using gasketed and bolted metal blanking plates. Pressure vacuum gauges shall be provided by the Seller for the monitoring of gas pressure in the main tank of the transformer during shipping. Gauges shall be mounted so as to be well protected during shipment.

4.18.1.10 Final shipping information and required delivery dates are specified in the Appendix. Delivery earlier than the date listed in the Appendix is not permitted without prior approval from the Employer.

4.18.1.11 Delivery of the transformer and all parts and accessories shall be made on the same day. The Purchaser reserves the right to hold a truck so that all offloading can be done on the same day.

4.18.1.12 The Seller shall email complete packing list of parts to the Engineer at least 48 hours prior to shipment. Packing list shall include number of shipping groups or separate containers, contents of each container, expected date of arrival, shop order number and substation name.

4.18.1.13 No transportation media transfers are to be made without written approval from the Employer.

4.18.1.14 The Seller shall provide satisfactory trip lease arrangements where rail shipments to private rail sidings are used.

4.18.1.15 Where practicable, transformers shall be shipped with oil filling to cover core and windings but, when shipped under pressure of gas, shall be fitted for the duration of delivery to Site and for such time thereafter as is necessary, with a gauge and gas cylinder adequate to maintain internal pressure above atmospheric.

4.18.1.16 Small transformers may be shipped oil-filled. When the Contract also includes the provision of oil, the seller shall fill the transformer with oil at site.

4.18.1.17 All earthing transformers shall be shipped full of oil.

4.18.2 Drying Out

4.18.2.1 All transformers shall be dried out by an approved method at the Manufacturer's works and so arranged that they might be put into service without further drying out on site.

4.18.2.2 Clear instructions shall be included in the Maintenance Instructions regarding any special precautionary measures (e.g. strutting of tap changer barriers or tank cover) which must be taken before the specified vacuum treatment can be carried out. Any special equipment necessary to enable the transformer to withstand the treatment shall be provided with each transformer.

4.18.3 Receiving

4.18.3.1 After the Employers's representatives have been notified of the transformer's arrival at the specified shipping destination and/or project site, they and the Contractor's representatives will inspect the transformer for apparent damage or loss. In the event there is evidence of loss, damage, or rough handling, the Contractor's representative will be responsible for noting such on the carrier's delivery receipt. If the Contractor desires to make an internal inspection of a suspect transformer prior to its unloading from the carrier's vehicle, he will be required to pay for any fees related to delays caused by his inspection. If the Contractor does not choose to make an internal inspection and instead asks that the transformer be moved to the foundation for oil filling and field testing, the Contractor shall be required to bear all transportation charges in addition to the repair or replacement expenses in accordance with the provisions of the General Terms and Conditions and assume full liability if it is necessary for any part of the transformer to be returned to the factory due to concealed damage incurred during shipment.

4.18.3.2 The Contractor shall be responsible for processing any claims against the carrier (rail, water, or road) and for bearing costs, liabilities, etc., in accordance with the provisions of the General Terms and Conditions if it is necessary to return a transformer to a repair shop in order to correct damage incurred during transportation from the factory to the specified shipping destination.

4.18.3.3 The Contractor shall provide receipt inspection criteria.

4.18.3.4 Field supervision by a qualified employee of the Manufacturer is to provide technical assistance during the initial field assembly of the transformer.

4.18.4 Site Tests

4.18.4.1 Tests During Installation

The following tests shall be performed during and after installation on the entire equipment in order to ensure correct assembly of the equipment as well as to prove that the equipment has been correctly installed:

- Verification of proper and complete erection
- Verification of the proper condition of porcelains, sealing and external surfaces
- Verification of proper connection to the earthing system
- Verification of transformer bolted connections by torque spanner
- Voltage tests of all electrical LV circuits
- Verification of the proper cabling and operation of all electrical LV equipment
- Verification of control and protection circuits and wiring.

4.18.4.2Commissioning Tests

4.18.4.2.1 Main objective of the commissioning tests is to check proper and safe operation of the equipment, and in particular to verify and confirm the factory acceptance test results.

4.18.4.2.2 The following commissioning tests will be performed before putting the transformers into operation:

- Measurements of insulation resistances of windings and magnetic core.
- Capacitance (C), dielectric losses (tanδ) and winding inductance.
- Measurement of winding resistance at all tap changer positions.
- Measurement of voltage ratio at all tap changer positions and check of winding connection.
- Operation test of all protection units, measuring and alarm (signalling) units, Buchholz relay, contact thermometer, thermal image unit, etc.
- Operation test of cooling-system controls and alarms.
- Operation test of tap changer controls and alarms.
- Oil dielectric strength.
- Physical, chemical and electrical characteristics of oil.

4.18.4.2.3 One month after loading operation on transformers, the dissolved gases in oil shall be analyzed and compared with the factory test value. If any abnormal gas exceeds the standard value, the defect is processed after a detailed inspection at the manufacturer's expense.

4.18.4.2.4 The DGA utilized at the site should be either an Online Dissolved Gas (Multi-gas) and Moisture Analyser or a portable gas chromatograph type, as specified in BPS, which shall be supplied by the Contractor. The specifications of the

Online Dissolved Gas (Multi-gas) and Moisture Analyser are given in clause 4.20. The specifications of the portable DGA should have the performance equivalent to or higher than technical specification below.

- Compliant with ASTM D3612 and IEC 60567
- Measurement technology: Full gas chromatographic analysis
- Gas in oil measurement range: 0.1 ~ 100,000 ppm
- Highly sensitivity detection of up to 11 gases
- Accuracy/ Resolution: ±10% / 0.1 ppm
- Automatic sample oil injection

4.18.4.3Handling on Site

4.18.4.3.1 For installation purposes and to permit the moving of any three phase unit, the transformers are to be equipped with castors (rail wheels). A permanent rail transfer track system shall be provided, integrated with the transformer foundations. The castors should be able to swivel in both the longitudinal and transverse directions.

4.18.4.3.2 A system of wedges shall be included to stop any unwanted movement of the transformer during its operating life. The distance between rails must be compatible with the transformer dimensions and also the rail gauge prevailing at existing substation sites.

4.19Earthing & Auxiliary Transformer

4.19.1 Scope

This specification is intended to cover the design, engineering, manufacture, testing at manufacturer's works of 3 ph, Copper wound, oil immersed 33/0.415kV Earthing cum Auxiliary transformers for efficient and trouble free operation as specified herein.

The earthing transformer covered by this specification shall be complete in all respect. Any material or accessories which may not specifically mentioned here but which is usual and necessary for satisfactory and trouble free operation and maintenance of the transformer shall be supplied without any extra charge.

4.19.2 Standards

IEC 60076	Power Transformers, Part 1,2,3,4,5,6,10,11

IEEE Std C62.92.4	IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part IV—Distribution Systems
IEEE Std C62.92.5	IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part V—Transmission Systems and Sub transmission Systems
IEEE Std C57.32	IEEE Standard for Requirements, Terminology, and Test Procedures for Neutral Grounding Devices

4.19.3 General

i) 33/0.415kV Earthing Transformer, ONAN Cooled, 3 ph, oil-immersed, class A insulated, fitted with outdoor type bushings on HV side.

ii) Earthing transformers shall comply with IEC 60289 and shall be of the oil immersed ONAN type suitable for outdoor installation. They are to have a main interconnected star winding brought out via oil/air terminal bushings, which will be connected to the tertiary voltage terminals of the associated system transformer.

iii) The neutral points of the transformer shall be brought out of the tank through a bushing insulator. These points shall be connected to earth in order to provide an arthing point for the 33kV & LV system.

iv) The earthing transformers shall have a secondary winding to supply the substation auxiliary load. The voltage ratio shall be 33/0.415 kV. The star-connected secondary windings shall be arranged to give a three-phase, four wire supply with the star point solidly earthed. The secondary winding shall have a continuous rating (250 or 300 or 500 kVA or 1000kVA) as stated in the Schedule of Requirements and shall conform to IEC 60076.

4.19.4 Design Criteria

i) The transformer will be installed at outdoor. All equipment accessories and wiring shall be provided with tropical finish to prevent fungus growth.

ii) If not specifically mentioned in BOQ, the transformer shall be capable of withstanding a fault current as per TV [for Auto transformer] or LV [for Power Transformer] winding short circuit rating of the system transformer. The duration of short circuit shall be 10s if not specified in Requirement.

iii) The earthing transformer shall be capable of withstanding the mechanical and thermal stresses caused by the rated short time current flowing in the windings under fault conditions. This shall be determined by tests as per relevant IEC/IEEE standard and the results furnished along with the bid.

v) The thermal ability to withstand short circuit shall be proved by calculation and shall be furnished along with the drawings during detail Engineering.

vi) The transformer shall be free from annoying hum or vibration. The design shall be such as not to cause undesirable interference with radio or communication circuit.

vii) Rating:

a) Voltage class shall be of 36 kV; 3-phase, 50 Hz Copper wound, oil immersed, ONAN. Percent Impedance & kVA rating shall be as per Schedule of Requirement .

b) The rating and other guaranteed particulars of the earthing transformer shall be as per specific technical parameters of this specification.

4.19.5 Design & Construction

4.19.5.1 Zig-Zag-Wye Transformer

i) When specified in the schedule of requirement, interconnected zig-zag winding shall be provided for HV side.

ii) Z winding is required for Autotransformer system with tertiary side being Delta.

iii) Z winding shall be designed for low impedance to allow high single -phase -to ground current during short circuit in the tertiary side. It is required for quick detection of the fault and sub-sequent fault isolation.

iv) Normally, the Zig-zag transformers shall operate standalone, not parallel. However, Substation SLD shall dictate the operation mode. Bidder are guided to go through Substation SLD.

v) The HV winding shall have graded insulation.

4.19.5.2 Delta-Wye Transformer

i) When specified in the schedule of requirement, Delta winding shall be provided for HV side.

ii) D winding is required for Power transformer system with LV side being 33kV.

iii) Normally, the Delta-Wye transformers shall not operate standalone, rather parallel. However, Substation SLD shall dictate the operation mode. Bidder are guided to go through Substation SLD.

iv) The HV side shall have same insulation that of the 33kV system.

4.19.5.3 Core

i) Three legged core design shall be adopted, unless otherwise specified in the Data sheet.

ii) The material circuit of the earthing transformer shall be constructed from high quality, low loss and high permeability cold rolled grain-oriented silicon steel laminations especially suitable for transformer core.

iii) The maximum flux density in any part of the core and yokes, at normal voltage and frequency of each transformer shall be consistent with the material used. The maximum flux density shall be 1.7 Tesla.

iv) The prime core materials are only to be used. Bidders should furnish following document as applicable as a proof towards use of prime Core material to be submitted before the stage inspection :

- Invoice of supplier
- Mill's test certificate
- Packing List
- Bill of landing
- Bill of entry certificate by Custom.
- Description of material, electrical analysis, physical inspection, certificate for surface defects, thickness and width of the materials

v) Core materials should be directly procured from either the manufacturer or their accredited marketing organization of repute and not through any agent.

vi) Inter-laminar insulation shall be coated over laminations during manufacturing process.

vii) The legs and yokes of cores shall have similar section to minimize heating and noise. Necessary cooling ducts shall be provided for heat dissipation.

viii) The whole core shall be electrically connected by copper strip of not less than 10 sq.mm cross section to the tank inside for being earthed to drain off any electrostatic potential that may build up.

ix) Each core bolt and part of the core clamping frame work shall be insulated from the core lamination. The core shall be tested to withstand a voltage of 2500 volts AC for a duration of one minute.

x) Core losses are to be specified. The tolerance on specified Core losses will be 10%. Transformer losses shall be taken into account during tender evaluation. Capitalization of losses at rated voltage & frequency shall be guaranteed with tolerance limit as specified.

xi) Capitalization value of Core loss shall be as per the main system transformer loss capitalization.

xii) If losses after test are found beyond the guaranteed value declared in the bid offer with tolerance limits then penalty will be imposed for the excess losses for the corresponding guaranteed value by applying the above stated values. For fraction of a kW, the penalty shall be applied pro-rata, but no bonus will be applied or vice-versa. No changes in guaranteed figure will be allowed after tender opening.

4.19.5.4 Winding

i) Zig-Zag Earthing Transformer (ET) with single inter-star connected windings at HV side shall consist of two distinct sections, each representing one half of each inter-star winding and shall be rated for one-third of the line voltage.

ii) For Delta wye ET, HV side shall have internally delta connected winding & LV side being Wye connected.

iii) The winding shall be made of paper insulated continuous and smooth electrolytic copper conductor and shall be so designed that all the coil assemblies of identical voltage rating shall be interchangeable and field repairs to the winding can be made without special equipment.

iv) The insulation of the coils and assembly of windings shall be insoluble, non-catalytic, chemically inactive in the hot transformer oil & shall not be adversely affected under the operating conditions.

v) The insulation of the windings shall withstand the impulse and power frequency test voltages as specified in technical parameters.

vi) Windings shall be designed to withstand the Electromechanical stresses exerted during the short circuit conditions as per IEC-60076-5.

vii) Liberal ducts shall be provided for oil circulation and prevention of any hot spot temperature in the winding that may affect the life of the transformers.

viii) All leads and connections shall be mechanically strong, heavily insulated and rigidly clamped, so as to withstand stresses due to terminal short circuit.

ix) For connection of winding lead to bushing crimping method shall be used.

4.19.5.5 Continuous and Short Circuit Characteristics

1. The Earthing transformer shall have two rating:

   a) Continuous thermal rating to supply station auxiliary power supply. Normally, it shall be as stated in Schedule of Requirement.

   b) Short circuit rating with zero-sequence impedance. Normally this shall be proposed by manufacturer with the information given in data sheet or in this specification.

2. When Earthing transformers used for Grid substation, typically, they will normally equipped with Circuit Braker & Relay associated with them in order to isolate the Transformer during fault condition. The transformer neutral points in that case will be directly connected to substation grounding grid/ earth to permit low resistance path for earth fault current to flow and enable associated relay to pick-up as early as possible.

3. No provision shall be made for NGR grounding for Auto transformer (with delta connected tertiary) system.

4. The Earthing-Auxiliary Transformers (EAT) shall be capable of withstanding, both thermally and mechanically without damage, for a period of 10 seconds the application of normal three phase line voltage to its' HV terminals with one line terminal earthed. The winding temperature of the windings under this condition shall not exceed 2300C. During Detail Engineering, the manufacturer shall demonstrate that, the designed transformer can withstand the effect of short circuit both thermally and mechanically without adverse effect.

5. For the short circuit rating of transformer, the zero-sequence impedance will be designed by the manufacturer to limit the 33kV side single phase ground fault current. The three-phase short circuit duty of the 33kV side shall be assumed as follows:

   a) Delta-Wye ET: 1800MVA
   b) Zig-Zag ET: 1450MVA

6. The following aspects shall be considered for designing the Short time rating of the transformer

   a) X0/X1 ratio --- around 3
   b) COG (Co-efficient of Grounding) ---- less than 80%

c) Corresponding EFF (Earth Fault Factor) ---- COG x √3

The above shall be designed so that, use of surge arresters rated MCOV at 80% of line-to-line voltage could be considered at the substation.

7. The short time kVA rating shall be as follows:

a) When a wye-delta transformer is used as a grounding bank, the delta serves only to provide a path for the zero-sequence current. The actual (short time) rating in kilovolt-amperes is:
kVA = [(line - to - line kV) × neutral Amps]/ √3

b) For a zig-zag grounding transformer, since both windings are active in the primary circuit, the actual (short time) rating in kilovolt-amperes is:
kVA = ((line − to − line kV)× neutral Amps)/3

4.19.5.6 Secondary Windings

The three-phase, four-wire secondary windings shall be terminated at a three-pole ACB unit with bolted neutral link and gland entry for a four-core solid dielectric cable. This shall be accommodated in a lockable, fully weatherproof compartment together with a neutral earthing link. The purpose of the neutral earthing link is to connect the 400V system neutral to earth. It shall be connected between the transformer winding end and a suitably located earthing terminal to which the system earth can be connected.

4.19.5.7 Tap Changer -DETC

The primary windings shall be fitted with off-load tap changer to vary the HV voltage. Typically, voltage variation shall be assumed to be ±5 percent of the nominal open circuit value in 2.5 percent steps, unless otherwise specified in the schedule of Requirement/Technical Data. During these tap change, the impedance shall be constant.

The DETC shall be externally operated . The off-circuit tappings as specified in the Schedule of Requirements shall be provided on the higher voltage windings for a variation of no-load primary voltage as specified. The DETC shall include tap positions as described in the Appendix section/Technical datasheet. All taps shall be full capacity taps.

A positive type position indicator shall be furnished, complete with provisions for padlocking the DETC in any on-tap position with padlocks. A suitable weather shield shall be provided over the padlock and positioning pin and shall be designed to eliminate the need for tools for access. Any exposed portion of the mechanism, such as a position indicator or geneva gear, shall also be furnished with a weather shield. Off-load tap-changing shall be carried out by means of an external hand-operated tapping switch mounted on the side of the tank. All phases of the tapping switch must be operated by one hand wheel.

All DETCs on a transformer shall be operated by a suitable single external manual handle device, conveniently and safely operable from the ground, with the handle no more than 3 to 5 feet above the tank base. Multiple DETC operating handles are not acceptable.

The DETC operating handle is to be readily accessible for operation without interference from adjacent parts. All taps shall be rated for loading above maximum nameplate capabilities of the transformer as specified in Data Sheets.

Any shaft penetration designs directly through the tank wall at a location below the top of the core/coil assembly shall have double sealing on the rotating shaft and on the mounting flange.

Under no conditions shall a sprocket and chain drive arrangement be acceptable for connecting the DETC assemblies on each phase to the common operating shaft.

The tapping switch shall have a spring-loaded captive bolt or other approved means on the moving part that positively locates the switch correctly at each tapping position. This bolt must be lockable at each tapping position and shall be provided with a suitable padlock and keys. Moving the switch from one tapping position to another shall require that the bolt be withdrawn by hand from its locating socket on the transformer tank against the spring pressure.

Tap-position numbers corresponding to the tapping switch bolt-locating sockets shall be cast or engraved in a metal indication plate fixed to the tank and a keyed metal pointer on the tapping switch operating handle shall show clearly at which tapping number the transformer is operating.

All tap-position indicators shall be marked with one integer for each tap position, beginning at number 1. Adjacent taps shall be numbered consecutively in such a manner that when moving a tap to a new tapping position that has a higher number, the no-load output voltage of the untapped winding increases.

DETCs shall be prevented from being left between taps and shall be prevented from moving off tap due to vibrations or bumping.

All tapered pins used in DETC assemblies shall be fully driven into the holes, slightly below the surface of the entrance side of the holes, and the entrance side of the holes deformed.

4.19.5.8 Tank

Tank shall be of welded construction and fabricated from good quality sheet steel of adequate thickness. The thickness of top, bottom and side plates shall be stated by the bidder. The tank shall be so shaped as to reduce welding to a minimum. All seams shall be double welded for absolute oil tightness.

Bushing turret covers, access-holes covers, pockets of thermometer shall be so designed to prevent any ingress of water. The conservator shall be liberally dimensioned so that oil level remains above the bushing top at the lowest ambient temperature and no-load, and the oil shall

not spill into the breather pipe, or the exterior as waste. The conservator shall be provided with a window type oil gauge. The tank shall withstand specified pressure and vacuum tests without any deformation in excess of the permissible deflections.

4.19.5.9 Insulation Oil

The transformer oil shall be duly filled in with required quantity for first filling and to supply 10% extra. The oil shall conform to IEC60296. The transformer should be filled in with oil having dielectric strength 60 kV (rms) minimum after filtration. The oil in the transformer being supplied shall be provided with test result conforming to IEC60296.

4.19.5.10 Cooling Equipment

The Transformer shall be suitable for 100% continuous maximum current rating with ONAN Cooling within the specified maximum temperature rise of 600C by oil & 650C rise by winding over ambient of 400C . The transformer if required, shall be fitted with radiators of tubular construction. Thickness of radiator tubes should not be less than 2.5 mm and material should be mild steel.

The radiators shall be mounted with main tank directly or through individual pipes. Use of accumulator pipes is not acceptable.

4.19.5.11 Current Transformer for E/F Protection

The Transformer shall have two core bushing CTs at all side, i.e, HV, LV & Neutral bushing.

Moreover, Outdoor type current transformer conforming to IEC6189 having ratio 100-800/1A (33kV class) (if not specifically mentioned) of 5P20 class shall be provided.

4.19.5.12 Fittings & Accessories

The Earthing Transformer shall be complete with necessary fittings and accessories, but not limited to the following:

i) Conservator with filling hole, cap and drain valve having flanged terminal.
ii) Conservator and supporting bracket for mounting on transformer tank.
iii) Isolation valve for the conservator.
iv) Magnetic oil level gauge with low oil level alarm contacts.
v) Silica gel breather with oil seal and connecting pipe for non-inert gas sealed transformer .
vi) Pressure relief pipe, double diaphragm type, complete with port-hole type oil gauge for indication of the puncture of lower diaphragm and necessary air equalizer connection between the conservator and the pressure relief pipe.
vii) Access holes/Inspection holes with bolted covers for access to inner ends of bushing.

viii) Lifting eyes for cover, core and winding and lifting lugs for the complete transformer.
ix) Air release plugs on top of cover and bushing turrets.
x) Upper & Bottom filter valve and Drain valve flanged with oil sampling device.
xi) Jacking pads with hauling holes.
xii) Flat roller wheels.
xiii) Two nos. tank earthing terminal.
xiv) Buchholz (gas) relay, double float type with one set of alarm contacts and one set of trip contacts and a testing cock. The contacts shall be wired up to terminal cabinet with insulted cables.
xv) Dial type thermometer for oil temperature indication complete with two sets of alarm and trip contact.
xvi) Pocket for inserting alcohol thermometer for oil temperature with necessary thermometer.
xvii) Rating plate and Diagram plate.
xviii) Rigid type terminal connectors on the HV bushing.
xix) Insulating oil required for first filling.
xx) Winding Temperature indicator
xxi) Other attachment/accessories required to complete the equipment for satisfactory operation.

4.19.5.13 Painting

All steel surfaces shall be cleaned by sand blasting or chemical process as required to produce a smooth surface, free of scale, grease and rust. Steel surface in contact with insulating oil shall be painted with heat resistant oil insoluble insulating varnish. External surfaces shall be given a coat of high quality red or yellow chromate primer and finished with Munsell as per section 02 of this specification with two coats of synthetic enamel paints. Paints shall be carefully selected to withstand tropical heat, rain etc. The paint shall not scale off or crinkle or be removed by abrasion due to normal handling. Sufficient quantity of touch up paint shall be furnished by application at site.

4.19.5.14 Terminal Connections& Bushings

The 33 kV side of the earthing transformers shall be fitted with oil/air terminal bushings. The earth point connection of the neutral bushing shall be via a 33 kV conductor

The terminals shall be brought out through outdoor type bushings on HV side conforming to IEC: 60137 and provided with suitable Bi-metallic terminal connectors for suitable dia. ACSR conductors for phases and suitable size copper flat for neutral.

The bushing shall have high factors of safety against leakage to ground and shall be so located as to provide adequate electrical clearances between bushings and grounded parts. Bushings of identical voltage rating shall be interchangeable. All bushings shall be equipped with suitable terminals of approved type and size.

The insulation class of the high voltage neutral bushing shall be properly coordinated with the insulation class of the neutral of the high voltage winding. Each bushing shall be so coordinated with the transformer insulation that all flash-over will occur outside the tank.

All porcelain used in bushings shall be homogeneous and free from cavities or other flaws. The glazing shall be uniform in colour and free from blisters, burns and other defects. All bushings shall be porcelain shed type. The neutral bushings shall be insulated for 33 kV.

RIP type bushing is also acceptable. Bushings shall conform to IEC: 137. Main terminals shall be solder less. The short time current shall be 31.5kA for 2 seconds

The spacing between the bushings must be adequate to prevent flashover between phases under all conditions of operation.

All bushings shall be suitable for heavily polluted atmosphere. The HV Bushing shall have tangent delta measurement tap.

4.19.5.15 Equipment Foundation and Steel Structure

i) The earthing transformers shall be furnished complete with base frame, anchor/ foundation bolts and hardwares.

ii) The equipment shall be designed for mounting on concrete base.

4.19.5.16 Auxiliary Supply

The auxiliary supply available for the equipment are:

i) 110 V D.C±10% .

ii) 415 V ± 10%, 3 phase , 4 wire , 50 Hz AC.

4.19.6 Contract Drawings and Instruction Manuals

During Project execution, four (04) copies of following drawings, GTP & leaflets shall be furnished for approval:

i. Dimensional general arrangement drawing transformer showing constructional features and dispositions of various fittings and accessories.
ii. Technical leaflets on transformer and accessories explaining the functions and special features.
iii. Type test certificates on similar transformers.
iv. Transport/shipping dimensions with weights.
v. Dimensional general arrangement and sectional view with plan and elevation of bushing with technical parameters.

vi. Foundation and anchor details including dead-load and impact load with direction.
vii. Assembly drawing for erection at site with part numbers and schedule of materials.
viii. Electrical schematic and wiring diagram.
ix. Any other relevant drawings and data necessary for erection, operation and maintenance.
x. Instruction manuals and data sheets for each piece of equipment. The manuals shall clearly indicate the installation methods, checkups and tests to be carried out for covering the equipment and maintenance procedure.
xi. Rating & diagram plate and valve schedule of the transformer.
After approval four (4) sets of approved drawings and maintenance manual/catalogue of all equipment both in hard and soft copy shall be submitted for our record and distribution to site.

4.19.7 Test at Factory and Test Reports

All routine tests are to be carried out on each transformer as per relevant IEC 60076. Those routine test reports are to be submitted along with inspection offer.

After completion of the manufacture, the following routine tests shall be carried out at manufacturer's works on each Transformer in presence of representative from PGCB. In the event, when it is deemed to be necessary, PGCB shall have the right to waiver such inspection.

The contractor shall give at least one (1) month advance notice intimating the actual date of inspection and details of all tests that are to be carried out.

i) Visual & Dimensional Check
ii) Measurement of Zero-sequence impedance
iii) Measurement of no-load loss and no-load current.
iv) Measurement of winding resistance.
v) Measurement of insulation resistance.
vi) Induced voltage withstand test.
vii) Separate source voltage withstand test.
viii) Temperature rise test

Any other test not specified above but required to be carried out as per relevant IEC shall be within the scope of contractor. Rejection and retesting shall be guided by relevant IEC.

Porcelain bushing, Bushing current transformers, winding temperature indicating device, Dial Thermometers, Buchholz relays, Insulating oil and other accessories to be supplied by the manufacturer shall be tested by the manufacturer in accordance with the relevant IEC. Publication. Three (3) copies of test reports of each of the component shall be furnished along with the test certificate of the main equipment.

Loss of EAT (Earthing & Auxiliary Tr.) is evaluated same as Main Tr.

4.19.8 Test Reports & Type Tests

Only type tested Earthing transformer are to be offered conforming to the technical specification. Earthing transformer offered should be similar with ones on which type testing has been carried out as per relevant IEC. Three sets of complete type test reports carried out in reputed Test Laboratory accredited as per IEC17025 shall have to be submitted by successful bidder positively along with submission of drawing during detail engineering.

The submitted type test report shall proof that the type test have been carried out within five years from the date of submission of bid. Successful Bidder may require producing original copies of type test report at the time of detail engineering if asked by PGCB.

Each type test report shall comply the following information with test result

a. Compete identification, date and serial number.

b. Method of application, Where applied, duration and interpretation of each test.

c. Relevant drawings as documented with test report.

Following minimum type test shall be available in the Type Test Certificate

i) Visual & Dimensional Check
ii) Measurement of Zero-sequence impedance
iii) Measurement of no-load loss and no-load current.
iv) Measurement of Load-Loss and Percent Impedance
v) Measurement of winding resistance.
vi) Measurement of insulation resistance.
vii) Induced voltage withstand test.
viii) Separate source voltage withstand test.
ix) Temperature rise test
x) Short circuit Test (Special Test)

4.19.9 Transport & Shipment

All earthing transformers shall be shipped full of oil.

4.19.10 Guarantee

Electrical characteristics shall be guaranteed by the bidder. In case of failure of materials to meet the guarantee, PGCB shall have right to reject the material. Guaranteed Technical Particulars are to be submitted by successful bidder during detailed engineering along with submitted drawings/documents. However, Values shall also be put in the GTP during Bidding along-with the Bid.

4.20 Transformer Online Dissolved Gas Analyser (DGA)

Online Dissolved Gas (Multi-gas) and Moisture Analyser

a) Online Dissolved Gas (Multi-gas) and Moisture Analyser (if specified in BPS) along with all required accessories shall be provided with each transformer for measurement & analysis of dissolved gases and moisture in the oil. Interpretations shall be as per IEC 60599-1999.

b) The equipment shall detect, measure and analyse the following gases:

Gases & Moisture Parameters	Typical Detection Range
H2	5 – 3,000 ppm
CH4	5 – 5,000 ppm
C2H6	5 – 5,000 ppm
C2H4	3 – 5,000 ppm
C2H2	1 – 3,000 ppm
CO	10 – 10,000 ppm
CO2	20 – 30,000 ppm
O2	500 – 25,000 ppm
H2O	2 – 100 % RS should have facility for measurement of moisture in oil in ppm

c) The analyser should measure (not calculate) all above gases and should have 100% sensitivity. The equipment shall be IEC 61850 compliant to integrate with SCADA system. The results shall be communicated to control room or remote location (through SCADA) and shall be compared with the standard preset results to indicate the possible severe damage/failure.

d) Equipment shall have facility to give SMS alert to at least three users whenever any fault gas violates the predefined limit.

e) Equipment should work on station auxiliary supply. In case other supply is required for the equipment then suitable converter shall be included. All the necessary power and control cables, communication cables, cable accessories as required shall be provided by the supplier.

f) Online DGA shall be installed out door on transformer in harsh ambient and noisy condition (Electromagnetic induction, Corona, and capacitive coupling). The equipment shall be suitable for proper operation in EHV substation (800kV)environment where switching takes place in the EHV/HV System. The suitable indications for power On, Alarm, Caution, normal operation etc. shall be provided on the front panel of the equipment. The equipment shall have IP55 Stainless Steel enclosure, suitable for 55ºC ambient temperature and EMI and EMC compatibility. The Equipment must carry a minimum of two (2) years manufacturer's Warranty.

g) The equipment shall connect to the transformer's main body in two locations. One connection is for the supply of oil from the transformer. Second connection is for the return of the oil to the transformer. The connecting oil lines must be of Stainless Steel rigid pipes or flexible hoses.

h) The equipment shall be able to measure gas concentration and when downloaded should immediately compare it with user selected alarm & caution level for immediate display. The sampling rate shall be selectable as 2 or 4 or 6 or 12 hours etc. The equipment shall have inbuilt memory to store these results for complete one year even if sampling is done at the lowest interval.

i) The Equipment must have an automatic Calibration facility at fixed intervals. For calibration if anything required including cylinder must be mounted with the Equipment.

j) The technical feature of the equipment shall be as under:

Accuracy + 5% [except for N_2, for N_2 accuracy ±10%]

Repeatability <1 to <2% depending upon gases [except for N_2, for N_2 Repeatability <20%]

Oil temperature range - 20^0 C to + 75^0 C

External Temp. Range - 20^0 C to + 55^0 C

(External temp range of 55^0 C should not be compromise due to hot ambient & operating conditions.)

Humidity range 5 to 95 %

Operating Voltage 230 Vac; 50 Hz (±20% variation)

Communications USB & IEC 61850 compliant

k) Software for fault indication and fault diagnostics shall include following:

Fault indication:

i) IEEE, IEC or user configurable levels of dissolved gases

ii) Rate of change trending

Fault Diagnosis:

i) Key gases

ii) Ratios (Rogers, IEC. etc.)

iii) Duval's Triangle

l) The equipment shall be supplied with all necessary accessories required for carrying out DGA of oil sample complete in all respect as per the technical specification. The following shall be also form a part of supply.

i) Software

ii) Operation Manual (2 set for every unit),

iii) Software Manual and

iv) Compact disc giving operation procedures of Maintenance Manual & Troubleshooting instructions.

v) Basic 8 Gas Monitor with Monitor Mounting Kit

vi) Calibration Cylinder

vii) Bleed Fixture & Junction Box with 3.5ft. Cables

viii) Carrier gas tank regulator, dryer and supply lines

ix) Load Guide & Ambient Temperature Sensors

x) Manual DGA sample port assembly

xi) Oil supply and return assembly

xii) Associated Software

xiii) Carrier Gas Cylinder with 99.999% purity with gas regulator and

pressure guages

xiv) Suitable SS Tubing of required dia and length for oil & gas

xv) Moisture Probe for monitoring Moisture

xvi) Any other accessories required for with the supplied item other than what is specified.

APPENDIX

Appendix Auto Transformer

A. 400 / 230 / 33 kV Auto Transformer, Datasheet

Please refer to volume 03, Schedule E

B. 400 / 132 / 33 kV Auto Transformer, datasheet

Please refer to volume 03, Schedule E

C. 33/0.415 kV Earthing Transformer, Datasheet

Please refer to volume 03, Schedule E

D. Transformer Oil Specification, general

Test Requirements			
Type of Test		**ASTM Designation**	**Test Limits**
Aniline Point *		D611	63-80°C
Color *		D1500	0.5 Maximum
Corrosive Sulfur		D1275	Non–Corrosive
Dielectric Strength *		D877	30 kV Minimum
Dielectric Strength		D1816 (0.04'' Gap)	28 kV Minimum
Flash Point		D92	145 °C Minimum
Gassing Tendency *		D2300	Negative
Interfacial Tension *		D971	(Unfiltered) 40 Dynes/Cm.
Minimum Moisture Content *		D1533	30 ppm Maximum
Neutralization Number *		D974 (Modified)	0.015 mg KOH/g Maximum
Oxidation Inhibitor Content *		D2668	0.15 Percent – 0.30 Percent by Mass
Oxidation Stability or		D2112	220 Minutes Minimum
Oxidation Stability		D2440	
72 Hrs:	Percent Sludge by Mass		0.1 Percent Maximum
	Total Acid No.		0.3 mg KOH/g Maximum
164 Hrs:	Percent Sludge by Mass		0.2 Percent Maximum
	Total Acid No.		0.4 mg KOH/g Maximum
PCB Content *		D4059	Non–Detectable
Pour Point		D97	–40 °C Maximum
Power	100oC	D924	0.30 Percent Maximum

Test Requirements			
Type of Test		**ASTM Designation**	**Test Limits**
Factor	25oC	D924	0.05 Percent Maximum
Specific Gravity		D1298	0.865–0.910
Viscosity, 40 °C *		D88	62 SUS Maximum
		D445	11.0 CST Maximum
Oxidation inhibitor content % by weight		ASTM D 1473 ASTM D 2668	0.3% max.

5. Protection, Metering & Control and Substation Automation System

5.1 General

This specification covers the design, manufacturing, factory tests, delivery to sites, erection, setting, parameterisation and architecture configuration, field testing, commissioning, warranty and lifetime support of 400kV substations automation system including protection, metering and control included in the contract works.

All systems, subsystems and components shall be of approved and reliable design. The highest degree and state-of-the-art of uniformity and interchangeability shall be attained, as far as possible. The design shall facilitate easy maintenance, fault diagnosis and repair of the components.

Relay panels shall be supplied by the respective relay manufacturers, with relays fully assembled, wired and tested under their close supervision; they shall be fully responsible for design and engineering of protection systems, schematic diagrams and mature performance.

Testing of protection functions, including the full schemes involving control, communication, supervision, etc., shall be performed at the workshop (manufacturer's test field/laboratory) prior to shipment.

The protection, metering and control facilities shall be suitable for the power system arrangement as shown on the bid drawings.

For standardisation of operating performance, facilities and spare requirements, the protection relays, control systemsand Substation Automation System (SAS), together with complete panels, to be supplied under this project shall be manufactured by: ABB (Switzerland/Sweden), Alstom/GE (France/USA/UK), SEL (USA/UK/Canada), Siemens (Germany) or equivalent.

Since some of the above mentioned make, viz., ABB (Switzerland/Sweden), Alstom/GE (France/USA/UK), SEL (USA/UK/Canada) and Siemens (Germany) make Relay, Control systems and Substation Automation System (SAS) are already existed in PGCB's System and their performance is proven, only Manufacturer's Authorization letter among the Qualification Criteria of clause 2.5 of Section 3 of volume 1 of 3 of the Bidding Document is required to be submitted with the bid of the bidders who choose to propose Relay & SAS from these proven manufacturers. Acceptance of any other Relay, control system and SAS with similar characteristics shall have to fulfil the Qualification Criteria of clause 2.5 of Section 3 of volume 1 of 3 of the Bidding Document.

From operational experience, including system stability, protection condition, integration with existing protection and control equipment, capitalizing of staff experience and familiarization

with equipment, protection settings calculation mechanism and methodology of operation, standardization of operation performance, facilities and spare requirements, the protection relays, control & automation systems including complete panel shall be rationalized to specific types. The system designer shall make every effort to ensure smooth operation and better reliability of the system and to avoid system malfunctioning.

All relays shall operate correctly within system frequency limits of 47Hz to 51Hz.

Installation, Testing and Commissioning of Control, protection and metering system shall be done by the Manufacturer(s) Engineer(s).

5.2 Protection System

The general purpose of the protection equipment is to isolate every fault on the power system with sensitivity, reliability and selectivity, and in the minimum desirable time. Protection equipment shall be designed and applied to provide maximum discrimination between faulty and healthy circuits. All equipment is to remain inoperative during transient phenomena which may arise during switching or other disturbances to the system.

Simplified arrangements of the main connections and protection for the various items of plant are shown in the bid drawings.

Protection relays must operate correctly and predictable, and must be stable during all passing system transients caused by switching, external unconnected faults and other disturbances.

Current transformers, where possible, are to be located so as to include the associated circuit breaker within the protected zone and shall be located generally as indicated on the schematic drawings included in this specification.

As far as possible, numerical protection relays and products shall be provided. The hardware devices shall be based on offering integrated functionality, a higher degree of self-supervision and data exchange with computer control systems (SAS) via serial communication ports using IEC protocols. Where appropriate, 3rd party interrogation software shall be supplied to access the database of settings and configuration files from SAS and allow read and modify relay operational settings and configurations.

Insulation of all the related circuits shall comply with IEC60255 or other international standard(s).

All protection relays and associated auxiliary equipment shall be of standard construction from the manufacturers ABB (Switzerland/Sweden), Alstom/GE (France/USA/UK), SEL (USA/UK/Canada), Siemens (Germany) or equivalent.In addition to the fault measuring capabilities, important functions and features shall include:

(a) Programmable scheme logic
(b) Remote communication interface for setting/interrogation from SAS or control centre
(c) Local communication interface via LCD keyboard and/or front panel serial port facilities
(d) Time-tagged status events, alarms, fault and disturbance records
(e) Display of measured/processed quantities
(f) Self-monitoring (hardware/software)
(g) Inter-protection communication
(h) Real-time fault locating (distance relay)
(i) Electronic transducer communication, if applicable

The protection scheme(s) shall include all hardware and software to permit remote setting /interrogation /fault evaluation from the SAS (engineering) workstation or from the computer monitoring system.

If existing protection on a running remote-end circuit terminal needs to be modified for any reason, e.g. to operate with newly installed equipment, the Bidder/Contractor shall supply all necessary relays, boards, wiring terminals, wiring, etc. in order to ensure satisfactory coordination and performance.

Protection requirements shall include the necessary modifications of the "remote end" (other station and/or other switchgear part) of any protected circuit/ system. The Bidder/Contractor shall also modify /improve the corresponding drawings, erect all necessary equipment and perform the commissioning with the requirements given in the specifications as agreed upon with PGCB.

Tests shall include secondary, primary and load tests on those protection systems affected by the modifications. The Bidder/Contractor shall also be responsible for providing the new as-built drawings for the remote-end circuit terminals showing the design and engineering changes undertaken in both Auto-Cad and PDF formats, in addition to supplying hardcopy drawings as agreed upon with PGCB.

In addition to all equipment and components, the Bidder/Contractor shall supply documents and calculations to prove the correct functioning of the equipment, and shall ensure and demonstrate that the setting range of relays and the operating limits of all new and existing equipment are suitable for the intended applications.

Control and relay circuits, current and voltage transformer secondary circuits, battery and auxiliary power supply wiring, supervisory, alarm and communication circuits shall be protected against conductive, electrostatic and electromagnetic influences.

Wiring of CT and VT circuits and (cores) shall be in separate multi-core cables carefully segregated and screened. The CT neutral shall be earthed either on S3 or S2 terminals (depending on the ratio chosen) in the respective relay panels via an isolation bolted link. This link shall preferably be located in the protection relay panel. The primary CT terminals P1 and

P2 correspond to CT secondary terminals S1 and S2/S3 respectively, the latter depends on CT secondary tap selection. The CT secondary star points (neutral) S2/S3, is towards the item of plant being protected by the CT. This neutral is earthed via a bolted link.

The minimum cross section of CT circuits inside the protection cubicle / control cubicle shall not be less than 4.0 mm², whereas for the inter panel / field cabling it shall not be less than 4.0 mm².

CT / VT field cables shall have the colour code of red, yellow, blue and black.

All CT / VT cables shall be of multi-stranded cores.

The Bidder/Contractor shall supply block and circuit diagrams of the protection scheme, which shall be subject to approval. These diagrams shall include information concerning control and alarm circuits, secondary circuits of current and voltage transformers, circuit breaker trip coils, DC supplies and communications circuits.

The block diagrams and any other documentation shall be updated whenever modifications are made at a later date during contract execution.

Current transformer requirements shall be determined to ensure high protection performance. The Bidder/Contractor shall submit a comprehensive technical report that includes the required CT adequacy calculations. The report shall confirm that CTs will be designed to ensure a saturation-free performance under both transient and steady state fault conditions, taking due account of system X/R ratios, system fault levels and remnant flux conditions in the CT core.

Whether explicitly indicated or not, all necessary elements to coordinate and assure the approved and correct functioning of the protection system, new or existing, in accordance with the requirements of this specification shall be included.

The design life of numeric protection relays shall be more than 25 years. The Bidder /Contractor shall state how long lifetime support for the protection and associated systems will be provided, shall assure lifetime support maintenance and make recommendations on spare part provision.

The Bidder/Contractor shall give a one-year advance notice of the Manufacturer's intention to cease supply of protective relaying hardware used in the contract works.

The bids shall include a list of spares required for the first 5 years of operation and additionally over the design lifetime of protection.

Transformer Buchholz, winding temperature and tap changer protective devices which mounted on/in the Transformer are to be supplied under the Transformer manufacturer’s

contract, and all necessary interposing relays, tripping relays and cabling associated with these devices shall be supplied and mounted under this contract.

The protection shall be sufficiently sensitive to cater for the minimum fault level condition. This will be advised later. The protection shall also be suitable for a system fault level equal to the switchgear rating as mentioned in section 1 of this specification for all voltage system.

All the Auxiliary relays (Contactor, TCS, Tripping relays, thermostat, humidity controllers etc.) used for protection scheme shall be of Europe/USA originor from other eligible countries with equivalent quality.

5.3 Fault Clearance Times

400kV, 230 kV, 132 kV and 33 kV systems overall fault clearance times (i.e. from fault initiation to arc extinction) shall not exceed the following:

Type of Fault	**Maximum Fault Clearance Time**				
Nominal system voltage between phases	kV	400	230	132	33
Substation and transformer fault Line faults:	msec.	80	100	120	160
Up to 72% of the line length (i.e. 90% of a distance relay zone 1 reach setting of 80% of the line impedance)	msec.	80	100	120	160
72% of 100% of the line length where (@) plus protection signaling time	msec.	100	130	150	190

These requirements must be fulfilled under all system conditions including maximum dc current offset and any time delay. Clearance within these times shall be achieved for all types of faults except high resistance earth faults detected by DEF protection or under circuit breaker failure conditions.

5.4 Arrangement of Facilities

The Substation Automation System and associated protection and automation equipment will be installed in the Main Control Building which are to be constructed in 400kV/230kV switchyard. The automation server, HMI, Ethernet switches, substation gateways and communication facilities will be installed in Main Control Building. Communication between Local Control Cubicles and Main Control Facilities shall be based communication protocol of IEC 61850 standards. The architectures and system configurations are shown in the attached
Drawing and detailed design shall be approved by the Employer during the design approval stage.

Control and relay equipment shall be mounted on panels and cubicles as specified and shall be installed in permanent buildings on the substation sites. The order of the panels shall follow the sequence shown on the drawings.

Panels provided as extensions or for erection in the same room as existing panels shall be of similar design and appearance to those existing. Equipment, meters, etc., mounted on such panels shall like-wise be of style and scaling similar to the existing equipment. Characteristics of relays, etc., and all connections of equipment to be associated with existing equipment shall be such that they are fully compatible with and can operate satisfactorily in conjunction with the existing equipment. The characteristics and appearance of all such equipment shall be to the approval of the Engineer.

Backup Control panels shall incorporate all necessary control and indication facilities for the operation of the plant and equipment at the associated substation even in the case of failure of Substation Automation System. In addition, the plant may be remotely controlled and supervised from the National Load Dispatch Centre (NLDC) in Dhaka.

The Gateway system for communication to the NLDC shall be supplied under this contract including all necessary items like auxiliary switches, relays and changeover switches etc. All circuits provided under this contract whether or not they are subject to the system control requirements at the present time, shall be designed and constructed so that the standard facilities specified can be readily provided as required in the future.

The Contractor shall be responsible for ensuring the correct operation of the protective equipment and shall submit for approval recommended relay settings supported by design calculations for all protective equipment being supplied. The Engineer reserves the right to ask the Contractor to get the design calculations approved by the Manufacturer of the Protection equipment and/or get the confirmation for the suitability of the particular protective relay for the proposed application. In case the proposed Protective relay is not suitable for the proposed application the Contractor shall change to a suitable relay as recommended by the Manufacturer without any cost implications to the Engineer.

5.5 Multi-Core Cable Diagrams

Diagrams of communication arrangements will be made available to the Contractor who will be required to coordinate the provision of necessary multi-core cabling. This contract includes the preparation of cabling schematic diagrams, showing the approved routing of cores in the various cables, and detailed cable schedules and connection diagrams for all the cables associated with each item of equipment.

5.6 Test and Earthing Facilities

Each control or relay panels shall be provided with a copper earth bar of not less than 150 sq.mm cross-section and arranged so that the bars of adjacent panels can be joined together to form a common bus.

The common earthing busbar of control and relay panels shall be connected to the main station earthing system via a copper earthing connection of not less than 150 mm^2.

Software for testing the protection & control devices shall be included in the scope of supply. In addition, for secondary injection testing of the protection & control devices, provision shall be made in the panel for current & voltage injection using standard test set and disconnecting type terminal blocks with facility for short circuiting of current transformer secondary circuit etc. by means of movement of links from their normal operating position, or any other testing arrangement approved by the Engineer.

5.7 Cubicles, Panels and Wiring

All cubicles and enclosures with their auxiliaries described in this specification are intended for continuous duty at the specified ratings under the climatic conditions prevailing at the location where the relevant equipment will be installed.

5.7.1 Panel Construction Features

It is the responsibility of the Contractor to ensure that the equipment specified and such unspecified complementary equipment required for completeness of the protective/control schemes be properly accommodated in the panels without congestion and if necessary.

Panels shall be completely metal-enclosed and shall be dust, moisture and vermin proof. The enclosure shall have protection class IP54 or better in accordance with IEC 60529.

All panels shall be of free-standing, floor-mounted type and shall comprise structural frames completely enclosed with specially selected smooth finish, cold rolled sheet steel with a thickness not less than 3mm for weight bearing members of the panels such as base frame, front sheet and door frames, and 2.00mm for sides, door, top, and bottom portions.

Swing frames for mounting of relays with glass door shall be provided. Doors shall have handles with built-in locking facility. Panels shall be accessible from the front and rear sides after installation at the final location.

Base frames shall be provided with anti-vibration strips made of shock-absorbing material.

Cable entries shall be from the bottom. Cable gland plates fitted on the bottom of the panel

shall be connected to the earthing of the panel/station through a flexible braided copper conductor.

5.7.2 Panel Mounting

All equipment on and in the panels shall be mounted and completely wired to the terminal blocks ready for external connections.

All protection relays shall be mounted on the swing frame. Other components shall be mounted on mounting plates to be fitted inside the cubicle. The arrangements shall be shown in the general arrangement drawing and be subject to approval during the detailed design stage.

Equipment shall be mounted in such a way that removal and replacement can be done individually without interrupting the service to adjacent devices. Equipment shall be readily accessible without needing special tools. The terminal marking on the equipment shall be clearly visible.

5.7.2.1 Panel Internal Wiring

Panels shall be supplied with interconnecting wiring between all electrical devices mounted and wired in the panels and between all electrical devices mounted and wired in the panels and between the devices and terminal blocks for the devices to be connected to equipment outside the panels. When panels are arranged to be located adjacent to each other all inter panel wiring and connections between the panels shall be carried out internally.

The minimum cross-section of cables shall be 2.5 mm^2 for any secondary wiring of transformer circuits. The minimum cross-section of cables in other circuits shall be 1.5 mm^2. Cables shall be placed in insulated cable ducts with 30% free space.

All internal wiring shall be securely supported, neatly arranged, readily accessible and connected to equipment terminals and terminal blocks.

Auxiliary bus wiring for AC and DC supplies, voltage transformer circuits, annunciation circuits and other common services shall be provided near the top of the panels running throughout the entire length of the panels.

Wire termination shall be made with solderless crimping type and tinned copper lugs, which firmly grip the conductor. Insulated sleeves shall be provided at all the wire terminations. Cross feruling shall be provided at both ends of each wire, the source and destination device and terminal block information shall be available on the ferrule. The ferrules shall fit tightly on the wire and shall not fall off when the wire is disconnected from terminal blocks.

The Contractor shall be solely responsible for the completeness and correctness of the internal

wiring and for the proper functioning of the connected equipment.

5.7.3 Terminal Blocks

All internal wiring to be connected to the external equipment shall terminate on terminal blocks consisting of a clamping yoke system, preferably vertically mounted on the side of the cubicle.

The terminal block design shall be such that various types and sizes can be mounted on TS 35 rails to profile details in DIN 46277/EN. The surface protection of the mounting rail has to be zinc plated and yellow cremated. Each individual block design shall have a foot design that ensures a secure fit on the rail and allows removal of individual terminals from the centre of an assembly.
The moulding design shall ensure that all metal parts are shrouded to meet the requirements of the IEC finger test (finger-safe) and to BS 3042 without the need for additional covers.

The rated current of the terminal blocks shall be according to DIN VDE 0611-1 with reference to the rated cross-sections. The current bar shall be of a suitable electrical conducting material like copper /alloy or copper plated with tin lead combination to guarantee the best connection between the conductor and the current bar. The current bar shall be designed to retain high clamping pressure. The rated voltage of the terminal block shall be based on the insulation tests and creepage distances according to VDE 0110-1.

The terminals shall be such that the maximum contact area is achieved when a cable is terminated. The terminal shall have locking characteristics to prevent cable from escaping from the terminal clamp unless it is done intentionally.

The terminal blocks shall be feed through clamping yoke type.

The terminal blocks shall be extendible design.

The terminal blocks shall have a self-locking arrangement to prevent its escape from the mounting rails.

The terminal blocks shall be fully enclosed with removable covers of transparent, non-inflammable, non-deteriorating type plastic material. Insulating barriers Partition plate? shall be provided between the terminal blocks. These barriers shall not hinder the operator from carrying out the wiring without removing the barriers.

The terminals shall be provided with the marking tags for wiring identification on both sides.

The arrangements shall be such that it is possible to safely connect or disconnect terminals on live circuits and replace fuse links when the cabinet is live.

Terminal blocks shall be numbered consecutively, preferably beginning with 1, from left to

right or top to bottom.

All terminals shall have two separate pressure clamping points suitable for connection of incoming or outgoing stranded or solid conductors, respectively, however only one wire per terminal will be accepted. Terminals with clamping screws in direct contact with the conductor and soldering are not acceptable. If stranded or fine stranded wire are in use the wire-end have to be prepared with wire-end-ferrules made from copper und has to be crimped on the wire according DIN 46228 T 1 & T 4.

The following minimum categories of terminals shall be used:

(a) Terminals for power circuits of 10 mm², 6 mm² and 2.5 mm² wire size
(b) Terminals utilised in the secondary circuit of CTs (4mm² wire size), VTs and measuring transducers shall be supplied with a terminal with the following characteristics:
    i) sliding link disconnect function
    ii) cross connecting disconnecting facilities
    iii) short circuit facilities for CT and instruments
    iv) two integrated test sockets for test instruments per terminal, colored yellow, green & lilac
    v) it shall be possible to cross-connect the K-point of the CT by a fixed cross connecting link on the terminal, not by a wire link. A locking mechanism shall be included.
(c) Terminals for wiring of 1.5 mm² and 0.5 mm² wire size with bridging facilities to the neighbouring terminals.

Terminal blocks for protective conductors shall be designed to pollution severity category 3, rated to DIN VDE 0110-1, VDE 0611, part 3 and IEC 60947-7-2 and coloured green/yellow. They shall be fixed onto the mounting rail by means of a separate screw and clamping foot mechanism or by independent, self-locking metal foot clamping directly onto the assembly rail and shall have the ability to be arranged in the relevant sequences to match the phase circuits.

5.7.4 Labels

The boards shall be clearly labelled with the name of the circuit on the front, at the rear and inside the board. All labels shall be in English.

Each relay and electronic card in the board shall be identified by labels fixed permanently to the board next to the equipment concerned. If the equipment is connected to a terminal and to a socket, the terminal and the socket shall have permanent identification labels.

The labels shall be solidly fixed using screws. The use of adhesive tape to fix labels will not be acceptable.

5.7.5 Miscellaneous Accessories

5.7.5.1 Plug Point

240V, single phase 50Hz, AC socket shall be provided in the interior of each cubicle with ON-OFF switch.

5.7.5.2 Interior Lighting

Each panel shall be provided with a fluorescent lighting fixture rated for 240 V, single phase, 50 Hz supply for the interior illumination of the panel controlled by the respective panel door switch.

5.7.5.3 Space Heater

Each panel shall be provided with a thermostatically connected space heater rated for 240V, single phase, 50Hz AC supply for the internal heating of the panel to prevent condensation of moisture.

5.7.6 Earthing

All panels shall be equipped with an earth-bus securely fixed. The material and sizes of the busbar shall be at least 25x6 mm² copper with threaded holes at a gap of 50 mm with provision of bolts and nuts for connection with cable armours and mounted equipment etc. for effective earthing. When several panels are mounted adjoining each other, the earth bus shall be made continuous, and necessary connectors and clamps for this purpose shall be provided. Provision shall be made for extending the earth busbars to future adjoining panels on either side.

All metallic cases of relays, instruments and other panel mounted equipment including gland plate, shall be connected to the earth bus by yellow/green copper wire of not less than 2.5 mm².

5.7.7 Testing Facilities

Software for testing the protection and control devices shall be included in the scope of supply. In addition, for secondary injection testing of the protection & control devices, provision shall be made in the panel for current & voltage injection using standard test set and disconnecting type terminal blocks with facility for short circuiting of current transformer secondary circuit etc. by means of movement of links from their normal operating position, or any other testing arrangement approved by the Engineer.

Panel front mounted Test Terminal Blocks (TTB)/Test Sockets have to be provided for online testing of all Protective relays. Facility of online CT shorting, VT circuit isolation should be available in the TTB. 2 sets of associated Test Plugs should also be supplied for each substation under contract.

5.8 Relay and Scheme

5.8.1 General

Relays shall be of approved types complying with IEC 60255 or British Standard 142 and 5992, Parts 1,2 and 3 as appropriate, fully tropicalized, and shall have approved characteristics. **Relays designedidentical to relays with a minimum of five years proven field experience will only be accepted**.Supply record of proposed relays shall be furnished for the last five years. The Engineer will reject any design he considers unsatisfactory or having insufficient field experience. All the **protective relays shall be numerical type only**. Numerical relays shall be configured in such a way that at least 2 nos. relays shall be provided for each feeder. The protection relays, shall be located in conventional panels and shall be flush mounted in dust and moisture proof cases and of the draw out type with rear connections.

Relays shall be of approved construction and shall be arranged so that adjustments, testing and re-placement can be effected with the minimum of time and labour. Relays of the hand reset type shall be capable of being reset without opening the case.

Electrically reset tripping relays shall be provided where necessitated by the system of control, such as for those circuits subject to remote supervisory control.

Relay contacts shall be suitable for making and breaking the maximum currents which they may be required to control in normal service but where contacts of the protective relays are unable to deal directly with the tripping currents, approved auxiliary contacts, relays or auxiliary switches shall be pro-vided. In such cases the number of auxiliary contacts or tripping relays operating in tandem shall be kept to the minimum in order to achieve fast fault clearance times. Separate contacts shall be provided for alarm and tripping functions. Relay contacts shall make firmly without bounce and the whole of the relay mechanisms shall be as far as possible unaffected by vibration or external magnetic fields.

Relays, where appropriate, shall be provided with LED or flag indicators, phase coloured where applicable. LED or Flag indicators shall be of the hand reset pattern and shall be capable of being reset without opening the case. Where two or more phase elements are included in one case, separate indicators shall be provided for each element.

All Relay settings shall be visible and readable without having to remove the relay front cover. It shall not be possible to amend relay settings with the front cover in place; other than over a serial link.

If a connector for local use is provided this shall be accessible only after removing the front cover. Where a port is provided for permanent connection to a modem or other peripheral equipment, remote access shall be password protected.

Relays which rely for their operation on an external DC supply shall utilize for this purpose the trip supply of the associated circuit breaker trip coil. This supply shall be monitored and an alarm provided in the event of failure.

Any auxiliary supplies needed shall be drawn from the main station batteries and not from separate internal batteries in the protection equipment.

Relays, whether mounted in panels or not, shall be provided with clearly inscribed labels describing their function and designation in addition to the general purpose labels.

Attention is practically drawn to the tropical climate and relay designs should be entirely suitable for duty under full tropical conditions.
To minimize the effect of electrolysis, relay coils operating on DC shall be so connected that the coils are not continuously energized from the positive pole of the battery.

Relay shall be suitable for operation on 110 V nominal, 121 V float DC systems without the use of voltage dropping resistors or diodes

Numerical protection shall be designed in such a way that in case of a failure of DC auxiliary infeed,the full information needs to be maintained at least 24 hrs. After a recovery of DC auxiliary infeed the last information and alarms will be displayed and the alarm "failure of DC auxiliary infeed" released. The relay reset shall not erase the relay memory.

The Numerical protection functions shall be in the form of software such that additional or different functions, application specific logic etc. can be readily implemented without changes to the existing hardware. It shall be possible to programed/ parameterized by a portable computer (PC) all the numerical protective relays and the entire relay operating and configuring software and the portable computers and other accessory equipment needed to communicate with the relays shall be provided.

All numerical relays shall be adequately protected against damage from incoming surge and shall meet relevant IEC, BS and ANSI SWC test standards. Relays shall utilize a DC-DC converter type regulated power supply to provide transient surge isolation between the station battery and protection equipment. Each DC supply shall be designed to protect it from high voltage and surge and provide electrically isolated contacts for annunciation.

In addition, to all equipment and components, the Contractor shall supply documents and calculations to prove the correct functioning of the equipment and he shall ensure and demonstrate that the setting range of relays and the operating limits of all equipment is suitable for the intended applications.

5.8.2 Electromagnetic Compatibility

In certain cases, e.g. distance protection, current differential etc., electronic relays, or devices utilizing microprocessors are specified and electromagnetic devices will not be accepted.

Where such devices are required, they and the ancillary circuits connected to them, such as power supplies, current and voltage transformer secondary, status or tripping or alarm circuits shall be de-signed to ensure that they are compatible for use in the hostile electrical environment found in an EHV substation.

Adequate steps, by means of suitable design, shall be taken to prevent Electromagnetic Interference (EMI) (generated by sources such as circuit breakers, dis-connectors, lightning, radio or radar emissions, switching contactors in dc circuits etc.) or Electrostatic Discharges (ESD) from affecting relay performance or causing damage to components.
All relays offered must therefore have been type tested to meet the current requirements of IEC 60255 with respect to High Frequency disturbance, Fast Transients, Electrostatic Discharge, Radio Frequency Interference testing etc.

5.8.3 Scheme

The protection schemes shall incorporate any interface facilities to transform any insufficient contact rating used in the protection-related equipment, such as protection signalling equipment, to the rating required in the input/output circuits, e.g. for tripping requirements of the relay functions with the appropriately designed contacts.

Any protection relay output contact shall be coordinated with the station requirements.

5.8.3.1 Trip Relays

Trip relays shall be provided, as per requirement of the protection schemes. Following shall be the main features of a high speed tripping relays:

(a) Tripping relays shall have an operation indicator. They shall be high-burden relays to ensure capacitor discharge due to panel wiring fault will not cause trip relay to operate.
(b) All tripping relays shall be of the heavy-duty type suitable for panel mounting, and shall have operating coils, which are rated sufficiently to operate in conjunction with series flag relays.
(c) If necessary, normally closed contacts in series with the relay operating coil, shall be delayed for a period which will allow series flag relays to operate satisfactorily. All other tripping contacts should be instantaneous i.e. no intentional time delay.
(d) The operating range of the relay shall be from 70% to 120% of rated voltage.
(e) Electrical reset facilities shall be available for operation from remote and supervisory controls.
(f) High-speed tripping relays shall prevent closing of the associated circuit breakers until reset.

(g) Wherever the tripping relay contacts need to break the DC current, sufficiently rated magnetic blow-out contacts or other approved means shall be used.
(h) Trip-repeat relays shall have fast operating times (below 10 ms at rated voltage) to achieve an overall trip time of the scheme within the specified limits.
(i) The trip relay must have a sufficient number of NO/NC contacts to cover all essential functions.

5.8.3.2 Trip Circuit Supervision

The tripping circuit of each phase of a circuit breaker shall be continuously monitored with both pre-close and post-close supervision facilities. i.e. the tripping circuits of each phase of a circuit breaker shall be continuously supervised in both circuit breaker positions.
Trip circuit supervision relays shall have sufficient contacts for visual/audible alarm, indication and interlocking purposes.

Relay elements shall be delayed on drop-off to prevent false alarms during faults on DC wiring on adjacent circuits, or due to operation of a trip relay contact.

The trip circuit supervision relays shall be such that in the event of a fault in any one component it shall not be possible to inadvertently trip the circuit breaker. The trip circuit supervision relays shall be equipped with a delayed alarm indication and initiate alarm in the station.

This alarm shall operate for loss of trip supply and for any interruption in the trip circuit wiring. Relay alarm elements shall be equipped with hand/electrical resetting flag indicators.

5.8.3.3 Protection Supply Supervision Relays

Protection supply supervision relays are to be provided to detect loss or interruption of supply of protection schemes so that the operator can clearly differentiate via the available alarms between loss of supply due to a blown fuse / tripped MCB and failure of a protection relay.

5.8.3.4 VT Supervision Relays

VT supervision relays shall be provided for complete protection, synchronizing, measurements and interlocking circuitries purposes, for necessary blocking and alarm.

Every cubicle and panel shall have at the top left-hand corner one easily visible lamp to indicate that an element in the cubicle or panel has initiated an alarm.On the station alarm panel, an alarm shall be given which can only be reset when this cubicle alarm has been reset at the panel or cubicle. The panel alarm lamp can only be reset when the element in the cubicle causing the actual alarm has been reset. The reset button shall be located outside on the door.

Where two groups of relays are used to protect a circuit, the VTcircuits and DC supplies shall be arranged in a redundant manner so that one group may be switched off without affecting the performance of the other group.

Tripping supplies for each bay shall be engineered directly from the DC distribution boards. Any interruption of DC supply to relays (internal and external) shall initiate an alarm. Converters and inverters used for energizing the relays shall have their outputs monitored and shall initiate an alarm in the event of any failure. These devices shall be of short circuit-proof design.

Test blocks shall be provided to facilitate tests by secondary injection of all major fault-measuring relays without disconnecting any wire or permanent connection. The test block shall permit direct injection of currents and voltages into the individual relays.
The test terminal blocks shall isolate the trip contacts of main protection relays on both sides. Injection sockets shall be arranged so that it is impossible to open the circuit of the current transformer secondary circuits when inserting test plugs.

The trip functions, if not interrupted by a test switch, shall be blocked when inserting the test plugs. All main protection relays shall be individually provided with an IN/OUT switch (lockable).

The incoming voltage, current and DC circuits shall be connected to the bottom of the test block and the relay connection shall be taken from the top.

Four plugs for each type of test plug, provided per station, shall be supplied and handed over to PGCB.

When separate interposing current transformers (ICTs) are used, there shall be a test socket or link to measure both the primary and secondary currents of the ICTs.

5.9 Overhead Line Protection

5.9.1 400kV, 230kV and 132 kV Transmission Line Protection

For the entire system, the following line protection philosophy shall be applicable:

	Main Scheme		Scheme	Reclosing	Details
	Relay	Comm.Ch			
Main 1	Current Ratio Differential Protection [Transfer Trip	Optical	Differential (87L) Distance (21) [as Backup] 67/67N	Multiple 1ph, 3ph, 1+3ph	Current Ratio Differential Protection with Full scope of Distance and Multiple OC Function as backup

	(PUTT/POTT) for Distance (21) function]		50 Stub 68, VTF Trip Supv		
Main 2	Current Ratio Differential Protection [Transfer Trip (PUTT/ POTT) for Distance (21) function]	Optical	Differential (87L) Distance (21) [as Backup] 67/67N 50 Stub 68, VTF Trip Supv	Multiple 1ph, 3ph, 1+3ph	Current Ratio Differential Protection with Full scope of Distance and Multiple OC Function as backup
Backup	67/67N 68, VTF 50/50N 51/51N				For 132kV only

The Main 1 & Main 2 relays shall be for 400kV, 230kV voltage system, and for 132kV system, only Main 1 & backup relay shall be applicable. The Main 1 & Main 2 relay shall be preferably from two different manufacturers or different models from same manufacturer.

During the Design stage, the Contractor can propose different arrangement like:

- Main 1 Protection and Main 2 Protection in the same cubicle and separate Control cubicle
- or Both Protection and Control in the same cubicle for lower voltage class like 132kV & lower

The final solution will be subject of the Employer's final approval. However, the bidder/manufacturers of relay shall provide at least 5 years of warranty for its product, i.e., for complete Protection system.

Protective devices for Main 1 and Main 2 overhead line protection are shown on Bid Drawing. These devices shall comply with the following.

Main 1 and Main 2 protection of 400kV & 230 kV lines shall be of Line differential protection with back-up distance protection and directional over-current to earth fault protection. The Main 1 protection of 132 kV line shall be of Line differential protection with back-up distance protection and directional over-current to earth fault protection and the Back-up protection of 132 kV line shall be of Directional overcurrent & Directional Earth fault protection. Both main protections and directional earth fault protection should operate in conjunction with tele-protection channels over optical fiber for tele-protection schemes of distance protection. All relays shall be of numerical type. The philosophy of PSLD & Trip logics will be applied in all aspects.

Each set of protection will be energized from separate current transformers and shall have facilities for independently tripping duplicated circuit breaker tripping coils and initiating

auto-reclosing, breaker failure protection, inter-tripping, alarms, fault location equipment, disturbance recorders etc. The Contractor shall ensure that the relay contacts used for initiation of auto reclosing shall have the same dwell time as the main tripping contacts to avoid any problems arising from contact racing with the auto re-close relay.

Two sets of protection shall consist of different types of relays either from the same Manufacturer or from different Manufacturers. Separate elements shall be provided for phase and earth fault measurement. Separate elements shall also be provided for each zone. Phase and earth fault compensation features shall be incorporated to ensure accurate distance measurement for all types of fault and to allow for variation in the path of earth faults on the system.

5.9.2 Main Protection 1 (Distance)

The main protection (Main-1 & Main-2 for 400kV & 230kV and Main-1 & Backup for 132kV) shall be of numerical type and shall be provided by distance relays for use with a signaling channel.
The relay scheme offered shall be suitable for use in the permissive under-reaching, permissive over-reaching, blocking and unblocking modes. All these options shall be contained and selectable in the standard relay scheme. The relay should be applicable to all neutral ground possibilities and should be suitable for the protection of long or short overhead lines or cables, double circuit lines, heavily loaded lines, lines with weak infeed etc.

The permissive overreach scheme shall operate in a permissive under-reach/overreach transfer tripping mode with under-reaching zone I elements and overreaching zone 2 elements and suitable logic to achieve fast tripping at the sending end in the event of a weak infeed at the receiving end. The weak infeed logic shall comprise a zone 3 element set to look in the reverse direction, which "echoes" back the received signal to the sending end if the reversed zone 3 comparator does not operate.

To provide high speed tripping when a line terminal is open a 'signal echo feature' shall be provided, which is initiated when either the feeder dis-connector is open, or when the associated circuit breakers are open.

The Zone 1 elements will normally be set to approximately 80 per cent of the line impedance. They shall trip the local line circuit breaker.

The Zone 2 elements will be set to overreach the remote substation and in the case of permissive over-reaching mode operate in conjunction with teleprotection signaling channels to form a permissive over-reaching scheme. They shall also act as a back-up time delayed zone which trips the local circuit breaker. In the case of permissive under-reaching mode protection the overreaching Zone 2 unit will be used as the permissive element to permit instantaneous tripping of the local circuit.

The Zone 3 elements shall provide a further time delayed back-up zone.

Distance protection back-up zones shall also trip the remote end circuit breaker(s) via a direct intertripping channel.

Partially cross polarized mho or polygonal impedance characteristics relays are preferred for Zones 1 and 2 for 3-phase and 2-phase faults but other characteristics will be considered. Quadrilateral characteristics with adaptive reactance measurement to avoid overreach or under-reach for resistive faults with pre fault load are preferred for earth faults. The relays shall operate for faults in the direction of the protected line only. Under no circumstances shall they operate for reverse faults even when the voltage supplied to the relay falls to zero on all three phases nor shall they operate due to the transient response of the capacitive voltage transformers following reverse close-up faults. Details of methods used for polarizing the relays to deal with faults close to the relaying point shall be provided. Zone 3 shall be capable of being set as either directional or non-directional and shall be capable of being independently off set in both directions.

The reach of each zone and reverse element shall be individually adjustable by means of a multi-tap voltage transformer or other approved method. The characteristic angle shall be adjustable between approximately 40 and 80 degrees.

Where used in a permissive overreach transfer tripping scheme with weak infeed tripping the zone 3 unit may be set looking in the reverse direction. The reverse looking impedance/directional elements shall detect all reverse faults capable of being detected by the Zone 2 relay at the remote substation. Bidders shall explain how this is achieved.

Single pole tripping and auto-reclosing are being employed and the auto-reclosing scheme requirements are given in Section 5.12. The distance protection shall be suitable for such a scheme and the Contractor shall substantiate by calculation or other means that phase selective tripping will be achieved under the system conditions anticipated in the daily operation.

The Contractor may request whatever information he requires for carrying out the necessary calculations.

Auto reclosing shall be capable of being blocked for

(a) Any three phase fault
(b) Any Zone 2 or Zone 3 time delayed trip
(c) Carrier channel out of service
(d) DEF aided trip
(e) DEF back up time delayed trip
(f) Switch on to fault.

The necessary circuitry shall be incorporated to inhibit the Zone 1 and Zone 2 phase fault elements when necessary during single phase to earth faults and during the single phase auto-reclose dead time. These features shall be selectable by links or switches. Provision shall also be made to ensure that the earth fault elements reset during the single phase dead time.

The protection sensitivity shall be shown to be adequate for the minimum fault level conditions. These will be advised to the Contractor at a later stage.

Where fault resistance may be significant, the Contractor shall illustrate that the distance protection can cover such values taking fault current distribution and load conditions into account.

The operating time of each distance protection zone shall be substantially independent of fault current magnitude. The operating times shall be stated in the Schedule of Particulars and, in addition, curves shall be provided showing the effect of line and source impedance, fault position and operating current.

Under no circumstances shall any line protection operate because of normal system switching including de-energization of the line.
A feature shall be incorporated to ensure instantaneous tripping in the event that the circuit breaker is closed onto a fault on a previously de-energized line.

Distance protection back-up Zone 2 and Zone 3 time delay setting ranges shall be 0.2 to 1.0 seconds and 0.5 to 3.0 seconds respectively.

A carrier receives signal extension timer with a delay on reset of 100 msec. shall be provided to ensure that relays at both ends of a parallel feeder circuit have sufficient time to trip for faults occurring in the end zones of the protected line.

A monitoring system shall be provided to supervise the voltage transformer supply to each set of distance protection. In the event of loss of one, two or three phases, the monitoring system shall inhibit relay operation and initiate an alarm. The VT supervision unit associated with the distance relay shall also inhibit the DEF protection in the event of VT fuse failure.

All relays shall incorporate indicators to show the relay tripped, zone indication and the phase or phases faulted. Indication must not be lost in the event of a supply failure.

Directional earth fault protection operating in a permissive overreach scheme shall be provided to cater for high resistance faults which cannot be detected by the distance protection. The same teleprotection signaling channel shall be used for the directional earth fault scheme and the distance protection scheme. An echo feature shall be included with the DEF Scheme and shall be subject to approval by the Engineer.

The directional relays shall be dual polarized i.e. polarized with zero sequence voltage and current. The relay sensitivity shall be adjustable between approximately 5 and 10% of rated current. A relay characteristic angle of 60 degrees is preferred but alternative angles will be considered. It is appreciated that because the 400kV, 230 kV, 132kV system zero sequence source is an auto-transformer with a delta tertiary winding, that current polarizing of a dual polarized relay is unreliable without careful analysis. The Contractor shall be responsible for determining whether such a current signal can be taken from the auto transformer neutral and safely used for polarizing the relay within three months of being advised of all trans-former impedance parameters.

The directional earth fault protection shall initiate three pole tripping. It must therefore include a short time delay to permit single pole tripping by the distance protection. Initiation of three pole reclosing following operation of a DEF aided trip shall be selectable by means of a switch.

Directional earth fault relays shall incorporate a back-up stage in addition to the aided tripping unit. The time delay range shall be 0.2 to 5.0 seconds or inverse time delayed with a characteristic to IEC 60255.

Neither the distance protection scheme nor the directional earth fault scheme shall mal-operate due to fault current reversal during sequential clearance of a fault on the parallel circuit.

The effect of zero sequence mutual coupling between the double circuit lines on the protection shall be described, together with any measures considered necessary to overcome this effect.

The distance protection time delayed back-up Zones 2 and 3 and the directional earth fault back-up stage shall intertrip the remote station circuit breakers over direct intertripping channels.

Auto reclosing shall not be initiated on receipt of direct intertripping signal. Direct intertripping shall also be initiated in the event of a 3 phase fault in any zone, or following a switch on to fault trip.

Distance relays shall be supplemented by power swing blocking relays. Power swing blocking relays shall be compatible with their appropriate distance relays, and for distance relays having offset mho zone 3 characteristics or starters shall comprise an offset mho characteristic which encompasses and is concentric with the distance relay impedance starter or zone 3 characteristic. Similarly where it is possible to shape the zone 3 or starter characteristic the power swing blocking relay characteristic shall also be capable of similar shaping. Where zone 3 is set reverse looking the power swing blocking characteristic shall be set such that it encompasses the forward looking zone 2 characteristic.

Facilities shall be provided to block zones 1, 2 and 3 of the distance relay from the power swing blocking logic as required.

Blocking logic shall be derived by determining the time taken for the apparent impedance of the power swing locus to pass from the characteristic of the power swing relay to the appropriate distance relay characteristic. Blocking shall not take place until the apparent impedance has passed through the two power swing characteristics and the set time delay has expired.

The associated time delay relay shall have a setting range of 50-250ms.

Relays shall be of numerical design. Electromechanical relays will not be accepted. The Numerical relays shall be design with 16 bit Analogue to Digital converters, powerful Digital signal processors, CPU etc. The relay should have continuous self-supervision and diagnosis. A local display unit shall be provided on the front of the relay for measure and display, Distance to fault indication, diagnostics, etc. and also for acknowledging and resetting of latched outputs. The required software for setting and configuring the relay shall be provided with the relay and this man machine communication (MMC) shall be user friendly and should not require any special programming knowledge. It should be possible to do the settings off line and load the settings on to the relay with a standard portable PC with a fiber optic connection. A separate communication port shall be provided so that the distance relays can in future communicate with the Station monitoring system as well as easily be integrated into Station Control Systems. A PC with a man machine communication (MMC) software for setting of the relay shall be included in the scope of supply.

Reset times shall be low to ensure the associated distance relay reverts to its normal role as soon as possible following a power swing.

Power swing blocking shall be inhibited during the single pole dead time of an auto reclose cycle so that if a power swing develops during this period the distance protection can give an immediate three phase trip. The Bidder shall advise whether it is possible to extend the inhibition of the power swing blocking to cover a period immediately following auto reclosing so that if a power swing develops on reclosing onto a permanent fault a 3-phase trip would be permitted. The Bidder shall also advise whether power swing blocking can be inhibited if an earth fault occurs during a power swing.

If the associated VT supplies are lost due to VT fuse failure the power swing blocking relay shall not operate.

Where protection is supplied from multi-ratio current transformers, the lowest ratio will be used for the initial system configuration, when fault levels are low. The working ratio will be increased when the system expands and the fault levels and load transfers increase.

Detailed relay setting calculations shall be furnished and submitted for approval. It is the Contractor's responsibility to compile all required data for setting calculations in close coordination with PGCB. Final setting tables shall be prepared and the relays shall be configured accordingly. All settings available in the protection with set values shall be

available in the setting table. All reference datasheets used for setting calculations shall be attached to the setting calculations.

5.9.3 Main Protection 1-1 (Differential Current)

The main protection method is the current differential method and shall have the following functions and characteristics.
The operating characteristics shall be provided with independent current differential protection relay elements for each phase and shall be provided with a function to prevent malfunction due to CT saturation.

High resistance ground fault detection performance should be provided.

The CT ratio compensation function should be provided so that CT ratios can be applied differently.

Modulation is PCM (Pulse Code Modulation). It shall be applied as a spare (always available for dual communication) and shall be automatically switched to the spare line if the main line is defective, and shall be switched manually or automatically to the spare line if the main line is defective.

Sampling Data at both ends should be compensated automatically with time synchronization. PCM signal delay and signal transmission path change should be compensated automatically. PCM transmission line monitoring function that monitors transmission line abnormality (data loss, CRC error, communication unit switching, etc.) should be alarmed and prevented malfunctions of protective relay. Protection function should be recovered automatically and recorded event when the signal transmission line recovered.

It should be transfer trip function about the breaker failure(B/F). the function should have signal input (D / I) for transfer trip and transfer signal to opposite side. In addition, a breaker failure (B/F) transfer trip function should be received a Circuit Breaker Failure signal transmitted from the opposite side and a breaker on the own side should be tripped

The following functions are to be provided to prevent the malfunction of the main protection and supervising protection relays

It must have 27S, 27G, UVD (Voltage Change Rate), OC, OCG, OCD (Current Change Rate). In addition, one or more of each element should be available for selection.

It should be a function to make instantaneous trip (SOFT: Switch Onto Fault Trip) in case of forced power transmission in ground state of transmission line.

In 1.5CB type, the STUB protection function should be provided as follows when operating the STUB bus.

- Protection against failures between CB and LS on line
- Protection of transmission line at own terminal during STUB operation of opposite substation
- Function to prevent malfunction in case of failure other than protection section

The Automatic Reclosing operation function should be configured as follows (details 5.12).

- Circuit breaker line check function
- 3-phase final trip function
- Reclosing transfer function

Fault record storage function of protection relay should be provided as follows.

- All analog inputs of protective relay
- All digital input signals of protective relay
- All operating elements and final trip element of protective relay
- Event Record and Fault / Disturbance Record should be saved as fault record and record capacity should record at least 4 times of data more than 1 second.

The protection relay shall have the functions equivalent to the following to prevent the loss of stored data due to the interruption of the DC power supply.

- Setting value of protective relay stored permanently
- Avoid other stored data loss (save at least 3 days)

Differential protective relay shall be provided with distance expression function for transmission line failure and comply with the following criteria.

- Error range: Less than ± 5% of the failure point (based on the test by the test equipment), and the indication is expressed in distance

The fault analysis function of the protective relay shall be provided with the following functions or more.

- LAN port must be provided at the front and rear of the protective relay to connect to the PC so that the fault record can be downloaded using a portable computer (PC).
- Fault analysis software should be provided, and the harmonic analysis function of analog signal, voltage and current magnitude and phase analysis function, protection relay element operation time analysis function, analysis of impedance and power in case of failure, conversion to COMTRADE file, fault data synthesizing (including visual synchronization adjustment) shall be provided.

The remote access and data acquisition functions of the protective relay shall be provided with the following functions or more.

- Since the protection relay has a remote (server) connection function, it must be possible to check the correction data and to meter in real time, and to transmit the failure data to the server.

- When requested the operating software, the manufacturer shall provide the operating software for the Sever for remote access, which shall store the fault data transmitted from the protection relay on the server and allow the user to access the server and read the fault data.

5.9.4 Directional Overcurrent and Earth Fault Protection

The overcurrent and earth fault relays shall be fully numerical and shall have multi characteristics (inverse, very inverse, extremely inverse) to IEC 60255.
Overcurrent relays shall have a current setting range from at least 50% to 200% in 25% setting steps.

Earth fault relays shall have a current setting range from at least 20% to 80% in 10% setting steps. Time multiplier settings shall be continuously adjustable from 0 to 1 or, as an alternative, in steps of 0.025 from 0.05 to 1.0.

Transformer circuits relays shall be provided with high-set instantaneous units which can be set to 1.25 times the fault current in the HV winding for a fault on the LV terminals computed using the transformer minimum impedance and assuming negligible source impedance. The instantaneous unit shall have a low transient overreach (less than 5% for system X/R ratio of 10) and an operating time of less than 40 msec. at two times the current setting.

Line circuit relays should have a reset ratio greater than 95% to enable settings to be made which are close to the circuit emergency rating. The relay contacts must close at a current equivalent to 110% of the setting and relay overshoot must not exceed 50 msec.

Overcurrent and earth fault relays shall trip via the CB duplicate trip coils and shall initiate duplicated direct intertripping to the remote line end CB.

Relays shall be thermally rated such that the operating time of the relay at the highest practical current levels on any combination of current and time multiplier settings shall not exceed the thermal withstand time of the relay. The Bidder shall provide copies of type test reports to show that this requirement is met.

Where directional back-up overcurrent and earth fault devices are specified, directional elements shall be voltage-polarised.

Directional units for directional overcurrent protection shall be quadrature-connected with a relay characteristic angle setting of 30˚ or 45˚ current leading voltage.

Directional units for directional earth fault back-up protection shall employ residual voltage quantities, and the relay characteristic angle shall be variable 0˚, 45˚ and 60˚, current lag.

The nominal operating boundary shall be ±90° from the relay characteristic angle, and the operating time of the directional unit shall not exceed 20 ms at the relay characteristic angle. The relay shall be capable of operating correctly when both the operating current and polarising voltage quantities are 1% of rated values at an angle equal to the relay characteristic angle.

The residual polarising voltage for earth faults may reach 190.5 volts; therefore it should withstand this value continuously. The continuous withstand current should be no less than twice rated current.

5.10 Busbar Protection

5.10.1 Busbar Protection

The busbar protection for 400kV, 230 kV and 132 kV shall be low impedance type numerical relay capable of detecting all types of phase and earth faults under all system generation conditions. The protection shall be extensible to cover the final substation arrangements and Bidders shall state what extra material is required. Main 1 & Main 2 for 400kV Busbar Protection system shall be from different manufacturers.

The busbar protection shall have the following features:

(a) Two independent measurement & tripping criteria. One based on stabilized current differential algorithm and the other on directional current comparison and shall be capable of detecting three phase, phase-phase and phase to earth faults, under all system generation plant conditions. They shall meet the fault clearance time of 100ms including breaker operation time under all conditions.
(b) Two independent hand or electrically reset busbar protection trip relays shall be associated with each circuit breaker. These trip relays may also be employed for circuit breaker failure. Operation of either of these relays shall block closing of the associated circuit breaker.
(c) Each trip relay shall trip the circuit breaker via both trip coils. Both relays on the transformer circuits shall trip the associated circuit breakers.
(d) The operating time of the measuring relays shall not exceed 30msecs at five times the relay current setting.

The busbar protection will be supplied from multi-ratio current transformers. The working ratio will be selected on the basis of maximum load transfer in the same manner as the line current transformer ratios.

The overall fault setting shall be between 10% and 30% of the minimum fault current available for any type of fault, unless otherwise specified. The minimum fault current for busbar faults will be advised at a later stage.

The rated stability limit of the protection shall not be less than the switchgear short circuit rating.

Automatic and continuous supervision of current transformer circuits shall be provided to give an alarm when the out-of-balance current reaches an undesirable value. Operation of current transformer supervision equipment should take the defective protection zone out-of-service.

The Contract shall include for all necessary current transformers, relay panels, marshalling boxes, isolating and shorting links, etc. A lockable busbar protection ON/OFF switch shall be provided.

Current transformer secondary bus wiring should be suitably dimensioned to reduce current transformer burdens to a minimum.

Suitable voltage limiting devices shall be provided as necessary, including across the unused part of the CT secondary when tappings are employed.

Full details of the scheme offered, together with performance figures for stability and sensitivity, shall be provided.

The numerical busbar protection shall be multi-processor in structure, with extensive self-supervision, 16 bit analogue to digital converters, together with appropriate algorithms to provide phase segregated measuring principles and multi criteria evaluations before initialization of trip commands. The busbar protection shall be of decentralized, with redundant DC/DC supplies type and the bay units shall be fixed as close to the CTs as possible reducing the copper wiring to a bare minimum and thereby also reducing the CT burden and CT dimension.

If the intercommunication between the bay unit and central unit by fiber optic cables, the required fiber optic cable and all necessary items shall be supplied, connected and commissioned by the Contractor.

Extension of existing busbar protection: The scope of work under this contract is to extend theexisting busbar protection for new bays with the same equipment.

5.10.2 Conditions of Acceptance of Busbar Protection Systems Submitted on the Basis of Calculated Performance

The Contractor shall prepare for approval calculated performance data for differential busbar protection systems in lieu of heavy current tests, subject to the following:

(a) The rated stability limit shall be no less than the three phase symmetrical breaking capacity of the associated switchgear.
(b) The overall fault setting for any type of fault shall be between 10% and 30% of the minimum fault current available. The minimum fault current available for a busbar fault will be advised later.
(c) Current transformer knee point voltages shall not be less than twice the relay circuit setting volt-age.
(d) The maximum peak voltage across current transformer secondary wiring shall not exceed 3 kV under maximum internal fault conditions.
(e) Associated current transformers shall be Class X or 5P, low reactance type. Split core type current transformers will not be accepted.
(f) The Contractor shall submit for the Engineers approval a design report detailing the protected equipment, design parameters of associated current transformers, details of connections and burdens between current transformers and relays, details of the relay circuits and performance calculations.

5.11 Circuit Breaker Failure Protection

Breaker failure protection shall be fitted to all 420, 245 kV and 145 kV circuit breakers of the substation. The breaker failure protection on a circuit breaker shall be initiated by all the other protection devices which normally initiate tripping of that breaker including the receipt of a direct intertripping signal from a remote line end. In the event of the circuit breaker failing to open within a pre-selected time, the breaker failure protection shall initiate tripping of all adjacent circuit breakers. It shall also incorporate provision for initiating tripping of any remote infeeds, via direct intertripping channels over optical fiber communication link or power line carrier circuits.

In the case of 420, 245 kV and 145 kV circuit breaker failure protection, the position of each circuit breaker shall be monitored by a current check relays fed from the protection current transformers as shown on the drawings. The relay outputs shall be connected in series in a "two out of two" arrangement. The relays shall have an operating time of approximately 10 msec. and a consistent reset time of less than 15 msec. The relays shall be capable of remaining in the operated position continuously and of carrying twice the circuit rated current continuously.

The scheme provided shall be suitable for use in a single pole and three pole tripping and auto reclosing schemes as appropriate.
The operating time from initiation to back tripping output shall be selected by means of duplicated timers with a setting range of 0-500 msec. The two timers per circuit breaker in the

case of the 400kV, 230 kV scheme shall be connected in a two-out of two basis and shall energize both trip coils of all adjacent circuit breakers via two back tripping circuits from separate D.C. supplies. In the case of the 132 kV scheme the two timers shall also be connected in a two-out of two basis and energize both trip coils of all adjacent circuit breakers but via a single trip relay.

The timers shall be of a modern design to minimize overtravel. With the approval of the Engineer the busbar protection trip circuits may be employed for circuit breaker fail back tripping.

In the event that a circuit breaker is unable to trip due to low gas pressure, low hydraulic oil pressure etc. the associated alarm shall be arranged to by-pass the breaker fail time delay. The breaker fail relay/scheme shall be designed to accept this input.

Operation of the breaker fail protection shall block manual and automatic reclosure of the associated circuit breaker. Breaker failure protections inbuilt in distance / transformer relays will not be accepted.

5.12 Auto-Reclosing Scheme

Three pole and/or single pole, single shot repetitive auto-reclosing equipment, shall be provided for the overhead line circuit breakers.

Reclosure shall be initiated following tripping by either main protection operating in Zone 1 or in conjunction with a teleprotection receive signal. Selection facilities shall also be provided to enable or block three pole delayed auto-reclosing following operation of the directional earth fault protection aided trip output. Reclosure shall not be initiated in the event of a three phase fault, nor any type of fault in the second or third back-up zones, nor when a direct intertripping signal is received, nor when the circuit breaker is closed onto a fault on a previously de-energized line, nor when the DEF back-up protection operates nor if the carrier channel is out of service.

The following modes of operation shall be selectable by means of a switch or switches or programmable.

(a) Single pole, high speed, auto-reclose: Auto-reclosure shall only be initiated in the event of a single phase to earth fault. All other types of faults shall result in three phase tripping without auto-reclosing.
(b) Three pole delayed reclosing: Delaying reclosing shall only be initiated in the event of a single phase or two phase fault. Three phase faults shall result in tripping without auto-reclosing.
(c) Single pole, high speed and/or three phase delayed, auto-reclosing as appropriate.

Single pole, high speed auto-reclosing shall be initiated only in the event of a single phase-earth fault and delayed reclosing initiated in the event of a two phase fault. Three phase tripping without re-closing shall take place for three phase faults.

(d) No auto reclosing: Three phase tripping without auto-reclose shall take place for any type of fault.

If a second earth fault occurs during the single pole auto-reclose dead time, and the selector switch is in the single and/or three pole reclosing mode three phase tripping with subsequent delayed three pole auto-reclose shall take place. If the auto-reclose selector switch is in the single pole reclose mode, three phase tripping with lockout should follow. Any auxiliary relays required to meet this logic shall be deemed to be included.
The high speed and delayed reclosing dead times have to be coordinated with the equipment being provided at the remote substation. Tentative ranges are, as follows:

- High speed single pole reclose dead time: 0.3 to 3 seconds
- Delayed three pole reclose dead time: 3 to 30 seconds

Bidders shall state available ranges.

The reclaim time i.e. the time period following the automatic reclosing of the circuit breaker, during which any further fault results in three phase tripping and lockout, shall be chosen to match the duty cycle of the circuit breakers, assuming the shortest available dead time is chosen. The reclaim time shall, however, not be less than five seconds, and the reclaim timer range shall extend to 180 seconds. (The reclaim time commences at the instant the reclose command is given to the circuit breaker and, therefore, includes the circuit breaker closing time).

The closing command shall be limited to two seconds, after which time the reclosing equipment shall be automatically reset without resetting the reclaim timer. The reclosing equipment shall also reset if dead line check or synchronism check conditions are not satisfied within a predetermined time of the check relays being energized.

A counter shall be provided to record the number of reclosures and lockout after a pre-selected number of reclosures has been reached.

The rated duty cycle of the circuit breaker as defined in IEC 60056 (and subsequent amendments) states that following an initial trip and auto reclosure a further reclosure is not permitted for a further 3mins.

Reclosing schemes shall include voltage monitoring and check synchronizing relays as appropriate.

Dead line check relays shall monitor the condition of the line and busbar and permit three pole reclosing only when the line is de-energized and the busbar is energized. The line is considered to be de-energized when the voltage is less than twenty percent of rated voltage, and the busbar is considered to be energized when the voltage is greater than eighty percent of rated voltage.

(A signal shall be provided from the dead line check relays for interlocking of the line earth switches to prevent the switches being closed onto a live line).

When a voltage is present on both sides of a circuit breaker, the synchronism check relay shall monitor the magnitudes of the two voltages across the open circuit breaker, and the phase angle and slip frequency between these voltages. Closing shall only be permitted when these are within prescribed limits.

Check synchronizing relays shall comply with the requirements of Clause 5.24. 1. The same relays may be used as for manual closing.

5.13 Overcurrent and Earth Fault Protection

The overcurrent and earth fault relays shall be fully Numerical and have multi characteristics (inverse, very inverse, extremely inverse) to IEC 60255.

Overcurrent relays shall have a current setting range from at least 50% - 200% in 25% setting steps.

Earth fault relays shall have a current setting range from at least 20% - 80% in 10% setting steps.

Time multiplier settings shall be continuously adjustable from 0 to 1 or, as an alternative in steps of 0.025 from 0.05 to 1.0.

In the case of transformer circuits relays shall be provided with high set instantaneous units which can be set to 1.25 times the fault current in the HV winding for a fault on the LV terminals computed using the transformer minimum impedance and assuming negligible source impedance. The instantaneous unit shall have a low transient overreach (less than 5% for system X/R ratio of 10) and an operating time of less than 40 msec. at two times the current setting.

In the case of underground line circuits relays should have a reset ratio greater than 95% to enable settings to be made which are close to the circuit emergency rating. The relay contacts must close at a current equivalent to 110% of the setting and relay overshoot must not exceed 50 msec.

Overcurrent and earth fault relays shall trip via the CB duplicate trip coils and initiate duplicated direct intertripping to the remote line end CB.

Relays shall be thermally rated such that the operating time of the relay at the highest practical current levels on any combination of current and time multiplier settings shall not exceed the thermal withstand time of the relay. The Contractor shall provide copies of type test reports to show that this requirement has been met.

Directional back up overcurrent and earth fault relays shall be provided for underground Cable feeders and the directional elements shall be voltage polarized.

Directional units for directional overcurrent protection shall be quadrature connected with a relay characteristic angle setting of 30° or 45° current leading voltage.

Directional units for directional earth fault back up protection shall employ residual voltage quantities and the relay characteristic angle be variable 0°, 45° and 60°, current lag.

The nominal operating boundary shall be ±90° from the relay characteristic angle and the operating time of the directional unit shall not exceed 20ms at the relay characteristic angle.

The relay shall be capable of operating correctly when both the operating current and polarizing voltage quantities are 1% of rated values at an angle equal to the relay characteristic angle.

The residual polarizing voltage for earth faults may reach 190.5 volts and therefore it should withstand this value continuously. The continuous withstand current should be no less than twice rated current.

5.14 Coupling Bay Protection

The Coupler bay shall be provided with overcurrent instantaneous trip relay protection (50 BF) and overcurrent time delay relay protection (51, 51N). Relays shall comply with the requirements of clause 5.12.

All trip-signal of OHL and transformer feeder protection shall be transferred to the coupling breaker in case the feeder breaker is bypassed and the feeder is protected by the coupling-bay circuit breaker. This shall be provided by auxiliary relay, not by auxiliary contacts of the circuit breaker by-pass isolator.

5.15 Transformer Protection and Shunt Reactor Protection

The auto transformers shall be provided with Main 1 & Main 2 biased differential protection. Main 1 & Main 2 shall be preferably from two different manufacturers or different models from same manufacturer. Directional over current relay and over current relays also shall be installed for back up protection. Additionally, over flux (V/Hz) relay shall be provided in order to avoid any overheating. Relay and protection connections refer to the Drawing, and detailed protection scheme shall be approved by Employer.

For 400kV shunt reactor shall be provided with Main 1 & Main 2 biased differential protection. Main 1 & Main 2 shall be from different Manufacturer. Over current relay and earth fault relays also shall be installed for back up protection.

5.15.1 Biased Differential Protection

The transformer differential protection shall be fully numerical design with 16 bit Analogue to Digital converters, powerful Digital signal processors, CPU etc. The relay should have continuous self-super-vision and diagnosis. A local display unit shall be provided on the front of the relay for measure and display, Trip indications, diagnostics, etc. and also for acknowledging and resetting of latched outputs. The required software for setting and configuring the relay shall be provided with the relay and this Human Machine Interface (HMI) shall be user friendly and should not require any special programming knowledge. It should be possible to do the settings off line and load the settings on to the relay with a standard portable PC with a fiber optic connection.

Overall differential protection shall be of the biased differential type and capable of detecting phase and earth faults.

Separate facilities shall be provided to enable bias and operating settings to be adjusted. The minimum operating setting shall not be greater than 20 percent of the rated full load current of the transformer.

The protection shall be designed to ensure stability on any transformer tap position under maximum through fault conditions with maximum D.C. offset. An infinite source is to be assumed and the through fault current calculated using the transformer impedance only.

Correction for matching transformer vector groups and main CT ratio's for Transformer Differential protection shall be performed within the relay without the use of external interposing-transformer.

The relays shall have magnetizing inrush current restraint of the second harmonic or other approved means. All necessary interposing current transformers shall be provided under the contract.

5.15.2 Restricted or Balanced Earth Fault Protection

Where specified, or shown on drawings, transformer/reactor windings and connections shall be protected by restricted earth fault protection. 2 (two) separate Restricted Earth Fault (REF) Protections have to be established for 3 (three) winding Transformers operating in voltage level 230kV or above. 1 (one) will be low impedance type having restraining characteristics and stability against heavy through fault even in case of severe CT saturation. Low Impedance type REF protection can be embedded in Main-1 Transformer differential relay.

The 2nd REF protection will be of high impedance type with necessary protection against over voltages. For reliability reasons the restricted earth fault relay shall be separate from the transformer differential relay.

2 (two) winding Transformers and transformers operating in 132kV may have only 1 (one) REF with low impedance type and embedded in Main-1 transformer differential relay having operating characteristics described above.

Delta connected windings shall be protected by balanced earth fault protection.

33kV winding of Earthing transformer (if any) will also be protected with low impedance type REF protection. Relays shall have maximum sensitivity and minimum operating times consistent with stability for faults outside the protected zone and on magnetising inrush surges

The rated stability limit shall not be less than the maximum current available for an external fault. This shall be taken as 16 times the rated current of the protected winding of the power transformer, or any other value agreed by the Engineer.

For the purpose of calculations, it shall be assumed that any neutral earthing impedance is short circuited.

The Contractor shall prepare for approval calculated performance for instantaneous high impedance restricted earth fault protection in lieu of heavy current tests, subject to the conditions in Clause 5.13 except:

(a) The rated stability limit shall be as specified above.
(b) The fault setting shall be as specified below.

i) When the transformer winding is connected to a solidly earthed power system, the fault setting shall be between 10% and 60% of the rated current of the winding. When the transformer winding has more than one rating, the setting shall be based on the lower rating.
ii) When the protected transformer is not connected to a solidly earthed power system the fault setting shall be between 10% and 25% of the minimum current available for an earth fault at the transformer terminals.

5.15.3 Transformer Back-up Overcurrent Protection

Three-pole inverse time back up overcurrent and earth fault protection shall be provided as shown on the drawings. This shall comply generally with Clause 5.13 but in addition the overcurrent elements shall also be a two stage device. Stage 1 will comprise the inverse time unit and stage 2 will comprise an additional definite time unit with a setting range of 50 msec. - 5 secs.

(a) Over Current and Earth Fault Protection

Separately mounted three phase directional overcurrent IDMT elements of numerical type shall be provided for back up protection on each and every transformer winding of the transformer. These IDMT elements shall comply with IEC 60255-3 and they shall incorporate a range of standard characteristics. The "Normal Inverse" characteristic (i.e. curve Type A) will be applied in service.

The over current IDMT elements shall have current ranges of at least 50% to 200% rated current, adjustable in steps of less than 10%.

The earth fault elements shall have current ranges of at least 10% to 80% rated current, adjustable in steps of less than 10%.
The time multiplier settings for both over current and earth fault IDMT elements shall be adjustable, with steps of at least 0.05, from 0.05 to 1.0.

Each of the IDMT elements shall have separate trip and alarm contacts and separate trip indicators. In addition the protection shall have the necessary contacts for initiating breaker failure protection and the disturbance recorder.

Back up over current protection tripping shall initiate trip coil 2 of the circuit breaker.

(b) Stand by Earth Fault Protection

Earth fault elements shall be provided for each and every power transformer winding having its neutral earthed. The earth fault element shall be connected to the power transformer's neutral current transformer and shall have the same curve specification like the over current elements. For Delta winding the neutral current transformer shall be the neutral current transformer of the earthing transformer.

The earth fault elements shall have current ranges from 10 % to 80%, adjustable in steps of 10%.

The time settings for both over current and earth fault IDMT elements shall be continuously variable from 0 to 1.0 or, as an alternative, with steps of at least 0.05 from 0.05 to 1.0.

The IDMT elements provided for earth fault protection shall also have separate trip and alarm contacts and separate trip indicators.

Back up earth fault protection tripping shall initiate the trip coil 2 of the circuit breaker.

(c) Earthing & Auxiliary Transformer Protection

Transformer Delta winding shall be earthed normally via an earthing transformer. This earthing transformer shall be included in the protection zones of the main transformer differential and the Delta winding REF.

5.15.4 Gas Pressure (Buchholz) Protection

Power transformers and earthing transformers shall be fitted with Buchholz devices under this contract. The Buchholz device will be of the two element type giving operation under gassing and under surge conditions.
All necessary flag indication, tripping relays and alarm relays associated with this protection shall be provided, mounted and connected under this contract.

5.15.5 Oil and/or Winding Temperature

Transformers will be provided with oil and/or winding temperature protection under this contract. These will be of the two stage type with adjustable settings giving alarm and trip facilities.

All necessary flag indication, tripping relays and alarm relays associated with this protection shall be supplied and connected under this contract.

5.15.6 Low Oil Level and Pressure Relief Devices

Transformers shall be provided with low oil level with contacts for the purpose of providing remote alarm. Transformers shall also be provided with a pressure relief device with contacts for purposes of remote alarm and trip function.

The alarm relays associated with these devices shall be supplied and connected under this contract.

5.15.7 Tap Changer Oil Surge

Transformers will be provided with an oil surge or pressure operated device having contacts for purposes of remote alarm and trip.

A relay associated with this device shall be supplied and connected under this contract.

All necessary flag indication, tripping and alarm relays associated with tap change oil surge shall be provided.

5.15.8 Tripping Relays

All tripping relays, where specified shall be of the heavy duty type suitable for panel mounting. The trip relays of the offered numerical protections shall be directly capable of tripping the breaker coils. It shall not be required to add additional trip relays

Trip relay contacts shall be suitably rated to satisfactorily perform their required duty and relay operating time shall not exceed 5 ms. from initiation of trip relay operating coil to contact close.

Where specified latching type relays shall have hand or electrically reset contacts and hand reset flag indicators. Resetting of the flag indicator and the contacts shall be possible without having to open the relay case.

Tripping relays shall operate when the supply voltage is reduced to not higher than 30% of nominal battery voltage. It shall not operate for wiring leakage currents and discharge of wiring capacitance

400kV, 230 kV and 132 kV circuit breakers are equipped with two trip coils. One tripping relay shall initiate tripping via one trip coil and the other tripping relay via the second trip coil.

5.16 DC Auxiliary Voltage Operating Range

DC operated relays, coils, elements, etc. will be operated from a 110V rated dc. battery, which under float charging conditions operates at about 125V. DC operated relays coils elements etc. shall be suit-able for operation over a voltage range of 66V to 143V. i-e. 110 - 40% + 20%.

5.17 Teleprotection Signaling

Details of protection initiation and various permissive and direct inter-tripping signals are as specified in Section-14 of Volume 2.

5.18 Digital Fault and Disturbance Recorder (DFDR)

The DFDR shall be delivered only for all new substations.

For the purpose of standardization, the DFDR to be supplied under this project shall be from Qualitrol (Belgium/UK)/SIEMENS (Germany)/SEL, USA or equivalent.

Since some of the above mentioned make, viz., Qualitrol (Belgium/UK), SIEMENS (Germany) make DFDRsare already existed in PGCB's System and their performance is proven, only Manufacturer's Authorization letter among the Qualification Criteria of sub-clause 2.5 of Section 3 of volume 1 of 3 of the Bidding Document is required to be submitted with the bid of the bidders who choose to propose DFDR from these proven manufacturers. Acceptance of any other DFDR with similar characteristics shall have to fulfill the Qualification Criteria of sub-clause 2.5 of Section 3 of volume 1 of 3 of the Bidding Document.

Installation, testing & commissioning of the DFDR shall be done by the DFDR Engineer(s) of the DFDR Manufacturer(s).

The DFDR shall have the following features:

(a) The equipment shall be an independent stand-alone system to monitor analogue and digital signals from all 400kV, 230 kV& 132 kV feeders, including transformer, reactor, buscoupler and bu-section bays that require to be monitored.

(b) For 400kV system, Travelling wave type fault locator [TWFL] shall be provided for 400kV Lines having length greater than 50km. TWFL can be inbuilt feature of Relay or can be a sepearte IED. However, when Travelling wave fault location measurement is provided, a Backup Impedance based measurement shall always be present in the IED.It shall have Phasor Measurement options also. It shall be possible to integrate both TW based & traditional Impedance based IEDs in the complete DFR system. The TWFL shall be suitable both for Single ended & Double ended application.

(c) The Manufacturer shall prove the system's reliability and good site performances by providing substantial evidence of the systems already installed and commissioned for at least a duration of 5 years [both for TWFL & DFDR], accompanied by the customer's recommendations and type test reports from internationally acclaimed laboratories.

(d) The DFDR system shall be modular in design for easy expansion, upgrade and maintenance.

(e) The acquisition system or its storage unit shall not be based on a PC platform.

(f) A DFDR module shall be equipped with a minimum of 40 digital and 8 analogue signals per bay and shall be suitable for AC/DC measurement without any hardware changes.

(g) The system shall be equipped to monitor, detect and record simultaneously fast transient faults (short-term) and slow phenomena disturbances (long-term) like power swing, frequency variation, voltage drop, etc., covering all the required feeders. Features

(h) All input signals shall be able to scan and record simultaneously at least 2 or 3 user-programmable sampling rates from 500Hz to 24kHz for fast (short-term) transient monitoring and from 1Hz to 500Hz for slow phenomena (long-term) monitoring in order to detect and record fast (short-term) and slow phenomena (long-term) events.

(i) Sufficient storage capacity, not lss than 2GB, shall be provided. There shall be no moving parts in the storage system

(j) At least 25 sec. of memory for transient fault data recording (at 24 kHz sampling rate) and over 1000 sec. for slow (at 30 Hz) phenomena recording shall be provided in addition to the auto-maintained, inbuilt hard disk unit which shall be installed for data storage. The inbuilt hard disk unit shall be managed and operated by the identical industrially proven operating system of the DFDR.

(k) The graphical data should be recorded for all feeders simultaneously (snap shot image). The re-cording should contain the data prior to the event and after the event, including the dynamic length of the event / fault without any alterations.

(l) The system should possess a library of sensors (triggering criteria), which should be selected by the user and shall be able to detect and record various type of incidents. The system shall be able to detect incidents by the selected starting criteria and should be able to produce a record.

(m) The recordings shall contain the graphical data of physical inputs (voltage, currents, digitals) and virtual inputs (e.g. frequency, dp/dt, dq/dt (3 phases / single phase), RMS values etc.).

(n) The DFDR shall be able to communicate with local and / or remote master stations, using master communication and analysis software. This software should permit the user either locally or re-motely to download the recorded data, to ascertain the system's operational status, to change parameters, etc.

(o) Master communication should be able to communicate via RS 232 (direct connection), through modem (dial-up telephone line) &LAN (Ethernet (TCP / IP) - IEEE 802.3) networking and through IEC61850.

(p) While distributed scheme is deployed for DFR solution of the complete substion, Parallel Redundancy Protocol [PRP] shall be implemented within the devices redundant ethernet switches. At lest one ethernet switch shall be provided as spare

(q) The DFR shall perform the following functions:

i) fault location (including impedances and report, for 400kV TW based fault location withimpedances measurement back-up),
ii) graphical display of data,
iii) phase measurement & display,
iv) transient fault recording,
v) dynamic swing recording,
vi) harmonics' measurement & display,

vii) integrated SER function,
viii) calculated channels etc.

(r) The system shall be able to calibrate at site, and the required menu-driven software and other required accessories shall be supplied along with a notebook computer, colour printer etc. The calibration shall be easier , not requiring any typical fault creation for exact values of calibrated quantities.
(s) The system shall be equipped for time synchronization by the external GPS clock receiver for real time synchronizing (including antenna).
(t) Local printing facility shall be provided with the system.
(u) The master station (a latest version of PC) and the relevant software shall be supplied with the equipment for analysis and communication.
(v) Power quality monitoring or continuous monitoring (periodical recording) shall be made available for at least 4 feeders.

In addition to above, manufacturer shall provide warranty for its product at least for 5 years.

TYPICAL SIGNAL LIST OF DFDR :

General Notes:

1. Necessary engineering software with license (if required) for configuring the DFDR has to be provided to PGCB.
2. The following signals are typical for each type of feeder of the mentioned substations. Please note that, same numbers of spare analog and digital inputs have to be provided for Future Line and Transformer feeders as well as shown in the tendering SLD.

i. *400kV Lines*

Sl No.	*Signal Description*
1	*Main-1 Relay Line Differential Protection Trip (if any)*
2	*Main-1 Relay Distance Protection (Z1) Trip*
3	*Main-1 Relay Distance Protection (Z2/Z3) Trip*
4	*Main-1 Relay Faulty*
5	*Main-1 Relay VT fuse fail*
6	*Main-1 Relay SOTF Trip*
7	*Main-1 Relay PSB Operated*
8	*Main-1 Relay A/R in progress*
9	*Main-1 Relay A/R blocked*

Sl No.	***Signal Description***
10	*Main-1 Relay Distance send*
11	*Main-1 Relay Distance received*
12	*Main-1 Relay DEF send*
13	*Main-1 Relay DEF received*
14	*Main-1 Relay Aided Trip*
15	*Main-1 Relay O/C, E/F Trip*
16	*Main-1 Relay O/V Trip*
17	*Main-1 relay 87L communication fail (if any)*
18	*Main-2 Relay Line Differential Protection Trip (if any)*
19	*Main-2 Relay Distance Protection (Z1) Trip*
20	*Main-2 Relay Distance Protection (Z2/Z3) Trip*
21	*Main-2 Relay Faulty*
22	*Main-2 Relay VT fuse fail*
23	*Main-2 Relay SOTF Trip*
24	*Main-2 Relay PSB Operated*
25	*Main-2 Relay A/R in progress*
26	*Main-2 Relay A/R blocked*
27	*Main-2 Relay Distance send*
28	*Main-2 Relay Distance received*
29	*Main-2 Relay DEF send*
30	*Main-2 Relay DEF received*
31	*Main-2 Relay Aided Trip*
32	*Main-2 Relay Back up Trip*
33	*Main-2 Relay O/C, E/F Trip*
34	*Main-2 Relay O/V Trip*
35	*Main-2 relay 87L communication fail (if any)*
36	*CB Trip*
37	*CB TCS 1 or 2 Faulty*

Sl No.	*Signal Description*
38	*CB Faulty*
39	*BFP Main Trip (Stage-1)*
40	*BFP Redundant Trip (Stage-1)*
41	*BFP Main Trip (Stage-2)*
42	*BFP Redundant Trip (Stage-2)*

ii. ***400/230kV Transformers (400kV side)***

Sl No.	*Signal Description*
1	*Main-1 Relay 87T Trip*
2	*Main-1 Relay Over-fluxing Protection Trip*
3	*Main-1 Relay Faulty*
4	*Main-2 Relay 87T Trip*
5	*Main-2 Relay Over-fluxing Protection Trip*
6	*Main-2 Relay Faulty*
7	*Main TR Restricted Earth Fault (87N) Trip*
8	*33kV side REF Trip*
9	*400kV side O/C Protection Trip*
10	*400kV side E/F Protection Trip*
11	*400kV side back up relay faulty*
12	*33kV side O/C Protection Trip*
13	*33kV side E/F Protection Trip*
14	*33kV side back up relay faulty*
15	*0.415kV E/F Protection Trip*
16	*0.415kV E/F relay faulty*
17	*Main TR Mechanical Protection Alarm*
18	*Main TR Mechanical Protection Trip*
19	*Auxiliary TR Mechanical Protection Alarm*
20	*Auxiliary TR Mechanical Protection Trip*

Sl No.	*Signal Description*
21	*400kV CB Trip*
22	*400kV CB TCS 1 or 2 Faulty*
23	*400kV CB Faulty*
24	*400kV BFP Main Trip (Stage-1)*
25	*400kV BFP Redundant Trip (Stage-1)*
26	*400kV BFP Main Trip (Stage-2)*
27	*400kV BFP Redundant Trip (Stage-2)*
28	*33kV CB Trip*
29	*33kV CB TCS 1 or 2 Faulty*
30	*33kV CB Faulty*

iii. ***400kV Bus Coupler/Bus Section***

Sl No.	*Signal Description*
1	*Over-current Protection Operated*
2	*Earth Fault Protection Operated*
3	*O/C & E/F Relay Faulty*
4	*CB Trip*
5	*CB TCS 1 or 2 Faulty*
6	*CB Faulty*
7	*BFP Main Trip (Stage-1)*
8	*BFP Redundant Trip (Stage-1)*
9	*BFP Main Trip (Stage-2)*
10	*BFP Redundant Trip (Stage-2)*

iv. ***400kV BBP***

Sl No.	*Signal Description*
1	*BBP Main Panel DC-1 Fail*
2	*BBP Main Panel DC-2 Fail*
3	*BBP Redundant Panel DC-1 Fail*

Sl No.	***Signal Description***
4	*BBP Redundant Panel DC-2 Fail*
5	*BBP Main Relay Faulty*
6	*BBP Redundant Relay Faulty*
7	*BBP Main Relay Isolator Alarm*
8	*BBP Redundant Relay Isolator Alarm*
9	*BBP Main Relay Differential Alarm*
10	*BBP Redundant Relay Differential Alarm*
11	*BBP Main Relay Blocked*
12	*BBP Redundant Relay Blocked*
13	*BBP Main Panel BBP/BFP/Output/All Blocked*
14	*BBP Redundant Panel BBP/BFP/Output/All Blocked*
15	*BB1 Main Relay Operated*
16	*BB1 Redundant Relay Operated*
17	*BB2 Main Relay Operated*
18	*BB2 Redundant Relay Operated*

v. *230kV Lines*

Sl No.	***Signal Description***
1	*Main-1 Relay Line Differential Protection Trip (if any)*
2	*Main-1 Relay Distance Protection (Z1) Trip*
3	*Main-1 Relay Distance Protection (Z2/Z3) Trip*
4	*Main-1 Relay Faulty*
5	*Main-1 Relay VT fuse fail*
6	*Main-1 Relay SOTF Trip*
7	*Main-1 Relay PSB Operated*
8	*Main-1 Relay A/R in progress*
9	*Main-1 Relay A/R blocked*
10	*Main-1 Relay Distance send*
11	*Main-1 Relay Distance received*

Sl No.	***Signal Description***
12	*Main-1 Relay DEF send*
13	*Main-1 Relay DEF received*
14	*Main-1 Relay Aided Trip*
15	*Main-1 Relay Back-up Protection Trip*
16	*Main-1 relay 87L communication fail (if any)*
17	*Main-2 Relay Line Differential Protection Trip (if any)*
18	*Main-2 Relay Distance Protection (Z1) Trip*
19	*Main-2 Relay Distance Protection (Z2/Z3) Trip*
20	*Main-2 Relay Faulty*
21	*Main-2 Relay VT fuse fail*
22	*Main-2 Relay SOTF Trip*
23	*Main-2 Relay PSB Operated*
24	*Main-2 Relay A/R in progress*
25	*Main-2 Relay A/R blocked*
26	*Main-2 Relay Distance send*
27	*Main-2 Relay Distance received*
28	*Main-2 Relay DEF send*
29	*Main-2 Relay DEF received*
30	*Main-2 Relay Aided Trip*
31	*Main-2 Relay Back up Trip*
32	*Main-2 Relay Back-up Protection Trip*
33	*Main-2 relay 87L communication fail (if any)*
34	*CB Trip*
35	*CB TCS 1 or 2 Faulty*
36	*CB Faulty*
37	*BFP Trip (Stage-1)*
38	*BFP Trip (Stage-2)*

vi. ***400/230kV Transformers (230kV side)***

Sl No.	*Signal Description*
1	*230kV side O/C Protection Trip*
2	*230kV side E/F Protection Trip*
3	*230kV side back up relay faulty*
4	*230kV CB Trip*
5	*230kV CB TCS 1 or 2 Faulty*
6	*230kV CB Faulty*
7	*230kV BFP Trip (Stage-1)*
8	*230kV BFP Trip (Stage-2)*

vii. ***230/132kV Transformers (230kV side)***

Sl No.	*Signal Description*
1	*Main-1 Relay 87T Trip*
2	*Main-1 Relay Over-fluxing Protection Trip*
3	*Main-1 Relay Faulty*
4	*Main-2 Relay 87T Trip*
5	*Main-2 Relay Over-fluxing Protection Trip*
6	*Main-2 Relay Faulty*
7	*Main TR Restricted Earth Fault (87N) Trip*
8	*33kV side REF Trip*
9	*230kV side O/C Protection Trip*
10	*230kV side E/F Protection Trip*
11	*230kV side back up relay faulty*
12	*33kV side O/C Protection Trip*
13	*33kV side E/F Protection Trip*
14	*33kV side back up relay faulty*
15	*0.415kV E/F Protection Trip*
16	*0.415kV E/F relay faulty*

Sl No.	*Signal Description*
17	*Main TR Mechanical Protection Alarm*
18	*Main TR Mechanical Protection Trip*
19	*Auxiliary TR Mechanical Protection Alarm*
20	*Auxiliary TR Mechanical Protection Trip*
21	*230kV CB Trip*
22	*230kV CB TCS 1 or 2 Faulty*
23	*230kV CB Faulty*
24	*230kV BFP Main Trip (Stage-1)*
25	*230kV BFP Main Trip (Stage-2)*
26	*33kV CB Trip*
27	*33kV CB TCS 1 or 2 Faulty*
28	*33kV CB Faulty*

viii. ***230kV and 132kV Bus Coupler/Bus Section***

Sl No.	*Signal Description*
1	*Over-current Protection Operated*
2	*Earth Fault Protection Operated*
3	*O/C & E/F Relay Faulty*
4	*CB Trip*
5	*CB TCS 1 or 2 Faulty*
6	*CB Faulty*
7	*BFP Trip (Stage-1)*
8	*BFP Trip (Stage-2)*

ix. ***230kV and 132kV BBP***

Sl No.	*Signal Description*
1	*BBP Panel DC-1 Fail*
2	*BBP Panel DC-2 Fail*
3	*BBP Relay Faulty*

Sl No.	*Signal Description*
4	*BBP Relay Isolator Alarm*
5	*BBP Main Differential Alarm*
6	*BBP Relay Blocked*
7	*BBP Panel BBP/BFP/Output/All Blocked*
8	*BB1 Relay Operated*
9	*BB2 Relay Operated*

x. *132kV Lines*

Sl No.	*Signal Description*
1	*Main Relay Line Differential Protection Trip (if any)*
2	*Main Relay Distance Protection (Z1) Trip*
3	*Main Relay Distance Protection (Z2/Z3) Trip*
4	*Main Relay Faulty*
5	*Main Relay VT fuse fail*
6	*Main Relay SOTF Trip*
7	*Main Relay PSB Operated*
8	*Main Relay A/R in progress*
9	*Main Relay A/R blocked*
10	*Main Relay Distance send*
11	*Main Relay Distance received*
12	*Main Relay DEF send*
13	*Main Relay DEF received*
14	*Main Relay Aided Trip*
15	*Main Relay Back-up Protection Trip*
16	*Main relay 87L communication fail (if any)*
17	*Back-up Relay O/C Protection Trip*
18	*Back-up Relay E/F Protection Trip*
19	*Back-up Protection Relay Faulty*

Sl No.	*Signal Description*
20	*CB Trip*
21	*CB TCS 1 or 2 Faulty*
22	*CB Faulty*
23	*BFP Trip (Stage-1)*
24	*BFP Trip (Stage-2)*

xi. ***230/132kV Transformers (132kV side)***

Sl No.	*Signal Description*
1	*132kV side O/C Protection Trip*
2	*132kV side E/F Protection Trip*
3	*132kV side back up relay faulty*
4	*132kV CB Trip*
5	*132kV CB TCS 1 or 2 Faulty*
6	*132kV CB Faulty*
7	*132kV BFP Trip (Stage-1)*
8	*132kV BFP Trip (Stage-2)*

xii. ***132/33kV Transformers (132kV side)***

Sl No.	*Signal Description*
1	*Main-1 Relay 87T Trip*
2	*Main-1 Relay Over-fluxing Protection Trip*
3	*Main-1 Relay Faulty*
4	*Main-2 Relay 87T Trip*
5	*Main-2 Relay Over-fluxing Protection Trip*
6	*Main-2 Relay Faulty*
7	*Main TR Restricted Earth Fault (87N) Trip*
8	*132kV side O/C Protection Trip*
9	*132kV side E/F Protection Trip*
10	*132kV side back up relay faulty*

Sl No.	***Signal Description***
11	*33kV side O/C Protection Trip*
12	*33kV side E/F Protection Trip*
13	*33kV side back up relay faulty*
14	*Main TR Mechanical Protection Alarm*
15	*Main TR Mechanical Protection Trip*
16	*Auxiliary TR Mechanical Protection Alarm (if any)*
17	*Auxiliary TR Mechanical Protection Trip (if any)*
18	*132kV CB Trip*
19	*132kV CB TCS 1 or 2 Faulty*
20	*132kV CB Faulty*
21	*132kV BFP Main Trip (Stage-1)*
22	*132kV BFP Main Trip (Stage-2)*
23	*33kV CB Trip*
24	*33kV CB TCS 1 or 2 Faulty*
25	*33kV CB Faulty*

5.19 Relays (Lockout, Flag, Auxiliary relay)

5.19.1 General Requirements

Offered relays shall conform with the following IEC standards.

- Dielectric test — 2kV, 50Hz, 1min, as per IEC 60255-5
- Impulse voltage test — 5kV, 1.2/50µs, 0.5J, as per IEC 60255-5
- Insulation resistance — >100 M ohms at 500V DC as per IEC 60255-5
- Dry heat test — IEC 60068-2-2 +55℃ and +70℃
- Damp heat cyclic test — IEC 60068-2-30 12hrs+12hrs cycle at +55℃ / +25℃ with RH98% for 6days
- Storage test — IEC 60068-2-8 +70℃ for 72hrs and -25℃ for 72hrs

- Vibration response IEC 60255-21-1 class-1 10-150Hz, 0.5g, 3 axis
- Endurance test IEC 60255-21-1 class-1 10-150Hz, 1.0g, 3 axis

5.19.2 Lockout relay

The relays that are used as "Lockout" relays shall be "Bistable" type relays. There shall be two relay coils known as "Set" and "Reset" coils. Once the "Set" coil is energized externally armature shall move towards one side and be locked permanently even if the "Set" coil is de-energised. It shall be unlocked and moved to the other side when the "Reset" coil is energized. Once the armature is moved towards one side due to energization of either coil the supply to the respective coil shall be cut-off internally in order to avoid additional heating and power consumption. Both coils shall be protected by fly back diodes.

The relay coil circuits shall be insensitive to capacitive discharge current that can occur due to DC circuit earth faults.

It shall be possible to reset the relay manually through a hand-operated mechanism. Additionally when the relay "Set" coil is operated and armature is moved a visual indication shall be available for the user in the relay itself.

Relay shall fulfil the following specifications.

Operating Voltage (U_N) in V (DC)		110V
Operating Range in % of U_N		80-110
Permitted Ambient Temperature in ℃		0 to +55
Current Carrying Capacity in A	200ms	90
	1s	50
	Continuous	10
Breaking Capacity (At L/R<40ms) in A	110V DC	3
Insulation Tests	Dielectric tests, 50Hz, 1 min in kV	2.5
	Impulse voltage test, 1.2/50µs, 0.5J in kV	5

5.19.3 Flag relay

Flag relays used in mechanical protection tripping and alarming in transformer bays shall contain at least four N/O outputs. They shall contain clear flag indication to the user when the relay is operated. All the relays shall be of hand resettable type.

Relay shall fulfil the following specifications.

Operating Voltage (U_N) in V (DC)		110V
Operating Range in % of U_N		80-110
Permitted Ambient Temperature in ℃		0 to +55
Current Carrying Capacity in A	200ms	90
	1s	50
	Continuous	10
Breaking Capacity (At L/R<40ms) in A	110V DC	3
Insulation Tests	Dielectric tests, 50Hz, 1 min in kV	2.5
	Impulse voltage test, 1.2/50μs, 0.5J in kV	5

5.19.4 Auxiliary relay

Auxiliary relays shall be used for contact multiplication purposes are discussed in this chapter.

Those relays shall fulfil the following specifications.

Operating Voltage (U_N) in V (DC)		110V
Operating Range in % of U_N		80-110
Permitted Ambient Temperature in ℃		0 to +55
Continuous Current Carrying Capacity in A		5
Breaking Capacity (At L/R<40ms) in A	110V DC	3
Insulation Tests	Dielectric tests, 50Hz, 1 min in kV	2.5
	Impulse voltage test, 1.2/50μs, 0.5J in kV	5

5.20 Protection Settings, Testing and Inspection

5.20.1 Protection Settings

Relay settings with calculation for all unit-type protective schemes shall be submitted to the Engineer and Employer prior to commissioning of any plant for approval. Settings shall also be provided for those relays and other equipment provided under this section of the contract which do not require an intimate knowledge of existing relay settings e.g. circuit breaker fail relays. Detailed calculations shall be provided supporting all recommended settings.

Computer Aided Setting Calculation shall be performed by the contractor and submit to the Engineer and Employer for approval. Software used for simulation shall be acceptable to & used to by PGCB. PGCB have PSCAD software with license from Manitova HVDC Research Centre or PSSE. Hence, Contractor is requested to consider this software for simulation. Other software is also acceptable with the consent approval of Employer. Contractor shall submit soft copy files of software for review & approval from Employer. A Power point demonstration is to be foreseen by the contractor for final approval.

Any additional information needed by Contractors should be requested.

5.20.2 Testing and Inspection

All relays (including panels) shall be tested in the Manufacturer's work. The Bidder/Contractor may be required to carry out any or all of the tests stated in this specification in presence of PGCB or its representatives according to clause SCC23 of section-8 of volume-I.

Testing of relays and their components shall be performed in line with this specification and in accordance with the relevant IEC standards (as minimum requirement) and other standards as may be approved by PGCB.

Acceptance by PGCB's Representative of any relay tests shall not relieve the Manufacturer from any of his performance guarantees or from any other obligations.

PGCB reserves the right to perform checks during the manufacturing process at any time or all the times. It shall be at the discretion of PGCB to witness tests on 100% or any percentage of each lot for routine tests, apart from the type tests, wherever called for.
Tests of relays shall comprise factory tests and site tests.

5.20.2.1 Type Tests

Evidence shall be given that the proposed relays to be supplied under the contract had already been subjected to all type tests (including transient and steady-state tests) at an internationally recognized testing station like KEMA or equivalent. If deemed necessary, PGCB will decide whether the Bidder/Contractor shall perform additional tests.

An internationally recognised laboratory shall certify the type test reports.

The Bidder/Contractor shall submit certified copies of type test certificates covering the proposed relay components.
Type test certificates/reports shall be considered acceptable if they are in compliance with the relevant standards and the following:

(a) Type tests conducted at an internationally recognised laboratory acceptable to PGCB.
(b) Type tests conducted at the Manufacturer's laboratory and witnessed by representatives from an internationally recognised laboratory acceptable to PGCB.

If the presented type test reports are not in accordance with the above requirements, PGCB may decide to ask for the type tests to be carried out afresh in the Manufacturer's premises or other places subject to the approval of PGCB and at no additional cost. These tests shall be performed in the presence of an internationally recognised laboratory, which should issue the relevant type test certificates upon successful completion of all tests.

5.20.2.2 Routine Tests

Protection relays and their components shall be subjected to routine tests as per the relevant IEC standards. Protection relays mounted in cubicles shall be completely wired, tested and inspected at the relay Manufacturer's factory.

Factory tests shall cover a subset of the following:

- Secondary injection, scheme checks, relay logic, performance of engineer interface, functional-trip tests, setting ranges and calibration accuracy, response(trip) times, functional availability and application limits, system supervision, performance of communication interfaces with SAS, events and disturbance records, etc.

The Bidder/Contractor shall provide to PGCB a generic list of tests for approval, depending upon the duration of factory tests, the importance and complexity of the protection system, familiarity of the system being inspected, etc., However, test procedures shall be prepared to verify adequately the performance, functionality and protection reliability.

The Bidder/Contractor shall indicate that the equipment has been manufactured, racked and correctly wired by carrying out approved factory tests.

Routine test certificates shall be submitted to PGCB's review and approval before shipment of the relays /panels.

5.20.2.3 Site Tests

The site tests of relays shall be mainly based on functional tests, in addition to the visual and wiring checking of the relays, in order to ensure that all components are correctly installed and properly aligned and that there are no imperfections due to damage during transport to site.

Relay site tests shall include comprehensive tests and checks with the protection equipment fully connected to the array of all field devices (SAS, FMS, teleprotection signalling equipment, switchgear, CTs/VTs, DC system, etc.).

Checks and tests shall include:

- Secondary and primary injections, scheme checks, relay logic, performance of engineer interface, functional-trip tests, setting ranges and calibration accuracy, response (trip) times, functional availability, system supervision, performance of communication interfaces with SAS, events and disturbance records etc.

Transient tests shall be included, simulating DC off-sets and harmonics, in order to verify the dynamic behaviour, including the circuit breaker trip time, communication channel time and the effectiveness of the settings adopted.

After energization, load tests shall be carried out.

Prior to field tests on protection relays, the Bidder/Contractor shall provide to PGCB for approval operational settings and parameters to set the protection relays/systems to the substation conditions and power grid requirements.

Calculations for the revision of relay settings (e.g. zone 2 and 3 of distance relays) in the remote end substations shall also be submitted to PGCB for approval.

Setting recommendations shall be submitted for approval at least 2 months before commissioning/energization.

Separate schedules for on-site tests shall be submitted for approval at least one month before start of the tests.

The results of all tests shall be submitted immediately after satisfactory completion of tests in the form of computer print-outs along with the hand written test sheets signed by PGCB for witness of the tests.

Site test reports shall illustrate all test details as well as details of all applied testing equipment and their calibration validity.

The Bidder/Contractor shall provide a sufficient number of experienced test personnel during inspection tests and at site.

The Bidder/Contractor shall not withdraw or change the test engineer(s) before the completion of all the testing activities, unless it is the requirement of PGCB in the event that the test personnel lacks adequate skills, knowledge or technical expertise for the concerned protection systems /equipment.

Overall tests involving more than one Bidder's/Contractor's equipment shall be suitably and professionally coordinated and arranged by the main Bidder/Contractor. The test and commissioning programs shall be subject to approval by PGCB at site.

The Bidder/Contractor shall carry out any additional site tests, other than those mentioned in the approved site test program, if deemed necessary by PGCB, due to some unforeseen technical requirements arising from operational contingencies in the network and loading conditions.

5.21 Substation Automation System

5.21.1 Scope of Supply

This specification covers the design, manufacture, inspection, testing at the Manufacturer's works, erection and commissioning of a substation automation system, as shown in drawing of this technical specifications & described in the following sections, to control and operate the 400kV, 230 kV &132 kV grid substation.

This describes the facilities required to provide the control of plant and system within a substation and outlines the facilities to be provided on site, interface requirements and performance criteria.

Manufacturer of either Main 1, Main 1-1 or Main 2 protection and control IEDs shall be the manufacturer, supplier and the integrator of Substation Automation System (SAS) and shall be responsible for providing the Control/Protection and SAS panels as per the specifications.
The supplier of the SAS shall be the system integrator who will configure, test and commission the SAS and shall be the one to provide the license for the software.
Commissioning of the SAS shall be carried out by the Authorized Commissioning Engineer/s of the supplier only. Partners of the supplier are not allowed to configure, test and commission the SAS.

The substation automation system (SAS) shall comprise full station and bay protection as well as control, monitoring and communication functions based on IEC 61850 standards. It shall perform local station control, monitoring and data acquisition via redundant Rack mounted Industrial PCs by means of a human machine interface (HMI) and control software package, and shall perform the necessary system control and data acquisition functions.

It shall include independent remote network monitoring and control from the National Load Dispatch Centre (NLDC) via a separate communication gateway. The Gateway protocols and hardware configurations as per the approved signal list shall connect to the (NLDC) by IEC 60870-5-104 connections.
It shall include interbay bus, intelligent electronic devices (IED) for bay control and protection as shown in the enclosed general system architecture drawing.

Even if the Station PCs are not available, it shall be possible to control the station from NLDC through the gateway as well as from the inbuilt local graphic display of IEDs or separate back up control mimic in the individual bays with all interlocks. Maintenance, modification or extension of components shall not require a shutdown of the whole station automation system. Self-monitoring of single components, modules and communication shall be incorporated to increase the availability of the equipment while minimizing maintenance time to repair.

The communication gateway shall secure control from and information flow to remote network control centres. The inter-bay bus shall provide independent station-to-bay and bay-to-bay data exchange. The bay level intelligent electronic devices (IED) for protection and control shall be directly connected to the instrument transformer and trip/close coils in the switchgear without any interposing equipment and perform control, protection, and monitoring functions subject to a detail proposal approved by the Employer.

The Contractor will have the option to choose different types of communication networks for the bay level and the process level based on IEC 61850. However, network topology and access mode shall be clearly indicated. The availability shall be maintained with suitable topology of ring, star or bus. The physical medium of those shall be glass fiber optics.

The IEDs for protection and control functions shall maintain high availability and reliability together with bay independence through extensive self-supervision and state-of-the-art technology. All IEDs shall be directly connected to the IEC 61850 bus and shall use only the IEC 61850 protocol for communication. No proprietary protocols shall be used. The SA system must have interoperability between IEDs of different manufacturers. Such shall be verified by test and submitted along-with the bid. The interoperability feature of SA must be verified during FAT also. System not having interoperability feature shall not be accepted.

The system shall be capable of having its computing power increased in the future through the additional computing systems.

The system design life shall be not less than 20 years.

The capacity of the SA system shall be sufficient for the ultimate development of the substation as set out in the project master plan.

The SA Supplier shall demonstrate that the proposed system has been designed, installed and commissioned in accordance with the IEC 61850 standard and shall provide evidence of satisfactory service experience during the past 5 years.

For detailed technical data, please refer to the technical data schedules.

These specifications describe the functional requirements of the substation control and supervisory system. The frame structure of these systems is also defined. For implementation of these requirements, the Contractor shall use standard hardware and software to the maximum possible extent. The optimum solution of the substation control and monitoring system for the considered substation is realized by three functionally independent subsystems:

- The substation control system
- The protection system and protection supervision system
- The switchyard interlocking system

The protection system is described in a separate section of these specifications. Both substation control and interlocking system should a have hierarchical structure, which best suits the substation design, functions and its importance for the power system. The Contractor has to propose such a particular, his own, optimal solution and confirm its advantages and give the related references confirmed by the Employer. The Contractor shall confirm continuity of his preferable philosophy of the proposed solutions, utilization and compatibility of new products in the next 15 years after commissioning. The system between the bay control level and the substation control level and linked with higher level control centre shall be of the "open" system design, i.e.:

- It must be possible that equipment from different manufacturers works together,
- Easy extension shall be possible,
- Future upgrades (hardware and software) must be easily possible without changing existing equipment or interfaces. Implemented protocols should also be replaceable without major modifications (e.g. future IEC standards).

For the purpose of the cooperation of equipment from different manufacturers, the internationally recognized and approved standard communication protocol shall be applied. The substation control and supervision system shall have minimum 2 (two) interfaces for communication with the control centre.

The SAS shall have option for integration of Transformer Fire Prevention/Protection system integration.

Necessary system configuration and switches shall be available for the S/S master plan.

Extension of existing SAS: The scope of work under this contract is to extend the existing SAS systemfor new bays. All necessary input and output shall be provided as per existing bays.

5.21.2 Compliance with Standards

For design and type-testing of the protection and control equipment, the following standards shall apply:

5.21.2.1 General List of Specifications

- IEC 60255: Electrical Relays
- IEC 60038: IEC Standard voltages
- IEC 60050: International electrotechnical vocabulary
- IEC 60068: Environmental testing
- IEC 60073: Basic and safety principles for man-machine interface
- IEC 60801: Electromagnetic compatibility for electrical and electronic equipment
- IEC 60870: Telecontrol equipment and system
- IEC 61000: Electromagnetic compatibility
- IEC 60654: Operating conditions
- IEC 60664: Insulation co-ordination for equipment within low-voltage systems
- IEC 61850: Standard for Substation integrated protection and control data communication

5.21.2.2 Detailed List of Specifications

- IEC 60068-2-3 Electrical Relays
- IEC 60038: IEC Standard voltages
- IEC 60605-7: Equipment reliability testing
- IEC 60664: Insulation co-ordination for equipment within low-voltage systems
- IEC 60068-2-3: Test Ca: Damp heat steady state
- IEC 60068-2-30: Test Db and guidance; Damp heat, cyclic
- IEC 60255-11: Measuring relays and protection equipment
- IEC 60255-22: Electrical disturbance tests for measuring relays and protection equipment:
- IEC 60255-22-1: 1 MHz burst disturbance test
- IEC 60255-22-2: Electrostatic discharge test
- IEC 60255-22-3: Radiated electromagnetic field disturbance test
- IEC 60255-22-4: Fast transient disturbance test

- IEC 60255-11: Interruptions to and alternating component (ripple) in D.C. auxiliary energizing quantity to measuring relays
- IEC 60255-6: Measuring relays and protection equipment
- IEC 60255-21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment:
- IEC 60255-21-1: Vibration tests(sinusoidal)
- IEC 60255-21-2: Shock and bump tests
- IEC 60255-21-3: Seismic tests
- IEC 60255-0-20: Contact performance of electrical relays
- IEC 60870-3 class 2: Digital I/O, Analogue I/O dielectric tests
- IEC 60801-5/class 3: digital I/O Surge withstand test
- IEC 60870-3/class2: Radio interference test
- IEC 60801-4/4: Transient fast burst test
- IEC 60801-2/4: Static discharge
- IEC 60801-3/3: Electromagnetic fields

5.21.3 Design and Operating Requirements

5.21.3.1 General

The SAS shall monitor and control the entire substation. It shall be a fully integrated system to bring together independently operating subsystems, such as SCADA, communication, protective relaying, control of substation primary equipment, metering and alarm annunciation, into a unified data acquisition, monitoring and control system in the substation. Maximum use shall be made of digital information /communication resulting in minimal hard wiring. It shall have a LAN backbone to allow coordination and integration of these subsystems.

The SAS shall be suitable for operation and monitoring of the complete substation including future extensions. The offered products shall be suitable for efficient and reliable operation and maintenance support of the substations.

The SAS system shall have state-of-the art design, suitable for operation in a high voltage substation environment, follow the latest engineering practice; it shall ensure long-term compatibility requirements, continuity of equipment supply and the safety of the operating staff.

As shown in the SAS structure, protection is an integral part of the SAS, and protective relays shall be directly connected to the inter-bay bus in order to provide unrestricted access to all data and information stored in the relays and for changing protection parameters from the remote control location.

Failure behaviour of the hardware and software functions shall be addressed, and related diagnostic and rectification working instructions shall be provided. The system's performance in case of failure of communication to NLDC, main and redundant computer base workstations, central functions, data model, control and protection IEDs, station and bay level communication shall also be clearly addressed (shall be provided by the Manufacturer).

The 400kV, 230 kV and 132 kV substation, can also be controlled from the control panel installed in the control room. The following modes of operation shall be possible:

(a) Emergency operation of breaker, disconnector, earthing switch etc. from the LCC.
(b) Emergency operation of breaker, disconnector, earthing switch etc. from the backup mimic panel located in the new control room. Both, bay controller-guided and unguided operation shall be possible from this panel.
(c) Normal operation of breaker, disconnector, earthing switch etc. from the station automation system's HMI located in the new control room.

5.21.3.2 Architecture & Components

The SAS design shall consider Parallel Redundancy Protocol (PRP) for 400kV or Higher Voltage level and Rapid Spanning Tree Protocol (RSTP) for 230kV & 132kV level shall be applicable.

A general arrangement of the Automation system shall include IEDs (Relay, BCU& meters), Ethernet switches, Server (Hot & Standby) with software, Operator Workstation, an Engineering PC, A 75'' LCD monitor, Printers, Hot & standby Gateway with redundant switch & hardware firewall, cables (Fiber optic, Ethernet, copper) & connector, panels etc.

The workstation & server PC shall be merged into one unit in general& it is preferable one. However, segregated design is also acceptable within the same price; No additional price shall be claimed due to such design. The Ethernet switches shall have at least 20% spare switches for future use. One spare ethernet switch shall be supplied as spare for each level (bay level, station level etc.). All components of SAS shall be IEC 61850 compliant. The SAS shall be located in the Main Control Room unless otherwise specified. Final design shall be subject to approval of Employer. The Engineering PC shall have minimum core i7, latest generation, clock speed of 3.4 GHz, 16GB RAM, 1 TB SSD Hard Driver, 27''*2 display (UHD level) etc.

5.21.3.3 Modes of Operation

The operator stations and specified remote users shall have the following operational modes, each password protected.

Monitoring	Ability to select graphic displays and lists for display only. No capability to acknowledge alarms, complete controls or select items for inclusion in program functions.

Control	Selection of graphic display and lists. Able to acknowledge station and SAS alarms, complete controls, dressing etc. associated with normal real time of the control of the substation.
SAS Engineering	To provide all SAS monitoring functions, together with online facilities for program /database /format modifications and checking without the possibility of executing power system controls.
System Manager	To provide access to all system functions, including assignment of passwords and system maintenance activities.

In addition, a facility to provide access to the numerical protection relays, change / modify relay settings & AVR parameters and fault recorder data shall be provided.

A series of passwords shall be personally assigned to operators in each of the above categories.

Substation operators shall have the possibility to log on to either substation workstation and to be allocated the appropriate mode of operation relevant to the password. SAS engineering work and access to the protection relay and disturbance reorder information shall generally be carried out at the engineering workstation or the remote master station.

All workstations and the system database shall function as a system. It shall not be necessary for example to acknowledge an alarm at more than one workstation.

Similarly, an operator's manual entry applied at one workstation shall be immediately displayed at other workstations where this data is presented.

5.21.3.4 Project Specifications

Specific functions required and boundary conditions of the SAS are detailed elsewhere in this specification. The following project-specific drawings are attached:

- Overall single line diagram
- General system architecture
- Location of substation buildings
- Control and operation principles
- Protection schemes

5.21.3.5 Vendor's Experience and Local Support

Only experienced and technically capable Manufacturers with minimum 5 years' experience in design and supply of control and protection systems for electricity transmission and distribution applications will be accepted. Preferred Manufacturers will be those who have experience in deliveries of the full scope of station automation systems and services. This experience has to be substantiated by means of reference installations being in service under

similar environmental conditions for at least 5 years. The vendor shall provide long-term, i.e.10 years, guarantee of the complete SA system. In order to assess the Vendor's experience with similar projects, the Vendor is required to submit the following with his bid:

- Technical design specifications and description of SAS
- Catalogues and brochures of equipment and devices offered
- Reference list

The Vendor shall assure long-term maintenance and availability of spares. Moreover, a guarantee shall be submitted for the availability of 25% spares during the lifetime of the SAS equipment (not less than 20 years).

5.21.3.6 Quality Assurance and Inspection

Quality assurance of design and development, production, installation and servicing of material and workmanship shall be governed by ISO 9001. Supporting documents to prove ISO 9001 third party approvals shall be provided with the offer.

The SAS shall be pre-assembled and tested at the Vendor's workshop before shipment.

5.21.4 General System Design

The system shall be so designed that personnel without any background in microprocessor-based technology can operate the system easily after having received some basic training.

System control from the substation main control room will be done by means of an industrial computer (PC) operated by a mouse. The following HMI (Human Machine Interface) functions shall be provided:

(a) Acquisition and plausibility check of switchgear status
(b) Control of switchgear
(c) Remote checking of device parameters and activation of alternative parameter sets in the connected protective relays
(d) Display of actual measured values (U, I, P, Q, f)
(e) Display of events
(f) Display of alarms
(g) Display of trends
(h) Sequence control functions
(i) Disturbance records and fault location
(j) System self-supervision
(k) Hard copy printing
(l) Dynamic busbar colouring
(m) Two gateways

The offered SAS shall support remote control and monitoring from the NLDC via an industrial grade gateway with redundant CPU as well as redundant DC/DC converters. PC-based gateways which contain moving parts will not be accepted. The gateway should be designed for a life of at least 20 years. The gateway shall provide for communication to/from remote control centres via the IEC 60870-5-101 protocol. Even if the station PC is not available, it shall be possible to control the station from the NLDC as well as from the backup control panel in the individual bays with all interlocks. Interlocking in case of emergency (i.e. if the bay controller fails) should be waived locally by means of a switch with key lock by the Maintenance Engineer for all the switchgear.

Maintenance, modification or extension of components shall not require a shutdown of the whole station automation system. Self-monitoring of single components, modules and communication shall be incorporated to increase the availability of the equipment while minimizing maintenance time to repair.

As shown in the system drawing, the SAS shall be structured in two levels - station level and bay level. The data exchange between the electronic devices on both levels shall take place via an inter-bay bus using IEC 61850 standards. The entire station shall be controlled and supervised from the station level PC. It shall also be possible to control, monitor and protect each individual bay from the respective bay level equipment for maintenance purposes or if the communication to a particular bay fails. Clear control priorities shall prevent initiation of operation of a single switch at the same time from more than one of the various control levels viz. NLDC, station level, bay level or switchgear (apparatus) level. The priority shall always be with the lowest enabled control level.

Bay control and protection units shall be independent of each other and their functioning shall not be affected by any fault occurring in any of the other bay control and protection units of the station.

All Automatic Voltage Regulators (AVR) shall be integrated to SAS by means of IEC 61850 protocol. Under the bay view of each transformer, all the functions in AVR shall be controlled by SAS. Control and monitoring functions of AVR are as follows.

- Auto / Manual
- AVR Remote / Local
- Master / Follower / Minimum Circulation Current / Operation / Independent
- OLTC Remote / Local
- Alarms

Theoperatorshall be providedameansofautomaticallycontrolling transformertapchangers.It shall be possible to allow individual groups of transformers to be selected / deselected for automatic control and parallel control oftransformers.

The SAS shall contain the following main functional parts:

(a) Human Machine Interface (HMI) with process database

(b) Gateway function for remote control via an industrial grade hardware
(c) Dial-in facility / laptop workstation for protection relay parameterization, disturbance analysis and SAS fault analysis.
(d) Data exchange between the different system components via high speed bus
(e) Bay level devices for control, monitoring and protection
(f) Bay-oriented local control and protection panels with mimic inserts
(g) Facility for emergency operation of all the switchgear, if the bay controller fails (key / master key system).

The main process information of the station shall be stored in distributed databases. The system shall be based on a decentralized concept with bay-oriented distributed intelligence for safety and availability reasons. Functions shall be decentralized, object-oriented and located as close as possible to the process.

The substation monitoring/protection system shall supply data for maintenance, repair and remote parameter setting of protection and control devices in the switchyard.

ln the event of a fault in the electrical network, the substation monitoring shall provide a quick means for collecting the relevant and critical data of the fault.

The monitoring system shall be suitable for the supervision and monitoring of all the secondary (lED) and primary devices in a substation including future extensions.

Maintenance, modification or extension of components shall not cause a shut-off of the whole station monitoring system. Self-monitoring of single components, modules and communication shall be incorporated to increase the availability and the reliability of the equipment and to minimize maintenance.

It shall be possible to access all protection and control devices for reading the terminal parameters (settings). The setting of parameters or activation of parameter sets shall be restricted by password to the Protection Engineer.

One remote computer should be provided with access to the SMS and with different access levels. The required SMS software and application-specific firmware (for relay parameterization) shall be provided with associated tools and equipment. The required engineering tools and analyzing software shall also be provided/installed both in the station PC and the remote master analysis station. A backup copy of all the software shall be provided on separated storage memory (SSD 1 Tera).

The SMS shall be capable of communicating with the remote master analysis station at the protection development branch through a modem over a dedicated or dial-up voice grade telephone line or micro-wave channel.

5.21.5 Flexibility and Scalability

The offered SAS concept shall be flexible and shall permit future extensions to be implemented easily. Preference will be given to those Suppliers who are in a position to provide protection and control devices that can be freely adapted to the required application functions.

5.21.6 System Hardware

5.21.6.1 Operator Station

The main operator station shall be based on an industrial PC hardware and high-resolution full-graphics screen with the Manufacturer's standard type-tested software operating under Windows NT environment. The Industrial processor shall be high-end like Intel Xeon or similar. An event printer and a hard copy printer shall be connected via a printer server and LAN to the operator station.

Dual station computers shall control the SAS and drive the work stations and other peripherals. One of the station computers shall operate the system in the "online" state while the other acts as a "redundant hot standby". The standby computer shall be continuously updated and shall immediately take over the SAS duties without interruption or transfer mechanism should the online operator workstation fail.

Disturbance records shall be analyzed using the installed disturbance record analysis programs. The disturbance records will be collected, over the inter-bay bus, from the connected IEDs by the system software. All necessary facilities shall be provided to allow the system to perform spontaneous upload of disturbance data or their upload in a pre-programmed manner. The event printer shall print events spontaneously as they arrive in the main operator station.

Each uploaded data report file shall be reported on one line that shall contain:

(a) The event date and time
(b) The name of the event object
(c) A descriptive text
(d) The state or value of the object

The information fields above shall be structured in columns for maximum readability.

The hard copy printer shall permit printing of any picture (or part thereof) from the station level PCs using easily accessible commands from the window menus.

The main station PCs shall be supplied by the station DC battery and a UPS system with a supply duration of not less than 30 minutes to supply the monitor and the printers.

All alarms, annunciations and abnormal/faults occurred in substation shall be promptly displayed in all the Monitors of SAS simultaneously with different sound modes.

SAS shall have a function that an operator can make locked-boundaries (areas) at monitors to protect workers who participate O&M or construction or any other matters, which shall be never operated with any means of manner including interlocking cancelation until an operator remove the locked-boundaries.

5.21.6.2 Station Inter-bay Bus

The LAN connecting the industrial computer-based operator workstations and printers shall be Ethernet LAN IEEE 802.3 LAN, protocol TCP/IP (100 Mbps or higher), and the physical medium shall be glass fibre optic bus ring topology. The IEDs shall be connected via glass fibre optic cables to bay level industrial grade Ethernet switches.

The station bus according to IEC 61850-8 is today mapped to MSS / Ethernet (with priority tagging and with 100 MS/s). The standard is not making any provision on the Ethernet communication infrastructure. To at least ensure a certain level of quality, performance and availability, the Ethernet switches and topology shall fulfil at least the criteria described below.

- Industrial-grade Ethernet switches that fulfil the hardened requirements concerning temperature, EMC and power supply (110 V DC from the station battery) suitable to be installed in substations shall be provided, i.e. the same data as common for numerical protection.
- The use of Ethernet hubs is not permitted as they do not provide collision-free transmission.
- The switches shall support priority tagging and open standards for ring management like fast spanning tree to ensure that e.g. for later system extension the utility has not to rely on one switch supplier only.
- External switches shall be supplied as they have the advantage that there is no interruption or re-configuration of the Ethernet ring, if one or several bay devices are taken out of service.
- To increase reliability, the Ethernet switches shall have redundant power supply & shall be powered from two different station batteries.

5.21.6.3 Protection and Control IEDs and Local Back-up Control Mimic

The bay control IEDs, based on microprocessor technology, shall use numerical techniques for the calculation and evaluation of externally input analogue signals. They shall incorporate select-before-operate control principles as safety measure for operation via the HMI. They shall perform all bay-related functions such as protection, commands, bay interlocking, data acquisition, data storage, event and disturbance recording, and shall provide inputs for status indication and outputs for commands. They shall be directly connected to the switchgear without any need for separate interposing equipment or transducers.

The numerical bay control IED shall be provided with a minimum of nine (9) configurable (current or voltage) analogue input channels and an adequate number of binary input &output channels which are galvanically isolated from the SAS. The channels shall also be individually separated from each other. HV switchgear and instrument transformers shall be directly connected to the bay level IED without any interposing equipment.

The devices shall meet the requirements for withstanding electromagnetic interference according to relevant parts of IEC 60255 to conform to the high requirements for operation on the secondary system of HV switchgear.

The bay control & protection IEDs shall have the following features:

(a) A minimum of 9 configurable analogue channels
(b) At least 32 binary inputs, 24 signal relays and 2 command relays
(c) 16 nos. LED's and/or Graphic LCD on the front of the unit for indication
(d) Auto-reclose function
(e) Synchrocheck function
(f) Power function which can be configured to measure forward or reverse, active or reactive power
(g) Four (4) independently settable parameter setting groups, settable/selectable locally or remotely via the HMI program
(h) 4 line local display units (LDU or front HMI) on the front of the relay which can display both input as well as measured quantities: frequency, phase currents, phase voltages, active power, reactive power, etc.
(i) High-speed bus serial communication port as per IEC 61850 standards.
(j) Sequence of events recorder with a buffer for 256 events and a resolution of 1 msec. The events to be recorded should be freely programmable. These could be alarm/trip signals, external signals connected to opto-coupler inputs, internal signals, etc. Once events are defined, they are recorded in chronological order as they occur.
(k) Disturbance recorder function which can record 9 analogue values, 16 binary signals and 12 analogue channels for internal measurement values. It shall be possible to trigger the disturbance recorder function by any internal or external binary signal or internal protective function.
(l) Comprehensive self-supervision
(m) Battery-free memory back-up of event and disturbance records
(n) Logic functions (AND, OR, bistable flip flop, etc.)
(o) Delay/integrator function

The numerical bay control IEDs shall be mounted together with all the relevant bay protective relays in cubicles of protection class IP54 or better. Distributed back-up control mimics with associated switches, meters and Indicating LEDs shall also be provided on these cubicles. These cubicles shall be installed in an air-conditioned room in the substation.

The distributed backup mimic for local control shall be installed next to the bay controller IED, which can be used in case of maintenance or emergency or if bay control IED fails. Local bay control via the back-up control mimic on the control & protection cubicles shall incorporate the same user safety measures e.g. bay interlocking, synchrocheck, interlock override user guidance etc. as the station HMI. Local bay control shall be key-locked, and the control either from remote control panel (in the new control room), the station HMI or from remote shall be disabled if the local/remote selector switch on the back-up control mimic is in the "local" position.

The electronic system has to be provided with functions for self-supervision and testing. Each circuit board shall contain circuits for automatic testing of its own function.

Faults in the bay control IED shall be indicated on a front HMI, and a message shall be sent to the station-level HMI. The time for fault tracing and replacement of a faulty unit shall be reduced to a minimum. The supervision shall also cover the power supply system, the internal system bus and the ability of the central processing module to communicate with different printed circuit boards.

Failure of any single component within the equipment shall neither cause unwanted operation nor lead to a complete system breakdown. The N-1 criterion must be maintained in worst case scenarios, also. Further, a single failure must not have any effect on the primary system, which is monitored and controlled.

Main and backup protections shall not be incorporated in the bay control unit. Main and backup protections shall be provided separately.

All IEDs shall have at least 5 years of successful proven experience in HV applications, and the MTBF for the offered units shall be provided.

5.21.7 Material Inspection and Testing

Approval of systems inspection and test results, acceptance of hardware and software/firmware or waiving of inspection and tests thereof, shall in no way relieve the Contractor of the responsibility for furnishing equipment which meets the requirements of these specifications, nor shall such actions invalidate any claim which the Employer may make because of defective or unsatisfactory hardware, software and firmware.

The Employer reserves the right to request the additional tests on the system and/or its elements at no extra charge on any work the Employer determinates not to be in accordance with these specifications. Whenever the result of any inspection or test performed or requested by the Employer in accordance with the requirements of this section indicates that the specific hardware, software, firmware or documentation does not meet the specification requirements, the Contractor shall replace, modify or add, at no cost to the Employer, adequate hardware, software, firmware or documentation as necessary to correct the noted deficiencies.

5.21.8 Routine Tests

The Contractor shall perform routine tests in accordance with the requirements of the Contractor's test specification approved by the Employer. The Contractor shall permit the Employer access to the equipment and software to determine or assess compliance with the provisions of these specifications and to witness the Contractor's routine tests. The Contractor shall submit test reports of routine tests.

The routine tests shall include:

(a) Visual check for completeness,
(b) Wiring check,
(c) Test of conformity with IEC standards,
(d) Functional test of the individual systems at the works and commissioning.

5.21.9 Type Test

The Contractor shall carry out all type tests (if technical full equivalent type test not available) called for in these specifications and as required in the standards to obtain required performance data. The Employer may waive the requirements for type tests called for in these specifications and/or specified in the standards, provided the Contractor can submit results of tests on identical equipment together with test certificates from an independent testing internationally accredited agency approved by the Employer and proof that the equipment covered by the test certificates is identical to the equipment being supplied.

5.21.10 Factory Acceptance Tests

Prior to shipping the substation control and supervision system from the Contractor's plant, it shall be subjected to the following tests and inspections:

5.21.11 Inspection

Representatives of the Employer shall have free entry into the shops of the Manufacturer at any time during design, manufacturing, or testing of the equipment and into any mill, shop, or factory where the hardware or software/firmware described in these specifications is produced.

The Contractor shall provide to the Employer's Representative, free of cost, all reasonable facilities, equipment, and documentation necessary to satisfy the Employer's Representative that the substation control and supervision system are manufactured in accordance with the specifications. The inspection rights described above shall apply to facilities of the Contractor or Contractor's subcontractors where the system is manufactured. These inspection rights shall not apply to the facilities of subcontractors supplying unit components to the system manufacturer. Such items will be inspected and tested by the Employer's Representative at the

manufacturing site. Inspections by the Employer will include visual examination of the physical appearance of the hardware, cable dressings, and equipment and cable labelling. The Contractor's documentation will also be examined to verify that it adequately identifies and describes all system hardware, software, firmware and spare parts. The Employer shall have access to inspect the Contractor's and Manufacturer's quality assurance standards, procedures, and records, which are applicable to this project. Inspection shall not relieve the Contractor of the responsibility for furnishing material and equipment conforming to the requirements of the specifications nor shall such inspection invalidate any claim, which the Employer may make because of defective or unsatisfactory substation control and supervision system hardware, software, or firmware.

5.21.11.1 Test Procedures

The Contractor shall submit the substation control and supervision test plans for approval six (6) weeks prior to the start of FAT and SAT. Fully approved FAT and SAT test procedures shall be submitted to the Employer at least four (4) weeks prior to the commencement of the tests. The Employer will only approve test procedures if they are inclusive, thoroughly testing each section of the equipment. The Contractor shall use IEC standards as a guide in preparing the substation control and supervision test procedures.

The test procedures shall include the following:

(a) The test schedule, including provision for eight hours of unstructured tests to be performed by Employer,
(b) The purpose of each test,
(c) The function to be tested,
(d) The plans/ procedures to be followed,
(e) Specific references to project documentation for correlation with the procedures and for verification of the documentation,
(f) The test set -up, equipment, and conditions for each part of the test,
(g) All test inputs and outputs,
(h) Test software/firmware descriptions and listings,
(i) A copy of any certified test data to be used in lieu of testing,
(j) Expected results,
(k) The acceptance criteria,
(l) Procedures for handling the variances that are identified during testing.

5.21.11.2 Test Records

The Contractor shall maintain a complete record of all test results. This record shall be keyed to the steps enumerated in the previously approved test procedures.
The record shall include the following items:

(a) Reference to the appropriate section of the test plan,
(b) Description of any special test conditions or special action taken,
(c) Test results (pass/fail).

A copy of the test records shall be delivered to the Employer at the completion of the tests.

5.21.11.3 Test List

The factory acceptance tests shall test the substation level equipment while communicating with all bay level equipment.

The Contractor shall verify the operation of the output devices in the I/O units and simulate the correct response of the remote devices. The test boards may be used for one or more I/O units at a time and be moved as required.

The factory acceptance tests shall commence by switching on power to all equipment bootstrapping and loading the software system for each computer terminal, verifying that each step is properly described in the operating instructions. The substation control system shall be tested with all software loaded and running.

The test shall include:

(a) Inventory check and inspection for general appearance, cabling drawing conformance and labelling,
(b) Checks of proper functioning of all hardware, software and firmware by a true exercise of all system functions,
(c) An input overload test, in which all test inputs are changed simultaneously and following which the system shall proceed with normal processing of data and shall not require outside manipulation for return to normal operating conditions (for telemetry inputs, values shall be changed beyond the set alarm limit),
(d) Verification of compliance with operating speed requirements,
(e) Verification that orderly computer system shut-down procedures are initiated following an interruption of the AC supply,
(f) Verification that system performance is not affected by AC power source abnormalities involving voltage variations of ± 10%,
(g) Demonstration to the Employer's satisfaction that the control system and its component parts meet all performance requirements of these specifications and all performance claims made by the Contractor. This demonstration shall include verification of functional requirements, and verification that are not unduly interdependent, furthermore verification that incorrect manipulation via the man-machine interface is properly identified and does not cause causes system lockups,
(h) Test of all discrete input points,
(i) Test of all control outputs,
(j) Test on bay interlock units,

(k) Test on assembled interlocking system,
(l) Check of analogue accuracy, noise rejection and overvoltage protection on 10% of all analogue points,
(m) Test of SOE buffering, retrieval, and local logging,
(n) Test of equipment spare through substitution,
(o) Demonstration of techniques and methods for modifying the database, including point additions and deletions,
(p) Demonstration of techniques for changing a communications port to use another protocol,
(q) Test of communication within protection monitoring system, and dialogue with distributed protection demonstration.
(r) Demonstration of access level controls and security protocols implemented and adequacy of the same.

5.21.12 Commissioning and Site Performance Tests

The Contractor shall be responsible for field installation, commissioning and test. The Contractor will perform the installation and testing under the Employer's supervision (as a witness). All hardware will be aligned and adjusted, interfaces to all inputs established operation verified, and all test readings recorded in accordance with the Contractor's recommended procedures. The field performance test will exercise all functions of the system and duplicate selected factory acceptance tests to the extent possible.

This testing will include, but not be limited to, the following conditions:

(a) Each subsystem initialisation,
(b) Diagnostics of primary equipment and self-diagnostic,
(c) Checks of proper functioning of hardware, software, and firmware by exercising of selected subsystems functions,
(d) System communication interfaces including failure modes,
(e) Database modification and expanding,
(f) Inspection and approval of the HMI presentations (Note: all labels on single line diagrams should be in English),
(g) Test dialogues,
(h) Operation of HV apparatus,
(i) Test of interlocking system,
(j) Test of event list (Note: event list should be in English),
(k) Test of measuring functions (including trends),
(l) Test of operation of tap changer,
(m) Test of alarms (Note: alarms should be in English.),
(n) Test of substation monitoring system.

5.21.13 Packing Shipping and Transport

The Supplier shall define the packing in which the equipment is delivered. The shippinglist shall state the precautions to be taken during unpacking, repacking and transport of the equipment.

The document list to be supplied with each equipment is contractual. It must be added to the special specifications.

5.21.14 Documents Shipped with the Equipment

As a minimum, the documents included in the equipment packing must allow the Employer to:

(a) correctly unpack the equipment,
(b) install and commission it in accordance with the instructions,
(c) understand its operation,
(d) ensure maintenance and repair operations,
(e) correctly repack the equipment or a part of it.

5.21.15 Spare Parts and Tools

The Contractor shall supply spare parts for all substation control and supervision equipment. The number of spare components shall be dependent on the total number of modules installed. The spares shall consist of one unit of each type of module or printed circuit card installed, plus one additional spare unit for every ten units installed. In addition, the Contractor shall provide consumable items consisting of not less than 5,000 sheets fanfold paper for each printer as well as a one-year supply of printer ribbons or cartridges for each printer.

Spare parts and materials supplied shall be additional to those used up during commissioning.

Regarding the main components of the substation control monitoring system, the following spare parts shall be provided:

(a) One workstation,
(b) One station computer,
(c) All the necessary BCU modules/boards,
(d) Two switches with optical and Ethernet ports,
(e) Two switches with Ethernet ports,
(f) One power supply module,
(g) Spare GPS clock server.

The Bid must include a complete set of software tools for configuration, editing, set-ups, testing etc. for all devices and/or modules (hardware and software). In addition, all communication parts must be included. If needed, the Bid must specify all testing plugs, cords, sockets,

interfaces, test equipment, tools etc. All utility software must work under Windows 7 professional operating system, and must work on a maintenance notebook PC (as a minimum). Necessary interfaces (LAN, optic, RS232/485, modem...) shall be foreseen.

The following tools and test equipment shall be provided:

- Laptop with all the software used on the project IEDs and its accessories,

5.21.16 Training

The Contractor should offer a training plan for the Employer's personal for all delivered substation subsystems (hardware and software). Training, range and other details related to the training course are subject to the Employer's approval. Training must be on a sufficient level to enable the Employers to use, maintain, modify and expand the control system.

The training for 4 Employer's Representatives from the Employer for 10 days on the SCADA equipment included in the contract shall enable them to do the maintenance, respectively.

All courses instruction and documents shall be in English language. The personnel selected by the Employer for this training will have the basic knowledge required to benefit from the training.

International travel, local transportation abroad and hotel accommodation shall be taken into account for quotation.

The Bidder shall be responsible for providing all necessary documentation and facilities to properly train the Employer's staff. Training fees shall be included in the contract.

5.21.17 Documentation

The Contractor shall provide hard copies of the complete documentation. In addition, the documentation for both hardware and software shall be provided on magnetic media or on CD ROM together with copies for viewing and printing of the documents.

5.21.17.1 Hardware Documentation

The Contractor shall provide documentation for all hardware supplied to the Employer. Documentation describing the circuitry, operation of the circuitry, troubleshooting and maintenance procedures shall indicate the applicable hardware revision level.

Documents shall include, but shall not be limited to, the following:

(a) Schematic and terminal-block diagrams,

(b) Manuals for installation and maintenance,
(c) Complete technical specifications of the equipment,
(d) Catalogues,
(e) Flow charts,
(f) Descriptions and logic block diagrams of hardware and software,
(g) Test report.

5.21.17.2 Software Documentation

The Contractor shall supply documentation for all software and firmware provided with the delivered system.

This documentation shall include the following data as a minimum:

(a) An inventory of all modules to be provided and a cross-referenced index to the software / firmware documentation.
(b) A functional overview document, which describes the software / firmware on a subsystem basis and includes a brief description of the hardware interfaces. This document shall functionally describe all software / firmware to be provided with simplified block diagrams. The relationship among each, the database, and the system hardware shall be included.
(c) A software / firmware documentation standards manual that describes in detail the documentation format for items stated below.
(d) Existing design documentation and Employer's manuals for the Contractor's standard software /firmware that satisfies the requirements of the specification submitted to the Employer in their existing form.
(e) Standard software and firmware, which requires modification to fulfil the Employer's requirements in the specifications, shall be subject to the Employer review and approval.

The Contractor shall provide a detailed description of the communication protocols and a list of the data and transfer telegrams utilized for the substation control system and remote communications.

In addition, where third party or custom-built software is used, including the operating system, the Contractor shall deliver valid software licenses to cover the lifetime operation of the system. The licences should adequately cover the support and update procedures such as further patches issued by the software supplier to cover at least the defects liability period.

The following software packages shall be provided:

(a) Complete SCADA software with two full licences for severs (minimum 5 user licences),
(b) Two full licences for HMI (minimum 5 user licences),
(c) One full additional licence for HMI (for 5 users),
(d) A database server software with minimum 5 user licences for every server,

(e) Antivirus, anti-spyware and anti-worm server software package with 25 user licences
(f) 5 Microsoft Office software packages,
(g) Acronis Backup software.

All documentation shall be in English.

5.21.18 Software Structure

The software package shall be structured according to the SAS architecture and shall be strictly divided into various levels. It shall be possible to extend the station with minimum possible effort. Maintenance, modification or extension of components of any feeder may not force a shutdown of the parts of the system which are not affected by the system adaptation.

Confirmation that the software programs will be supported for a minimum of 20 years is required to be submitted with the bid.

It shall be the responsibility of the Contractor to obtain any license required for the operation software. The Contractor shall indemnify the Client against all claims of infringement of any patent, registered design, copyright, trademark or trade name or other intellectual property right.

5.21.18.1 Station Level Software

(a) **Human Machine Interface (HMI)**

The base HMI software package for the operator station shall include the main SAS functions and shall be independent of project specific hardware version and operating system. It shall further include tools for picture editing, engineering and system configuration. The system shall be easy to use, to maintain, and to adapt according to specific user requirements. The system shall contain a library with standard functions and applications.

(b) **Operating System**

A Windows NT workstation operating system shall be used for the operator station as it supports several standard system features, e.g. support for several Windows office applications, multi-tasking, security levels, data exchange mechanisms (DDE, OLE), open data base communication standards (ODBC) and a standardized, user-friendly look & feel HMI.

5.21.18.2 Bay Level Software

(a) **System Software**

The system software shall be structured in various levels. This software shall be placed in a non-volatile memory. Its lowest level shall assure system performance and contain basic functions, which shall not be accessible by the Application and Maintenance Engineer for modification. The system shall support the generation of typical control macros and a process database for user-specific data storage.

(b) **Application Software**

In order to ensure robust quality and reliable software functions, the main part of the application software shall consist of standard software modules built as functional block elements. The functional blocks shall be documented and thoroughly tested. They shall form part of a library. The application software within the control/protective devices shall be programmed in a functional block language.

5.21.19 System Testing

The Supplier shall submit a test specification for factory acceptance test (FAT) and commissioning tests of the station automation system for approval. For the individual bay level IEDs, applicable type test certificates shall be submitted.

The manufacturing phase of the SAS shall be concluded by a FAT. The purpose is to ensure that the Contractor has interpreted the specified requirements correctly. The general philosophy shall be to deliver a system to site only after it has been thoroughly tested and its specified performance has been verified with site conditions simulated to the extent possible in a test lab. If the FAT involves only a certain portion of the system for practical reasons, it has to be assured that this test configuration contains at least one unit of each and every type of equipment incorporated in the delivered system.

If the complete system consists of parts from various suppliers or some parts are already installed at site, the FAT shall be limited to sub-system tests. In such cases, the complete system test shall be performed at site together with the site acceptance test (SAT).

5.21.20 System Functions

5.21.20.1 Control Unit Functions

(a) **Control**

The different high voltage apparatuses in the station shall either be operated manually by the operator or automatically by programmed switching sequences.
The control function shall comprise:

i) Commands from different operator places, e.g. from the associated control center (NLDC), station HMI, or the control panel (in control room) according to the operating principle
ii) Select-before-execute commands
iii) Operation from only one operator place at a time.
iv) Operation depending on conditions from other functions, such as interlocking, synchrocheck, operator mode, or external status conditions.

The control function shall also include:

i) Prevention of double operation
ii) Command supervision
iii) Selection of operator place
iv) Block/de-block of operation
v) Block/de-block of updating of position indications
vi) Manual setting of position indications
vii) Overriding of the interlocking function (Second key switch.)
viii) Switchgear run time supervision

(b) **Status Supervision**

The position of each switchgear, e.g. circuit breaker, isolator, earthing switch, etc., shall be permanently supervised. Every detected change of position shall be immediately visible on the screen in the single-line diagram, be recorded in the event list, and a hard copy printout shall be produced. Alarms shall be initiated in case spontaneous position changes took place.

Each position of an apparatus shall be indicated using two binary auxiliary normally closed (NC) and normally open (NO) contacts. An alarm shall be initiated if these position indications are inconsistent or indicate an excessive running time of the operating mechanism to change position.

(c) **Interlocking**

The interlocking function prevents unsafe operation of apparatuses such as isolators and earthing switches within a bay or station-wide. The operation of the switchgear shall only be possible when certain conditions are fulfilled. The interlocking function is required to be decentralized so that it does not depend on a central control device. Communication between the various bays for the station inter-locking shall take place via bay communication system.

An override function shall be provided, which can be enabled to by-pass the interlocking function via a key/password, in cases of maintenance or emergency situations.

(d) **Measurements**

Analogue inputs for voltage and current measurements shall be connected directly to the voltage trans-formers (VT) and the current transformers (CT) without intermediate

transducers. The correlated values of active power (W), reactive power (var), frequency (Hz), and the rms values for voltage (U) and current (I) shall be calculated.

(e) **Event and Alarm Handling**

Events and alarms shall be generated either by the switchgear, by the control devices or by the station level unit. They shall be recorded in an event list in the station HMI. Alarms shall be recorded in a separate alarm list and shall appear on the screen. All or a freely selectable group of events and alarms shall also be printed out on an event printer. The alarms and events shall be time-tagged with a time resolution of 1 ms. The time tagging shall be done at the lowest level where the event occurs, and the information shall be distributed with the time tagging.

(f) **Time Synchronization**

The time within the SAS shall be set via a GPS clock receiver connected directly to the bay level LAN.

The time shall then be distributed to the control/protective devices via the high speed optic fiber bus.

An accuracy of ±1 ms within the station is required.

(g) **Synchronism and Energizing Check**

The synchronism and energizing check functions shall be distributed to the control and/or protective devices and shall have the following features:

i) Adjustable voltage, phase angle, and frequency difference.
ii) Energizing for dead line - live bus, or live line - dead bus.
iii) Settings for manual close command and auto-reclose command shall be adaptable to the operating times of the specific switchgear.

(h) **Voltage Selection**

The voltages, which are relevant for the synchrocheck functions, depend on the station topology i.e. on the positions of the circuit breakers and/or the isolators. The correct voltage for synchronizing and energizing is derived from the auxiliary switches of the circuit breakers, isolator, and earthing switch and shall be selected automatically by the control and protection IED.

5.21.20.2 HMI Functions

(a) **General**

The operator station HMI shall provide basic functions for supervision and control of the substation. The operator shall give commands to the switchgear via the station monitor with the help of mouse clicks on soft-keys.

The HMI shall provide the operator with access to alarms and events displayed on the screen. Besides these lists on the screen, there shall be a print out of hard copies of alarms or events in an event log. The alarm list shall indicate persisting and fleeting alarms separately.

An acoustic alarm shall indicate abnormalities and all unacknowledged alarms shall be accessible from any screen selected by the operator.

The following standard pictures shall be available from the HMI:

i) single-line diagram showing the switching status and measured values
ii) control dialogues
iii) measurement dialogues
iv) blocking dialogues
v) alarm list, station / bay oriented
vi) event list, station / bay oriented
vii) system status
viii) checking of parameter setting

(b) **HMI Design Principles**

Consistent design principles shall be provided with the HMI concerning labels, colours, dialogues and fonts. Non-valid selections shall be dimmed out.

The object status shall be indicated using different status colours for:

i) selected object under command
ii) selected on the screen
iii) not updated, obsolete value, not in use or not sampled
iv) alarm or faulty state
v) warning or blocked
vi) update blocked or manually updated
vii) control blocked
viii) normal state
ix) busbar colouring to show live & dead bus.

(c) **Process Status Displays and Command Procedures**

The process status of the substation in terms of actual values of currents, voltages, frequency, active and reactive power as well as the positions of circuit breakers, isolators and transformer tap changers are displayed in the station single-line diagram.

In order to ensure a high degree of security against unwanted operation, a special "select-before-exe-cute" command procedure shall be provided. After the "selection" of a switch, the operator shall be able to recognize the selected device on the screen and all other switchgear shall be blocked. After the "execution" of the command, the operated switch symbol shall blink until the switch has reached its final new position.

The system shall permit the operator to execute a command only if the selected object is not blocked and if no interlocking condition is going to be violated. the interlocking conditions shall be checked by the interlocking scheme which is implemented on bay level.

After command execution, the operator shall receive a confirmation that the new switching position is reached or an indication that the switching procedure was unsuccessful with the indication of the reason for non-functioning.

(d) **System Supervision Display**

The SAS shall feature comprehensive self-supervision such that faults are immediately indicated to the operator before they possibly develop into serious situations. Such faults are recorded as faulty status in a system supervision display. This display shall cover the status of the entire substation including all switchgear, IEDs, communication links, and printers at the station level etc.

(e) **Reports**

The SAS shall generate reports that provide time-related information on measured values and calculated values. The data displayed shall comprise:

Trend reports:

i) day (mean, peak)
ii) month (mean, peak)
iii) semi-annual (mean, peak)
iv) year (mean, peak)

Historical reports:

i) day
ii) week
iii) month
iv) year

It shall be possible to select the displayed values from the database online in the process display. Scrolling between e.g. days shall be possible. Unsure values shall be indicated. It shall be possible to select the time period for which the specific data are kept in the memory.

This report shall be printed automatically at pre-selected times. It shall also be possible to print this report on request.

(f) **Trend Display (Historical Data)**

A trend is a time-related follow-up of process data. The analogue channels of all connected bay level devices on the 132 kV level shall be illustrated as trends. The

trends shall be displayed in graphical form as columns or curve diagrams with 10 trends per screen as maximum.

It shall be possible to change the type of value logging (direct, mean, sum, or difference) online in the window. It shall also be possible to change the update intervals online in the picture as well as the selection of threshold values for alarming purposes.

(g) **Event List**

The event list shall contain events, which are important for the control and monitoring of the substation.

The time has to be displayed for each event.

The operator shall be able to call up the chronological event list on the monitor at any time for the whole substation or sections of it.

A printout of each display shall be possible on the hard copy printer.
The events shall be registered in a chronological event list in which the type of event and its time of occurrence are specified. It shall be possible to store all events in the computer. The information shall be obtainable also from printed event log.

The chronological event list shall contain:

i) position changes of circuit breakers, isolators and earthing devices
ii) indication of protective relay operations
iii) fault signals from the switchgear
iv) violation of upper and lower limits of analogue measured value
v) loss of communication

Filters for selection of a certain type or group of events shall be available. The filters shall be designed to enable viewing of events grouped per:

i) date and time
ii) bay
iii) device
iv) function
v) alarm class

(h) **Alarm List**

Faults and errors occurring in the substation shall be listed in an alarm list and shall be immediately transmitted to the control center. The alarm list shall substitute a conventional alarm tableau and shall constitute an evaluation of all station alarms. It shall contain unacknowledged alarms and persisting faults. Date and time of occurrence shall be indicated.

The alarm list consists of a summary display of the present alarm situation. Each alarm shall be reported on one line that contains:

i) The alarm date and time
ii) The name of the alarming object
iii) A descriptive text
iv) The acknowledgement state

The operator shall be able to acknowledge alarms, which shall be either audible or only displayed on the monitor. Acknowledged alarms shall be marked at the list.

Faults that appear and disappear without being acknowledged shall be specially presented in a separate list for fleeting alarms. For example due to bad contacts or intermittent operation.

Filters for selection of a certain type or group of alarms shall be available as for events.

(i) **Object Picture**

When selecting an object such as a circuit breaker or isolator in the single line diagram, first the associated bay picture shall be presented. In the selected object picture, all attributes such as

i) type of blocking,
ii) authority
iii) local / remote control
iv) NLDC/SAS control
v) errors,
vi) etc.,

shall be displayed.

(j) **Control Dialogues**

The operator shall give commands to the system by means of soft keys located on the single line diagram. It shall also be possible to use the keyboard for soft key activation. Data entry is performed with the keyboard.

(k) **User Authority Levels**

It shall be possible to restrict the activation of the process pictures of each object (bays, apparatus, etc.) to a certain user authorization group. Each user shall then be given access rights to each group of objects, e.g.:

i) Display only
ii) Normal operation (e.g. open/close apparatus)
iii) Restricted operation (e.g. by-passed interlock)
iv) System administrator

For maintenance and Engineering purposes of the station HMI, the following authorization levels shall be available:

i) No Engineering allowed
ii) Engineering/configuration allowed
iii) Entire system management allowed

The access rights shall be defined by passwords assigned during the log-in procedure. Only the system administrator shall be able to add/remove users and change access rights.

5.21.20.3 System Performance

The refresh/update times on the operator station PC under normal and calm conditions in the substation shall be according to the levels specified below:

Function	Typical values
Exchange of display (first reaction)	< 1 s
Presentation of a binary change in the process display	< 0.5 s
Presentation of an analogue change in the process display	< 1 s
From order to process output	< 0.5 s
From order to update of display	< 1.5 s

5.21.20.4 System Reliability

The SAS system shall be designed to satisfy very high demands for reliability and availability concerning:

(a) Solid mechanical and electrical design
(b) Security against electrical interference (EMI)
(c) High quality components and boards
(d) Modular, well-tested hardware
(e) Thoroughly developed and tested modular software
(f) Easy-to-understand programming language for application programming
(g) Detailed graphical documentation, according to IEC 61131-3, of the application software
(h) Built-in supervision and diagnostic functions
(i) After sales service
(j) Security
(k) Experience of security requirements
(l) Process know-how
(m) Select before execute at operation
(n) Process status representation as double indications
(o) Distributed solution
(p) Independent units connected to the local area network

(q) Back-up functions
(r) Panel design appropriate to the harsh electrical environment and ambient conditions
(s) Panel grounding to provide immunity against transient ground potential rise

5.21.20.5 Configuration Tools

The configuration of the station HMI shall be made using the operator station working in Windows NT environment. The various functions shall be customized by easy to use interactive configuration tools. Configuration shall include the visual presentation of the object, adaptations needed in process data-base and adaptations of the communication configuration data.

A portable personal computer (PC) as a service unit shall be foreseen for on-site modifications of the control and protection devices. The service unit shall be used for documentation, test and commissioning.
The PC based service & support system shall be used for the following purposes:

(a) System configuration
(b) System testing
(c) Help functions
(d) Program documentation
(e) Down- and up-loading of programs
(f) System commissioning
(g) Data base management
(h) Changing peripheral parameters

The service & support system shall be able to monitor data in the running substation control system and to present changing variables on the display screen in graphic representation.

5.21.20.6 Documentation

The following documentation shall be provided for the system during the course of the project and they shall be consistent, CAD supported, and of similar look/feel:

(a) List of drawings
(b) Control room layout
(c) Assembly drawing
(d) Single line diagram
(e) Block diagram
(f) Circuit diagram
(g) List of apparatus
(h) List of labels
(i) Functional design specification (FDS)

(j) Test specification for factory acceptance test (FAT)
(k) Logic diagram
(l) List of signals
(m) Operator's manual
(n) Product manuals
(o) Calculation for uninterrupted power supply (UPS) dimensioning
(p) High-quality SCD file.

5.21.9.7 Indicating Meters in Local Back-up Control Panels

Each circuit shall be equipped with Indicating meter for measurement of three phase currents, voltages, frequency, power factor, active and reactive power. Repeat pulse outputs are to be provided from all energy meters, where specified.

(Please refer to chapter specifies the requirements of the local back-up control mimic. This back-up control shall be used during emergency conditions, or bay control IED is out of service or when control from HMI workstation or from remote NCC has been lost.)

5.21.21 Availability Calculations

The Contractor shall submit availability calculations for the offered substation automation system.

5.22 Trip Circuit and Power Supply Supervision

Trip circuit supervision relays shall be provided to monitor each of the trip circuits of circuit breakers in the relay panel and each relay shall have sufficient contacts for visual/audible alarm and indication purposes.

The trip circuit supervision scheme shall provide continuous supervision of the trip circuits of the circuit breaker in either the open or closed position and independent of Local or Remote selection at the local operating position.

The trip circuit supervision scheme shall operate satisfactorily and correctly under such conditions.

Relay elements shall be delayed on drop-off to prevent false alarms during faults on dc wiring on adjacent circuits, or due to operation of a trip relay contact.

Series resistances shall be provided in trip circuit supervision circuits to prevent mal-tripping of a circuit breaker if a relay element is short circuited.

Relay alarm elements should be equipped with self-resetting flag indicators.

Where specified, time delayed power supply supervision relays shall be provided to monitor the duplicated D.C. power supplies for tripping, closing, CB fail, Busbar protection etc. within a relay panel. An alarm shall be given if either supply voltage falls below 70% of nominal voltage for a period in excess of 3 secs. The relay shall be equipped with a self-resetting flag indicator, and shall be suitable for continuous operation at 125% of nominal D.C. voltage. The relay used shall be of Europe/USA originor other eligible countries with equivalent quality.

5.23Busbar Voltage Selection

Where required, selected voltage references, one for each busbar, shall be employed for all indications, metering, protection and synchronizing where appropriate. The correct voltage selection for the requirements of each circuit according to the busbar to which it is connected shall be obtained by direct use of auxiliary contacts on busbar selector switches.

5.24 Synchronizing

5.24.1 Synchronizing Scheme

Synchrocheck facilities are required at all circuit breakers controlling feeder circuits and bus coupler circuits, and LV circuit breakers controlling transformers. Interlocking is not required between the HV and LV circuit breaker on the transformer circuit since the transformer could be energized from either network.

The system provided under the Contract is to be to the approval of the Engineer and is to be such that the synchronizing circuit must be established before the circuit breaker can be closed. Check synchronizing relays to prevent circuit breaker closing under adverse conditions are to be included where specified.

Synchrocheck relays shall check the phase and magnitude and slip frequency of the voltage difference across the open circuit breaker with contacts connected to prevent inadvertent manual closing outside acceptable limits.

It shall be possible when closing via HMI Workstation or remote NCC to close a circuit breaker when both the line side and the busbar side of the circuit are dead by bypassing the check synchronizing relay. The dead line/dead busbar check shall be made by means of 3 phase undervoltage devices. The primary circuit shall be deemed to be dead if the voltage of all three phases is less than 20% of nominal voltage.

It shall only be possible to operate on one circuit at a time.

5.25 Diagrams

The Contractor shall submit schematic diagrams for consideration of the Engineer within six months of the contract commencement date. Prior to preparation of schematic diagrams, the Contractor shall provide Single line, block and logic diagrams **with Protection philosophy, Trip matrix, Interlocking scheme table, Auto-reclosing initiation table etc. in order to agree the circuit schemes and operating modes in advance.**

The Contractor will be provided with a set of drawings for Substations as soon as possible after award of Contract. As part of the contract documentation, the Contractor shall provide integrated sets of complete drawings (schematic and wiring diagrams and cable schedules etc.) for protection and substation automation. The detail list of documentation is given under clause 5.21.

5.26 Current Transformer Calculations

The Contractor shall submit to the Engineer detailed calculations substantiating the parameters of the current transformers he proposes to provide. They shall be presented within six weeks of the contract commencement date.

5.27 Energy Meter (Tariff Metering)

For each substation, the Contractor has to foresee one (or more) separate Metering cubicle(s). During the Design stage, the Contractor has to propose the final solution, which will be subject of the Employer's final approval

5.27.1 Meter Requirements

(a) Programmable meter
(b) Adjustable different tariff
(c) 0.1S accuracy class meter
(d) 110-400V flexible input voltage setting
(e) 1(10) A current rating
(f) Accuracy class to be ±0.1 for kWh and ±0.5 for kvarh
(g) RS232/485 port for modem interface
(h) Standard metering protocol for remote interface
(i) Data storage of 16 channel@30min interval and of 90 days

(j) Optical head and software to upload and download of meter data
(k) Password protection for programming and for configuration
(l) Configurable display, including meter ID, power quadrant display etc.
(m) Provision for quick reading scroll, reset etc. (programmable)
(n) Ability to measure synchrophasor
(o) Communication facility to a remote center
(p) Power quality measurement with built-in HMI display

5.27.2 Additional Requirements

(a) Online test facility of meter (with TTB) and with security sealing provision
(b) TTBs should be at the suitable accessible panel front location with meter
(c) Meter cabinet should be exclusively for tariff metering only and have sufficient security sealing provision, provided with 220V, 5A, two-pin socket outlet for modem power, auxiliary bias power, testing equipment power, etc.
(d) All main metering CTs and VTs should be directly terminated to the metering panel including star point (4 wire)
(e) The backup metering circuit may be shared for other purpose
(f) The VT MCBs (both main and backup) should be located in the metering panel; downstream VT MCB rating should be less than that of upstream
(g) All CT & VT terminals should have security sealing provisions.
(h) Ability to measure Harmonics Angle, Power harmonics up to 60th or above order with THD
(i) Storage capacity minimum 800MB

5.27.3 Normal Display List

Scroll Order	Display Item Name
1	Complete LCD test
2	Present date
3	Present time
4	Current billing total kWh-Del
5	Current billing total kWh-Rec
6	Current billing total kvarh-(Q1+Q4)
7	Current billing total kvarh-(Q2+Q3)
8	Current billing maximum kW-Del
9	Current billing maximum kW-Del Date
10	Current billing maximum kW-Del Time
11	Current billing cumulative kW-Del

Scroll Order	Display Item Name
12	Current billing maximum-Rec
13	Current billing maximum kW-Rec Date
14	Current billing maximum kW-Rec Time
15	Current billing cumulative kW-Rec
16	Phase A Voltage
17	Phase B Voltage
18	Phase C Voltage
19	Phase A Current
20	Phase B Current
21	Phase C Current
22	Phase A voltage angle
23	Phase B voltage angle
24	Phase C voltage angle
25	Phase A current angle
26	Phase B current angle
27	Phase C current angle
28	System PF-arithmetic
29	Line frequency

5.27.4 Alternate Mode Display List

Scroll Order	Display Item Name
1	Complete LCD test
2	Present date
3	Present time
4	Current billing total kWh-Del
5	Current billing total kWh-Rec
6	Current billing total kvarh-(Q1+Q4)
7	Current billing total kvarh-(Q2+Q3)
8	System PF-arithmetic
9	Line frequency

Load profile (cumulative meter reading) and Instrumentation profile data in the following format should be stored in intervals of 30 min for at least 100 days:

5.27.5Interval Date (Load Profile)

Interval Data Mode: Cumulative Engineering Units

Time	kWh-Del	kWh-Rec	KVARh-(Q1+Q4)	kVARh-(Q2+Q3)
Date:				
00:00	0	0	0	0
00:30	0	0	0	0
01:00	0	0	0	0
01:30	0	0	0	0

5.27.6 Interval Date (Instrumentation)

Set-1

Time	End Phase A Voltage	End Phase A Voltage	End Phase A Voltage	Average System kW
Date:				
13:45	61.0544	61.1424	61.072	0

Set-2

Time	End Phase A Current	End Phase A Current	End Phase A Current	Average System PF-Arithmetic
Date:				
13:45	0.0008	0.0004	0.0004	-0.7002

Self-read feature for at least 12 months' billing history.

5.28 Protection Relays & Associated Equipment

5.28.1 Line Distance Protection:

SL.No	Description	Unit	PGCB's requirements
1	Manufacturer		ABB/SIEMENS/ALSTOM or GE/SEL or equivalent
2	Country of Origin (Place of Manufacturing)		Switzerland/Sweden/Germany/UK/USA or other eligible countries with equivalent quality.
3	**Relay Identification**		
3.1	Relay Type & model		Should be filled up by bidder
3.2	Relay Software version		Should be filled up by bidder
3.3	Relay Hardware version		Should be filled up by bidder
4	Language		English
5	Housing & mounting		Flush mounting housing and capable of sustaining in harsh environmental condition
6	Relay auxiliary voltage	V	Minimum range of 88V to 250V DC and minimum range of 115V to 230V AC
7	Operating frequency	Hz	50Hz, ±5%
8	**Current transformer requirement**		
8.1	No of Inputs	Nos.	4
8.2	Nominal current	A	Operable in 1A and 5A (User settable)
8.3	Minimum continuous current capacity	A	3 *Nominal current
8.4	Thermal withstand capacity	A	100*Nominal current for at least 1s
9	**Voltage transformer requirement**		
9.1	No of Inputs	Nos.	6 (For Line VT & Bus VT)
9.2	Nominal voltage	V	110
9.3	Minimum continuous withstand voltage	V	220
10	**Binary input module**		
10.1	Minimum number of inputs	Nos.	10 (programmable) (Should be increased as per the scheme design)
10.2	Minimum operating range	V	110V and 220V DC (±20% tolerance)

SL.No	Description	Unit	PGCB's requirements
11	**Binary output module**		
11.1	Minimum number of outputs	Nos.	20 (minimum 8 Nos. high speed trip output and 2 Nos. watchdog outputs) (Should be increased as per the scheme design)
11.2	Minimum operating range	V	110V and 220V DC (±20% tolerance)
11.3	Minimum continuous current capacity	A	5
11.4	Short time withstand capacity	A	10A for at least 1s
11.5	Maximum operating time	ms	10
12	Number of LEDs	Nos.	15 (programmable) (Should be increased as per the scheme design)
13	HMI		Front mounted, should be suitable to access all functions, settings and stored records without externalcomputer
14	Software requirement		1. Should be able to configure, operate and monitor with user friendly engineering and disturbance handling tool. 2. Necessary software for configuration, disturbance handling and parameterization has to be supplied free of cost and without any time-bounded license
14	GPS Time synchronization		Should be available
16	**Communication interface**		
16.1	Standard protocol		IEC 61850 (have to be able to communicate to IEC 61850 based Substation Automation System)
16.2	Ethernet speed and connector		100Mbps, RJ45 plug connector/RS232 serial connector as front port
17	**Main protection function**		Impedance protection
17.1	Tripping options		Single and/or three phases
17.2	Number of parameter setting groups	Nos.	Minimum 4 (Independently settable)
17.3	Pre-configuration		For all basic functions
17.4	Number of impedance protection zones	Nos.	5
17.5	Shape of impedance zone		Mho/Quadrilateral

SL.No	Description	Unit	PGCB's requirements
17.6	Reverse looking element		Settable in all 5 zones
17.7	Can resistance and reactance reaches be set independent of each other	Yes/No	Yes
17.8	Arc forward and reverse reach setting independent of each other?	Yes/No	Yes
17.9	Switch on to fault	Yes/No	Yes
17.10	Power swing block	Yes/No	Yes
17.11	Communication aided impedance protection		PUTT, POTT, CB Echo logic, Weak infeed echo logic, DTT, Zone-1 extension etc.
17.12	Communication aided Directional Earth Fault	Yes/No	Yes
17.13	Impedance zone operating time	Sec	Settable between 0s and 30s (or higher range) with step size of 0.01s
17.14	Impedance setting range	Ohm	0.1 to 1000 or higher with the step size of 0.001/In
18	Back up protection function		Instantaneous/delayed, directional/non-directional, over current and earth fault
19	Control functions		Synchrocheck and 1P/3P auto-reclose for single and multi CB arrangements
20	**Monitoring functions**		
20.1	Fuse failure supervision, current circuit supervision	Yes/No	Yes
20.2	U, I, P, Q, S, f, PF monitoring	Yes/No	Yes
20.3	Fault locator	Yes/No	Yes
20.4	Event records and oscillographic disturbance records		Event recorder should keep at least 20Nos previous records and disturbance recorder should handle at least 8Nos analogue channels and at least 24Nos binary channels
21	Tripping and indication logics		Should be programmable
22	Standards		Should conform IEC-60255 in all aspects
23	Type test certificate		Should be provided

5.28.2 Line Differential Protection:

SL. No.	Description	Unit	PGCB's requirements
1	**Manufacturer**		ABB/SIEMENS/ALSTOM or GE/SEL or equivalent
2	**Country of Origin (Place of Manufacturing)**		Switzerland/Sweden/Germany/UK/USA or other eligible countries with equivalent quality.
3	**Relay Identification**		
3.1	Relay Type & model		Should be filled up by bidder
3.2	Relay Software version		Should be filled up by bidder
3.3	Relay Hardware version		Should be filled up by bidder
4	**Language**		English
5	**Housing & mounting**		Flush mounting housing and capable of sustaining in harsh environmental condition
6	**Relay auxiliary voltage**	V	Minimum range of 88V to 250V DC and minimum range of 115V to 230V AC
7	**Operating frequency**	Hz	50Hz, ±5%
8	**Current transformer requirement**		
8.1	No of Inputs	Nos.	8
8.2	Nominal current	A	Operable in 1A and 5A (User settable)
8.3	Minimum continuous current capacity	A	3 *Nominal current
8.4	Thermal withstand capacity	A	100*Nominal current for at least 1s
9	**Voltage transformer requirement**		
9.1	No of Inputs	Nos.	6 (For Line VT & Bus VT)
9.2	Nominal voltage	V AC	110
9.3	Minimum continuous withstand voltage	V AC	220
10	**Binary input module**		
10.1	Minimum number of inputs	Nos.	10 (programmable) (Should be increased as per the scheme design)
10.2	Minimum operating range	V	110V and 220V DC (±20% tolerance)

SL. No.	Description	Unit	PGCB's requirements
11	**Binary output module**		
11.1	Minimum number of outputs	Nos.	20 (minimum 8 Nos high speed trip output and 2 Nos watchdog outputs) (Should be increased as per the scheme design)
11.2	Minimum operating range	V	110V and 220V DC (±20% tolerance)
11.3	Minimum continuous current capacity	A	5
11.4	Short time withstand capacity	A	10A for at least 1s
11.5	Maximum operating time	ms	10
12	**Number of LEDs**	Nos.	15 (programmable) (Should be increased as per the scheme design)
13	**HMI**		Front mounted, should be suitable to access all functions, settings and stored records without external computer
14	**Software requirement**		1. Should be able to configure, operate and monitor with user friendly engineering and disturbance handling tool.
15	**GPS Time synchronization**		1. Should be able to configure, operate and monitor with user friendly engineering and disturbance handling tool. 2. Necessary software for configuration, disturbance handling and parameterization has to be supplied free of cost and without any time-bounded license Should be available
16	**Communication interface**		
16.1	Standard protocol		IEC 61850 (have to be able to communicate to IEC 61850 base Substation Automation System)
16.2	Ethernet speed and connector		100Mbps, RJ45 plug connector/RS232 serial connector as front port
16.3	Protection communication		Should be suitable for multiplexed, routed, switched or dedicated fiber optic communication
16.4	Binary input transfer		Should be able to transfer at least 8Nos binary signals between the IEDs
17	**Main protection function**		Line differential protection
17.1	Tripping options		Single and/or three phases

SL. No.	Description	Unit	PGCB's requirements
17.2	Number of parameter setting groups	Nos	Minimum 4 (Independently settable)
17.3	Pre-configuration		For all basic functions
17.4	Differential characteristics		Restrained biased characteristics with charging current compensations
17.5	Harmonics blocking		2nd and 5th harmonics
17.6	CT summation		Internal CT summation facility should be available for 1 and ½ CB arrangement
17.7	Emergency protection (Should be enabled in case of differential communication failure)		Impedance protection with at least 4 mho/quadrilateral zone setting options, PSB, SOTF, VTFF and all scheme communication features1
17.8	Display options		There must be provision of displaying restraining and differential current on the HMI
17.9	Tripping time		Instantaneous Should be able to protect at least 150km of line
17.1	Protected distance		and further facility of extending protected line length in the relay should be provided
18	**Back up protection function**		Instantaneous/delayed, directional/non-directional, over current and earth fault
19	**Control functions**		Synchrocheck and 1P/3P auto-reclose for single and multi CB arrangements
20	**Monitoring functions**		
20.1	Fuse failure supervision, current circuit supervision	Yes/No	Yes
20.2	U, I, P, Q, S, f, PF monitoring	Yes/No	Yes
20.3	Event records and oscillographic disturbance records		Event recorder should keep at least 20Nos previous records and disturbance recorder should handle at least 8Nos analogue channels and at least 24Nos binary channels
21	**Tripping and indication logics**		Should be programmable
22	**Standards**		Should conform IEC-60255 in all aspects
23	**Type test certificate**		Should be provided

5.28.3 Transformer Differential Protection (3 Winding):

SL. No.	Description	Unit	PGCB's requirements
1	**Manufacturer**		ABB/SIEMENS/ALSTOM or GE/SEL or equivalent
2	**Country of Origin (Place of Manufacturing)**		Switzerland/Sweden/Germany/UK/USA or other eligible countries with equivalent quality.
3	**Relay Identification**		
3.1	Relay Type & model		Should be filled up by bidder
3.2	Relay Software version		Should be filled up by bidder
3.3	Relay Hardware version		Should be filled up by bidder
4	**Language**		English
5	**Housing & mounting**		Flush mounting housing and capable of sustaining in harsh environmental condition
6	**Relay auxiliary voltage**	V	Minimum range of 88V to 250V DC and minimum range of 115V to 230V AC
7	**Operating frequency**	Hz	50Hz, ±5%
8	**Current transformer requirement**		
8.1	No of Inputs	Nos.	12
8.2	Nominal current	A	Operable in 1A and 5A (User settable)
8.3	Minimum continuous current capacity	A	3 *Nominal current
8.4	Thermal withstand capacity	A	100*Nominal current for at least 1s
9	**Voltage transformer requirement**		
9.1	No of Inputs		6 (For Line VT & Bus VT)
9.2	Nominal voltage	V AC	110
9.3	Minimum continuous withstand voltage	V AC	220
10	**Binary input module**		
10.1	Minimum number of inputs	Nos.	20 (programmable) (Should be increased as per the scheme design)
10.2	Minimum operating range	V	110V and 220V DC (±20% tolerance)
11	**Binary output module**		
11.1	Minimum number of outputs	Nos.	20 (minimum 8 Nos high speed trip output and 2 Nos watchdog outputs) (Should be increased as per the scheme design)

SL. No.	Description	Unit	PGCB's requirements
11.2	Minimum operating range	V	110V and 220V DC (±20% tolerance)
11.3	Minimum continuous current capacity	A	5
11.4	Short time withstand capacity	A	10A for at least 1s
11.5	Maximum operating time	ms	10
12	**Number of LEDs**	Nos.	15 (programmable) (Should be increased as per the scheme design)
13	**HMI**		Front mounted, should be suitable to access all functions, settings and stored records without external computer
14	**Software requirement**		1. Should be able to configure, operate and monitor with user friendly engineering and disturbance handling tool. 2. Necessary software for configuration, disturbance handling and parameterization has to be supplied free of cost and without any time-bounded license.
15	**GPS Time synchronization**		Should be available
16	**Communication interface**		
16.1	Standard protocol		IEC 61850 (have to be able to communicate to IEC 61850 base Substation Automation System)
16.2	Ethernet speed and connector		100Mbps, RJ45 plug connector/RS232 serial connector as front port
17	**Main protection function**		Transformer differential protection
17.1	Application		For 3 winding and Auto-Transformers
17.2	Number of parameter setting groups	Nos.	Minimum 4 (Independently settable)
17.3	Pre-configuration		For all basic functions
17.4	Differential characteristics		Restrained biased characteristics with stabilization during magnetizing inrush and CT saturation
17.5	Harmonics blocking		2nd and 5th harmonics
17.6	CT ratio matching and vector group compensation		Internally done, Software based
17.7	CT connection		CT connections from each voltage level should be connected individually without external summation
17.8	Display options		There must be provision of displaying restraining and differential current on the HMI
17.9	Tripping time		Instantaneous
17.1	Restricted Earth Fault		High / low impedance type

SL. No.	Description	Unit	PGCB's requirements
18	**Back up protection function**		Instantaneous/delayed, directional/non-directional, over current and earth fault
19	**Control functions**		Synchrocheck and 1P/3P auto-reclose for single and multi CB arrangements
20	**Monitoring functions**		
20.1	U, I, P, Q, S, f, PF monitoring	Yes/No	Yes
20.2	Event records and oscillographic disturbance records		Event recorder should keep at least 20Nos previous records and disturbance recorder should handle at least 8Nos analogue channels and at least 24Nos binary channels
21	**Tripping and indication logics**		Should be programmable
22	**Standards**		Should conform IEC-60255 in all aspects
23	**Type test certificate**		Should be provided

5.28.4 Over current and Earth fault protection:

SL. No.	Description	Unit	PGCB's requirements
1	**Manufacturer**		ABB/SIEMENS/ALSTOM or GE/SEL or equivalent
2	**Country of Origin (Place of Manufacturing)**		Switzerland/Sweden/Germany/UK/USAor other eligible countries with equivalent quality.
3	**Relay Identification**		
3.1	Relay Type & model		Should be filled up by bidder
3.2	Relay Software version		Should be filled up by bidder
3.3	Relay Hardware version		Should be filled up by bidder
4	**Language**		English
5	**Housing & mounting**		Flush mounting housing and capable of sustaining in harsh environmental condition
6	**Relay auxiliary voltage**	V	Minimum range of 88V to 250V DC and minimum range of 115V to 230V AC
7	**Operating frequency**	Hz	50Hz, ±5%
8	**Current transformer requirement**		

SL. No.	Description	Unit	PGCB's requirements
8.1	No of Inputs	Nos.	4
8.2	Nominal current	A	Operable in 1A and 5A (User settable)
8.3	Minimum continuous current capacity	A	3*Nominal current
8.4	Thermal withstand capacity	A	100*Nominal current for at least 1s
9	**Voltage transformer requirement**		
9.1	No of Inputs	Nos	4
9.2	Nominal voltage	V	110
9.3	Minimum continuous withstand voltage	V	220
10	**Binary input module**		
10.1	Minimum number of inputs	Nos.	10 (programmable) (Should be increased as per the scheme design)
10.2	Minimum operating range	V	110V and 220V DC (±20% tolerance)
11	**Binary output module**		
11.1	Minimum number of outputs	Nos.	10 (minimum 6 Nos high speed trip output and 2 Nos watchdog outputs) (Should be increased as per the scheme design)
11.2	Minimum operating range	V	110V and 220V DC (±20% tolerance)
11.3	Minimum continuous current capacity	A	5
11.4	Short time withstand capacity	A	10A for at least 1s
11.5	Maximum operating time	ms	10
12	**Number of LEDs**	Nos.	8 (programmable) (Should be increased as per the scheme design)
13	**HMI**		Front mounted, should be suitable to access all functions, settings and stored records without external computer
14	**Software requirement**		1. Should be able to configure, operate and monitor with user friendly engineering and disturbance handling tool. 2. Necessary software for configuration, disturbance handling and parameterization has to be supplied free of cost and without any time-bounded license.pliedfree of cost and without anytime-bounded license.

SL. No.	Description	Unit	PGCB's requirements
15	**GPS Time synchronization**		Should be available
16	**Communication interface**		
16.1	Standard protocol		IEC 61850 (have to be able to communicate to IEC 61850 base Substation Automation System)
16.2	Ethernet speed and connector		100Mbps, RJ45 plug connector/RS232 serial connector as front port
17	Main protection function		Instantaneous/delayed, directional/non-directional, over current and earth fault protection with IEC and ANSI/IEEE characteristics curves
17.1	Number of parameter setting groups	Nos.	Minimum 4 (Independently settable)
17.2	Minimum stages in each setting groups for Over-current	Nos	3
17.3	Minimum stages in each setting groups for Earth fault	Nos	3
17.4	Pre-configuration		For all basic functions
17.5	Tripping time		Settable between 0s to 150s
17.6	Pick up setting range for Time delayed Directional/Non directional OC	A	0.1*In to at least 20*In (step size 0.01)
17.7	Pick up setting range for High set Directional/Non-directional OC	A	0.5*In to at least 35*In (step size 0.1)
17.8	Pick up setting range for Time delayed Directional/Non-directional EF	A	0.01*In to at least 20*In (step size 0.01)
17.9	Pick up setting range for High set Directional/Non-directional EF	A	0.5*In to at least 35*In (step size 0.1)
17.10	TMS setting range for IDMT		0.025 to at least 1.5 (step size 0.025)
18	**Other protection functions**		Comprehensive voltage protection functionality including over-voltage, under-voltage, negative sequence overvoltage, residual over-voltage, underfrequency, over-frequency, Rate of Change of Frequency (ROCOF) protection
19	**Monitoring functions**		
19.1	U, I, P, Q, S, f, PF monitoring	Yes/No	Yes
19.2	Event records and oscillographic disturbance records		Event recorder should keep at least 20Nos previous records and disturbance recorder should handle at least 8Nos analogue channels and at least 24Nos binary channels

SL. No.	Description	Unit	PGCB's requirements
20	**Tripping and indication logics**		Should be programmable
21	**Standards**		Should conform IEC-60255 in all aspects
22	**Type test certificate**		Should be provided

5.28.5 Bay Control & Protection Unit (BCPU):

SL. No.	Description	Unit	PGCB's requirements
1	**Manufacturer**		ABB/SIEMENS/ALSTOM or GE/SEL or equivalent
2	**Country of Origin (Place of Manufacturing)**		Switzerland/Sweden/Germany/UK/USA or other eligible countries with equivalent quality.
3	**Relay Identification**		
3.1	Relay Type & model		Should be filled up by bidder
3.2	Relay Software version		Should be filled up by bidder
3.3	Relay Hardware version		Should be filled up by bidder
4	Language		English
5	**Housing & mounting**		Flush mounting housing and capable of sustaining in harsh environmental condition
6	**Relay auxiliary voltage**	V	Minimum range of 88V to 250V DC and minimum range of 115V to 230V AC
7	**Operating frequency**	Hz	50/60Hz, ±5%
8	**Current transformer requirement**		
8.1	No of Inputs	Nos	4
8.2	Nominal current	A	Operable in 1A and 5A
8.3	Minimum continuous current capacity	A	3*Nominal current
8.4	Thermal withstand capacity	A	100*Nominal current for at least 1s
9	**Voltage transformer requirement**		
9.1	No of Inputs	Nos	10 (For Line voltage and Bus voltages)
9.2	Nominal voltage	V	110
9.3	Minimum continuous withstand voltage	V	220

SL. No.	Description	Unit	PGCB's requirements
10	**Binary input module**		
10.1	Minimum number of inputs	Nos	10 (programmable) (Can be increased as per the scheme design)
10.2	Minimum operating range	V	110V and 220V DC (±20% tolerance)
11	**Binary output module**		
11.1	Minimum number of outputs	Nos	10 (minimum 5 Nos fast operating trip output and 1 Nos watchdog outputs) (Can be increased as per the scheme design)

5.28.6 Busbar and Breaker Failure Protection

SL. No.		Description	Unit	PGCB's requirements
1	1.1	Manufacturer		ABB/SIEMENS/ALSTOM or GE/SEL or equivalent
	1.2	Country of origin		Switzerland/Sweden/Germany/UK/USAor other eligible countries with equivalent quality.
	1.3	Type of installation		Distributed
	1.4	Standards		IEC
	1.5	Central Unit (CU)		
	1.5.1	Terminal type		Insert
	1.5.2	Terminal version (software version)		Insert
	1.5.3	Central unit for busbar protection must be supported for min. 16 bays		Yes
	1.6	Bay Unit (BU)		
	1.6.1	Terminal type		Insert
	1.6.2	Terminal version (software version)		Insert
2	2.1	Auxiliary supply voltage		
	2.1.1	CU, BU Rated auxiliary supply voltage	V d.c.	110 ±15 %
	2.1.2	CU auxiliary supply redundant Interruption in auxiliary d.c. voltage:		Yes
	2.1.3	• Without resetting	ms	> 50

SL. No.		Description	Unit	PGCB's requirements
		• Restart time	s	Insert
	2.2	a.c. current inputs BU		
	2.2.1	Number of inputs		Min. 3
	2.2.2	Rated current Ir	A	1
	2.2.3	Permissive overload, continuous		4xIr
	2.2.4	Permissive overload, 1 s		100xIr
	2.2.5	Burden at Ir	VA	< 0.5
	2.3	Binary inputs CU, BU		Min. 20 / 8
	2.3.1	Number of modules		Insert
	2.3.2	Number of inputs per module		Insert
	2.3.3	Rated voltage	V d.c.	110 ±15 %
	2.4	Binary outputs CU, BU		Min. 6 / 4
	2.4.1	Number of modules		Insert
	2.4.2	Number of outputs per module		Insert
	2.4.3	Rated voltage	V d.c.	110 ±15 %
	2.4.4	Breaking capacity at inductive load With L/R<40 ms, at rated voltage	A	0.1
	2.4.5	Current carrying capacity at rated voltage for signalling contacts continuous	A	Insert
	2.4.6	Number of tripping contacts (high-speed output)	pcs.	Min. 3
	2.4.7	Current carrying capacity at rated voltage for tripping contacts, continuous	A	5
	2.5	LED indications CU, BU		
	2.5.1	Number of LED's		Insert
	2.5.2	Multi-colour LED's	Yes/No	Insert

SL. No.		Description	Unit	PGCB's requirements
	2.6	Communication ports CU, BU		
	2.6.1	Port for front-connected PC		
	2.6.1.1	Protocols supported		Insert
	2.6.1.3	PC connector type		Insert
	2.6.2	CU, BU communication media		FO
	2.6.3	CU rear station (system) communication ports		
	2.6.3.1	Number of rear ports		Insert
	2.6.3.2	Protocols supported		IEC 61850
	2.6.3.3	Communication speed	Mbit/s	Insert
	2.6.3.4	Connector type		RJ45
	2.6.4	Time synchronisation		SNTP
	2.7	Busbar differential protection		
	2.7.1	Operating time	ms	< 20
	2.7.2	Internal CT radio adaptability		Yes
	2.7.3	Multiple tripping criteria, check and Bus zone		Yes
	2.7.4	Current transformer supervision		Yes
	2.7.5	External signal of load transfer starting		Insert
	2.7.6	Busbar protection system should be suitable/adaptable for future switchgear extension or modification		Yes
	2.7.7	Bay-selective intertripping		Yes
	2.7.8	Phase-segregated measurement system		Yes
	2.8	Breaker failure protection		
	2.8.1	Setting range	% Ir	Insert

SL. No.		Description	Unit	PGCB's requirements
	2.8.2	Re-trip time delay range	s	0-1
	2.8.3	Re-trip operation mode 1/3ph		Yes
	2.8.4	Back-up time delay range	s	0-1
	2.8.5	Trip operating time setting resolution	ms	1
	2.8.6	Trip delay range	s	0-1
	2.8.7	Single-phase with/without current		Yes
	2.8.8	2-stage operation bay trip repeat/trip busbar		Insert
	2.8.9	Selectable operation mode (current, unbalance, low current)		Insert
	2.8.10	Independent settable delay times for all operation modes		Yes
	2.8.11	Low current mode using the circuit breaker auxiliary contact		Yes
	2.8.12	End fault protection		Yes
	2.8.13	Independent breaker failure protection per bay unit		Yes
	2.9	Disturbance recorder CU, BU		
	2.9.1	Number of digital signals		Insert
	2.9.2	Number of analogue signals		Insert
	2.9.3	External/manual initiation of recording		Insert
	2.9.4	Sampling rate	kHz	Insert
	2.9.5	Pre-fault time	ms	≥ 300
	2.9.6	Recording time	ms	≥ 2000
	2.9.7	Number of recorded disturbances		Min. 5
	2.9.8	Total recording time with max. analogue and binary signals	s	> 10
	2.9.9	Output file comtrade format		Yes
	2.1	Event recorder CU, BU		

SL. No.		Description	Unit	PGCB's requirements
	2.10.1	Max. number of events		Insert
	2.10.2	Time tagging resolution	ms	1
	2.11	Self-supervision CU, BU		Yes
3	3.1	Test socket BU		Yes
	3.2	Setting and configuration approved by Engineer		Yes
	3.3	**Centralised, user-friendly configuration and all necessary software tools for full parameterization, and (re)configuration in case of extensions should be delivered**		**Yes**

5.28.7 Trip Circuit Supervision Relay

SI No.		Description	Unit	PGCB's Require-ment
1	1.1	Manufacturer		ABB/SIEMENS/ALSTOM or GE/SEL or equivalent
	1.2	Country of origin		Switzerland/Sweden/Germany/UK/USA or other eligible countries with equivalent quality.
	1.3	Type		Insert
	1.4	Standards		IEC
2	2.1	Auxiliary supply voltage		
	2.1.1	Rated auxiliary supply voltage	V d.c.	110 ±15 %
	2.2	Binary outputs		
	2.2.1	Number of outputs	NO/NC	Min. 2/2
	2.2.2	Rated voltage	V d.c.	110
	2.2.3	Breaking capacity at inductive load With L/R<40 ms, at rated voltage	A	0.1
	2.2.4	Current carrying capacity at rated voltage for signalling contacts, continuous	A	Insert
	2.3	Supervised circuits		

	2.3.1	Voltage range of supervised circuits	V d.c.	110 ±15 %
	2.3.2	Injected current of supervised circuits	mA	Insert
	2.3.3	Operating time range	s	Insert
	2.3.4	Resetting time range	s	Insert

5.28.8 Tripping Relays (High Speed High Impedance Type)

SL. No.		Description	Unit	PGCB's Requirement
1	1.1	Manufacturer		ABB/SIEMENS/ALSTOM/SEL or equivalent
	1.2	Country of origin		SWEDEN/SWITZERLAND/ UK/USA/Europe or other eligible countries with equivalent quality.
	1.3	Type		Insert
	1.4	Standards		IEC
2	2.1	Auxiliary supply voltage		
	2.1.1	Rated auxiliary supply voltage	V d.c.	110 ±15 %
	2.2	Binary outputs		
	2.2.1	Number of outputs	NO/NC	Min. 2/2
	2.2.2	Rated voltage	V d.c.	110
	2.2.3	Breaking capacity at inductive load with L/R < 40 ms, at rated voltage	A	Insert
	2.2.4	Current carrying capacity at rated voltage for signaling contacts, continuous	A	Insert
	2.2.5	Make and carry continuously		Insert
	2.2.6	Make and carry for 3 sec.		Insert
	2.2.7	Break: resistive inductive	W VA	Insert
	2.3	Supervised circuits		
	2.3.1	Voltage range of supervised circuits	V d.c.	110 ±15 %

SL. No.		Description	Unit	PGCB's Requirement
	2.3.2	Injected current of supervised circuits	mA	Insert
	2.3.3	Operating time range	ms	Insert
	2.3.4	Resetting time range	s	Insert

5.28.9 Test Socket

SL. No.	Description	Unit	PGCB's Requirement	Guaranteed
1.1	Manufacturer		Insert	
1.2	Country of origin		Sweden/Switzerland/ UK/USA/Europe	
1.3	Type			
	- Line main 1 and 2			
	- Line back-up and bus coupler		Insert	
	- Transformer main 1 and 2			
	- Bay unit BBF			
	- Distance protection			
1.4	Standards		IEC	
1.5	Each protection device must have its own test socket		Yes	
1.6	Test socket must obtain safe online protection testing and maintaining, and performing whole tripping test with following AR		Yes	
1.7	Test socket should have enough contacts to:			
	- Short-circuit current inputs from CT's			
	- Isolate voltage inputs from VT's			
	- Isolate trip circuit for each phase separately			
	- Isolate CB close command		Yes	
	- Isolate signalling voltage			

SL. No.	Description	Unit	PGCB's Requirement	Guaranteed
	- Inhibit breaker failure initialising			
	- Inhibit sending of communication signal			
	- Allow functional testing of protection			
1.8	Socket should be designed for 4 mm banana plugs access		Yes	

5.28.10 Front Panel Annunciation for OHL & Power Transformers

SL. No.	Description	Minimum Requirements	
		Unit	Data
1	Panel mounting		Yes
2	Number of inputs		Min. 16
3	Contact type		NO/NC
4	Galvanic isolation		Yes
5	Self-monitoring		
	via front indication		Yes
	via relay contact		
6	Response delay time		Adjustable
7	Bright LED technology		Yes
8	Audible device output		Yes
9	Lamp test button		Yes
10	Acknowledgement button		Yes
11	Horn acknowledgement button		Yes

Front panel annunciation must be parameterized, configured and delivered as per Engineer's requirements.

5.28.11 Front Panel Annunciation for Control Room

No.	Description	Minimum Requirements	
		Unit	Data
1	Panel mounting		Yes
2	Number of inputs		Min. 48
3	Contact type		NO/NC
4	Galvanic isolation		Yes
5	Self-monitoring		
	via front indication		Yes
	via relay contact		
6	Response delay time		Adjustable
7	Bright LED technology		Yes
8	Audible device output		Yes
9	Lamp test button		Yes
10	Acknowledgement button		Yes
11	Horn acknowledgement button		Yes

Front panel annunciation must be parameterized, configured and delivered as per Engineer's requirements.

5.28.12 Overall Fault Clearance Times

SL. No.	Description	Unit
1	400 kV Busbar Faults:	
	Main protection relay operating time	ms
	Auxiliary and tripping relay time (where used)	ms

SL. No.	Description	Unit
	Circuit breaker time	ms
	Total	ms
2	230 kV Busbar Faults:	
	Main protection relay operating time	ms
	Auxiliary and tripping relay time (where used)	ms
	Circuit breaker time	ms
	Total	ms
3	400/230/33 kV Transformer Faults:	
	Main protection relay operating time	ms
	Auxiliary and tripping relay time	ms
	Circuit breaker time	ms
	Total	ms
4	400/132/33 kV Transformer Faults:	
	Main protection relay operating time	ms
	Auxiliary and tripping relay time	ms
	Circuit breaker time	ms
	Total	ms
5	400 kV Line Faults:	
5.1	Fault Clearance at Rahanpur:	
	Distance protection maximum operating time	ms
	Permissive scheme time delay	ms
	Auxiliary relay time (where used)	ms
	Circuit breaker time	ms

SL. No.	Description	Unit
	Total	ms
5.3	Fault Clearance at Bogura	
	Distance protection maximum operating time	ms
	Permissive scheme time delay	ms
	Auxiliary relay time (where used)	ms
	Circuit breaker time	ms
	Total	ms
5.6	Fault Clearance at Future Transmission Line	
	Distance protection maximum operating time	ms
	Permissive scheme time delay	ms
	Auxiliary relay time (where used)	ms
	Circuit breaker time	ms
	Total	ms
6	230 kV Line Faults:	
6.1	Fault Clearance at Bogura:	
	Distance protection maximum operating time	ms
	Permissive scheme time delay	ms
	Auxiliary relay time (where used)	ms
	Circuit breaker time	ms
	Total	ms
6.2	Fault Clearance at : Barapukuria	
	Distance protection maximum operating time	ms
	Permissive scheme time delay	ms

SL. No.	Description	Unit
	Auxiliary relay time (where used)	ms
	Circuit breaker time	ms
	Total	ms
6.3	Fault Clearance at Future Transmission Line:	
	Distance protection maximum operating time	ms
	Permissive scheme time delay	ms
	Auxiliary relay time (where used)	ms
	Circuit breaker time	ms
	Total	ms

5.28.13 Multi-Phase Auto reclose

SL. No.	Description	Bidder's Data
1	Country of origin	
2	Type	
3	Model No.	
4	Standard	
5	Single phase auto reclose	
6	Three phase auto reclose	
7	Multi-phase auto reclose	
8	Main -1 Protection	
9	Main -2 Protection	

APPENDIX

Appendix Substation Automation System

A. Substation Automation System

1. General Requirement		
	Standards to be complied with Substation Automation system	
	Test Cab: Damp heat, steady state	IEC 60068-2-78
	Test Db: Damp heat, cycle(12h + 12h cycle)	IEC 60068-2-30
	Digital I/O, Analogue I/O dielectric Tests	IEC 60255-27
	Digital I/O, Surge withstand test	IEC 61000-4-5
	Radio interference test	IEC 60870-3/Class 2
	Transient fast burst test	IEC 61000-4-4
	Static Discharge	IEC 61000-4-2
	Electromagnetic fields	IEC 61000-4-3
	Temperature range (min/max)	°C 0/50
	Relative humidity	93%
	Intelligent Electronic Devices (IED's)	
	serial communication interface included?	Yes
	Protection & Control IED's connected same bus?	Yes
	self monitoring	Yes
	display of measured values	Yes
	remote parameterization	Yes
	disturbance record upload and analysis	Yes
	Availability Calculation shall be furnished for each equipments as well as for the entire system	Yes
	The main part of the system, HMI, Gateway,IED shall be furnished with dual communication port against any failure.	Yes
	SNTP server shall provide GPS time-sync information to all communication (HMI, Gateway, IED) and the system shall be synchronized.	Yes

	Ethernet switch shall have dual system topology not to lose entire system with single switching system failure.	Yes
2. Detailed Requirements:		
	Number of years of proven field experience of offered (Note: proof of experience should be furnished. The components used in the offered system and those with field experience should be the same)	5 Yrs.
	Design life of substation Automation System	15Yrs
	Manufacturers quality assurance system	ISO 9001/9002 or equivalent
	Dimensions of cubicle	
	Width	mm
	Depth	mm
	Height	mm
	Floor load	N/m2
3. Station Level Equipment:		
	Station Controller	Industrial PC
	MTBF (Mean time between Failures)	50000Hrs
	Station computer shall have dual connection to Ethernet switch as redundant (hot, standby)	Yes
	Hot standby take over time	Seconds
	Dual Wide Monitor each HMI (over 25”)	Yes
	Single wide screen	Yes
	Number of years of proven field experience of offered software	5 Yrs.
	Operating System	Windows
	All standard picture as per spec included in HMI	Yes
	Process Status Display & Command Procedures	Yes
	Event processing as per spec	Yes
	Alarm processing as per spec	Yes
	Reports as per spec	Yes
	Trend Display as per spec	Yes

	Graphical fault information receiving function	Yes
	Disturbance & Fault recording and analysis with graphical format	Yes
	User Authority levels as per spec	Yes
	System supervision & monitoring as per spec	Yes
	Automatic sequence control as per spec	Yes
4. Gateway to National Load dispatch Center		
	Number of years of proven filed experience of offered unit	5Yrs
	Insulation tests	IEC 60255-27
	Fast disturbance tests	IEC 61000-4-4,Calss 4
	Industrial environment	EN61000-6-4
	Industrial grade hardware with no moving parts (PC based gateway is not accepted)	Yes
	Design life of offered equipment	15 Yrs
	Redundant communication channel	Yes
	Redundant CPU	Yes
	Redundant DC/DC Supply	Yes
	MTBF (Mean time between Failures)	50000Hrs
	Gateway shall have dual connection to ethernet switch(hot and standby)	Yes
5. Station Bus:		
	Physical Meduim	Glass fibre optic
	Each communication devices shall have dual connection, hot and standby.	Yes
6. Interbay Bus		
	Physical Meduim	Glass fibre optic
7. Printer server		
	MTBF	200000Hrs
8. Hard Copy colour Printer		
	MTBF	180000Hrs
9. Master Clock – GPS (Global Positioning System) Receiver:		
	MTBF	150000Hrs

10. Bay control Unit - HV		
	Number of years of proven field experience of offered unit	5 Yrs.
	Separate Bay controller unit provided for each bay & feeder	Yes
	Type of bay controller offered HV/MV	HV
	Select Before Operate with Open Execute & Close Execute	Yes
	Single bit dependence	No
	Interlocking, bay & Station wide	Yes
	Synchro check function	
	Maximum Voltage difference	Specify range
	Maximum Frequency difference	Specify range
	Maximum Phase difference	Specify range
	Double command blocking	Yes
	Independent settable parameter groups	4
	Local Display Unit	Yes
	Sequence of event recorder	
	Events	256
	Time resolution	1 ms
	Disturbance recording file transfer function	Yes
	Comtrade file generation function of Distrubance Recorder	Yes
	IED shall have dual connection to Ethernet switch (hot & standby)	Yes
	Comprehensive self-supervision	Yes
	Battery free backup of events and disturbance records	Yes
	Insulation tests	IEC 60255-27
	Fast disturbance tests	IEC 61000-4-4, Class 4
	MTBF	
	Temperature range: IED's	
	Operation	℃-10 to +50

	Transport and storage	℃-10 to +50
	Relative humidity:	
	Operating max./min	% 93
	Transport and storage	% 93
11. Back up control mimic –HV (400kV)		
	Control functionality:	
	Control of breaker as well as all isolators/earthing switch (Control functionality should not be affected if bay controller fails)	Yes
	Key-Locked	Yes
	Interlock override function	Yes
	Separate backup control mimic provided for each bay & feeder	Yes
12. Bay Control Unit – MV		
	Number of years of proven field experience of offered unit	5Yrs
	Separate Bay controller unit provided for each bay & feeder	Yes
	Type of bay controller offered HV/MV	HV
	Select Before Operate with Open Execute & Close Execute	Yes
	Single bit dependence	No
	Interlocking, bay & Station wide	Yes
	Synchro check function	
	Maximum Voltage difference	Specify range
	Maximum Frequency difference	Specify range
	Maximum Phase difference	Specify range
	Double command blocking	Yes
	Independent settable parameter groups	4
	Local Display Unit	Yes
	Sequence of event recorder	
	Events	256
	Time resolution	1 ms

	Disturbance recording file transfer function	Yes
	Comtrade file generation function of Distrubance Recorder	Yes
	IED have dual connection (hot & standby)	Yes
	Comprehensive self-supervision	Yes
	Battery free backup of events and disturbance records	Yes
	Insulation tests	IEC 60255-27
	Fast disturbance tests	IEC 61000-4-4, Class 4
	MTBF	
	Temperature range: IED's	
	Operation	^{o}C -10 to +50
	Transport and storage	^{o}C -10 to +50
	Relative humidity:	
	Operating max./min	% 93
	Transport and storage	% 93
13. Back up control mimic – MV 230kV		
	Control functionality:	
	Control of breaker as well as all isolators/earthing switches	Yes
	Separate backup control mimic provided for each bay & feeder	Yes
14. Bay Control Unit - LV		
	Number of years of proven field experience of offered unit	5Yrs
	Separate Bay controller unit provided for each bay & feeder	Yes
	Type of bay controller offered HV/MV	HV
	Select Before Operate with Open Execute & Close Execute	Yes
	Single bit dependence	No
	Interlocking, bay & Station wide	Yes
	Synchro check function	
	Maximum Voltage difference	Specify range

	Maximum Frequency difference	Specify range
	Maximum Phase difference	Specify range
	Double command blocking	Yes
	Independent settable parameter groups	4
	Local Display Unit	Yes
	Sequence of event recorder	
	Events	256
	Time resolution	1ms
	Disturbance recording file transfer function	Yes
	Comtrade file generation function of Distrubance Recorder	Yes
	IED have dual connection to Ethernet switch (hot & standby)	Yes
	Comprehensive self-supervision	Yes
	Battery free backup of events and disturbance records	Yes
	Insulation tests	IEC 60255-27
	Fast disturbance tests	IEC 61000-4-4, Class 4
	MTBF	
	Temperature range: IED's	
	Operation	℃-10 to +50
	Transport and storage	℃-10 to +50
	Relative humidity:	
	Operating max./min	% 93
	Transport and storage	% 93
15. System Performance:		
	Exchange of display (First reaction)	< 1 S
	Presentation of a binary change in the process display	< 0.5 S
	Presentation of an analogue change in the process display	< 1 S
	From order to process output	< 0.5 S
	From order to updated of display	< 1.5 S

B. Digital Fault and Disturbance Recorder (DFDR)

Sl. No.	Description	Unit	Rating
	GENERAL		
1	Manufacturer's name & address		
2	Type		
3	Power Supply	V DC	110
	Power supply for printer	V AC	230
	ANALOGUE INPUS		
1	Number of Channel		Refer to B-1
	Expandability		Min.120
2	Nominal Current	Amp	1A/5A
3	Nominal voltage	Vac/Vdc	
	Current	mA/Amp	
4	Frequency response		
5	Cut-off frequency		
	(a) Bandwidth	dB	
	(b) Attenuation at	dB	
	(c) Auto adjusted anti-aliasing filters for chosen sampling rate	Yes/No	Yes
	(d) Simultaneously programmable sampling rate for all feeders/inputs		Min 2 for FAST and SLOW Recording
	- Locally Changeable	Yes/No	Yes
	- Remotely Changeable	Yes/No	Yes
	(e) Possible sampling rates	Samples/sec	Slow. 1Hz-500Hz
		Samples/sec	Fast 1kHz-24kHz
		Samples/sec	Continuous(variable rate)
6	DC coupled inputs	Yes/No	Yes
7	Resolution	bits	12 or better
8	Accuracy	%	Min 0.5

Sl. No.	Description	Unit	Rating
9	Burden		
	1. Current Circuit at IN	VA	
	2. Voltage Circuit	VA	
10	Over load		
	1. Current	% In	100% In continuously, Min600% in for Second
	2. Voltage circuit	% Vn	2Vn and Max 350 Vn
	DIGITAL INPUTS		
1	Number of Channel		Refer to B-1
	Expandability (Without any time skew)		Min.480
2	Selectable input level	Vdc	N/O or N/C, 220 Vdc
3	Type		Potential or potential free contact
4	Resolution	Ms	
	MEMORY		
1	Size	GB	4GB or Higher
2	Type		Solid State
3	Pre-fault time (fast scanning rate)	sec	0.1-2 user programmable
4	Post-fault (fast scanning rate)	sec	0.1-2 user programmable
5	Pre and Post-fault time (slow scanning rate)	sec	min. 180 user programmable
6	In-Built hard disk (auto-maintained)	TB	min. 1 TB
	SENSORS/ TRIGERRING CRITERIA		
1	All sensors / trigers are preferable	Yes/No	Yes
	Programmable and Virtually recordable		
	Logical combination sensor	Yes/No	Yes
2	Three phase over or under Voltage / Current	Yes/No	Yes
3	Mono phase over or under Voltage / Current	Yes/No	Yes

Sl. No.	Description	Unit	Rating
4	*du/dt, dp/dt, dq/dt, [Single/3 Phases], df/dt.etc.	Yes/No	Yes
5	RMS [Voltage / Current]	Yes/No	Yes
6	Zero Sequence	Yes/No	Yes
7	Negative, Positive Sequence	Yes/No	Yes
8	Frequency	Yes/No	Yes
9	DC Step	Yes/No	Yes
10	Pendling / Swing	Yes/No	Yes
11	Digital level and edge	Yes/No	Yes
12	Sensor trigger	Yes/No	Yes
13	Event Trigger	Yes/No	Yes
14	Manual Trigger	Yes/No	Yes
15	Remote Trigger	Yes/No	Yes
	CLOCK SYSTEM		
1	Internal Clock	Yes/No	Yes
2	Accuracy		
3	External Synchronization by GPS	Yes/No	Yes
	Time resolution between 2 synchronized pulses		
	OUTPUT ALARM RELAY CONTACT		
1	Max. operation Voltage DC/AC	Vac / Vdc	250 Vac or above, 60 Vdc or above
2	Make and carry for 0.5 sec	A	Min 8A
3	Carry Continuously	A	Min 5A
4	Break (DC) – resistive	W	
	INTERFACE FOR DATA COMMUNICAION		
1	Full definition compression	Yes/No	Yes
2	Maximum transmission rate	bits / Sec	
3	Standard serial port (EIA-232-D)	Yes / No	Yes
4	Printer Port	Yes/No	Yes

Sl. No.	Description	Unit	Rating
5	Dedicated serial port for modem	Yes/No	Yes
	PRINTER DATA		
1	Printer amplitude (scaling peak to peak)		
2	Time Scal (mm / s)		
3	Printer resolution	mm	
4	Auto printing	Yes/No	Yes
5	Fault Priority transmission	Yes/No	Yes
6	Fault location (distance calculation)	Yes/No	Yes
7	Test certificates from internationally recognized Laboratories	Yes/No	Yes
	COMMUNICATION AND REMOTE ANALYZING UNIT		
1	Processor Pentium	(MHz)Yes/No	Yes, at least 450 MHz Pentium
2	Co-Processor Pentium	Yes/No	Yes
3	Main memory capacity	(Mb) Yes/No	Yes, at least 512 MB
4	Color graphics board S-VGA	Yes/No	Yes
5	Screen S-VGA	Yes/No	Yes
6	Hard disk unit	Yes/No	Yes, at least 40 GB
7	Printer	Yes/No	Yes
8	Modem	Yes/No	Yes.

B-1. Number of Inputs per Feeder of DFDR

Voltage Level	Input Type	Type of Feeder/System	Number of Inputs per Feeder/System
400kV	Analog	Line feeder	4 currents + 4 voltages = 8 in total
		Transformer feeder (400/230/33kV or 400/132/33kV)	4 currents + 4 voltages = 8 in total
		Bus Coupler feeder (for Double Busbar)	4 currents
		Busbar Protection System	4 voltages
		DC System	2 voltage
	Digital	Line feeder	36
		Transformer feeder (400/230/33kV or 400/132/33kV)	30
		Reactor feeder	16
		Tie section (for 1 and half bus arrangement)	7
		Bus Coupler feeder (for Double Busbar)	12
		Busbar Protection System	16
230kV	Analog	Line feeder	4 currents + 4 voltages = 8 in total
		Transformer feeder (230/132/33kV)	4 currents + 4 voltages = 8 in total
		Transformer incoming feeder (400/230/33kV or 400/132/33kV)	4 currents + 4 voltages = 8 in total
		Bus Coupler feeder (for Double Busbar)	4 currents
		Busbar Protection System	4 voltages
		DC System	2 voltage
	Digital	Line feeder	34
		Transformer feeder (230/132/33kV)	28
		Transformer incoming feeder (400/230/33kV or 400/132/33kV)	8
		Tie section (for 1 and half bus arrangement)	5
		Bus Coupler feeder (for Double Busbar)	12
		Busbar Protection System	8

Voltage Level	Input Type	Type of Feeder/System	Number of Inputs per Feeder/System
132kV	Analog	Line feeder	4 currents + 4 voltages = 8 in total
		Transformer feeder (132/33kV)	4 currents + 4 voltages = 8 in total
		Transformer incoming feeder (230/132/33kV)	4 currents + 4 voltages = 8 in total
		Bus Coupler feeder	4 currents
		Busbar Protection System	4 voltages
		DC System	2 voltage
	Digital	Line feeder	26
		Transformer feeder (132/33kV)	24
		Transformer incoming feeder (230/132/33kV)	8
		Bus Coupler feeder	8
		Busbar Protection System	8

6. Auxiliary Power and Control Cables

6.1 Scope

A complete cabling system for the substation auxiliary power requirements and the control and protection multicore cabling shall be designed, provided, installed and commissioned by the Contractor as specified in the Project Requirements and schedules. All ducts, cable racking and supports are to be supplied under the Contract. The Contractor shall, furnish satisfactory evidence as to the competence of the electricians and jointers, he proposes to employ on the cable installation and jointing works. All cable shall be FRLS type.

6.2 General Description of Installation

The complete cabling installation, including that associated with control and instrumentation, shall be managed by the Contractor, who shall be responsible for design, procurement, installation and works/site testing of the whole installation.

The Contractor shall employ a cabling computer program to facilitate the above and the Bidder shall describe in his Tender the cabling management procedures he will adopt. A cable scheduling system will be imposed by the Engineer.

The Contractor shall provide an installation in accordance with the best modem practice and complete in every detail for continuous operation.

Cabling areas will include those which have natural ventilation. Cabling shall therefore be designed for the maximum ambient temperatures expected.

To cater for future requirements, adequate provision shall be made for the associated cables in respect of trench sizes, space for future racks or trays and numbers of cables permitted in areas or spaces required for future equipment.

The Contractor shall submit to the Engineer drawings for approval showing the proposed cable routes, cross-sections of the trenches and arrangements of the cable racks and trays.

The Contractor shall prepare and provide all necessary cable schedules. The cable numbering system to be used shall be advised to the Contractor and this system shall be followed.

The Contractor shall provide all necessary power, multicore and communications cables required as required and specified in the Project Requirements.

6.3 Standards

The cables shall comply with British Standards or IEC standards and recommendations, or any other internationally recognised standards, subject to the approval and acceptance of the Engineer.

6.4 Cable Installation

6.4.1 General

The cabling system shall be designed to incorporate maximum practical security, to ensure that an incident such as fire causing loss of cable circuits in any one route would at worst result in the interruption in operation of one unit only. Cables with reduced fire propagation characteristics shall be provided.

Cables shall be satisfactory for operation under the atmospheric and climatic conditions prevailing at the site and under such variations of current, voltage and frequency as may be met under fault and surge conditions on the system.

Cables shall be derated to allow for the likely number of cables following a given route.

The methods of installation shall be as follows:

(a) directly buried
(b) in concrete trenches (on racks or trays)
(c) in ducts
(d) in air

Control and instrumentation cables shall be screened/shielded to minimise interference, where necessary.

6.4.2 Installation Criteria

Specific requirements shall be as detailed in the project requirements.

System security shall be achieved by ensuring that cables are segregated or separated from each other as appropriate. Segregation shall be achieved by laying cables associated with any one high voltage circuit of a pair on separate trays or racks at least 600mm apart from the cables of the other of the pair with an airspace, but not necessarily a physical barrier, between them.

In general, to minimise interference, control cables and instrumentation cables shall be separated from power cables.

The following group classifications will be allocated for each cable:

- Group A: Single core power cables,
- Group B: Multicore power cables,
- Group C: Multicore control cables and protection cables,
- Group D: Multi-pair control and instrumentation or indication cables.

In general, single core (Group A) and multicore (Group B) power cables shall be allocated to separate racks. In a similar manner, multicore control (Group C) and multi-pair (Group D) instrumentation cables shall generally be allocated to separate trays.

There shall generally be a minimum separation of 600 mm between instrumentation cables (Group D) and power cables (Groups A and B), and a minimum separation of 300 mm between control cables (Group C) and power cables (Groups A and B). However, both these separation distances may be reduced where the two types of cable only run in parallel for a limited distance, provided the Contractor demonstrates that the level of interference resulting will not be detrimental to the operation of the equipment concerned.

6.4.3 Reduced Fire Propagation

A cable installation with reduced fire propagation characteristics shall be provided, utilising cables with organic compounds which are capable of extinguishing or considerably reducing the spread of flame along the cable.

Consideration shall also be given to ensuring that the minimum toxic or corrosive products are given off on combustion of any organic component used in cable construction.

6.4.4 Type Approval

Cables and accessories for use at all voltages shall have satisfactorily passed type approval tests equal to those required by the International Electro technical Commission or equivalent, and details for the cable designs offered shall be given in Schedule E of Particulars and Guarantees.

The Contractor is to certify that the cables and/or accessories offered will be identical in all essential particulars in respect of design, materials and workmanship with the cables and/or accessories for which type approval certificates are offered in support of his tender. The Contractor shall also ensure that all materials used will be subjected to and shall have satisfactorily withstood such tests as are customary in the manufacture of the types of cables specified. Records of such tests shall be available for inspection, if required by the Engineer.

6.4.5 Cable Sizing and Routing

The Contractor shall be responsible for all cable sizing and routing design, procurement, installation and testing.

Proposals for the following aspects of cable design shall be submitted for approval:

- Routing cables along the shortest route compatible with segregation/separation and capacity limitations
- Sizing cables in accordance with length grouping, ambient temperature and current rating
- Recording estimated lengths and later measured lengths for each cable
- Progressing the cable installation
- Producing and progressing cable schedules, cable termination schedules, and support steelwork schedules and drawings

All necessary de-rating factors shall be applied when sizing cables, to allow for maximum ambient temperatures, soil temperatures, values of thermal resistivity of soil, and grouping as necessary.

Due allowance shall be made for the method of installation, depth of laying, spacing and grouping factors.

All power cables shall be adequately rated to withstand the thermal and magnetic effects of short-circuit fault currents equivalent to the short circuit fault rating of the associated switchgear, except when ad-vantage can be taken of the peak current limiting effects of MCCB's and fuses. Screens and /or outer sheaths shall be designed to carry the full ground fault current.

The short-time rating of all transformer and interconnector feeders shall correspond to the maximum short-circuit conditions and be based on the previous maximum continuous rating operating temperature, followed by the initial asymmetric peak current, followed by the thermal steady state r.m.s. fault current for the total duration required for the associated main and back-up protection to operate and isolate the circuit. When protected by a circuit breaker which is not of the current limiting type, the cable shall withstand the maximum fault current, including asymmetric peak, for at least 3 seconds without damage.

For 400V motor supply cables the rating shall be based upon the duration of the let-through current of the associated main circuit breaker or fuse protection. The fault currents considered shall not include for the reduction due to the impedance of the cables concerned.

Maximum conductor temperatures permissible during the passage of short-circuit current shall be in accordance with cable Manufacturer's recommendations and joints and terminations shall be designed to match the cable characteristics.

For all alarm, control, indication, instrumentation, metering and protection cables, the Contractor shall determine the impedances, load burdens and other requirements of the cabling and associated equipment and shall provide cabling for satisfactory operation. Particular attention shall be given to protection circuits and the Contractor shall ensure that satisfactory operation will be achieved under overload or short circuit conditions on the system.

The Contractor shall furnish copies of calculations and other details to show how the ratings and cross-section areas of all cables have been obtained and the de-rating factors for which allowance has been made. Where a cable is routed through differing types of installation conditions, the condition giving the lowest cable rating shall determine the cable size.

The sizes of all cables shall be submitted to the Engineer for approval and the Engineer may require the Contractor to increase the cross-sectional area of the conductor to ensure that the required current carrying capacity and performance is obtained. All such changes shall be made by the Contractor with-out extra cost.

6.5 Cable Construction

6.5.1 Oversheaths

All cables shall have a black flame retardant low smoke PVC oversheath material, to meet the fire retardant characteristics of BS 4066 and IEC 60332.

PVC sheathing shall comply with IEC 60540 and shall have flame retardant properties such that the Oxygen Index is not less than 30 when tested in accordance with A.S.T.M. D2863-77. Test certificates stating measurement values for sample drum lengths of cable shall be provided.

The external surface of the oversheath shall be embossed along two or more lines approximately equally spaced around the circumference with the words "ELECTRIC CABLE" in English. Figures for the relevant voltage grade, together with Manufacturer's name, shall be embossed on the oversheath.

The letters and figures shall be raised and shall consist of upright block characters. The maximum size of the character shall be 13 mm and the minimum size 15% of the approximate overall diameter of the cable. The gap between the end of one set of embossed characters and the beginning of the next shall not be greater than 150mm.

The minimum thickness of oversheath shall not fall below the Manufacturer's stated value by more than 0.2mm plus 20 percent.

A means of identifying the Manufacturer shall be provided throughout the length of the cable.

6.5.2 Armouring

All multicore cables shall be provided with galvanised steel wire armour. Single-core cables shall have copper or aluminium wire or tape armouring.

The armour shall be protected by an overall PVC or plastic sheath.

6.5.3 Laying Up

The cores of multicore cables shall be laid up with a right hand direction of lay. Where necessary, non-hygroscopic fillers, which may be applied integrally with the bedding, shall be used to form a compact and circular cable.

6.5.4 Cable Drums

Cable drums shall be non-returnable and shall be made of timber, pressure impregnated against fungal and insect attack, or made of steel suitably protected against corrosion. They shall be lagged with closely fitting battens.

Each cable drum shall bear a distinguishing number on the outside of one flange. Particulars of the cable, i.e. voltage, conductor size and material, number of cores, type, length, gross and net weights shall also be clearly shown on one flange. The direction of rolling shall be indicated by an arrow on both flanges. The method of drum marking shall be to the Engineer's approval.

Cable spare lengths shall be wound on to steel drums before they are handed over to the Employer's stores.

6.5.5 Sealing and Drumming

Immediately after the Works tests, both ends of each cable length shall be sealed by means of a shrink-able cap and the end projecting from the drum shall be adequately protected against mechanical dam-age during handling. The ends of each drum length of multicore cables shall be masked red and green in accordance with BS 6346 or BS 5467.

6.5.6 Spare Cable

Spare cable and accessories, as detailed in the schedules, are required to be included in the Contract.

6.5.7 Jointing Accessories

Cables shall be installed in continuous lengths and straight through jointing between shorter lengths will not be permitted.

Jointing accessories shall include all necessary internal and external fittings, insulating materials, soldering metal, glands, filling and drain plugs, armour clamps, earth bonding terminals and filling com-pounds as appropriate.

Mechanical glands for the termination of elastomeric or thermoplastic insulated cables into straight-through joints and termination accessories shall meet the requirements of BS 6121 and shall be correctly designed for the termination of the armouring. The gland shall not only adequately secure the armour to provide efficient electrical continuity but shall also provide a watertight seal between the oversheath and the inner extruded or taped bedding to prevent the ingress of moisture. All glands shall be fitted with a substantial earth bond terminal.

The armour clamping device shall be capable of clamping the cable armour so that the clamp withstands any short circuit current from the armour wires, through the gland body to the integral bonding connector.

Sealing end porcelains shall be free from defects and thoroughly vitrified so that the glaze is not depended upon for insulation. The glaze shall be smooth and hard, completely cover all exposed parts of the porcelain and for outdoor types shall be a uniform shade of brown.

Porcelains must not engage directly with hard metals and, where necessary, gaskets shall be interposed between the porcelain and the fittings. All porcelain clamping surfaces in contact with gaskets shall be accurately ground and free from glaze.

Outdoor sealing ends and fittings shall be unaffected by atmospheric conditions, proximity to the coast, fumes, ozone, acids, alkalis, dust or rapid changes of air temperature between 15˚C and 65˚C under working conditions.

6.6 Types of Cable

6.6.1 Low Voltage Cables

These cables shall be in accordance with IEC 60502 with a voltage rating of 0.6/ 1 kV. Thesecables shall have stranded copper conductors. Insulation shall be XLPE with an operating temperature of 90˚C.

6.6.2 Control Cables and Instrumentation Cables

6.6.2.1 General

Two types of cable shall be provided for the control and instrumentation cabling.

The first is multicore cable with stranded (7/0.67mm wires) copper conductors of min2.5 sq.mm which is suitable for voltages up to 300V to ground a.c. or d.c. and currents up to 5A. These cables shall be used where a low impedance is essential i.e. the secondary wiring of current or voltage transformers and for circuit breaker or contactor controls. However, only for secondary wiring of current transformers, the copper conductors' cross section shall be considered as 4 sq.mm.

The second type designated "SIGNAL CABLE" is defined as those cables carrying milliamp, analogue or digital signals at low voltage levels (110V d.c. maximum) used on instrument and Logic Transmission Systems. These cables shall be multiple twisted pairs, screened and PVC covered with conductors sized 1.5mm²minimum. The use of cable cores shall be such that each plant analogue signal is trans-mitted in a twisted pair. Under no circumstances shall the signal positive be in a different twisted pair to the negative. 20% spare capacity shall be included in all multiple twisted pair cables. The combinations of multiple twisted pair cables used throughout the plant shall be restricted to 2, 5, 10, 20, 30, 50 and 100 pairs.

Inductive interference between primary and secondary cables due to load, switching or unbalanced fault conditions associated with the primary circuit shall be avoided. The more sensitive telephone, communication, analogue and digital circuit cables shall be spaced at least 600mm from power cables.

6.6.2.2 Multicore Control Cables

Cables shall comply with the construction here above and shall have cross-linked polyethylene (XLPE) insulation.

All cables shall be provided with a low smoke PVC oversheath.

Multicore control cables shall be generally in accordance with IEC 60502 with a voltage rating of 0.6/1 kV, except that 2.5 mm² copper conductors shall be stranded (7/0.67mm wires). Standard designs shall be for cables with 2, 3, 4, 8, 12, 16, 24 and 36 cores, and single strand conductors will be acceptedat 1.5 mm². Note that, the 2.5 mm² copper conductors shall be used as CT secondary cable also, how-ever, where required the Employer shall have the right to ask for 4 mm² copper conductors – The bidder shall consider the same in his bid.

All these cables shall have galvanised steel wire armouring.

These cables shall be used where a low impedance is essential, e.g. for the secondary wiring of current and voltage transformers and for circuit breaker and contactor control circuits.

6.6.2.3 Multi-Pair Instrumentation Cables

Multi-pair instrumentation cables shall be provided in accordance with industry standards. These cables shall have solid copper conductors, typically of 0.9 mm diameter laid in twisted

pairs, triplets or quads. The cables shall be polyethylene or XLPE insulated. They shall have galvanised steel wire armouring.

Cables shall be provided with either an overall metallic tape screen or individual tape screens round each conductor bundle to reduce interference from adjacent circuits.

These cables shall be used for circuits with a voltage rating not exceeding 125 V to earth and a current rating not exceeding 20 mA, where considerations of interference and cross-talk are of great importance. Typical applications include communications, computer signals, transducer circuits and alarms.

6.6.2.4 Oversheaths

All the cable types above shall have a black flame-retardant low smoke PVC oversheath. In normally manned locations, especially the control building, cables shall have a low smoke, zero halogen over-sheath, so as to minimise the generation of smoke and corrosive acid gases in the event of a fire.

6.6.2.5 Telephone Type Cables (TWPVC)

Construction

Multi-pair cables with 1/0.9mm tinned copper conductors complying with IEC 60228, PVC insulation, individual twisted pairs, PVC bedding, single wire armoured and low smoke PVC sheathed overall.

Insulation

PVC insulation shall be "Hard Grade" to BS 6746 with a radial thickness of 0.7mm nominal 0.57mm minimum. Minimum insulation resistance per 1000 metres of conductor at 20˚C shall be 10,000 Meg-ohms. Cable laid parallel to overhead lines shall be polyethylene insulated polyethylene inner sheath for l5kV between conductors and armour with a thickness of insulation 0.8mm nominal 0.66mm mini-mum. The Contractor shall provide calculations to show induced voltage levels under overhead line ground fault conditions.

Laying Up

The insulated conductors shall be uniformly twisted together with a right hand lay to form a pair. The length of lay is not to exceed 150mm and the lays for each adjacent pair are to differ from one anotherin length. In any case, the length of lay of the pairs shall be such that any cross-talk from pair to pair is the least possible.

Core Identification

The insulation of the cores shall be colour coded in accordance with IEC 60189-2 for 20 unique cabling elements (pairs) as described in Appendix A of IEC 60189-2.

6.6.2.6 Pilot Cables

Telephone-type cable laid in the ground alongside HV power cables shall take into account the effects of induced voltages.

6.7 Straight-through Joints

Each cable shall be run in one continuous length. Straight-through joints will not be permitted.

6.8 General Methods of Cable Installation

The arrangement of cables and the methods of laying shall be approved by the Engineer. Cables shall be installed by the following methods only:

- in concrete trenches
- in ducts
- on cable racks or trays.

Concrete trenches shall be provided in switchrooms. Cables shall be installed in a manner which permits the required ratings and with due regard to the number of cables following a given route, including future plant extensions.

All cables routed under roads and access ways usable by vehicular traffic shall be installed in ducts.

At all such crossings spare ducts shall be installed; the number of spare ducts shall be two, or 20% of the total number of ducts installed at each crossing, whichever is greater.

Mechanical protection to the Engineer's approval shall be installed at all, points where the cable is vulnerable to mechanical damage. Locations where this protection shall be installed shall include all points where cables pass through a wall, floor, side or top of a cable trench. In outdoor locations cables shall be provided with mechanical protection from ground level to a minimum height of 1 metre or the cable box on the apparatus, whichever is lower.

Cables shall be installed in such a manner as to avoid undue risk of damage during installation. The Contractor shall provide all necessary rollers and supports, and bending radii shall comply with the recommendations of cable specifications and be to the approval of the Engineer.

Sunshields shall be provided in all locations where the cable would otherwise be subjected to direct sunlight.

6.9 Cables laid Directly in the Ground

The method of installation shall be as follows:

Trenches shall be excavated to the minimum depth shown in Drawing for cable trench. Covers shall be provided over cables laid in the trench.

Filling in of trenches shall not be commenced before inspection and approval by the Engineer of the cables and accessories in-situ.

The Contractor shall lay the cables directly in the ground in the following manner:

70mm minimum of builders fine and graded and washed sand or other approved material shall be placed to form a bed for the cables.

After the cables have been laid they shall be covered with additional riddled sand well punned over and around the cables. No mechanical punners shall be used for this work. Protective covers of concrete shall be provided and installed.

Where, in the opinion of the Engineer, the soil on the site is unsuitable for backfilling, the Contractor shall arrange for the importation of suitable material.

Where three single core cables are laid direct in the ground and form one three phase circuit, they shall unless otherwise stated, be laid touching one another in trefoil formation, with one cable uppermost. In order to maintain a trefoil formation the three cables shall be tied together with tarred twine or by other approved means at intervals of 1.5m.

Unless otherwise approved, auxiliary control cables shall be laid under the same covers as the power cables and there shall be at least 50mm of riddled sand between the two types of cable. Above the protective covers (tiles) there shall be provided 150mm wide Teri-tape in yellow with "CAUTION - ELEC-TRIC CABLE" in English.

After any cable has been laid and until all of the cables to be laid in the trench have been covered with their protective covers, no sharp metal tools, such as spades or fencing stakes, shall be used in the trench or placed in such a position that they may fall into the trench. Rollers used during the laying of cables shall have no sharp projecting parts liable to damage the cables.

6.10 Cables drawn into Ducts

Ducts and pipes 35mm minimum in excess of cable diameter shall be supplied and installed by the Contractor in accordance with the building and civil works section.
Ducts shall be of rigid PVC and shall be surrounded by concrete of minimum thickness of 150.

Before pulling cables through ducts, the Contractor shall remove any loose material from the ducts, and prove them by drawing through a mandrel of slightly less diameter than the duct. Any lubricant used shall have no deleterious effect on the cables.

Any ducts or pipes not used shall be sealed by plugs (detail subject to approval) supplied by the Contractor before backfilling.

The ducts shall be water and vermin proof sealed, after completion of cable installation.

6.11 Cables installed in Concrete Trenches

The cable trench system shall be designed by the Contractor to the approval of the Engineer. It shall be complete with removable covers and shall comply with the building and civil works Section.

All cables routed in concrete trenches shall be suitably supported by means of cleats or racks and raised from the trench floor by means of suitable spacers. All cables shall be run in a neat and orderly manner and the crossing of cables within the trench shall not be acceptable without the prior approval of the Engineer.

The Contractor shall be responsible for removing and replacing the trench covers free of charge during the execution of his work as directed by the Engineer.

6.12 Cables Supported on Racks, Trays, Etc.

6.12.1 General

All single core and multicore main power cables shall be installed in cleats or saddles fixed at intervals. Multicore power cables shall be installed on trays or racks but segregated from other cables on the same tray by a space of 300 mm.

All control cables shall be installed on racks or trays with adequate clamps, cleats or ties to avoid excessive sagging. The Contractor shall include for the preparation and provision of single line cable routing drawings and detailed cable supporting steelwork drawings, necessary to enable the Engineer to give his approval for all main and subsidiary routes before installation commences.

Ample allowance shall be made in the design for additional cabling for future extensions.

Racks and trays shall be secured to channel or similar inserts installed in accordance with Building and Civil works section.

All cables shall be run with particular regard to the neatness of appearance. Multiple runs shall be arranged so that cables entering or leaving the run do so in a logical manner.

Trays and supporting steelwork shall be securely bonded and grounded to the main earthing/grounding system. Bonding and grounding connections shall be adequate to carry prospective fault currents without exceeding thermal or voltage limits.

6.12.2 Supporting Steelwork

All supporting steelwork shall be hot dip galvanised after manufacture and shall be to the approval of the Engineer.

Steelwork section shall not be less than 50 x 50 x 6 mm for steel channels and 50 x 50 x 5 mm for angles.

On all main cable runs, supporting structures shall be designed and drilled to accommodate additional cable racks or cleats to the extent of 20% of cables installed under the Contract and those required for known future extensions. The spacing between supporting structures shall be not greater than 1 m unless otherwise approved by the Engineer.

In cases where cables or their supports must be fixed to structural metal work, care shall be taken to avoid eccentric load transfer to beams or other structural metal. Also, local overloading or deformation of structures shall be avoided. The Contractor shall, if required, demonstrate that the loading resulting from the attachment of cabling steelwork has been taken into account in the steelwork design.

6.12.3 Cable Clamps, Cleats, Saddles and Ties

For single core cables carrying three phase alternating current, non-magnetic trefoil cleats shall be used and for other single core and three core cables claw type single or multicore unit cleats shall be used. The cleating arrangements for single core cables shall be adequate to withstand all short circuit forces.

Cable clamps shall be used at any change of direction of cable laying, but at agreed intervals on straight runs cable ties of approved design may be used.
Every non-flexible type cable shall be securely supported at a point not more than 1 m from its terminal gland to prevent stressing the termination, and on vertical runs passing through floors, immediately above the floor.

6.12.4 Trays and Racks

The Contractor shall provide all necessary trays or racks which shall be fixed at not more than 1 m centres. On all main runs trays or racks shall be installed to accommodate additional cables to the extent of 50% of those installed under the Contract or known future requirements.

Cables shall be installed on trays, in general as follows:

- Up to 16 mm²- double layer touching.
- 25to 70 mm² - single layer touching.
- Above 70 mm²- single layer with 25mm (minimum) spacing.

All cable trays shall be perforated.

All trays and racks shall be galvanised to a thickness not less than 1.6 mm and shall be PVC coated in exposed areas. The erection of steelwork, trays or racks shall not proceed until the Engineer's approval for such has been obtained.

Where cables are run on trays or racks, they shall be tied to the tray at 1 m intervals using materials approved by the Engineer.

The cable tray system shall have minimum of 20% spare cable capacity throughout.

6.13 Cables Installed on Structural Steelwork and Brickwork or Concrete

The majority of cables shall be routed on steel racks or trays but where cables have to be installed on buildings and building framework the cables shall be held by spacer saddles or cleats screwed or welded in position. The Contractor shall supply all necessary spacer saddles or cleats and fix these in position in the least obtrusive manner possible, copper cleats being used for copper sheathed MICS cable.

Cables shall not be routed on tiled, lagged or other special finished surfaces.

6.14 Terminations

6.14.1 General

The Contractor shall be responsible for making all terminations, checking and setting-to-work the completed installation. All cables provided as part of the Contract shall be terminated at both ends.
For control wiring the cable tails shall be so bound that each wire may be traced back to its associated cable without difficulty. Cores in twisted pairs or groups shall be kept together. Any

spare cores shall be numbered and terminated in the spare terminals furthest away from the cable gland. All cables shall be long enough to permit a second termination if necessary at a future date to the remotest termination location in the panel.

Cable glands shall be used at all equipment to support the weight of cable from the terminations and to seal the cable to the equipment, unless otherwise approved by the Engineer. PVC, XLPE, silicone rubber and PTFE insulated cables shall be terminated via glands to BS 6121.

Glands in all outdoor locations and within the Substation and other areas where water may impinge on cables shall be type EIU, with inner and outer seals and armour clamp. Unarmoured single core cables in these areas shall have type A2 glands.

Glands in indoor locations with the exceptions as noted above shall be type C for armoured cables and type A2 for unarmoured single core cables.

PVC shrouds shall be supplied and installed over each gland.

6.14.2 Power Cables

The Contractor shall ensure that the correct phase rotation and connections are achieved. Particular care shall be taken in the case of heavy cables, where a subsequent correction may be difficult. Phase tests will be witnessed by the Engineer and, if found necessary, the Contractor shall carry out the reversal of phase connections. Connections to electric motors shall be made as specified. Where motors have tails rather than bushings, a heat shrink or equivalent PVC tube for insulation of the crimp joint shall be provided.

Where insulated glands are provided, the Contractor shall ensure that the insulation is maintained after jointing the cable and shall, if required, demonstrate this to the satisfaction of the Engineer. The tails of two or three or four core cables in air insulated terminations shall be identified by a band of approved tape of appropriate colour over the self-sealing tape.

Single core cables shall be similarly identified by coloured tape over the cable beneath the gland.

6.15 Terminating and Jointing Conductors

Compression (indentation) type cable lugs and ferrules shall be provided and all necessary tools, including dies and other materials for making compression joints, shall be provided by the Contractor, who shall comply with the recommendations of the supplier of cables and lugs in the preparation and execution of each termination.

For stud type terminals approved crimping lugs shall be used.

Where clamp type terminals are used, the conductor shall be terminated without lugs, with the exception of flexible conductors having wires of 0.3mm or smaller which shall be fitted with crimps to more than one conductor shall be terminated in each clamp.

6.16 Core Identification

A uniform core identification system shall be used throughout the Station. The following clauses outline the broad requirements but the exact implementation shall be agreed with the Engineer.

Approved numbered ferrules shall be supplied and fitted to every cable core of control and instrument cables at each termination. The ferrules or sleeves shall be of interlocking ring insulating materials such as plastic which shall be black engraved on yellow background and have a glossy finish. The ferrules or sleeves shall be unaffected by oil or damp. Identification marks on self-sticking cloth shall not be used. The ferrules shall be of "O" or "D" cross section. Ferrules of "C" type cross section shall not be used.

Single d.c. wires shall be identified by a red or blue coloured ring (positive or negative polarity) followed by the identification of the polarity concerned (instrumentation, klaxon, alarm, etc.).

Direct a.c. circuits shall be identified by a yellow end piece followed by an identification of the phase concerned.

Wiring for secondary circuits of voltage transformers shall be identified by a grey end piece and wires in current transformer secondary circuits shall be identified by a green end piece. This identification shall be completed by a terminal index.

All markings for terminal blocks, cables, cable conductors and wiring shall be located on the corresponding fault finding drawing.

Characters suitably marked "TRIP" in white shall be fitted on all wires associated with trip circuits.

A common system of ferrule numbering shall be adopted such that ferrule numbers at terminations shall agree with ferrule numbers on the internal wiring of equipment.

6.17 Cable Identification and Schedules

The Contractor shall prepare and submit computerised cable schedules, the content and style of which shall be to the general approval of the Engineer. These shall include cable identification numbers for all cables except those provided for lighting and small power circuits and those which are connected to the load side of distribution boards for lighting and small power circuits.

The cable identification number system shall be such as to give a brief general indication of the type and function of individual cables and shall be approved by the Engineer.

The Contractor may use a fully computerised system for rating, and routing of cables, but shall provide a system that readily permits the cables to be scheduled on the following basis in sequence of cable identification number:

(a) By cable identification number only
(b) By type and size of cables
(c) By function of cable
(d) By main LV AC and DC, switchboard, actuator boards.
(e) By agreed electrical and mechanical plant functional groups.

The Contractor shall provide copies of the cable schedule in an approved format. The Contractor shall provide a standard software package together with a suitable personal computer to permit the Engineer to access, display, print and edit the schedules. The schedules shall be accessed by simple interactive dialogue using 'menu-selection' or other approved procedure.

In addition, the Contractor shall provide selected copies of the above schedules in a computer print-out form at agreed intervals.

Each end of every cable, except those provided for lighting and small power circuits and which are connected to the load sides of distribution fuse boards, shall be identified with a separate cable reference number fitted in a suitable position under the cable termination.

Where cables enter and leave ducts or pipes, suitable identification markers shall be fitted.

The materials of the markers and fastenings shall be such as to avoid corrosion or deterioration due to incompatibility of materials and shall ensure permanent legibility.

6.18 Inspection and Testing

Inspection and testing during manufacture and after installation on site shall be in accordance with Section 15 of this Specification.

3 Earthing System and Lightning Protection

7.1 Scope

7.1.1 These chapters describe the general requirements for the Grounding & Earthing (& Bonding) system along-with lightning protection and shall be read in conjunction with the project requirements and schedules.

7.1.2 The Work under this Section comprises the design, supply and installation including excavation, backfilling and site testing of earthing systems and connections to electrical apparatus at EHV & HV Voltage level (400kV, 230kV ,132kV & 33) substation. Moreover, work scope also includes the lightning protection scheme and the provision of supply of portable earthing devices.

7.1.3 Complete earthing system generally shall be designed in accordance with the requirements of this specification.

7.1.4 The earthing system shall include earth electrodes to provide the connection to the general body of the earth, all earthing conductors and connections to all electrical equipment and metallic structures on the site. The earth electrodes shall limit the potential rise under fault conditions and buried conductors shall be provided to limit potential differences on the site and adjacent to the site to ensure safety to people and animals.

7.1.5 Protection for all electrical equipment against lightning shall also be provided.

7.1.6 The Contractor shall be required to undertake all necessary earth resistivity tests at the substation sites and, from these tests, to undertake the design of the earthing systems. These designs, as well as providing safe passage to earth for the stated earth fault currents, shall also include calculation of step, touch and mesh potentials, which shall be within the allowable limits of the standards quoted in this specification.

7.1.7 The design calculations of step, touch and mesh potentials, accompanied by full installation drawings and material requirement schedules, shall be submitted to, and receive the approval of, the Engineer before materials procurement or installation commences.

7.1.8 After finishing the work, Full set of Design & Drawing documentation shall be provided as reference.

7.2 References

7.2.1 American Standards

IEEE std 80	IEEE Guide for Safety in AC Substation Grounding
IEEE std 81	IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potential of a Grounding System
IEEE Std 837	Standard for qualifying permanent connections used in substation grounding
IEEE std 1590	IEEE Recommended Practice for the Electrical Protection of Communication Facilities Serving Electric Supply Locations Using Optical Fiber Systems
IEEE Std 487™	IEEE Standard for the Electrical Protection of Communications Facilities Serving Electric Supply Locations—General Considerations
IEEE Std 367™	IEEE Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage from a Power Fault
IEEE std 998	
NFPA 780	

7.2.2 IEC

i. IEC 60479-1 Effect of current on human beings and livestock Part 1 General aspects
ii. IEC TR 60479-4 Effects of current on human beings and livestock - Part 4: Effects of lightning strokes
iii. IEC 60479-2 Effects of current on human beings and livestock - Part 2: Special aspects
iv. IEC 60479-5 Effect of current on human beings and livestock - Part 5 Touch Voltage threshold values for physiological effects
v. IEC 62305 Lightning protection standard
vi. CIGRE 44 Earthing of GIS- an application guide (Electra no.151, Dec ’93)

7.2.3 British Standards

i. BS EN 13601 Specification for copper for electrical purposes: high conductivity copper rectangular conductors withdrawn or rolled edges.
ii. BS EN 13601 Specification for copper for electrical purposes. Rod and bars
iii. BS EN 12449 Specification for copper and copper alloys. Tubes
iv. BS 2874 Specification for copper and copper alloy rods and sections (other than forging stock).
v. BS 4360 Specification for weldable structural steel
vi. BS 6360: Specification for conductors in insulated cables and cords.
vii. BS 6651 Protection of Structures against Lightning
viii. BS 6746 Specification for PVC insulation and sheath of electric cables.
ix. BS 7430 Code of Practice for Earthing

7.3 Definition

Item	Meaning
Step Voltage	Potential differences are established on the surface of the soil whilst fault current is flowing. Step Voltage in a particular direction is defined as the potential difference between two points a metre apart. Step potentials can be reduced by using potential grading electrodes or installing electrodes at a greater depth.
Touch Voltage	The potential difference between any item of metalwork and the soil around it (creating a hand-to-feet voltage difference) during the time that fault current flows. Touch voltages are calculated assuming that the feet of the person are 1m away from the metalwork being touched. Touch voltages are normally reduced by using potential grading electrodes such as buried copper tape or meshes intended to equalise potentials around equipment.
Remote Touch Voltage	The potential difference between a connected conductor (e.g. a metallic Sheath or pipe) and earth at a remote point when the object is earthed both in the substation and also at the remote end. (Compare with Transfer Potential below, which is defined as the voltage for touching if the object is earthed in the substation but not at the remote end).
Transfer Potential	A potential rise of an earthing system caused by a current flowing to earth, transferred by means of a connected conductor (e.g. a metallic sheath or pipe), which enters an area, with little or no potential rise relative to reference earth, and which is not connected to earth in that area. This results in a potential difference occurring between the conductor and its surroundings at the remote position.
Brownfield Sites	Brownfield sites are those where a bench or a portion of the bench exists and there is already a form of earthing system which requires assessment and augmentation.
CDEGS	Current Distribution Electromagnetic Interference Grounding Soil Structure Analysis software design package.
Contractor	A contractor engaged by PGCB or a Third Party to perform any design, construction or related services in relation to assets or infrastructure which are connected, or to be connected, to PGCB's transmission network.
Third Party	A party who wants to establish or modify a connection to PGCB's transmission network but is not included in formal contractual manner by PGCB.
CVT	Capacitive Voltage Transformer.
Designer	A party who designs assets or infrastructure which are connected, or to be connected, into PGCB transmission network.
Earth Grid	Interconnected uninsulated conductors installed in contact with the earth (or an intermediate material) intended for the conduction and dissipation of current and or for the provision of a uniform voltage reference.

Item	Meaning
Earth Grid Riser	Insulated conductor installed from the earth grid underground to surface equipment.
Earth Rod	Earth electrode consisting of a metal rod installed into the ground, commonly vertically.
ECC	Earth Continuous Conductor
effectively earthed	Effectively earthed is defined as a sufficiently low impedance such that for all system conditions the ratio of zero-sequence reactance to positive-sequence reactance (X0/X1) is positive and less than 3, and the ratio of zero sequence resistance to positive sequence reactance (R0/X1) is positive and less than 1. Effectively grounded systems will have a line-to-ground short circuit current of at least 60% of the three-phase short-circuit value.
EGVR	Earth Grid Voltage Rise is calculated by multiplying the earth grid resistance by the fault current.
EMC	Electromagnetic Compatibility.
'Hot' Substation	A substation where the Earth Potential Rise can exceed the value specified in this specification when the maximum earth fault current is flowing.
'Cold' Substation	A substation where the Earth Potential Rise does not exceed the value specified in this specification ~~(Table 2)~~ when the maximum earth fault current is flowing.
BACKUP PROTECTION	
GSP	Grid Supply Point – 400/230kV to Lower Voltage Substation
BSP	Bulk Supply Point - 132/33kV or 230/33 or 132/11 kV Substation
EPR	Earth Potential Rise. The potential on exposed metalwork and the earth electrode or conductor during fault conditions, relative to remote (or 'true') earth. Note that this value will differ at various points on a large earthing system, and should be considered for all voltage levels within a substation.
FCDIST	Fault Current Distribution Analysis. FCDIST calculates fault current distribution in multiple terminals, transmission lines and distribution feeders using minimum information and a simple set of data concerning the network.
Greenfield Sites	Greenfield sites are those built on new benches.
IEEE	Institute of Electrical and Electronics Engineers.
Maximum Fault Level	The current highest fault level of a substation at system normal excluding uncommitted generators.
NER	National Electricity Rules.
PEC	Parallel Earth Conductor.
PED	Portable Earthing Device.
PVC	Polyvinyl chloride.

Item	Meaning
RESAP	Soil Resistivity Analysis. RESAP is used to determine equivalent earth structure models based on measured soil resistivity data.
Standard Drawing	A drawing developed by PGCB as a complete design to be used for construction. Standard Drawings are not intended to be revised or renumbered.
Step Potential	The difference in surface potential experienced by a person bridging a distance of 1 m with their feet without contacting any other earthed object.
Template Drawing	A drawing developed by PGCB as the basis for design. Template Drawings are intended to be revised and renumbered as required to complete the design.
Touch Potential	The potential difference between the ground potential rise and the surface potential at the point where a person is standing while at the same time having a hand in contact with an earthed structure.
Ultimate Fault Level	The highest fault level expected in the future after all planned network augmentations have taken place.
VAB	Vehicle access barrier
EHV	Extra High Voltage, containing voltage level 230kV & Above
HV	High Voltage, containing voltage level above 33kV but upto 145kV
MV	Medium Voltage, containing voltage level from 1kV to 33kV
LV	LV Voltage, containing voltage level below 1kV

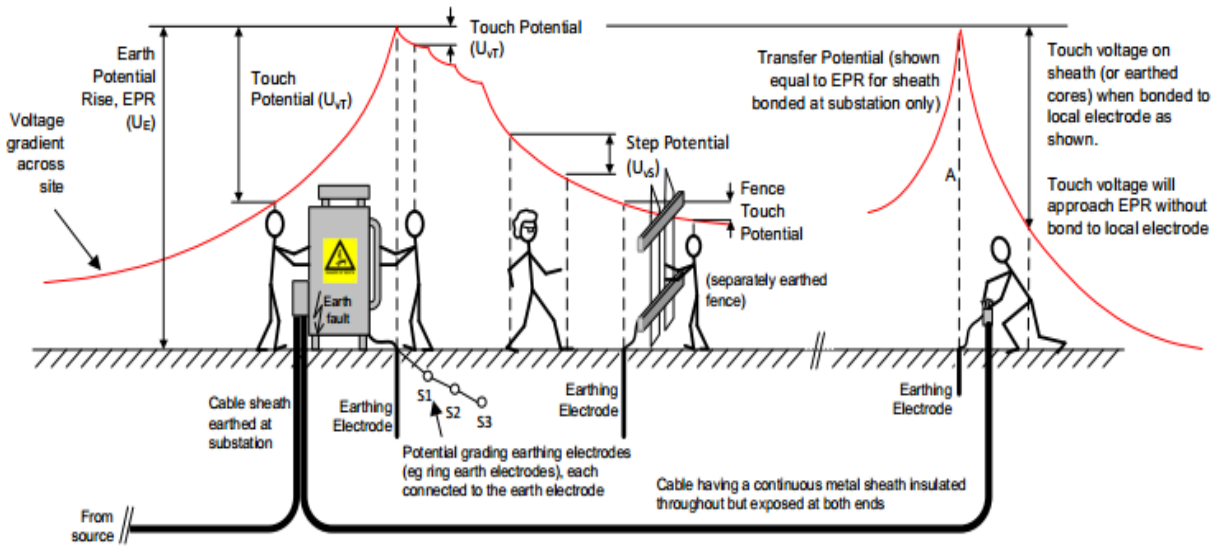


Figure 01: Touch, Step and Transfer Voltages Resulting from an Earth Fault

7.4 Service Condition

7.4.1 The Earthing and lightning protection systems are to be installed indoors and outdoors in electrically exposed locations; less than 1,000 metres above sea-level. The following air temperatures apply: -

Maximum ambient temperature	45°C
Maximum daily average ambient temperature	35°C
Annual average ambient temperature	25°C
Minimum ambient temperature	-5°C

The humidity is high and the atmosphere is not salt-laden.

7.4.2 It shall be the responsibility of the Contractor to determine the characteristics of the native soil for each project. Use of typical 100 Ω-m soil resistivity does not always guide to actual site condition. They shall consider particularly the impact of humid salty atmosphere in Bangladesh on non-galvanised ferrous parts and on aluminium and its alloys.

7.5 Soil Survey

7.5.1 Before starting any soil survey for electrical soil resistivity, soil survey for civil construction shall be carried out—typical depth vs SPT value curve to be derived. From where, the different strata of soil in the project area can be obtained. The depth of water table can also be obtained from this survey. This survey shall form the basis and start point of Soil resistivity survey and for substation grounding design.

7.5.2 Notwithstanding any civil or structural requirements, the analysis of the native soil carried out by the contractor shall determine its suitability (or otherwise) as a bedding layer for the bare earth electrode system.

7.5.3 The Contractor shall report in writing to the Engineer to carry out an earth resistivity survey of the sites and report in writing to the Engineer. The reporting shall detail the methods to be followed for resistivity measurement and instruments used in accordance with the approved programme.

7.5.4 The surveys shall also determine the depth and nature of any underlying rock, which may limit the depth for driving earth rods or if boring will be necessary for installing earth rods.

7.5.5 The Wenner four-electrode method shall be used. The proposed test method shall be submitted to PGCB for review. The positions of the probes used for the test, and their variation shall be chosen such to result in the most accurate results.

7.5.6 These measurements shall be carried out in presence of Employer's & Employer's Engineer (where applicable) representative. The signed report & measurements results therein shall be the basis for station Earthing Design.

7.5.7 The extent of measurements shall be sufficient to determine the thickness and resistivity of surface, bedrock and any intermediate layers. Typically, measurements shall be taken

at a range of probe spacings from 0.3 m out to 30 m and additionally further subject to site constraints.

7.5.8 The following probe spacing are typically used:
1, 2, 3, 4, 5, 7, 10, 15, 20, 25, 30 meters & when required additionally spacing shall be 50, 60, 70, 80, 90, 100, 110, 120, 130 meters.

7.5.9 The weather conditions prior to and at the time of the surveys shall be recorded in the report and an assessment made of the seasonal variations in resistivity based on meteorological data for the area. The programme for the project should, as far as possible, time the resistivity surveys to take place during a dry season.

7.5.10 At least two sets of measurements shall be made on site at approximately 90º angles. Further measurements (e.g. at 45º) shall be taken as appropriate to help clarify any potential anomalous measurements.

7.5.11 Probe positions adjacent to existing earth systems or buried metal objects shall be avoided as far as possible.

7.5.12 Immediately after the measurement is complete at site, the contractor shall prepare a comprehensive Soil Resistivity Report , including Proper Soil Model developed as discussed below . The report to be submitted to PGCB for review.

7.6 Soil Model

7.6.1 As outlined in section above, the Contractor shall perform soil resistivity measurements to establish an electrical model of the surrounding soil and rock, if any.

7.6.2 The Soil Resistivity report shall discuss the type of soil of the said site and layers therein. This analysis shall include soil characteristics & all possible layers upto the Water table.

7.6.3 The report shall identify contaminated soils or other characteristics (e.g. high salt content) which may be particularly corrosive to any buried elements of the earthing system. Where required, suitable mitigation shall be by agreement with PGCB.

7.6.4 Typically, uniform soil type may not be available for EHV & HV (400kV, 230kV, 132kV) AIS & GIS substation. Multi-layer Soil Model shall be developed using appropriate software mentioned in this specification. However, the contractor shall demonstrate & consult with PGCB that, whether equivalent Two-layer Soil Model is sufficient for the proposed site or not. If analysis found to be acceptable, equivalent Two-layer Soil Model may be adopted.

7.6.5 Preferred software is CDEGS software package, capable of modelling up to 5 soil layers.

7.6.6 Justification shall be provided for the soil model(s) selected, with reference to supporting information such as trial pit data, if available, and information regarding the

local geological conditions (bedrock types, etc.), where appropriate.

7.6.7 A graph showing change of resistivity at various depth of soil shall be provided. Tables shall be included in the report showing the measured apparent resistance and/or resistivity versus probe spacing for each of the sets of soil resistivity measurements taken. In cases where there is poor agreement between sets of data, sensitivity analysis shall be carried out and any modifications, simplifications or assumptions made in deriving the soil model shall be clearly explained.

7.6.8 The soil model shall also take account of any required cut or fill civil works at the site.

7.6.9 Based on the results the Contractor shall include in the report his proposals for the resistivity (s) & layer (s) of soil to be used in the design of the Earthing system.

7.6.10 The report shall be approved by the Engineer before proceeding with the design of the Earthing system.

7.6.11 The correct implementation of testing & measurement and use of the results is the sole responsibility of the Contractor.

7.7 Grounding System Design

7.7.1 Design Criteria

7.7.1.1 The most general, and overriding requirement is that the installation shall be designed to prevent danger, as required by Regulations.

7.7.1.2 The design and installation of an appropriate earthing system will ensure that a suitably low impedance path is in place for earth fault and lightning currents and control touch and step voltage hazards.

7.7.1.3 The main objectives are to:

a) design and install an earthing system that provides sufficient safety with regard to touch and step voltage limits;

b) To limit the EPR/GPR at sufficient acceptable level as mentioned in this speciation; and

c) satisfy Power Grid station that the site is safe to energise.

7.7.1.4 In practice, these objectives are usually satisfied by ensuring that:

a) Metallic items are connected together (bonded), as necessary, with dedicated low impedance connections to minimise touch voltages and to provide a path for fault current with adequate thermal capacity.

b) An in-ground earthing (electrode) system is installed and arranged to control touch and step voltages.

7.7.1.5 This serves two purposes:

a) To provide a low resistance connection to the general mass of earth (earthing), in order to a) limit the EPR to design values and b) provide a low impedance path sufficient to operate protection quickly in the event of an earth fault.

b) To minimise the touch voltage at operator positions (e.g. by providing a copper mesh or ring beneath the operator's feet that is bonded to the switchgear), and around metallic items (including fences, where necessary). In this way, the touch voltage experienced by an individual can be much smaller than the substation EPR**.**

7.7.1.6 The Designed lifetime of the grounding system shall not be less than 50 years

7.7.2 Design Requirements

7.7.2.1 To satisfy the design criteria, the earthing system shall satisfy the following requirements:

i. The attainable touch and step voltages in and around the substation shall be within allowable limit as specified in IEEE80 limits based on the installed substation earth electrode system and reliable parallel electrode contributions only (see clause 7.6), for normal protection operation.

ii. The EPR should be limited to 430V (or 650V where high reliability protection clears the fault within 0.2 seconds) as far as reasonably practicable to classify the site as COLD or below 2.33kV if the site is to be classified as HOT.

Note: The use of the terms HOT or COLD do not directly translate to safe or unsafe, as it is possible to have a safe HOT site or unsafe COLD site.

iii. The voltage transferred to any LV network or customers shall not exceed 430V (or 650V where high reliability protection clears the fault within 0.2 seconds) otherwise the LV system neutral/earth shall be segregated from HV/EHV systems.

iv. The impact of the EPR that may be transferred to Third Parties (e.g. telecommunications providers, pipelines, LV customers etc.) shall be considered at the design stage and appropriate mitigation put in place.

v. The EPR and safety voltage calculations shall be based on the calculated foreseeable worst-case earth fault level (*clause 7.6*).

vi. The substation should be designed with an independently earthed fence where practical.

vii. The earthing system shall be able to pass the maximum current from any fault point back to the system neutral without damage based on backup protection operation times.

viii. The earthing system shall be sized to ensure the temperature rise is limited so as not to cause failure of the electrode, conductor or joints. The maximum design or operating temperature for bare copper and joints is 300 ºC. The maximum design or operating temperature for PVC insulated conductor temperature is 160ºC.

ix. The overall surface area of buried electrode shall be sufficient to dissipate fault current without excessive heat/steam generation.

x. The earthing system shall maintain its integrity for the expected installation lifetime with due allowance for corrosion and mechanical constraints.

7.7.3 Design of Substation Grounding System

7.7.3.1 The earthing system shall be designed using latest version of the CDEGS design software package. Use of similar software with same capability shall be in agreement

with PGCB. The Designer shall use suitable CDEGS earthing design module to model the grid and any Third-Party infrastructure if it has been affected by development of the relevant substation infrastructure.

7.7.3.2 The Contractor must demonstrate due diligence in investigating and allowing for future metallic structures within the vicinity which may impact safety of the earthing system as well as effect of the earthing system on the public safety and on surrounding infrastructure. When two electrical installations are in close proximity the earthing systems can be designed as either standalone earth grids or as a combined earth grid system as dictated by the project requirements. When two earth grids are to be connected, a duplicated ECC, sized as a minimum equal to the earth grid conductor, must be provided.

7.7.3.3 An earthing system shall comprise the following components:

i. The main earthing electrode
ii. The conductors between the main earth bar and the metallic frames, enclosures or supports of electrical equipment
iii. The conductors between structural metalwork and non-electrical equipment and the main earth bar

7.7.3.4 The design calculations shall be to the approval of the Engineer and shall be based on the methods given in the standards listed and specified in this specification. The calculations shall include the following parameters:

(a) earth resistance of the whole system and of its components
(b) earth potential rise
(c) step, touch and mesh potentials inside mesh system and outside the perimeter fence
(d) requirements for a high resistance surface layer
(e) conductor ratings
(f) requirement of resistivity mitigation technique

7.7.3.5 The substation shall be provided with a complete Grounding system, comprising of a buried ground mesh electrode, connections to steel structures and where applicable the contribution of overhead shield wires or cable sheaths to ensure safe step and touch potentials.

7.7.3.6 If the design calculations show that a mesh alone is unable to limit the potentials to the required values, then the mesh shall be supplemented by the use of interconnected earthing rods driven into the ground or installed in bored holes.

7.7.3.7 In addition to efficiently reduce transient ground resistance against lightning and switching surge, needle type earthing rods shall be buried with the grounding wire at incoming gantries, SA, and HSGS (if installed) respectively.

7.7.3.8 Rods shall be installed inside the perimeter fence to enclose the maximum possible area compatible with the earthing of any metallic fence. (The spacing between rods shall not be less than their length, unless rating considerations determine otherwise). The copper bonded rod electrodes shall be interconnected in groups of four to eight rods by insulated copper conductors and non-ferrous clamps to form a ring. Each group shall be connected to the mesh by duplicate insulated copper conductor via disconnecting test links.

7.7.3.9 Individual rods may be connected directly to the mesh, provided the rod can be disconnected for testing.

7.7.3.10 The calculation of potentials in the design of the complete installation shall also be made without the group of rods with the lowest estimated resistance to simulate the condition with the group disconnected for testing.

7.7.3.11 Earthing points shall be provided such that the combined resistance of the Grounding grid and all other earthing points does not exceed the allowable limit dictated by the specification & standard specified herein for the fault current and duration specified & soil resistivity measured during the dry season. Typically, Earthing grid resistance shall be limited to 0.5Ω where practicable and economical. However, safety purpose is fulfilled and EPR is within practically acceptable limit, this requirement may be relaxed to some extent, provided that, such deviation however must be taken to the attention of PGCB for approval & proper guidance.

7.7.3.12 The rating of earth system conductors connected between an item of electrical plant and the earth electrode system shall be sufficient to withstand the fault currents and duration, after allowing for the parallel paths through the earth system conductors, with any one conductor disconnected.

7.7.3.13 The conductor shall be installed in trenches excavated by the Contractor to a depth of 500-800mm. The system will be installed after all foundations have been laid and the site filled to 100mm below finished level. When the earthing grid has been laid and backfilled, bricks will be laid up to finished site level. Where the excavated material is rocky or may be difficult to consolidate, the backfilling shall be carried out using other material to the approval of the Engineer. The cost of such material shall be deemed to be included in the Contract.

7.7.3.14 The design of earth system shall take into account the corrosiveness of the soil based on the soil survey.

7.7.3.15 Where the Third-Party Grounding system is adjacent to the PGCB substation and separation cannot be ensured, the two Grounding systems shall be interconnected using permanent connections.

7.7.3.16 However, as outlined in section below, the PGCB substation grounding grid shall also be designed to perform independently from any adjacent Third-Party system.

7.7.3.17 The design report shall include sufficient information on the various potential interconnection scenarios to allow direct comparison between the model and site measurements. The designer shall outline clearly any particular testing required to validate any assumptions made during the design process.

7.7.3.18 The design shall also include a map/graph/curve indicating the value and position of anticipated Earth Potential Rise contours around the perimeter of the substation (including any adjacent connected towers) during fault conditions.

7.7.3.19 The design comprising all the above mentioned items shall be submitted to the Engineer for approval within six months of the award of Contract.

7.7.4 Safety analysis

7.7.4.1 A safety analysis shall be carried out to demonstrate that step and touch potentials within the switchyard are within tolerable limits.

7.7.4.2 The safety analysis shall also consider transfer potential and particular attention shall be given to:

a) Adjacent electrode systems.
b) Cable screens (power, LV, & control /telecom).
c) Shieldwire and earth continuity conductor (ECC or also commonly referred to as counterpoise).
d) Other conductive paths (e.g. fences, railways, gas or water pipes).
e) Inadvertent bonding of systems intended to be isolated.

7.7.4.3 Tolerable voltages (Step, touch & mesh and Transfer potentials) shall be within the permitted limits calculated in accordance with the standards given in this specification for the proposed surface layer and the following parameters;

a) 50kg body mass;
b) 50Hz frequency,
c) Fault level and X/R ratio per clause 7.7 & 7.8 respectively,
d) Fault clearance time per clause 7.7 .

7.7.4.4 The earth potential rises shall not exceed the CCITT limits appropriate to the classification of the system unless special precautions are taken to cater for transferred potentials. Typical limits are 430V, 650V, 1750V etc.

7.7.5 Additional Resistances

7.7.5.1 An additional footwear resistance of 2,000 Ω (4,000 Ω per foot) may be considered inside the substation palisade fence.

7.7.5.2 The typical additional surface layers in Table 1 may be considered for preliminary design.

Table 1: Additional surface layers

Surface Layer	Typical Resistivity (Ω.m)	Standard thickness (mm)
Native soil / backfill	Per soil model	N/A
Crushed limestone	2,500	150
Tarmac	>10,000	50

7.7.5.3 The Contractor is responsible for ensuring that the resistivity properties of the material on site match those used in the design or that the design is amended accordingly. Where reasonable, PGCB shall have the right to ask the contractor that, test the surface layer material resistivity on site to assure the assumed resistivity are within design limit.

7.7.5.4 Standard layer thickness values in Table 1 shall be considered as minimum. Where greater thickness layers are installed the tolerable limits shall be adjusted accordingly.

7.7.6 Fault Current and Duration

7.7.6.1 For Designing Grounding system, SLG or double LG fault shall be used.

7.7.6.2 An earth fault current shall be calculated using the symmetrical short circuit current as specified in the section 1 of this specification.

7.7.6.3 Duration:

a) For Sizing conductor, the duration of fault shall be considered as 1s.

b) For Safety analysis & GPR calculation, maximum back-up earth fault clearing time shall be considered. This shall be minimum 500ms. For Details refer to protection scheme functional specification.

7.7.6.4 Fault current analysis and Split factor

a) Single line to ground fault (LG/SLG) current shall be found out for the given no. of line & transformer bay at each voltage level of the substation with appropriate software. FCDIST or CEDEGS may be used. Other software may also be used. The Connected Grid/substations to the designed substation shall be considered as effectively earthed, if no additional information is readily available.

b) Note that, I_f, Total SLG fault Current ,does not contribute to GPR totally, only a portion of it is responsible for GPR.

c) For a fault inside the substation, Part of the I_f , flows through the Substation ground Grid to Transformer Neutral , which is called circulating current. This current does not contribute to GPR.

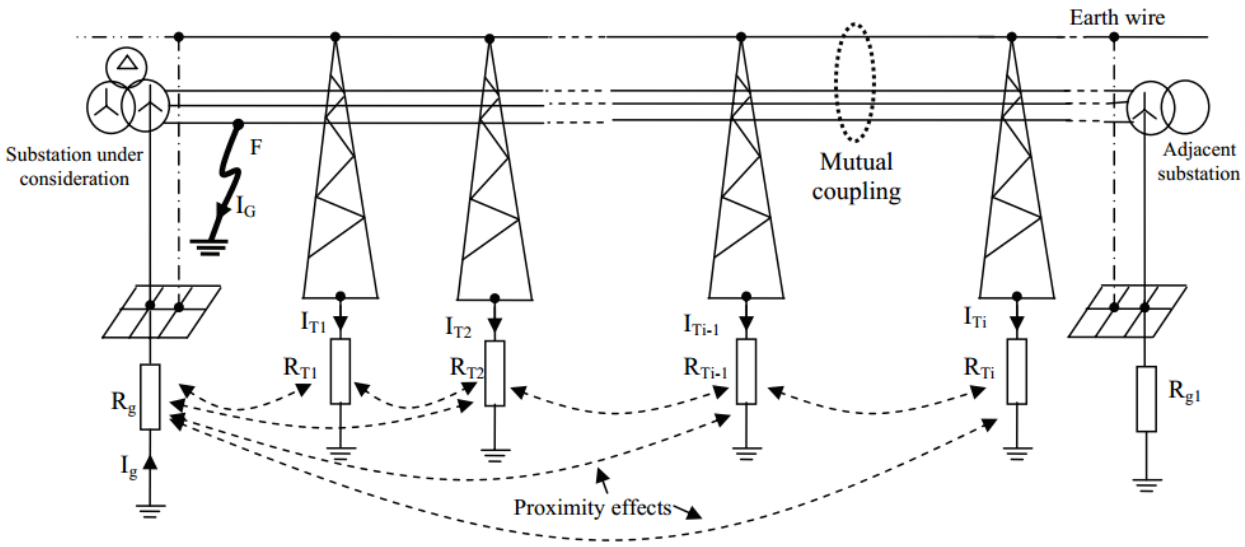
Part of the I_f , flows back to the remote source through general mass of earth giving rise to potential of the substation with respect to the Remote earth. This current is known as Ground current or Earth Return current, Ig. However, if fault is outside the station, this circulating current/current flowing back through transformer neutral will behave like Earth Return Current.

d) Note that, LG fault can be anywhere in power system. However, for finding the worst fault location it is sufficient to analyze the faults occurring in the considered station itself and on the outgoing lines.

e) The Contractor shall demonstrate / analyse the worst case of I_f which creates highest GPR. Hence, fault both at HV& LV and inside & outside the substation shall be analyzed.

f) In order to find out I_f, Total number of line bays & Transformer (with Size) including the future to be connected to the said substation shall be considered. The I_f, shall be calculated using zero sequence impedance/resistance of connected bays. When data is not readily available, Zero sequence data shall be approximated based on generic data acceptable to PGCB. It is also acceptable to consider the transmission network as effectively ground.

g) For a Δ-Y Transformer, if SLG faults occurs at Delta side, there will be no contribution of substation transformer or local contribution to the fault. However, for an Auto or Wye-Wye Connected transformer, there will always be local contribution.



h) Using the above methods, Local & Remote contribution of the fault shall be obtained. Next, IEEE 80 curve or analytical approach may be used to obtain split factor. It is desirable that, split factor shall be calculated using above mentioned or appropriate software when EPR is too high.

7.7.7 Fault Level

7.7.7.1 The EPR and safety voltage calculations shall be based on the foreseeable worst-case earth fault level. This shall be (at least) the maximum earth fault level at the point of connection including any contribution from generators, plus 10%. Refer to Table 2.

7.7.7.2 For EPR calculations, fault levels and durations should be considered for all voltage levels at the substation (excluding 33kV for substation with Auto transformer).

Table 2 – Fault Levels & duration for EPR and Safety Calculations

Voltage Level	Typical Backup Fault Clearance Time	Fault Level for Conductor Sizing	Remarks
132kV	600ms	Single line to ground Fault current or 40kA, whichever is higher	Please refer to section 01 of the technical specification for project specific Fault current Rating at different Voltage level
	600ms	Single line to ground Fault current or 31.5kA, whichever is higher	
230	500ms	Single line to ground Fault current or 50kA, whichever is higher	
	500ms	Single line to ground Fault current or 40kA, whichever is higher	
400	300ms	Single line to ground Fault current or 63kA, whichever is higher	
	300ms	Single line to ground Fault current or 50kA, whichever is higher	

- For duration, please also refer to protection scheme functional specification.

7.7.8 X/R Ratio

7.7.8.1 X/R data depends on system characteristics. This data can be approximated using Circuit breaker DC offset as stated in the technical datasheet.

7.7.8.2 When more accurate data is required, the contractor is requested to seek the data in writing to PGCB for project specific sites.

7.7.8.3 Use of generic data is not permissible. However, if GPR is sufficiently low (as applicable for cold site), generic data may be used, provided that, such assumption is explicitly brought to PGCB's attention.

7.7.9 Conductor and Electrode Sizing

7.7.9.1 Once the design is safe in terms of touch voltages determine appropriate earth conductor and electrode sizes to satisfy the fault currents and durations given in Table below. Select appropriate conductor sizes as per IEEE 80 whilst adhering to the

maximum fault level values. However, grounding conductor shall be stranded annealed copper wire and its size shall not be less than 150mm2.

7.7.9.2 Generally, the same standard conductor and electrode sizes should be used throughout the whole substation installation.

7.7.9.3 Spur connections to earth electrodes should be based on 60% of the worst-case value. Equipment connections with two or more conductors in parallel should be based on 60% of the worst-case value.

7.7.9.4 Determine the surface current density of the buried bare copper electrode system and check its adequacy

Note: Only earth electrode buried at a minimum depth of 0.6m (to avoid seasonal variation and soil drying) shall be included in the surface area current density calculations.

7.7.9.5 The surface area of the earth electrode in contact with the ground should be sufficiently large enough to prevent the ground around the electrode drying out and increasing in resistance during a fault. The minimum electrode surface area can be calculated using the formula in following table and then compared with the actual surface area of the installed earth conductor, tape and rods.

Table: Surface area of earth Electrode for current density calculation

Calculation	Formulae	
Minimum Surface Area	$A = \frac{1000 \times I_{gr}}{\sqrt{\frac{57.7}{\rho \cdot t}}}$	A = Required surface area of buried electrode (mm^2) I_{gr} = Ground return current flowing through electrode (A) ρ = Soil resistivity (Ωm) t = Backup fault clearance time i.e. 3 (s)
Conductor Surface Area	$A_{conductor} = 2 \cdot \pi \cdot \sqrt{\frac{CSA}{\pi}} \cdot l$	$A_{conductor}$ = Total conductor surface area (mm^2) CSA = Conductor cross sectional area (mm^2) l = Total conductor length (mm)
Tape Surface Area	$A_{tape} = 2 \cdot (w + d) \cdot l$	A_{tape} = Total tape surface area (mm^2) w = Tape width (mm^2) d = Tape depth (mm^2) l = Total tape length (mm)
Rod Surface Area	$A_{rod} = \pi \cdot d \cdot l$	A_{rod} = Total earth rod surface area (mm^2) d = Earth rod diameter (mm^2) l = Total earth rod length (mm)

7.7.10 Determine Approximate Resistance of the Earthing System

7.7.10.1 Determine the earth resistance as follows:

i. Obtain soil resistivity (Article 5,6).

ii. Design the earthing system to optimise resistance in relation to soil structure (Article 5,6).

iii. This estimate should involve a mesh of electrode covering the entire Switchyard area (footprint), where possible, unless known constraints exist.

iv. Calculate the earth grid resistance (R_G) using appropriate computer modelling software.

v. The target resistance shall be 0.5Ω. For 132/33kV or Distribution substation upto 1Ω is permissible if EPR is not a concern.

7.7.11 Calculate EPR & Transfer EPR

A) EPR

7.7.11.1 Establish the earth fault levels (*IF*) for all voltages at the substation. Note that EPR can result from faults at the substation or on circuits feeding from it, e.g. a 400/230kV substation design shall consider 400kV and 230kV fault levels, 132/33kV sites shall consider 132kV and 33kV fault levels, etc.

7.7.11.2 Establish the ground return current for each voltage level (*IE or IGR*). If any circuit into or out of the substation uses 3-wire overhead construction (no earth wire), the full earth fault current may be taken as the ground return current for that voltage level.

7.7.11.3 Calculate EPR using the ground return current (EPR = R_G x I_{GR}).

7.7.11.4 Plot the EPR at site for all voltage levels and all points within the site, based on this R_G;

7.7.11.5 For systems that are supplied via cable circuits, it is also necessary to calculate the transfer voltage from the source substation(s) (Article below).

B) Transfer EPR

7.7.11.6 A metallic object having some length (e.g. fences, pipes or cables) may import or export a potential into or out from the site. By such means a remote, or true earth (zero potential) can be transferred into an area of High *EPR* or vice-versa. This is called *Transfer Potential*. For example, a long metal substation fence may export the an *EPR* out of the site to the end of the fence, where it may pose an electric shock hazard to somebody standing on soil at true earth potential. Similarly, a metallic water pipe or cable may import a zero-volt reference into a substation, where local potential differences may be dangerous (see Figure below).

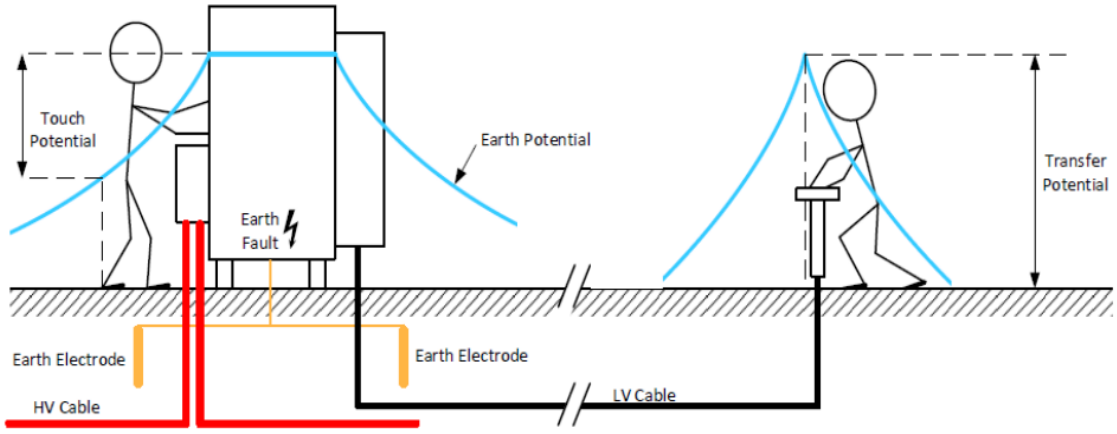


Figure 02 – Example of risk of Transfer Potential (cable installed from substation to remote location)

7.7.11.7 This additional contribution to the EPR results from transfer voltage needs to be considered if the source substation has a high EPR, and is cable connected to the new substation. An EPR event at the source could then theoretically cause a voltage rise at the new substation, as illustrated in schematics below

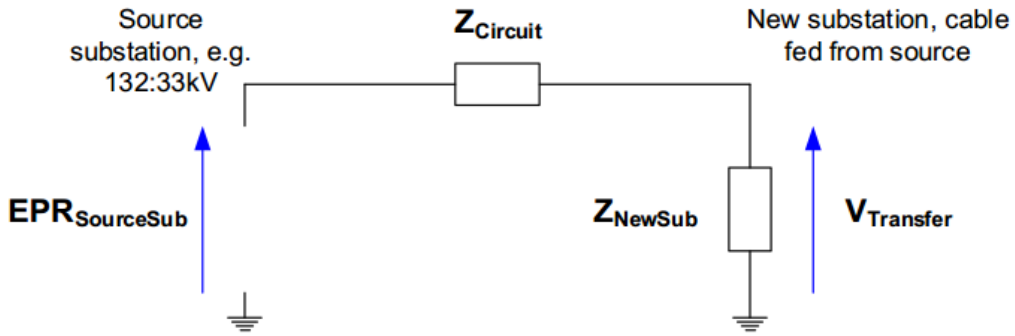


Figure 03 – Transfer Voltage-Schematics

7.7.11.8 Bonding the cable or pipe to the substation *Earthing System* may reduce risk in the substation but may create a problem elsewhere. Isolation units or insulated inserts are typical solutions that may need to be considered.

7.7.11.9 In secondary/load distribution substations, the consideration of *Transfer Potentials* is particularly important given that LV neutral/earth conductors may be connected to, or close to, HV *Earthing Systems* and consequently these conductors could export a *Transfer Potential* in to customer installations (e.g. on to a customer's LV earthing terminal).

7.7.11.10 The transfer voltage is calculated using the formula below. It will be necessary to determine the equivalent sheath impedance ($Z_{Circuit}$) between the substations in terms

of complex (real and imaginary) components. The new substation earthing impedance (Z_{NewSub}) can be treated as purely resistive for this purpose, i.e. $Z_{NewSub} \approx RG + 0j$.

$$V_{Transfer} = EPR_{SourceSub} \times \left(\frac{Z_{NewSub}}{Z_{Circuit} + Z_{NewSub}} \right)$$

In most cases, computer modelling software can assist with this calculation, but the above approximation will highlight if transfer voltage to the site is likely to be an issue. In any case it can be disregarded if the EPR is significantly lower than that for local faults.

7.7.11.11 Where possible, the EPR should be below 650V (COLD site). This is not mandatory but EPRs above this level will impose additional requirements. In any case high EPRs can be problematic; if it is not possible to achieve an EPR less than 2-5kV, additional advice should be proposed.

7.7.12 Area of Influence and Site Classification (HOT/COLD)

7.7.12.1 Zone of Influence (ZOI) of EPR shall be determined by appropriate means around the substation area.

7.7.12.2 The site shall be classified as HOT or COLD for the purposes of informing BT or other third parties. This is a requirement of the International Telecoms Union (ITU) since HOT sites can lead to hazards on the wider telecoms network. A site is HOT if its EPR exceeds 650V (132kV faults that will clear within 0.2 seconds) but within 2.33kV and Extremely HOT if EPR Exceeds 2.33kV.

7.7.12.3 The design shall include an assessment of the hot zone(s) and required mitigations where appropriate. 430, 650 and 2000 V Earth potential rise (EPR) contours shall be shown both in design & final documentation.

7.7.12.4 Hot zone assessment shall separately consider the substation earthing system in isolation as well as including any other systems intended to be bonded to the substation earthing system.

7.7.12.5 The hot zone assessment and recommendations shall be site specific, generic recommendations are not acceptable.

7.7.12.6 The Contractor shall be responsible for ensuring that adequate surveys are carried out to identify the location and condition of existing earthing systems or nearby conductive parts which may be subjected to hazardous voltages. These surveys shall also consider any known or reasonably expected development plans.

7.7.12.7 The touch and transfer potentials at any nearby conductive parts (such as street lamps or metal fences) which may be within the influence of the electrode system shall be considered.

7.7.12.8 If a site is HOT, its impact on third parties shall be established, since a significant ground potential rise can occur outside the immediate substation footprint. Using computer software, plot voltage contours outside the substation, for (at least) 430V, 650V, 1000V, 1150V ,1700V,2000V and 3000V if the EPR exceeds these values.

Note: A quantitative risk assessment may be necessary where third party impact outside the substation cannot be avoided at reasonable cost; this is detailed in standard, but its use is discouraged when risk can be mitigated at the design stage. In general terms all substations shall be safe by design, i.e. the touch voltages in and around the substation shall be below the BS EN 50522 limits. If a new (third party) development adjacent to an existing substation changes this situation, quantitative risk assessment may be applied if other solutions cannot be found.

7.7.13 Existing Substation Extensions

7.7.13.1 Where works involve the extension of an existing substation the following information may be requested and will be provided by PGCB subject to availability.

i. As built drawing showing existing earth electrode system.
ii. Any available recent earthing design reports and studies.
iii. Any available recent earthing system commissioning or maintenance records.

7.7.13.2 The Contractor shall remain responsible for satisfying themselves regarding the accuracy of any such information prior to incorporating it into their design model.

7.7.13.3 The Contractor shall be responsible for ensuring that the earthing system of the proposed extension is in full compliance with this specification. The Contractor shall also bring to the attention of PGCB any potential non-compliances or areas for potential improvement associated with the existing earthing system which may be identified during the design of the extension.

7.7.13.4 In general, the extension shall be built off-line as far as possible. The two earth grids (Works compound and existing substation) shall generally be kept separate during the construction phase. The means of separation and associated distances shall be confirmed by the Contractor.

7.7.14 Interconnections

7.7.14.1 The substation earth grid shall in the first instance be designed to operate in isolation. For this purpose, isolation is taken to mean without consideration of bonding to any earthing which will not be transferred into PGCB ownership.

7.7.14.2 If safe values of step and touch cannot be achieved using a standard electrode grid, suitable additional mitigation shall be applied. The use of additional electrode, earth rods and backfill / surface layer management shall be the primary methods to provide mitigation.

7.7.14.3 Reliance on external electrode or third party earthing systems, whose ownership will not be transferred to PGCB, to achieve safe step & touch values shall not be considered unless this has been explicitly agreed with PGCB.

Note: The Third-party shall be responsible for all safety issues associated with bonding any Third Party Earthing systems to the substation earth grid. This includes a full assessment of transferred voltages onto other Earthing systems.

7.7.14.4 The Contractor shall also agree the approach for assessment with any respective downstream or Third Party designers. The contractor shall provide clear information to other designers, as required, to ensure the risks associated with bonding earthing systems, are understood.

7.7.14.5 Where interconnections are considered in the design, the designer shall demonstrate how the earthing system will perform in all potential operational scenarios.

7.7.14.6 Example scenario list:

i. PGCB substation only (i.e. not including any parallel return paths),
ii. PGCB System (including parallel return paths),
iii. PGCB System and Third Party (substation only),
iv. PGCB System and Third Party (full connected earthing system).

7.8 Installation & Construction

7.8.1 General

7.8.1.1 The main earth grid shall be buried at least 500-800 mm below the substation graded ground level.

7.8.1.2 Where earthing conductors cross cable trenches or ducting it shall be laid a minimum of 300-400 mm below these trenches. Earth grid conductors fouling foundations shall be re-routed.

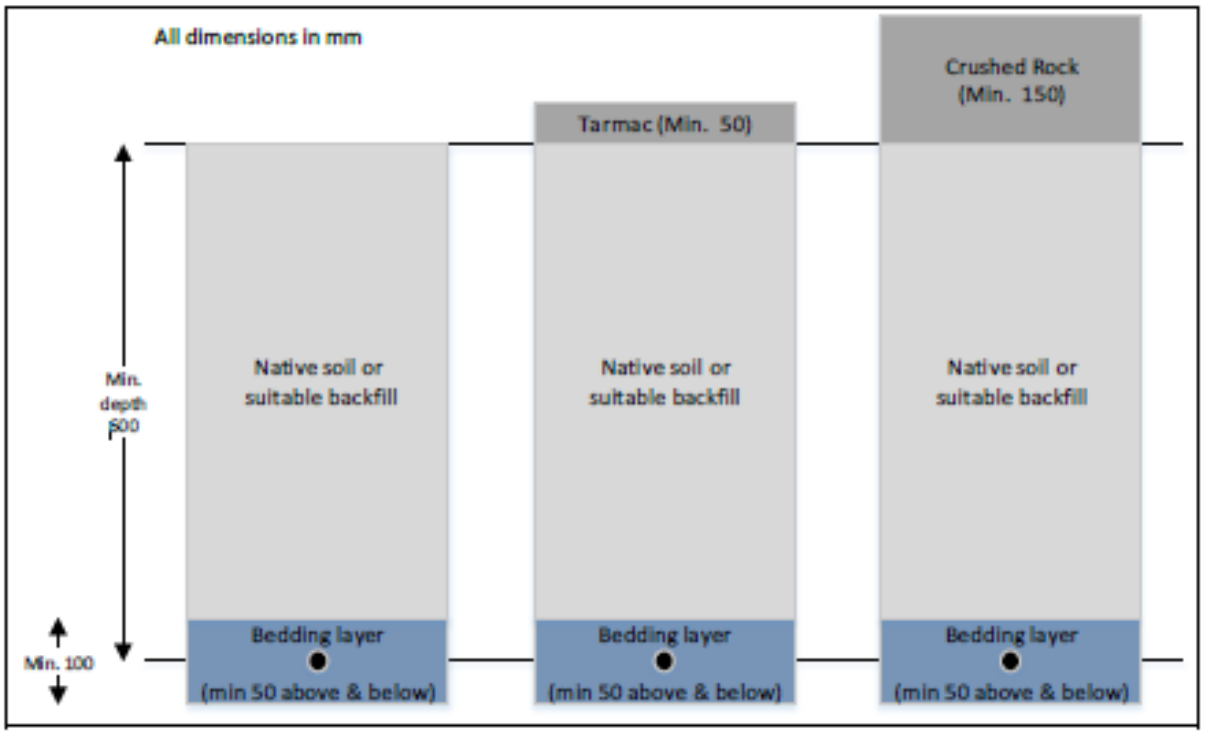


Figure: Electrode depth

7.8.1.3 Uninsulated copper shall not be installed directly in concrete. Where earth conductor passes through walls, at least 50 mm PVC piping shall be provided for the passage of the conductor. Both ends of the piping shall be sealed using a silicone based sealer after the installation of the conductor.

7.8.1.4 All backfill shall be compacted to ensure maximum contact to reduce the contact resistance.

7.8.1.5 Metallic conduits and water pipes shall not be used as part of the earth grid, or as continuity conductor. All pipes supplying water to the substation shall be PVC or Polyethylene.

7.8.1.6 The earth grid electrode shall be installed in a suitable bedding layer with a minimum layer of 50mm above and below the conductor. The bedding layer shall be free of stones or other sharp objects which may damage the electrode. The use of contaminated soil or sand or other with a high salt content shall not be permitted.

7.8.1.7 The number of splices shall be minimised as far as practical.

7.8.1.8 The use of plastic cable ties to hold/clamp the earths in place is not acceptable as they will not survive long term, metal straps are required.

7.8.2 Existing Substation Extensions

7.8.2.1 As per above mentioned, substation earth grid extensions shall be built offline as far as possible, however the contractor shall be responsible for determining the approach based on their own Risk Assessment.

7.8.2.2 Where appropriate, the Contractor shall outline the process for maintaining the separation between the 2 earth grids and the appropriate point in the programme for bonding them together.

7.8.2.3 Separation may include physical separation or insulation/shrouding. Typical separation distances for electrode are included, for guidance only, in Table 2.

Table - Typical Earth Grid Separation Distances

Voltage (kV)	132	230	400
Separation (m)	3	5	7

7.8.2.4 Construction vehicles and other equipment shall only be connected to the earth grid which they are working above (i.e. nothing inside the existing substation fence shall be connected to the Works compound earth grid, and vice versa). Special care shall be taken at the interface with the existing earthing system which is likely to extend beyond the existing substation palisade fence.

7.8.2.5 A deliberate and permanent connection between the 2 grids shall be made before any other connections which could effectively bond the 2 systems. Special care shall be taken to ensure the following potential mechanisms for inadvertent bonding of the adjacent systems are considered:

i. Metallic contact or close proximity between electrodes & tails.
ii. Metallic contact or close proximity between other earthed metallic structures (e.g. fences).
iii. HV/MV/LV power cables or ECC passing between or through the 2 earth grids. This includes bonded sheaths and any phase conductors which are earthed.
iv. Bonded Control or telecoms cable sheaths passing between or through the 2 earth grids.
v. Earthed LV neutral passing between or through the 2 earth grids.

7.8.2.6 The Contractor shall have a clear process to ensure that no temporary isolations are left in place prior to completion of works.

7.8.2.7 Special consideration shall be given to all works involving or in close proximity to the existing earthing system. Due consideration shall be given to the fact that this is part of the Transmission system and could experience significant rise of potential during system faults.

7.8.2.8 Where the earth grid (or elements thereof) for the extension compound has already been installed under previous works and is already connected to the existing substation, this shall be considered as part of the Transmission system and treated as live.

7.8.2.9 Suitable additional precautions shall be considered to ensure safety during the following activities:

i. Where separation of adjacent systems cannot be achieved or is not practical,
ii. During process of making deliberated connections between adjacent systems,
iii. Works on or in close proximity to the existing earth grid.

7.8.2.10 These precautions shall be determined by the Contractor, but might typically include:

i. the use of additional communication & hazard identification,
ii. Demarcation / control of areas,
iii. Use of insulated gloves & boots,
iv. Use of insulated workmats.

7.8.3 Galvanic Action

7.8.3.1 The Contractor shall protect all joints between dissimilar metals against corrosion. In particular where a copper earth conductor is supported on galvanised steelwork, contact between the two shall be prevented, in order to avoid galvanic action. Contact shall be avoided by use of insulated conductors for connecting equipment to the earth grid.

7.8.3.2 The conductors shall be secured to the steelwork by means of suitable clips or saddles. Plastic clips or saddles are not acceptable as they will not survive long term, metal straps are required.

7.8.3.3 All connectors in contact with galvanised steel shall be tinned. Where possible, connections shall be made to vertical faces only.

7.8.4 Materials

7.8.4.1 Conductor

7.8.4.1.1 Conductors shall be of high conductivity copper in the form of circular conductors stranded to IEC 60228 (BS 6360) or solid rods or bars to BS 1433.

7.8.4.1.2 Conductor sheaths shall be of PVC to meet the requirements of BS 6746 Grade TM1 or IEC 60502 Grade ST1 with a minimum thickness of 1.5 mm.

7.8.4.1.3 Conductors buried in the ground shall normally be laid in an excavated trench. The backfill in the vicinity of the conductor shall be free of stones and the whole backfill shall be well consolidated. Earthing conductors not forming part of a voltage control mesh shall be laid at the depth required by the approved design and, in the case of a PVC sheathed conductor, at the same depth as any auxiliary power or control cables following the same route.

7.8.4.1.4 All components of the earth electrode system shall be sized to carry the highest rated short circuit current at the substation. The temperature of the conductor shall not exceed 300° C based on the fault clearance time outlined in clause 7.6.

7.8.4.1.5 In general, stranded copper wire with a minimum area of 150 mm^2 shall be used for the main earth grid electrode. Alternative proposals may be considered, but only by formal agreement with PGCB, and these shall not introduce any non-standard proprietary connection methods.

7.8.4.1.6 The earth grid shall be formed by establishing permanent connections at all crossing points.

7.8.4.1.7 Where solid strip conductors are proposed, they shall have a cross section area to provide equal or greater current carrying capability (e.g. 20 x 5 mm Copper strip in place of 95 mm^2 stranded Copper wire). Larger cross section areas are required if different conductor material (e.g. stainless steel or aluminium) is used. Strip conductor is only acceptable for equipment grounding. They shall not be used for mesh or rod conductor.

7.8.4.1.8 Where connection between conductors is by compression connector, H type crimps shall be used. The use of C type crimps is not permitted.

7.8.4.1.9 Suitable reducing sleeves or other type tested proprietary clamping system shall be used where different sized conductors are being connected (i.e. 120 mm^2 tail onto 150 mm^2 electrode).

7.8.4.1.10 Where earth rods are used, these shall be copper-bonded steel with a minimum diameter of 12.5 mm and a length of 2500 mm. However, Earth rods shall be driven to a depth below the ground water table level, to be determined by the Contractor during soil investigation and survey of site.

7.8.4.1.11 Connection to earth rods shall be made with proprietary connectors in accordance with the earth rod manufacturer’s recommendation.

7.8.4.1.12 Where steel structures supporting high voltage equipment form part of the earth conductor, the cross section of steel shall be electrically equivalent to a 2 x 150 mm^2 stranded copper conductor.

7.8.4.1.13 Suitable clamps or cast in earth points shall be used to connect the earth electrode to rebar where required.

7.8.4.1.14 All reasonable measures shall be taken to reduce the probability of theft (e.g. minimise amounts of visible copper).

7.8.4.1.15 All conductors not buried in the ground shall be straightened immediately prior to installation and supported clear of the adjacent surface.

7.8.4.1.16 The GA , technical parameters of Earthing material along with its as used in the design and the methodology of earthing system installation shall be submitted for approval.

7.8.4.1.17 Connections shall be made of copper stranded conductor 150mm^2 cross section between the overhead earthed screen wire and the main substation earthing system at each support unless the galvanised steel support structure has sufficient area and current carrying capacity.

7.8.4.1.18 Earth wires shall be held in clamps with free pin type joints between clamps and supports.

7.8.4.1.19 Connections shall be provided for the terminations of the earth wires of the overhead lines, including bimetal connectors where necessary.

7.8.4.1.20 The design of all structures shall generally comply with Section 11 of the specification and in addition is to ensure that in the event of breakage of one earth wire, the Factor of Safety is not less than 1.5.

7.8.4.2 Earthing Rods

7.8.4.2.1 The earth rods shall be of hard-drawn high conductivity copper with a diameter of not less than 12.5 mm with hardened steel driving caps and tips. The rods should be as long as possible but couplings may be used to obtain the overall depth of driving required by the design.

7.8.4.2.2 The rods shall be installed by driving into the ground with a power hammer of suitable design to ensure the minimum of distortion to the rod. Where it is not possible to drive rods to the full depth required due to the presence of a strata of rock, then holes shall be drilled or blasted in the rock. The holes shall be filled with bentonite or other approved material prior to inserting the rod. If difficult driving conditions arising from hard or rocky ground are encountered or are anticipated or there is a need for deep rods, then high tensile steel rods shall be used. High tensile steel rods shall have a molecularly bonded high conductivity copper coating with a minimum radial thickness of not less than 0.5 mm. The overall diameter shall be not less than 12.5 mm. Rolled external screw threads shall be used on the rods for coupling and after rolling the thickness of the copper coating on the threaded portion shall be not less than 0.05 mm.

7.8.4.2.3 Rods, driving caps and tips shall abut at couplings to ensure that the couplings and screw threads are not subject to driving forces. All screw threads shall be fully

shrouded at the couplings. Alternatively, conical couplings may be used to the approval of the Engineer.

7.8.4.2.4 High conductivity copper for earth rods shall have a minimum copper content (including silver) of 99.90% to ISO 1337, Cu-ETP or Cu-FRHS (BS 2894 Grade C101 or C102) for copper earth rods and to ISO 1337 Grade Cu-ETP (BS 28734 Grade C101) for the molecular bonded copper coating of steel rods.

7.8.4.2.5 The steel for copper-bonded steel rods shall be low carbon steel with a tensile strength of not less than 570 N/mm² to ISO 630, Grade Fe 430A (BS 4360, Grade 43A) or better.

7.8.4.2.6 Couplings for copper rods shall be of 5% phosphor bronze (copper-tin-phosphorous) to ISO 427, CU Sn4 (BS 2874, Grade PB 102M) and for copper bonded steel rods of 3% silicon or 7% aluminium bronze to BS 2874, Grade CS 101 and BS 2871, Grade CA 102.

7.8.4.3 Reinforcing Steel

7.8.4.3.1 The reinforcing steel in the foundations of buildings containing the primary electrical equipment may be used as auxiliary electrodes, subject to the approval of the Engineer. The Contractor shall show in the design calculations that the fault currents and d.c. stray currents will not damage the structure.

7.8.4.3.2 Steel reinforcing mesh in the floors of the building may also be used for the control of step and touch potentials within the building, subject to the approval of the Engineer.

7.8.4.4 Conductors Outside Perimeter Fence

7.8.4.4.1 If the design calculations show that the step and touch potentials outside the perimeter fence or wall exceed the limits, then additional bare conductors shall be buried in the ground outside the fence in the form of rings encircling the whole site.

7.8.4.4.2 The distance of the conductors from the fence and the depth shall be determined in the design to ensure that step and touch potentials are within the limits.

7.8.4.4.3 The minimum conductor size shall be 150 mm² copper and shall be connected to the fence or the mesh with 150 mm² conductors at each comer of the site and at intervals of not more than 100 m. These conductors shall not be included in the calculations called for above.

7.8.4.5 Fittings

7.8.4.5.1 Clips for supporting strip conductors not buried in the ground shall be of the direct contact type and clips for circular conductors shall be of the cable saddle type. The clips shall support the conductors clear of the structure.

7.8.4.5.2 Conductors shall be connected to earth rods by a bolted clamp to facilitate removal of the conductor for testing the rod.

7.8.4.5.3 Disconnecting links shall comprise a high conductivity copper link supported on two insulators mounted on a galvanised steel base for bolting to the supporting structure. The two conductors shall be in direct contact with the link and shall not be disturbed by the removal of the link. Links for mounting at ground level shall be mounted on bolts embedded in a concrete base.

7.8.4.5.4 Disconnecting links mounted at ground level and the connections at the earth rods shall be enclosed in concrete inspection pits, with concrete lids, installed flush with the ground level.

7.8.4.5.5 All conductor fittings shall be manufactured from high strength copper alloys with phosphor bronze nuts, bolts, washers and screws. Binary brass copper alloys will not be acceptable. All fittings shall be designed for the specific application and shall not be permanently deformed when correctly installed.

7.8.4.5.6 Sheathed conductor support fittings may be of silicon aluminium, glass-filled nylon or other tough non-hygroscopic material for indoor installations.

7.8.4.5.7 Fittings not in direct contact with bare or sheathed conductors may be of hot-dip galvanised steel. Bi-metallic connectors shall be used between conductors of dissimilar materials and insulating material shall be interposed between metallic fittings and structures of dissimilar materials to prevent corrosion.

7.8.4.6 Joints

7.8.4.6.1 Permanent joints shall be made by exothermic welding below ground, or crimping for above ground connections.

7.8.4.6.2 Detachable joints shall be bolted and stranded conductors at bolted joints shall be terminated in exothermically welded lugs or a crimped cable socket. The diameter of any holes drilled in strip conductors shall not be greater than half the width of the strip.

7.8.4.6.3 Connections to electrical equipment shall be detachable and made at the earthing studs or bolts provided on the equipment by the Manufacturer. When an earthing point is not provided, the point and method of connection shall be agreed with the Engineer.

7.8.4.6.4 Connections to metallic structures for earthing conductors and bonding conductors between electrically separate parts of a structure shall be either by direct exothermic welding or by bolting using a stud welded to the structure. Drilling of a structural member for a directly bolted connection shall only be carried out to the approval of the Engineer.

7.8.4.6.5 Bolted joints in metallic structures, including pipework and which do not provide direct metallic contact, shall either be bridged by a bonding conductor or both sides

of the joint shall be separately bonded to earth, unless the joint is intended to be an insulated joint for cathodic protection or other purposes.

7.8.4.6.6 When the reinforcing in concrete is used as a part of the earthing system, the fittings used to provide a connection point at the surface of the concrete shall be exothermically welded to a reinforcing bar. This fitting shall be provided with a bolted connection for an earthing conductor. The main bars in the reinforcing shall be welded together at intervals to ensure electrical continuity throughout the reinforcing.

7.8.4.6.7 No connections shall be made to reinforcing bars and other steelwork which do not form part of the earthing system and are completely encased in concrete.

7.8.4.6.8 The resistance of any unit length of conductor with a joint or splice shall not be more than the resistance of an equivalent length of conductor without any joint. All joints shall be thoroughly cleaned before jointing, free from grease and oxidisation. Joints shall always be made by laying the conductors to be joined parallel next to each other.

7.8.4.6.9 A single crimp may be used at cross connections. All in line (or splice) connections shall be achieved by overlapping the 2 conductors and using 2 crimps spaced at least 300 mm apart.

7.8.4.6.10 The use of bolted connections is not permitted for buried joints.

7.8.4.6.11 All underground joints shall be welded with suitable alloy rod in accordance with IEC 60479 or EN 1011 or made by an acceptable compression system.

7.8.4.6.12 Details of the crimping connectors to be used shall be provided to PGCB for review prior to installation. All proposed welding processes shall be subject to agreement with PGCB.

7.8.5 Bonding of Equipment and Structures

7.8.5.1 General

7.8.5.1.1 All substation equipment, including disconnectors, earthing switches, main transformer tanks, current and voltage transformer tanks, switchgear, electrical supporting steelwork and gantries etc. shall all be connected with the earth grid.

7.8.5.1.2 All substation steelwork including control and marshalling kiosks shall be connected to the earth grid by means of stranded copper tail.

7.8.5.1.3 Metallic structures (including fences, gates etc.) even if painted or powder coated shall be considered as bare metal unless covered in an approved insulated coating that will not degrade over time.

7.8.5.1.4 Connections shall generally be by crimped lugs bolted to suitable Earthing points. Other proprietary connection types shall be by agreement with PGCB.

7.8.5.1.5 As per Table 3, and the below individual equipment requirements, Earthing connections to primary plant earth points & support structures shall consist of double connection. These connections shall be capable of carrying the maximum prospective short circuit fault level current. As per clause 7.6, a split factor may be applied.

7.8.5.1.6 Earthing conductors connecting equipment, housings and structures to the earth grid shall be as short as practicable and shall be made as spur connections (i.e. their removal shall not break the continuity of the earth grid conductor).

7.8.5.1.7 Except where a dedicated connection is specified, double connection paths may be achieved by looping between a number of earthing points in proximity. The extent of looping shall be agreed with PGCB. Looping shall be limited to a single equipment plinth and shall be such that it has a minimal effect on the tail lengths.

7.8.5.1.8 In such looped cases, suitable double lugs shall be used to ensure that no paths are broken when adjacent connections are removed from the equipment. In all other cases a single lug per tail shall be used.

7.8.5.1.9 The minimum size of conductor to be used for these tails shall be 150 mm².

7.8.5.1.10 All above ground earthing tails shall be neatly arranged and secured noting the following:

i. All outdoor tails shall be green PVC insulated in accordance with IEC 60227.
ii. Where an earthing conductor runs along any steel structure, it shall be insulated with green PVC.
iii. Tails shall be free of kinks and splices.
iv. All tails, ducts & containment shall be arranged to minimise trip hazard.
v. Plastic cable ties to hold/clamp the earth tails in place are not acceptable as they will not survive long term, metal straps are required.
vi. Tails shall be kept as short as possible.
vii. Where tails traverse concrete plinths:

(a) They shall be laid flat (i.e. not bundled).
(b) The length of the earthing tails run on top of the concrete base should be kept to a minimum.
(c) Number of runs shall be kept to a minimum.
(d) Tails shall be free of kinks and splices.

7.8.5.1.11 The earth tails shall be connected/ bolted to the steelwork by means of suitable lugs, details of which needs to be submitted to PGCB for review.

7.8.5.1.12 All earthing lugs shall be tinned, otherwise suitable bimetallic lugs shall be used.

7.8.5.1.13 Where earthing lugs are bolted to steelwork, the surfaces shall be thoroughly cleaned and free from scale, grease, paint, rust or dirt.

7.8.5.1.14 The earth tails shall be welded or crimped to the main earth grid. Details of all crimping clamps and welding processes to be used shall be submitted to PGCB for review.

Table 3: Equipment earth connections

Connection Type	**Applies to**	**Conductor size (mm^2)**
Single	Plant mechanism box*	Per primary fault level. Minimum 150
Double (can be looped)	All HV equipment bases & support steel, Earth switch, Instrument transformer, Fixed earthing points,	
Double (direct)	System neutral†, Surge arrester‡, LPS, Line tower & portal structure§	
Multiple	Transformer (tank), GIS	Per primary fault level & manufacturers recommendation Minimum 150
Single	Outdoor Kiosk, Metallic fence, Lighting column, Metal door frames & gate posts	Minimum 95
Single	Indoor LV (C&P etc.) panels & cabinets, Crane rails** ,	Minimum 75
Single	Metal doors (building), Metal gates.	Minimum 75 (flexible)

†This can be transformer neutral or earth connection at neutral earthing device (switch, resistor etc.).
‡ Single connection between surge arrester and counter / milliameter.
§ Applies to structures within the substation. Special consideration shall be given to structures in close proximity to the substation earth electrode
** Connected in at least 2 places.

7.8.5.1.15 Galvanised support structures shall:

i. Be connected to the earth grid by a double connection, larger support structures may require more connections points to the earth grid.
ii. Have structural joints such that a durable electrical connection is assured,
iii. Not contain any parts which are normally removed during maintenance,

iv. Not be used to earth High Voltage equipment which requires a separate connection directly to earth.

7.8.5.1.16 Connections between: (a) all HV electrical equipment and (b) LV electrical equipment comprising substantial multi-cubicle switchboards and the main earth bar shall be duplicated. The bare copper conductor size shall have a minimum cross section area of 150 mm².

7.8.5.1.17 Where necessary an earthing mat shall be installed at all operating positions for outdoor HV equipment manual operating mechanism boxes and local electrical control cubicles to ensure the safety of the operator. The mat shall be directly bonded to the cubicle and the conductors forming the mat and the bonding connection shall have a minimum copper cross-section area of 150 mm².

7.8.5.1.18 Galvanised structures comprising bolted lattice components shall not be used as the sole earth connection path to post and strain insulators or to overhead line earth conductors.

7.8.5.1.19 Buildings containing electrical equipment shall be provided, at each level, with a ring of earthing conductors which shall have duplicate connections to the earth grid outside the building. The frames of all switchgear, control and relay panels and other electrical equipment and exposed structural metal work shall be connected by branches to a ring. The ring and branch conductors shall be of the same material as the earth grid. Strip run within buildings, inside cable trenches or above ground level on apparatus shall be neatly supported in non-ferrous clamps.

7.8.5.1.20 Fixed earthing connectors for use with portable earthing devices specified below shall be provided on each busbar and on both sides of high voltage equipment

7.8.5.1.21 Rigid loops in the copper earthing strip branch bond between the equipment and the earthing grid shall be provided adjacent to each item of high voltage equipment for use with the portable earthing devices. The rigid loops shall be marked green.

7.8.5.1.22 Connections between other LV electrical equipment and the earth bar need not be duplicated. The single conductor shall be rated to withstand the fault rating of the equipment.

7.8.5.1.23 Connections shall generally be by crimped lugs bolted to suitable earthing points.

7.8.5.1.24 Other proprietary connection types shall be by agreement with PGCB.

7.8.5.1.25 All metalwork within the project area which does not form part of the electrical equipment shall be bonded to the main earth bar except where otherwise specified. The bonding conductor size shall be not less than 150 mm².

7.8.5.1.26 Individual components of metallic structures of plant shall be bonded to adjacent components to form an electrically continuous metallic path to the bonding conductor.

7.8.5.1.27 Small electrically isolated metallic components mounted on non-conducting building fabric need not be bonded to the main earth bar.

7.8.5.2 HV Earth Switches

7.8.5.2.1 Support steelwork shall be earthed using a double connection.

7.8.5.2.2 Each earth blade shall be connected to the earth grid by means of a double connection. This also applies to the earth switch element(s) of combined disconnect & earth switches.

Note: Not required if mechanism box is integrated into support structure and requirements of section 8.5.1 are satisfied.

7.8.5.2.3 The manufacturer's terminals shall be used for the earth connection. If a flexible connection is provided by the manufacturer between the earth blade and the base, it is sufficient to connect the base to the earth electrode with a double connection.

7.8.5.2.4 Except for neutral earth switches, these connections may be looped to provide the double paths required.

7.8.5.3 HV Disconnect

7.8.5.3.1 Support steelwork shall be earthed using a double connection. Any fixed earthing points (parking bars) mounted on the steelwork shall also have a double connection.

7.8.5.3.2 These connections may be looped to provide the double paths required.

7.8.5.3.3 The manufacturer's terminals shall be used for the earth connection.

7.8.5.4 Surge Arresters

7.8.5.5

7.8.5.5.1 Support steelwork shall be earthed using a double connection.

7.8.5.5.2 Surge arresters shall incorporate a surge counter and a milliammeter in the earth path. Mounting requirements for these are listed in the Surge Arrester Specification in the Project Functional Specification.

7.8.5.5.3 The earthing terminal of the arrester shall be connected to the counter (and milliammeter if separate) with a single tail. This shall be suitably supported and insulated from all other earthed metalwork. Suitable insulated bushing terminals shall also be installed as required.

7.8.5.5.4 The connection from the counter/milliameter to the earth electrode shall use a dedicated double connection separate from the support structure double tails.

7.8.5.5.5 The earth connections from the arresters to the earth grid shall be kept as short and straight as possible. Any sharp bending must be avoided.

7.8.5.5.6 As well as earthing for power frequency flashovers the earth conductor should provide a low impedance path for high frequency surges.

7.8.5.5.7 Because of the protective function of lighting arresters it is important that close attention be paid to the earthing requirements. A low impedance path for high frequency discharge currents shall be achieved by ensuring that there is a high density mesh in the vicinity of the arresters, thus providing multiple discharge paths. Please see below for detail.

7.8.5.6 Instrument Transformers

7.8.5.6.1 Support steelwork shall be earthed using a double connection.

7.8.5.6.2 The earth terminal of each instrument transformer shall also be connected to the earth grid by a double connection.

7.8.5.6.3 These connections may be looped to provide the double paths required.

7.8.5.6.4 The secondary wiring of instrument transformers shall be earthed in accordance with PGCB functional specification for instrument transformers. This shall generally be done in the protection cabinet or marshalling kiosk, but it should be noted that “slip over” or “ring” type CT housings and support structures shall be connected to the earth electrode with a single connection. If the terminal box is not an integral part of the steel support, or the conditions specified in article 8.5.1 above cannot be adhered to, the box shall be earthed separately with a single connection.

7.8.5.6.5 It is required that instrument transformer windings be wired out to a terminal board in an accessible place, outside the metal enclosure. The appropriate connections shall be bonded to earth at this terminal board and the link identified so that it cannot be removed in error.

7.8.5.6.6 Special consideration shall be given to earthing at capacitive Voltage Transformers. A low impedance path for high frequency discharge currents shall be achieved by ensuring that there is a high density mesh in the vicinity of the equipment, thus providing multiple discharge paths. Please see below for detail.

7.8.5.7 High Frequency Earths for Capacitor Voltage Transformers (CVTs), Capacitor banks andSurge Arresters

7.8.5.7.1 Switching transients from the high voltage system will see these devices as virtually a short circuit to earth and will be dispersed through them with little attenuation. The bonding connection and the in-ground electrodes need to be designed to cater for this.

7.8.5.7.2 Where equipment is required to pass high frequency current, a low impedance path to earth shall be provided to prevent voltage transients appearing at the earthed end of the equipment.

7.8.5.7.3 An independent High frequency earth rods shall be driven vertically into the ground to a depth of approximately same length as other Earth Rod. A connection shall also made to the main earth grid. Where this is not achievable, four horizontally buried conductors may be used in place of the rod dispersed at 90^0 intervals.

7.8.5.7.4 The connection to the rod or horizontal conductors shall be as short as practicable, shall have no sharp changes in direction and corners shall be smooth. The connection to the rod shall also have a fully rated connection to the main earth system.

7.8.5.8 Circuit Breakers

7.8.5.8.1 Bases and steel support structures shall be connected to the earth grid by a double connection.

7.8.5.8.2 If the mechanism is not an integral part of the steel support, or the conditions specified in article 8.5.1 above cannot be adhered to, the mechanism shall be earthed separately with a single connection.

7.8.5.9 Gas Insulated Switchgear

7.8.5.9.1 The earthing of the GIS equipment shall be as per the manufacturer's requirements and recommendations. The Contractor shall obtain approval from the manufacturer that the earthing design meets or exceeds these requirements. The earthing shall also satisfy the below minimum requirements:

7.8.5.9.2 A dedicated earth collector bar shall be installed around the GIS in the switchgear room. This shall be connected to the collector bar in the cable basement (typically installed near ceiling level) at a number of points.

7.8.5.9.3 Surge Voltage Limiters (SVLs) shall be connected between the HV cable termination box on the GIS (This does not apply where separable connections is available) and the HV cable screen to dissipate fast acting transients at this location during switching.

7.8.5.9.4 An earth bar shall be provided from the GIS cable sealing end earth bar to the high voltage cable link box. The route of this bar shall be kept as short as possible and sharp bends in the bar shall be avoided.

7.8.5.9.5 The Contractor shall outline any additional measures recommended to minimise the Transient Enclosure Voltage.

7.8.5.9.6 Additional requirements are also outlined in article 8.6.3 and PGCB specification for GIS.

7.8.5.9.7 Requirements for external test connections for earth switches and VT neutral points are outlined in PGCB GIS specification.

7.8.5.10 System Neutrals, i.e., Power Transformers and Reactors

7.8.5.10.1 The transmission system neutral points shall be earthed in accordance with the project specific requirements. If there is any ambiguity regarding the treatment of system neutrals, clarification may be requested from the PGCB or its' Engineer.

7.8.5.10.2 This can involve direct connection to system neutral point (e.g. transformer neutral bushing) or via other switching devices, impedances or surge arresters. The transformer Neutral connection to the main earth grid shall be double. These connection shall not be looped.

7.8.5.10.3 The transformer manufacturer shall provide insulated bushing arrangement along transformer tank to the earth grid. The earthing conductor shall be stranded copper conductor not less than 200 mm^2 for 400kV & 150 mm^2 for 230kV & 132kV and 120mm^2 for 33kV.

7.8.5.10.4 While providing earthing connection, it shall be ensured that no additional tension load to transferred to neutral bushing.

7.8.5.10.5 An insulation co-ordination study shall be performed if required to determine the insulation requirements of any intermediate connections.

7.8.5.10.6 The final connection to the earth electrode from the last equipment terminal point shall be a double connection. It is not acceptable to loop this connection.

7.8.5.10.7 The system neutral points within a substation shall have duplicate connections to the closest earthing point.

7.8.5.10.8 The Transformer Neutrals shall be directly Buried to earth upto 3-15 meter as per design requirement. If found to be acceptable, minimum three rods in delta format shall be used. Neutrals shall also be connected to Main Earth Grid.

7.8.5.10.9 The earth electrodes of a neutral earthing point shall be arranged in two groups with a conductor from each group to a test link and there shall be duplicate bare copper conductors from each test link to the earth grid. The duplicate connection may be in the form of a ring.

7.8.5.10.10 Neutral earthing connections between the substation system (transformer) neutral and the test links shall be of bare copper tape, secured and supported on stand-off insulators so that there is no contact between copper tape and transformer tank.

7.8.5.10.11 Neutral earthing conductors shall normally be buried directly in the ground but where necessary, they may be cleated to walls, fixed to cable racks or laid in the cable trenches.

7.8.5.10.12 The main tank shall be connected to earth as recommended by the manufacturer. A minimum of two separate connections shall be provided, each consisting of a double connection to the earth electrode. These shall not be looped.

7.8.5.10.13 Equipotential bonding of all associated steelwork shall be as per the manufacturers design.

7.8.5.10.14 Any separate free standing accessories (such as radiator banks etc.) shall have a separate double connection to the earth electrode.

7.8.5.11 Special Cases

7.8.5.11.1 Special consideration shall be given to the earthing arrangements around plant with high electromagnetic fields such as filters and series / shunt compensation devices.

7.8.5.11.2 In order to avoid induced currents, care shall be taken to ensure that conductive components (especially those forming closed loops) are not installed within the limits recommended by the equipment manufacturer.

7.8.5.11.3 Solutions may require the use of insulated rebar in foundations, radial (rather than mesh) earth electrode and isolated fence panels.

7.8.5.12 Post Insulators

7.8.5.12.1 Support steelwork shall be earthed using a double connection. These connections may be looped to provide the double paths required.

7.8.5.13 Control and Marshalling Kiosks (Outdoor)

7.8.5.13.1 All steel parts of these kiosks, intended to be earthed shall be bonded to the kiosk frame.

7.8.5.13.2 Each kiosk shall be provided with internal earthing bars in accordance with section 02, 03 & 05 of the PGCB specification.

7.8.5.13.3 Bases and steel support structures shall be connected to the grid by a single connection, unless these form part of primary equipment support in which case a double connection shall be applied.

7.8.5.14 Line Towers and Portal Structures

7.8.5.14.1 Steel towers, including the individual towers of portal structures shall be connected to the substation earth grid by double connection. This requirement applies to structures located within the grid area.

7.8.5.14.2 If the structure is marginally outside the safety fence (such as an OHL end tower) a double connection shall be run from the substation grid to a potential control ring surrounding the structure. The structure shall be bonded to the potential control ring by a double connection.

7.8.5.14.3 Where overhead shield wires are provided on the transmission lines they may be used to provide the necessary connection from the end tower to the substation portal structure, which shall be bonded to the substation earth electrode. This is subject to agreement with PGCB and generally only permitted at 230 and 400kV. However, to measure exact substation grounding resistance after construction, the shield wires shall be connected with a suspension insulator and earth bonding materials on the gantry sides.

7.8.5.15 Moving Parts and Operating Handles

7.8.5.15.1 Where moving parts are to be connected to earth (including building doors, compound gates etc.), flexible earthing conductors of minimum 95 mm^2 shall be used.

7.8.5.15.2 All equipment manufacturers recommended earthing requirements shall be implemented.

7.8.5.15.3 In order to provide mechanical protection and also allow visual inspection of the condition of the conductor, flexible connections shall have clear PVC insulation. Alternative proposals (e.g. due to security or other concerns) shall be subject to formal agreement with PGCB.

7.8.5.16 Maintenance Earths

7.8.5.16.1 This section describes requirements for AIS substations, maintenance earthing facilities shall be incorporated into GIS equipment in accordance with PGCB GIS specification and the project specific requirements.

7.8.5.16.2 It is a requirement that all maintenance work must be carried out between earthed points on all circuits by which the plant could be made live (i.e. there must always be an earth connection between the equipment being worked on and all potential sources).

7.8.5.16.3 Earthing shall be achieved through the use of temporary earth leads. Temporary earth connections are not required at points where fixed earth switches, capable of being locked in the closed position, are available.

7.8.5.16.4 Suitable earthing stirrups shall be provided on the HV conductor at appropriate locations in the substation.

7.8.5.16.5 It shall be possible to earth each phase independently of the others and all three phases together.

7.8.5.16.6 Earthing points shall be provided for each busbar section.

7.8.5.16.7 Fixed earth points (also known as parking bars) for attaching temporary earth leads during maintenance operations shall be provided as required by the primary plant layout.

7.8.5.16.8 These shall be connected to the earth electrode using a double connection. These connections shall be separate to any support structure earth point, but may be looped to provide the double paths required.

7.8.5.16.9 In determining the location of the fixed earthing points the designer shall consider:

i. Location of earthing stirrups.
ii. Length and routing of earthing leads.
iii. Accessibility to plant when leads are applied.

7.8.5.16.10 Temporary earth leads shall be suitably rated for the maximum expected short circuits.

7.8.5.16.11 The Contractor shall propose the quantity of leads to be provided. This shall be based on the substation configuration and shall be subject to agreement by PGCB.

7.8.5.16.12 These leads shall each be 6 m in length and comprise of PVC insulated 150 mm² flexible copper with a clamp at each end.

7.8.5.16.13 The leads, fixing points, stirrups and arrangement shall be subject to review by PGCB before installation takes place.

7.8.5.17 Cables

7.8.5.17.1 HV cable sealing end support steelwork shall be earthed using a double connection. These connections may be looped to provide the double paths required.

7.8.5.17.2 The cable sheath link box shall be separately earthed using a dedicated double connection. The link box earthing shall generally be carried out and verified by the cable jointer however alternative arrangements may be agreed on a project basis.

7.8.5.17.3 The arrangement and connection of screens inside the link box shall be co-ordinated with the cable design.

7.8.5.17.4 Specific arrangements are required at GIS cable sealing ends or where ring CTs or external surge voltage limiters are to be installed. Related Article and PGCB functional specification for GIS also refer.

7.8.5.17.5 Metallic sheaths or armour of control and protection (multicore) cables shall generally be earthed at both ends.

7.8.5.17.6 Certain data cables may also be earthed at one end only, subject to the following;

i. Requirement being explicitly brought to the attention of PGCB,
ii. Suitable insulating glands used at the unearthed end,
iii. Clearly indicated on design and as-built records.

7.8.5.17.7 The sheaths of data cables or multicore cables terminating in GIS switchgear rooms shall follow the relevant EMC requirements. Suitable (EMC type) glands shall be used.

7.8.5.17.8 Sheath and armour of HV power cables shall be earthed at the switchgear end only.

7.8.5.17.9 Multicore cables shall be routed to run parallel to the earth electrode and avoid being parallel to nearby primary conductors as far as possible.

7.8.5.17.10 Refer to related Article for requirements for cables which pass outside the earth electrode.

7.8.6 Buildings

i. An earth electrode shall be provided around all buildings within the substation earth electrode. This shall be installed a maximum of 1 m away from any touchable metalwork surrounding the building, including the external doors, hand rails etc.
ii. All building steelwork, cladding and miscellaneous support steelwork shall be bonded to the earth electrode. Doors shall be bonded using a flexible connection.
iii. This includes all outbuildings, relay rooms, stores and buildings housing ancillary items such as compressors, pumps, generators etc.
iv. Particular requirements are outlined below; all other metalwork shall be earthed in accordance with the requirements of Standards.

7.8.6.1 Control Room and Panel Room

7.8.6.1.1 A main earthing conductor ring (minimum 150 mm² bare stranded copper) shall be installed on the concrete floor in the control / relay room.

7.8.6.1.2 This conductor shall be connected to the substation earth electrode at two separate points (at opposite sides of the control room where possible), through the walls as described in this specification.

7.8.6.1.3 All the metallic stands of the raised flooring system shall be connected to this main earth.

7.8.6.1.4 Conductors (minimum 75 mm² stranded copper) shall be installed under each row of cabinets to serve as a collector for all panel earth connections.

7.8.6.1.5 The collectors shall be connected to each other or the main earthing conductor ring at the end of each row (both ends).

7.8.6.1.6 All relay cabinets inside the control room shall be earthed with a single connection to the collector. Conductor to be used for this shall be a minimum of 75 mm². Further internal cabinet earthing arrangements are outlined in PGCB functional specification for Protection scheme.

7.8.6.1.7 A separate telecoms earthing bar shall be provided*. This shall be suitable for connection of multiple 95mm^2 and 35 mm^2 Copper cables (typically 100 x 15 x 600 mm copper strip), wall mounted on suitable bushings, located in close proximity to the telecoms cabinets (generally near the DCC RTU) and clearly labelled Telecoms.

7.8.6.1.8 Telecoms cabinets shall be connected to this earth bar using minimum 150 mm².

7.8.6.1.9 The earth bar shall be connected to the main earthing conductor ring by a double connection (minimum 150 mm^2 stranded copper). These shall be PVC insulated and clearly labelled to distinguish them from all other connections to the bar.

7.8.6.1.10 These requirements also apply to any dispersed relay rooms or cabins. It should be noted that where such cabins or rooms are of metallic construction, the frames will also need to be bonded to the earth grid using a double connection.

*This is often commonly referred to as the main earthing bar or M.E.B.

7.8.6.2 Battery Room

7.8.6.2.1 No exposed earthing connections are to be made in the battery room.

7.8.6.2.2 Metal battery stands inside the battery room shall not be connected to the substation earth grid and shall remain isolated regardless of the provision or otherwise of an earth connection point.

7.8.6.2.3 Other Class I electrical equipment in the battery room shall be earthed using the relevant protective earth conductor that is part of the associated supply cable.

7.8.6.2.4 Any other metalwork which is deemed to require to be earthed per regulations shall also consider clearance to batteries to avoid the potential for simultaneous contact. Such instances shall be brought to the attention of PGCB for consideration.

7.8.6.3 GIS Building

7.8.6.3.1 In addition to the requirements listed elsewhere, the following section outlines requirements specific to GIS buildings.

7.8.6.3.2 The GIS switchgear room and HV cable room/basement earthing shall be adequately rated to cater for the full short circuit current rating of the primary equipment.

7.8.6.3.3 The GIS switchgear room and equipment earthing must be installed as per the manufacturers' requirements.

7.8.6.3.4 A High Frequency (HF) mesh shall be installed in the GIS switchgear room* . HF mesh grid dimensions and properties shall be as per specific switchgear manufacturers' requirements. Where no manufacturer requirements are outlined, guidance may be sought from the PGCB or its' Engineer.

7.8.6.3.5 Where HF mesh is installed it shall be interconnected by suitable clamps to ensure electrical continuity.

7.8.6.3.6 All re-bar in the GIS switchgear room and HV cable room floor/wall shall be earthed.

7.8.6.3.7 The HV cable room / cable basement shall contain a multiple main earthing bar conductor along the length of the room. This shall be minimum 50 x 6 mm Copper strip, wall mounted on suitable bushings and located to minimise the length of connections to the bar (i.e. typically near ceiling level).

7.8.6.3.8 This earthing bar shall be connected to the substation earth electrode at a minimum of two separate points (at opposite sides of the cable room where possible), through the walls as described in this specification. These connections (minimum 95 mm^2 stranded copper) shall be PVC insulated and clearly labelled to distinguish them from all other connections to the earthing bar.

7.8.6.3.9 The GIS switchgear room and cable basement earthing, including the associated tails to the substation earth electrode shall be independent of the control room and other LV earthing inside the building.

7.8.6.3.10 GIS earth system requirements and the proposed designs shall be agreed with the GIS manufacturer prior to installation of the earth grid.

***Note:** Required in all new build projects. The switchgear manufacturer's requirements shall determine if a High Frequency (HF) mesh is required in the GIS room in brownfield extensions or retrofit projects.

7.8.6.3.11 Additional requirements are also outlined in the chapter 3 of Specification for GIS.

7.8.7 Telecoms

7.8.7.1 A telecoms main earth bar shall be installed in the control room. However, if separate telecom room is available as per project requirement, M.E.B shall be laid in the separate Telecom Room.

7.8.7.2 Earth risers shall also be provided on all 4 sides of control buildings for telecoms use. These shall each be:

i. Single green PVC insulated 150 mm^2 stranded copper conductor.
ii. Bonded to the substation earth electrode.
iii. Routed (via suitable ducts where necessary) to avoid becoming a tripping hazard on walkways Clipped to the wall.
iv. Terminated with a compression lug at a height of 1000 mm above graded level.

7.8.7.3 Any alternative telecoms arrangements may also require additional connection to the substation earth grid and these shall be detailed separately on a case by case basis.

7.8.8 Rebar

7.8.8.1 The rebar in GIS switchgear room floor (and wall if appropriate) shall be bonded to the substation earth system. Unless specifically agreed with the GIS manufacturer, this shall be separate to any HF earthing required.

7.8.8.2 There is no other general requirement to earth rebar on plinths, provided that all interconnected pieces are fully encased in concrete. Otherwise, the requirement to connect sections of rebar shall be determined by the safety assessment as outlined .

7.8.8.3 Special consideration shall be given to the use of rebar in areas of high electromagnetic fields as measures may be required to avoid closed loops being formed.

7.8.8.4 Where rebar is to be bonded to the substation earth grid, the rebar shall be welded or clamped at suitable crossover points (maximum 3 m intervals) to ensure continuous conductive path.

7.8.8.5 Connections to the rebar shall be made using suitable clamps. Insulated conductor shall be used and the finished joint wrapped in dense tape (or an agreed equivalent).

7.8.8.6 Under no circumstances shall uninsulated copper electrode be installed directly in concrete.

7.8.8.7 For precast concrete solutions, the use of a suitable earth connection point shall be acceptable subject to review of the products design and manufacturing process.

7.8.8.8 The rebar in GIS switchgear room floor (and wall if appropriate) shall be bonded to the substation earth system. Unless specifically agreed with the GIS manufacturer, this shall be separate to any HF earthing required.

7.8.9 Fences & Gates

7.8.9.1 General

A distinction shall be made between the substation compound fence and the property boundary fence. Further details can be found in the Civil functional specification and project specific documentation.

Switchyard or compound fence surrounds the switchyard whereas Property fence surrounds the Property of substation.

7.8.9.2 Switchyard Compound Fence

7.8.9.2.1 This is the security fence which surrounds the substation compound(s) and is generally metallic palisade type.

7.8.9.2.2 Generally, where a metallic fence is used, the switchyard earth electrode shall extend for at least 1000 mm beyond the compound fence on all sides. The fence shall be connected to the switchyard earth electrode at every corner and regular interval (typically every 10 m) by a single (minimum 150 mm² copper) tail.

7.8.9.2.3 Unless specifically designed to be isolated, electrical continuity between all parts of the substation fence (e.g. panels and uprights) shall be achieved to ensure the entire fence and its parts are safely bonded to ground potential.

7.8.9.2.4 Where a non-metallic fence or wall is installed, and subject to the tolerable limits (step & touch) not being exceeded, the earth electrode may remain fully inside the fence / wall.

7.8.9.2.5 Where a substation compound fence is shared with a Third-Party compound or other cases where third party fence or metallic infrastructure are in close proximity, provision shall be made to ensure that no unintentional cross bonding between the earth systems occurs.

7.8.9.3 Method

7.8.9.3.1 Separately earthed fence arrangement (refer to related article) for Metallic fences is preferred where possible. This requires an above ground spacing of at least 2m between the fence and plant connected to the main earthing system, to prevent hand-to-hand contact. However, such cases shall require careful evaluation to ensure separation and provide mitigation against inadvertent cross bonding and shall be installed by explicit agreement with PGCB.

7.8.9.3.2 Examples of where separation may be required are where site conditions prevent the installation of the perimeter electrode or where isolation is required to avoid circulating current due to high electromagnetic fields

7.8.9.3.3 If the separation of 2m cannot be obtained, the fence shall be bonded to the main earthing system.

7.8.9.3.4 Moreover, a bonded fence arrangement (refer to related article) is most appropriate where space is limited, and where the substation is COLD. It should be noted that the full EPR will appear on a bonded fence, and the design shall ensure this does not pose an unacceptable risk to members of public outside the substation. Therefore, the electrode system shall extend up to, or ideally beyond the fence line to control touch voltages on the fence.

7.8.9.4 Separately Earthed Fences

7.8.9.4.1 An independently earthed fence shall be separated above ground by a minimum of 2 metres from substation earthing system and any exposed metalwork connected to it. A similar distance shall be maintained below ground, where practicable, taking into account the location of substation perimeter electrodes etc.

7.8.9.4.2 Where an independently earthed fence is used (unless specified differently on the earthing design drawing) 2.4 metre earth rods shall be installed and connected to the fence as follows:

7.8.9.4.3 All fence corners.

7.8.9.4.4 1 metre either side of where HV conductors cross the fence.

7.8.9.4.5 Additional locations such that the distance between rods does not exceed 50 metres.

7.8.9.4.6 The earthing of a fence shall be provided by connecting certain metallic fence posts to an earth rod by a copper conductor. The earth rod shall be driven adjacent to the posts inside the fence line to a depth of not less than 3.0m. Where no metallic posts are

provided, the earth rods shall be connected directly to the metal wires, mesh or other components of the fence.

7.8.9.4.7 If, owing to the nature of the ground, it is not possible to drive earth rods, then fence posts shall be connected to the centre point of a 20 m length of bare copper conductor buried in the ground at a depth of 500 mm, running closely parallel to the inside of the fence.

7.8.9.4.8 The earth rods or bare conductor electrodes shall be installed at each comer post, below the outer phase conductors of overhead line connections passing over the fence, at each gate and at intervals of not more than 50 m.

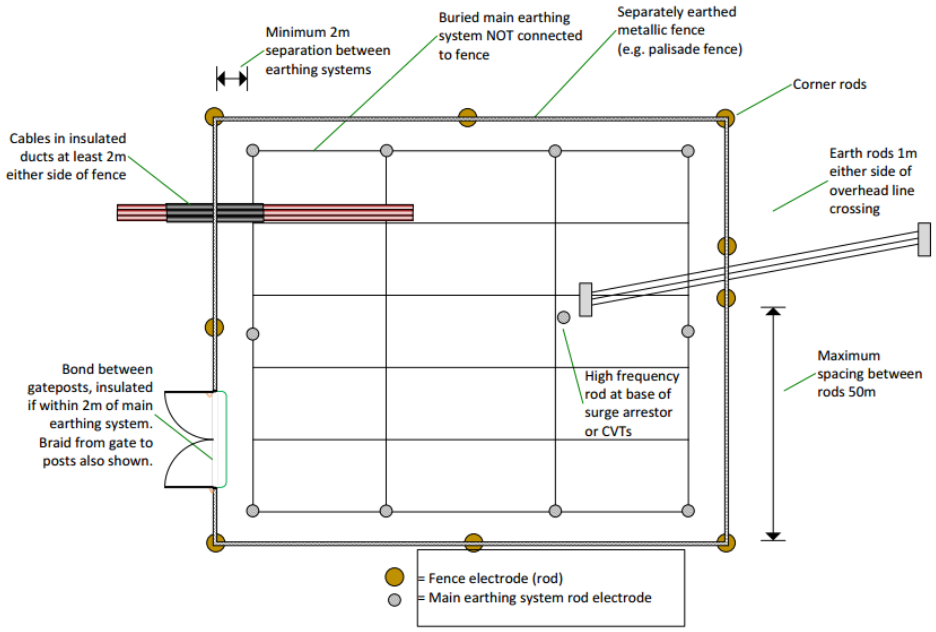


Figure 8-1 – Earthing Layout for separately Earthed Fence

7.8.9.4.9 The 2-metre separation between the independently earthed fence and the earthing system shall be maintained on an ongoing basis and shall not be compromised by alterations such as the addition of lighting or security installations.

7.8.9.4.10 Any earth tape, metal pipe, metallic sheathed or Hessian served cables passing under the fence shall be insulated or contained within insulated ducts for a distance of 2 metres either side of the fence.

7.8.9.4.11 If the compound fence is metallic and the earth grid extends beyond the compound fence, the frame of the gates shall be earthed by a 95 mm2 copper conductor connection with a minimum of 50 mm2 PVC coated flexible copper connection between the frame and the gate.

7.8.9.4.12 An additional run of 95 mm² copper conductor shall be installed in the ground spanning the opening of the gate. Although the gates shall be designed to open inwards only, this shall be confirmed and the full swing of all conductive gates and doors shall be considered as part of the touch voltage assessment.

7.8.9.4.13 Gate posts, and posts at each side of removable sections of fence, shall be bonded together to prevent potential differences arising, since both parts can be bridged by a person opening the gate or removing the fence panel.

7.8.9.4.14 The bond connection shall be made by laying a buried conductor from one post to the other. The bond connection to each post shall be visible, i.e. above ground level. Flexible bonds of 35mm2 copper braid shall be used to connect each gate to its appropriate post.

7.8.9.4.15 Each gate shall be connected to its gate post using a minimum 35mm2 flexible copper bond or copper braid.

7.8.9.4.16 Gate posts shall be bonded together with a below ground connection using a minimum 70mm2 PVC covered copper conductor.

7.8.9.4.17 Check that gates, when opened, do not infringe the 2-metre separation distance between the gate and any exposed metalwork that is connected to the substation earthing system.

7.8.9.5 **Bonded Fences**

7.8.9.5.1 Fences which need to be bonded to the main earthing system of the installation shall be connected by copper conductors to the nearest accessible point on the main earthing system at each point where the fence comes within 2m of any electrical equipment.

7.8.9.5.2 Bonds shall also be made to each corner post, below the outer phase conductors of overhead line connections passing over the fence, at each gate and at intervals of not more than 50 m.

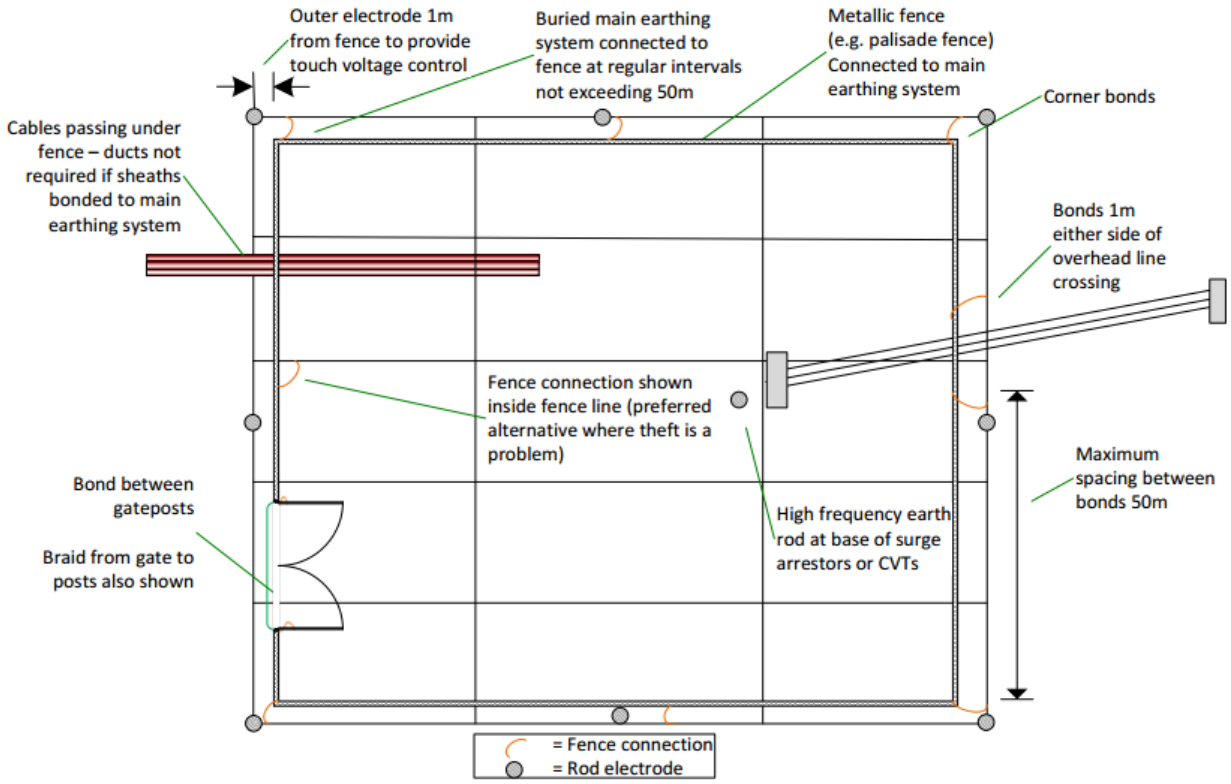


Figure 8-2 – Earthing Layout for Bonded Fence

7.8.9.5.3 Fences made up of bolted steel or other metallic components do not require bonding between components. Where such fences have non-metallic components, bonds shall be installed to maintain continuity between metallic components. Reinforced concrete components shall be treated as being non-metallic.

7.8.9.5.4 Longitudinal wires for supporting other fence components, or for anti-climbing guards and the wires of chain link, shall be directly bonded to each fence earth electrode or to each bond to the main earthing system.

7.8.9.5.5 Metallic components on masonry, brick, concrete or similar boundary wall shall be treated in the same manner as metallic fences.

7.8.9.5.6 Wire fence components coated for anti-corrosion protection shall be earthed in accordance with the related Clause.

7.8.9.6 Property Fence

7.8.9.6.1 This is the fence which demarcates the boundary of the PGCB property. The property fence shall generally be constructed from a non-conducting material.

7.8.9.6.2 The property fence shall not have a metallic connection to the substation fence at any point, nor shall it be connected to any Third-Party Fence.

7.8.9.6.3 Where the compound fence, or sections thereof, also forms the property boundary it may not be possible to ensure the integrity of an outer electrode is maintained. In such cases it may be necessary to ensure that the electrode is placed a minimum of 2 m inside the fence and the fence independently earthed. The solution in such instances shall be explicitly agreed with PGCB on a case by case basis.

7.8.9.6.4 Unless the safety analysis determines otherwise, there is no general requirement to earth the property boundary gate. An exception is where the substation compound entrance gate also serves as the property entrance gate, in which case the requirements apply.

7.8.10 Potential Control Outside Fences

7.8.10.1.1 Where the approved design calculations show that the touch or step potentials outside the fence or boundary wall would otherwise be excessive, bare copper conductors shall be buried in the ground outside the fence or boundary wall at such depths and spacings as are shown in the approved design calculations to give acceptable touch and step potentials. The conductors shall form complete rings surrounding the installation and each ring shall be bonded to the adjacent ring and to the fence at each comer, below the outer phase conductors of overhead line connections passing over the fence, at each gate and at intervals of not more than 100 m. In this case separate earth electrodes are not required for the fences.

7.8.10.1.2 If the boundary fence or wall is substantially non-metallic, the rings of conductors shall be bonded to the main earth system at each comer of the site and at intervals of not more than 100 m. Any metallic components on such boundary fences or walls shall be bonded to the earthing system in accordance with this Specification.

7.8.10.1.3 If the boundary fence is metallic and is not within 2 m of any part of the main earthing system or equipment bonded thereto, the fence and outer conductor rings shall not be connected to the main earthing system unless the approved design calculations show otherwise.

7.8.10.1.4 Any meshes formed by bonding the outer conductors to the main earthing system shall be sub-divided by additional conductors, if required, to give acceptable touch, step and mesh potentials.

7.8.11 Miscellaneous Items

7.8.11.1.1 All steelwork which could become live during HV earth fault conditions shall be connected to the earth grid by two 150 mm² connections.

7.8.11.1.2 Cable trays, ladders, metallic hand rails metallic conduits and pipes shall be bonded to ensure electrical continuity, and shall be bonded to the earth grid at regular

intervals (minimum every 20 metres or at least 2 locations for shorter runs. The minimum size of the conductor connecting to earth shall be a 95 mm2 copper connection. If small cable trunking has a type tested proprietary earth lead attached, it is acceptable to use that instead.

7.8.11.1.3 Bare earthing conductor shall not be run along metallic structures such as cable tray/ ladders, supports etc.

7.8.11.1.4 All miscellaneous items such as diesel generators, compressors, etc. shall be connected to the earth grid by a single connection, and buildings housing such equipment shall be encircled by a potential control ring.

7.8.11.1.5 All building steelwork and building support steel shall be connected to the earth grid by at least one connection. This includes any metallic stairways and access platforms.

7.8.11.1.6 Additional bonding shall be applied where removal of intermediate panels or sections could lead to a section becoming unearthed.

7.8.11.1.7 All crane rails within buildings shall be connected to the earthing system in at least two places.

7.9 Portable Earthing Devices

7.9.1 Portable earthing devices for use with outdoor 400kV, 230 kV and 132 kV apparatus in substations shall be supplied in the numbers stated in Schedule A of Requirements and shall comprise:

a. Copper alloy earth end clamp for connection to the rigid loops in equipment earth bonding connections.
b. Aluminium alloy line and busbar end clamp to suit the connectors of the type supplied under the Contract.
c. Flexible stranded aluminium alloy conductor with clear protective PVC sheath, sized suitable for the specified fault level and duration.
d. Telescopic operating pole of glass fibre or similar material, of sufficient length to reach the height of connections to high voltage equipment from ground, but retractable into a carrying length not exceeding 2.5 m, and complete with non-slip hand grips.

7.9.2 The preferred types of portable earthing devices are Ragnar Stalskog and Karl Pfisterer. However, device having origin at USA, Canada, Europe, Japan or other eligible countries with equivalent quality is also acceptable.

7.10 Interconnections

All interconnections to remote services shall be carefully considered to ensure that hazardous potentials which could be transferred out of the substation are suitably managed.

7.10.1 Shield wire

7.10.1.1 The requirement for shield wire on overhead line circuits is outlined on a case by case basis as part of the project OHL design.

7.10.1.2 Further details can be found in PGCB Policy statement on AC Overhead lines and Functional Specification for Transmission Line.

7.10.1.2.1 Where shield wire is present on a line, or section of line terminating at a substation, this shall be bonded to the substation earth grid. This shall be achieved via the end tower structure, and if necessary, the double connection from the tower to the substation earth grid, or by extension of the shield wire into the substation line gantry. However, to measure exact substation grounding resistance after construction, the shield wires shall be connected with a suspension insulator and earth bonding materials on the gantry sides.

7.10.2 Power and Pilot Cables

7.10.2.1 Depending on the cable design, the screens of power cables may also provide a connection between the earthing systems of the respective transmission substations.

7.10.2.2 The Contractor shall ensure that the earthing design at the substation is co-ordinated with the cable design.

7.10.2.3 Although no longer common practice at new installations, pilot or signalling cables may also be present at legacy substations. Generally, the sheaths and screens of these cables are bonded to the earth grids at both ends.

Note: Refer to related requirements for power and control cables which are within the earth electrode system.

7.10.3 Earth Continuity Conductor

7.10.3.1 Where earth continuity conductor (ECC) is installed along with a transmission cable circuit this shall be insulated to avoid dangerous step or touch potentials along the route.

7.10.3.2 The ECC shall be bonded to the substation earth electrode at the associated cable sealing end.

7.10.4 Telephone Lines

7.10.4.1 If the EPR exceeds the values in ITU-T directives Volume VI, the substation telecommunications shall require special isolating equipment. This shall be located outside the relevant hot zone contour.

7.10.4.2 In addition, a special insulated cable or fibre optic connection will be required from the isolation point to the substation

7.10.4.3 For information:

a. 2kV is the typical insulation level for third party telecommunications cables destined towards a transmission substation.
b. 15kV is the typical insulation level for telecommunications cables between the isolation point and substation.

7.10.5 Water Supplies

Water supply pipes to the substation shall be polythene or PVC.

7.10.6 Ancillary Buildings

7.10.6.1 Buildings or equipment located outside the earth electrode area, but within the property and receiving an electricity supply from the substation shall be encircled by a potential control ring, which shall be connected to the main substation grid. All local metal work shall be bonded to this control ring.

7.10.6.2 As per Appendix -D1, a safety assessment against tolerable limits in these areas is required.

7.10.7 Auxiliary Supply

7.10.7.1 If required, the preferred location for an auxiliary standby transformer shall be within the earth grid area. In this case, the tank and the LV cable end box shall be connected to the earth grid by a single 150 mm^2 copper earth conductor connection.

7.10.7.2 If the transformer is located outside the earth grid area, a double connection shall be run from the substation perimeter earth loop to the auxiliary standby transformer in the same trench as the LV power cable. It shall terminate in a potential control ring laid around the end-mast or pad mounted transformer. The transformer tank and the LV cable end box shall be bonded to the potential control ring by a single copper earth conductor connection of minimum 150 mm^2

7.10.7.3 If there is a large distance between the auxiliary transformer and the substation earth grid, a larger size earth conductor may be required depending on whether or not it satisfies the minimum earth fault loop impedance requirement.

7.10.7.4 As per Appendix - D1, a safety assessment against tolerable limits in these areas is required.

7.10.7.5 Earthing of the low voltage system(s) shall be carried out in accordance with IEC /IEEE or BS standard

7.10.7.6 Main and supplementary equipotential bonding is created via the substation earth grid.

7.10.7.7 The LV a.c. system shall typically be TN-C-S/TN-S.

7.10.7.8 The use of other earthing systems shall only be by specific agreement with PGCB.

7.10.7.9 The midpoint of any 230 V a.c. system shall be earthed.

7.10.7.10 PGCB functional specification for DC system outlines the earthing requirements for the various d.c. systems.

7.10.8 Third Party Systems

a. Where industrial Third Parties are fed from the substation the earthing arrangement shall be the subject of a special investigation and shall be agreed with PGCB before any work commences.
b. As far as possible, Third Party earthing systems shall be kept isolated from the transmission substation earthing system.
c. The Third Party/Contractor shall detail how inadvertent bonding of earthing systems is to be prevented.
d. As the related Clause, there are cases when the Third Partys' high voltage substation earthing may need to be connected to the transmission substation earthing system. Such cases shall only be by formal agreement with PGCB and shall be subject to very careful consideration in the design stage.
e. As a minimum, the following shall be considered:

    i. The full extent of the earthing system to be connected shall be established and assessed. The Contractor/Third Party shall outline how any further inadvertent bonding of earthing systems is to be prevented.
    ii. Whether the connection would form part of a global earthing system.
    iii. Whether the connection would permit transmission substation grid voltages to be exported (e.g. on cable sheaths or other metallic structures) to remote locations.
    iv. The effect on nearby MV or LV network neutral points or earthing systems.
    v. Step, touch & transfer potentials.
    vi. The effect on the hot zone and existing infrastructure (telephone lines, gas/water pipes, railways, fences etc.)
    vii. Ownership of the earthing system

7.10.8.1 **Third Party Ancillary Buildings**

7.10.8.1.1 Ancillary buildings owned by the Third Party remain the responsibility of the Third Party, but the following should be considered:

a. If the buildings are within the influence ("hot") zone of the earth grid;

i. Whether the grid should be extended to the buildings and all metallic structures and facilities in the buildings bonded to it.
ii. Whether a potential control ring should be placed around the building at a distance of 1m.
iii. Care should be taken to prevent the export of transferred potentials from the buildings to the public domain on telephone or other services.

b. If the buildings are outside the influence zone of the earth grid they may be isolated from the grid and separately earthed, taking care to prevent the transfer of potentials from the grid to the buildings on interconnecting cables and services. In this case it is recommended that all metalwork in the buildings be bonded to a local earth at the building. However, if the ancillary building includes a control room or if there are substantial interconnecting services it may not be possible or practical to isolate the two earth electrodes from one another.

7.10.8.1.2 As per Appendix -D1, a safety assessment against tolerable limits in these areas is required.

7.10.8.2 **Earth Potential Rise and Transferred Potentials**

7.10.8.2.1 The Contractor shall examine all existing or expected Third Party buildings and services located near the substation.

7.10.8.2.2 Linear metallic infrastructure (Fences, pipes, telephone lines, railways etc.) can be a significant source of transferred voltage.

7.10.8.2.3 The Contractor shall not engage directly with public bodies or Third Party service providers on this issue, all communication shall be via PGCB .

7.10.8.2.4 Possible hazardous situations and potential mitigation measures shall be clearly identified in the report and brought to the attention of PGCB.

7.11 Direct Stroke Lightning Protection

7.11.1 The Contractor shall provide adequate overhead shielding to effectively prevent direct lightning strikes to any equipment or energized bus within the switchyard areas. The system shall also be designed to provide "effective shielding" to ensure that no

insulation flashover can result from atmospheric discharges striking the overhead shielding. The screens shall be of aluminium clad steel wires of not less than 50 sq.mm. total section, and connected to provide low impedance paths to earth.

7.11.2 The lightning protection scheme shall be designed by the Contractor using the latest version of the electro geometric model (EGM) method as per IEEE 998. Detailed calculations demonstrating the adequacy of the proposed shielding shall be submitted to the Employer for approval prior to the overhead shielding design being finalized. The Detailed calculations shall accompany the layout with section drawing of the proposed system.

7.11.3 The Contractor may propose a lightning mast and/or shield wire system, however shielding by shield wires is preferred by the Employer. Conductor sag shall be considered when designing the overhead shielding system; however, conductor swing need not be considered.

7.11.4 Probability of failure shall be calculated as per IEEE 998.Probability of failure once in a 100 year is typically acceptable. Any lower probability shall be in agreement with PGCB.

7.11.5 The layout of the earth wires shall be such that equipment to be protected generally lies within areas bounded by two or more conductors, in which case the protected angle shall not exceed 45˚. Where equipment is protected by a single earth wire, the protective angle shall not exceed 35˚ to the vertical.

7.11.6 The overhead earthwire shall be suitable for extension to protect the substation equipment to be installed in future stages of development.

7.11.7 A minimum lightning protection system to achieve LPL level IV shall be installed.

7.11.8 A risk assessment shall be conducted based on the methods contained in IEC 62305, Protection Against Lightning, Part 2, Risk management. This risk assessment shall determine whether a more onerous lightning protection system (LPS) is required at the substation.

7.11.9 The design of the LPS shall based on the methods contained in IEC 62305 Protection against lightning, Part 3, Physical damage to structures and life hazard (i.e. the protection angle and rolling sphere methods). Use of the surrounding topography to assist in lightning protection is permitted.

7.11.10 The substation compound equipment and control room shall be protected against damage from lightning strikes. A design, including lighting shielding profile drawings shall be submitted to PGCB for review with the substation layout drawings.

7.11.11 Down conductors shall be clamped at intervals along the lightning masts, and connected to the main substation earth .

7.11.12 DSLP of Control & Panel Buildings shall be provided in accordance with IEC 62305 & NFPA 780.

7.12 Quality Assurance

7.12.1 All materials and workmanship shall be of suitable type and quality to ensure that the earth system will operate satisfactorily in accordance with the specification.

7.12.2 Registration to ISO 9001 is desired.

7.12.3 Connectors shall be class A in accordance with IEC 61238-1.

7.12.4 The Contractor shall ensure that all conductors shall be kept free of kinks.

7.12.5 Stranded conductors, particularly uninsulated conductors, are susceptible to unravelling (including "opening" or "birdcaging" effects). The Contractor shall ensure that suitable control measures are in place to confirm the integrity of all buried conductors prior to backfilling.

7.12.6 All on site welded connections shall be carried out in accordance with the manufacturer's recommendation. Only suitably trained staff shall be permitted to carry out on-site welding.

7.12.7 Prior to installation of earthing system, sample connections shall be made to demonstrate the process and equipment used. Samples shall be representative of all connections used in the installation (e.g. splice, cross, lug, double lug) and cover all buried conductor types & sizes.

7.12.8 The same personnel, components and tools used to carry out the installation shall be involved in the sample exercise.

7.12.9 PGCB shall be provided with an opportunity to witness the preparation of the samples.

7.12.10 The samples shall be sent to an independent facility for mechanical (pull) testing according to section 7 of IEC 61238-1.

7.12.11 Detailed photographic evidence of all below ground earthing installation shall be captured and made available to PGCB. All photographs shall include clear identification which shall be referenced on a suitable drawing and shall include:

i. A photograph of each connection.
ii. Photographs demonstrating depth of electrode and bedding layer.
iii. Photographs confirming the condition of the electrode prior to covering.

7.12.12 The Contractor shall outline their quality procedure to ensure the correct selection and use of crimping dies and tools.

7.13 Guarantee

7.13.1 The earth grid shall be guaranteed against all defects arising from faults in material and workmanship, for a period of 5 years from the date of installation.

7.14 Notification of Changes

7.14.1 Any changes in design, material, supplier or sub-contractor shall be notified to PGCB in writing prior to implementation. Such changes must be agreed with PGCB in writing prior to their introduction.

7.15 Tests

7.15.1 All components, including conductors and connectors, shall be type and routine tested in accordance with the relevant IEC standards. The relevant test reports shall be provided by the Supplier

7.15.2 Sample pull tests shall be performed on earthing connections as outlined in section 8.

7.15.3 The entire earthing system shall be tested upon completion of installation to verify compliance with the specification and design.

7.15.4 The following aspects shall be measured and recorded (this shall include measurements of the PGCB Substation earthing system in isolation):

i. Earth grid resistance.
ii. Step voltage.
iii. Touch voltage.
iv. Hazardous voltages on other infrastructure.
v. Voltage gradient (in several directions away from the electrode).

7.15.5 Measurement of current (magnitude and phase angle) flowing in known return paths (shieldwire, ECC, cable screens, and if possible any pipes etc.) shall be taken to provide a fuller picture of the entire earthing system and validate any current splits calculation.

7.15.6 Low current injection test is the preferred method for measurement. Use of the simple “fall of potential” or “slope” method shall only be used for small isolated earthing systems and subject to agreement by PGCB.

7.15.7 Testing shall be arranged to allow direct comparison between tested and modelled values. Full details of the test method shall be submitted to PGCB for review prior to the commencement of the tests. PGCB shall be given the opportunity to be present during the execution of these tests.

7.15.8 The results of the testing shall be fed back to the designer to confirm that no safe limits are exceeded when extrapolated to designed earth fault short circuit level level and under any alternative interconnection scenarios.

7.15.9 The earthing system shall be modified to attain values within the design and specified limits, if the test results indicate that any of the specified limits may be exceeded. Such modifications shall be subject to the full design, modelling and review process.

7.15.10 Mitigation measures should be proposed for any transferred voltage hazards identified during the tests as a result of the extent of the measured voltage gradients.

7.15.11 All primary connections (e.g. Earth switch, Surge Arrester and VT or power transformer Neutral) to the substation earth grid shall be verified by micro ohmmeter "ductor" testing. A combination of continuity testing and visual inspection shall be considered adequate to verify all other connections.

7.15.12 PGCB shall be given an opportunity to witness the testing.

7.15.13 Equipotential bonding shall be proven by simple electrical continuity test.

7.15.14 A test sheet and drawing listing the test results shall be submitted to PGCB for review.

7.15.15 Low voltage earthing and loop impedance measurement shall be performed in accordance with IEC

7.15.16 PGCB reserve the right to request further testing to be carried out by an independent testing authority.

7.16 Documentation to be Submitted

7.16.1 Before Installation

i. 01 Earth resistivity test results and Soil Model Report.
ii. Earthing Report and electrode design (including model file).
iii. Lightning Protection Risk assessment.
iv. LPS overall design.

v. Detailed (Construction) design.
vi. Details and descriptions of materials to be used e.g. conductors, rods, finials, clamps, connectors etc.
vii. Details of jointing methods.
viii. Proposed Test methods for verification of design values.

7.16.2 Before Handover and After Installation

i. 01 Photographic and other installation & testing QA records.
ii. Test results of electrode resistance, GPR and step / touch / transfer voltages.
iii. Results of sample pull tests.
iv. Test results of Ductor tests and joints.
v. Relevant information for inclusion in the safety file.

7.16.3 Substation Handover

iii. Full set of as-built drawings both at site, project office & Design office.
iv. As-built version of earthing model file at Design office.
v. Final test results site & Design office.
vi. Details of residual hazards and all other information required in the Safety file.

APPENDIX

Appendix A1 - Earth Resistivity Measuring Table:

Test Point	Test Meter Make: Model: Origin:					Remarks
	Latest Calibration certificate of the Test Meter (please attach & mention the Reference here)					
	Spacing(a) in meter	Position	Meter Reading in Ohm	Average Meter Reading in Ohm (r)	Soil Resistivity in Ohm-m $\rho = 2\pi s R$	
1	xx	North-South				
		East-West				
		+45° Position				
		-45° Position				
	yy	North-South				
		East-West				
		+45° Position				
		-45° Position				
2	xx	North-South				
		East-West				
		+45° Position				
		-45° Position				
	yy	North-South				
		East-West				
		+45° Position				
		-45° Position				
Temperature: Humidity:				Date:		
Test Conducted By:				Test Witnessed By:		

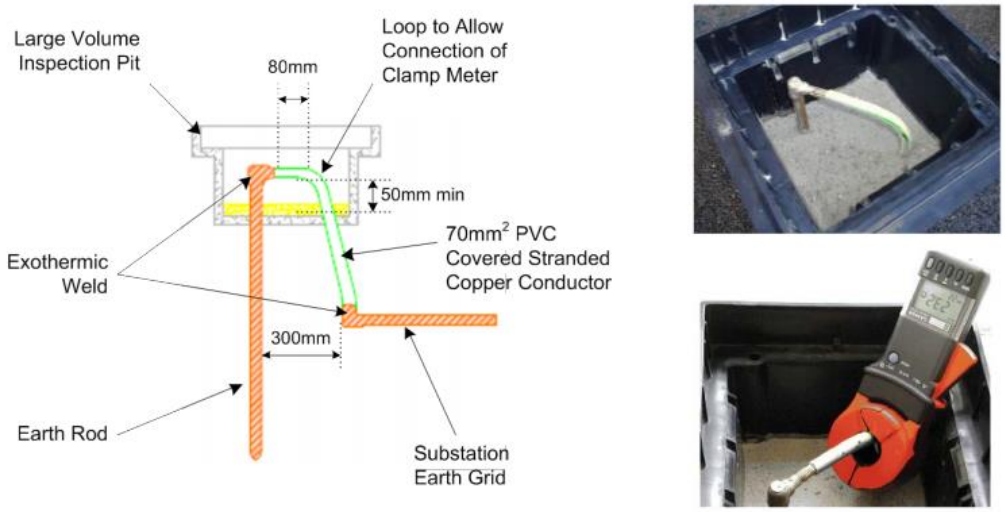
Appendix A2 – Table: Typical Ground Resistivity Values

SL	Ground Type	Resistivity (Ωm)
1.	Loams, garden soils etc	5 to 50
2.	Clays	10 to 100
3.	Chalk	30 to 100
4.	Clay, sand and gravel mixture	40 to 250
5.	Marsh, peat	150 to 300
6.	Sand	250 to 500
7.	Slates and slatey shales	300 to 3000
8.	Rock	1000 to 10000

Appendix B1– Anti-Theft Measures

1. The earthing system shall be constructed to ensure that it is secure and not vulnerable to theft. To prevent theft of the earth electrode by pulling it out of the ground it may be anchored via vertical rods or sections of the electrode may be encased in low sulphur concrete or similar proprietary materials as approved by PGCB.
2. Earthing conductor theft can be discouraged by suitable fixing to structures and use of camouflage, anti-vandal or bitumastic paint where required. For security fixing to concrete or steel structures, stainless steel anchors (i.e. Alcomet FNA II or approved equivalent) shall be used, generally spaced at 300mm centres.
3. Small sections of copper should be avoided as multiple joints in close proximity may be problematic.
4. All exposed copper sections should be fixed using one or more anti-theft fixing techniques such as:
    i. Pinning every 300mm. The pins should have plastic spacers to separate the pin from the conductor
    ii. Burying the copper tape and/or rods every few metres in concrete or in resin filled ducts (where contact with soil not required) to prevent removal.
    iii. Applying anti-climbing paint (e.g. Vandalene) on all above ground sections and/or painting all copper above ground to look like aluminium.
    iv. Fitting galvanised steel anti-theft capping over the conductor to a height of 3m or the equipment position.
    v. Fitting steel banding around structures and pinning the fixings.
    vi. Marking all copper electrodes with 'Property of PGCB'.
    vii. In all cases, it is important that pins, screws capping etc. are installed such that water cannot gather and cause corrosion.

Appendix B2– Indicative Drawings



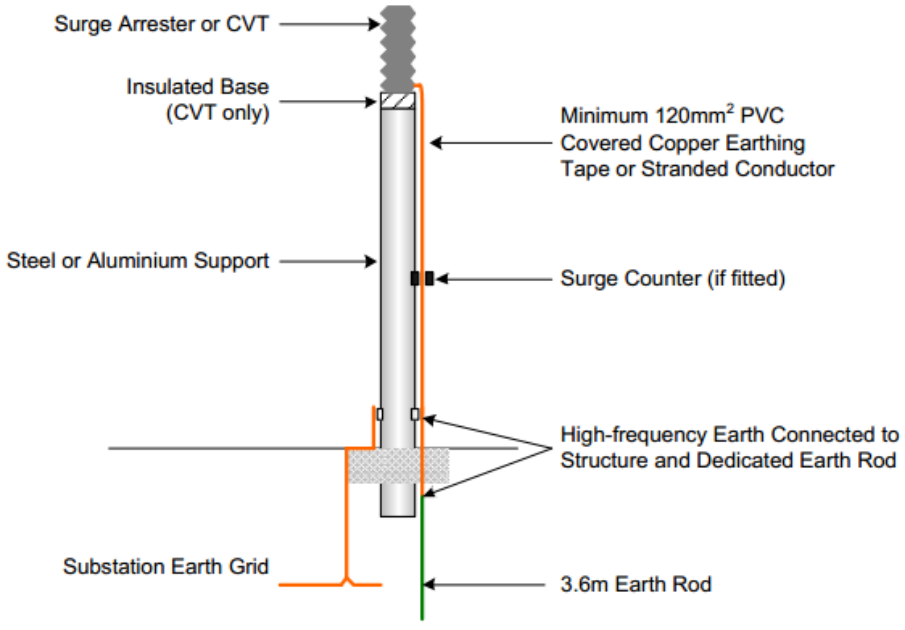


Figure: Surge Arrester and CVT Earthing



Figure: Galvanised Steel Surface Laid Operator Earth Mat

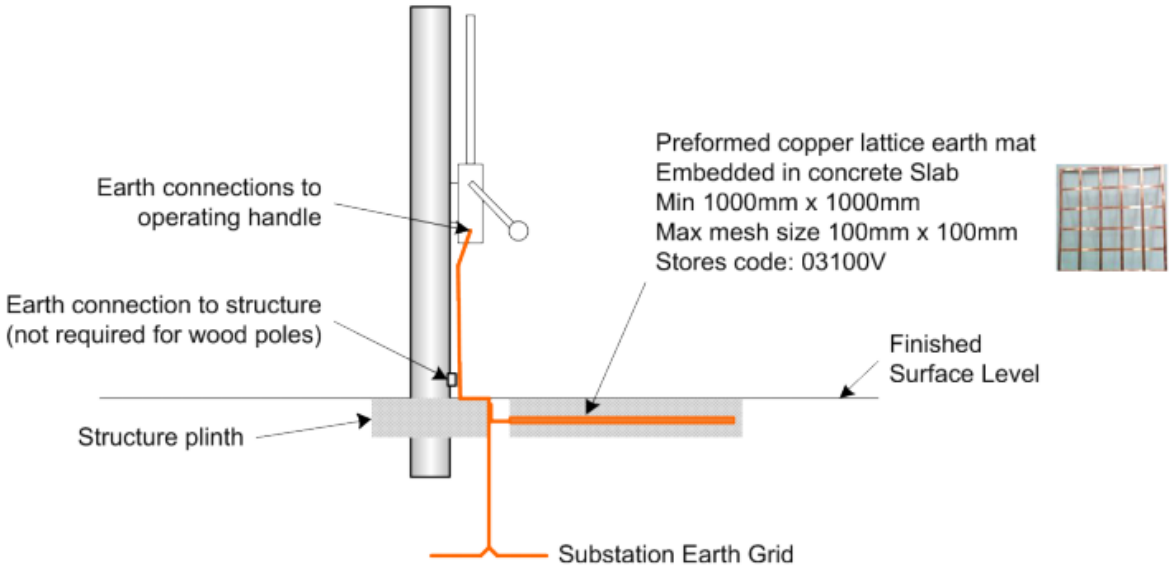


Figure: Preformed Copper Lattice Operator Earth Mat Embedded in Concrete

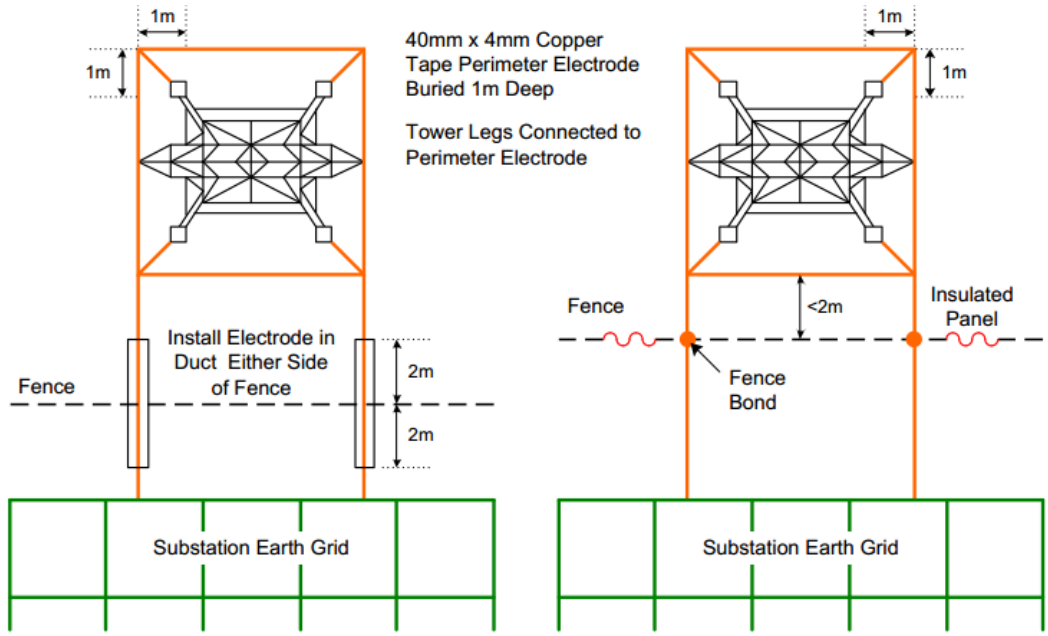


Figure: Terminal Tower Earthing

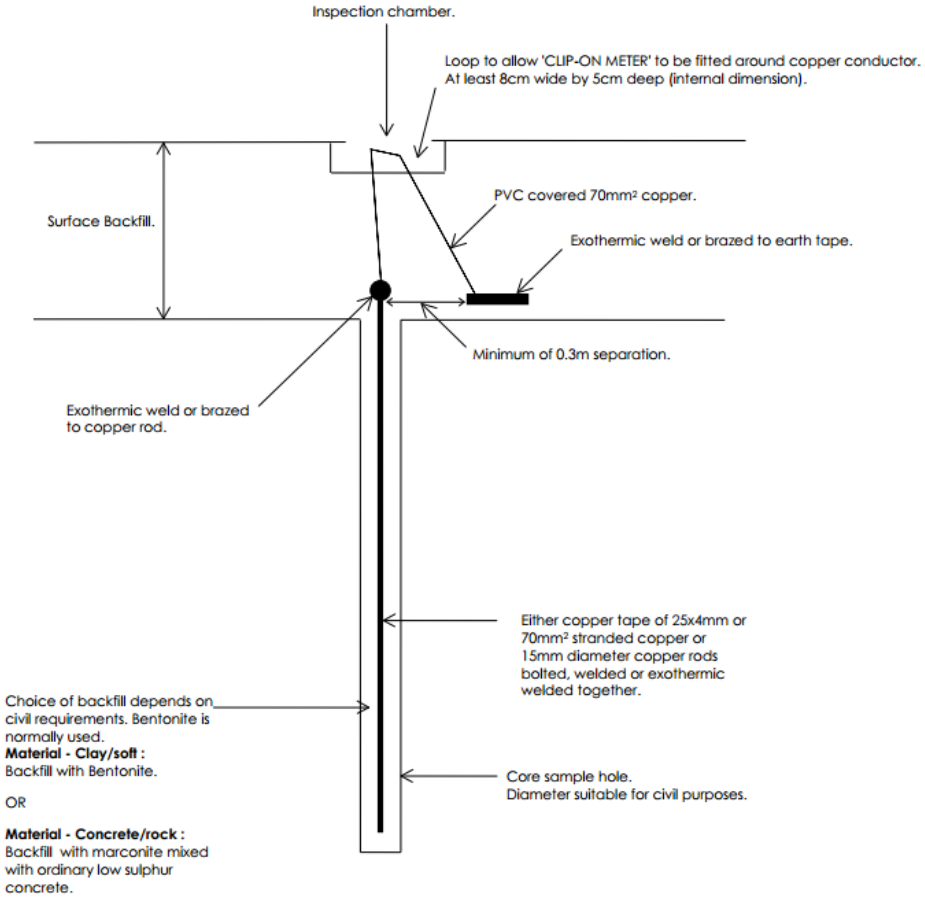


Figure: Inspection Pit

Appendix C–Hot site requirement

1. If a grid or primary substation has been classified as a HOT site the following requirements shall be applied within the substation:
   i. The hot zone contour distance shall be determined by the use of an approved substation earthing calculation program
   ii. All telecommunication cables shall be terminated via an isolation transformer.
   iii. All pilot cables shall be terminated in 15kV isolation boxes and 15kV isolation shall continue into the terminations in relay panels.
   iv. Appropriate operational procedures shall be used when working on pilot cables, telecommunication and power circuits, for example when jointing cables between two substations when one is HOT.
   v. The 'hot' substation designation and the extent of the hot zone shall be recorded in the hot site database.
   vi. All metallic services to the site shall be insulated to ensure they do not introduce a transfer potential risk. This can be achieved by the insertion of insulated inserts (normally one inside the substation and another 2 metres beyond the substation fence) or by the insertion of plastic pipe from 2 metres outside the substation fence.
   vii. Any exposed metallic services within the substation shall be bonded to the substation earthing system if there is any possibility of simultaneous contact.
   viii. LV supplies shall **not** be provided from a HOT site to external customers.
   ix. As a general rule the HV and LV earths at the first secondary distribution substation on each cable fed circuit shall be segregated by 8 metres. Alternatively, the transfer voltage can be assessed using the secondary substation earthing tool.

2. If the HOT zone extends outside the substation fence, there are a number of additional requirements:
   i. The requirements detailed above shall also apply the extended HOT zone.
   ii. BT or other telecommunication companies that use metallic cables shall be advised and a geographic map showing the surface potential contours provided.
   iii. Other services (e.g. gas, water, the petro-chemical industry, etc) with buried metallic pipe work within the HOT zone shall be advised so that appropriate operational precautions can be taken by their staff whilst working on any metalwork within the zone and mitigation measures considered.
   iv. The touch and step potentials shall be checked to ensure they are within the appropriate limits.

Appendix D1 – Risk Assessment Approaches

1. Whilst the use of a 'Risk Assessment' approach to design, construction and maintenance is recognised within the Health and Safety legislation, it is not appropriate within substations. Instead, a deterministic approach based on limiting step/touch voltages as described in this document shall be used.

2. Risk assessment is a valid tool for assessing risk to third parties outside a substation, for example if a housing estate is to be built within the 'hot zone' of a pre-existing substation.

3. For new build, the designer should keep the 1150V (or 1700V for 132kV faults) contour away from properties where possible. If the situation is unavoidable, and eliminating the Hot zone (making Cold) or reducing / re-shaping is not practical, the advice of a specialist or suitably qualified person should be sought.

4. In such cases a risk assessment may be warranted, which will inform the extent of mitigation (if any) required to reduce the risk to 'tolerable' levels. BS EN 50522, as well as HSE R2P2 publication (Reducing Risk, Protecting People).

5. The Individual Risk (IR) per year is the product of PE (probability of exposure), PFB (probability of fibrillation) and fn (faults/year) and must not exceed 1 in 10,000 fatalities per person per year for members of the public (or 1 in 1000 for workers). An IR of 1 in 1,000,000 is deemed to be 'Broadly Acceptable'. For values between 1 in 10,000 (1000) and 1 in 1 ,000,000 this is the ALARP (as low as reasonably practicable) region for which the cost of mitigation must be assessed.

$$IR \cong f_n * P_E * P_{FB}$$

6. Computer modelling or detailed calculations are normally required to establish the extent of high EPR zones and their impact on third parties. The probability of fibrillation can be established based on the voltages across and individual person as described in IEC 60479-1. Reliable fault statistics and individual exposure rates are required to achieve a sensible figure for individual risk, and the designer should err on the side of caution (or appoint a suitable expert) if such information is not forthcoming or if calculated IR is unacceptable.

7. As a general rule, isolation transformers / isolation units will be required for all telecoms circuits into HOT substations.

Appendix D2 – Earthing Checklist

SL	Design Items	(√)
1.	Earthing report provided?	
2.	Earthing drawing provided?	
3.	Soil resistivity analysis included?	
4.	Integrated earthing design?	
5.	Power Grid substation earth resistance?	
6.	Third Party/Customer substation earth resistance?	
7.	Combined earth resistance of Power Grid and Third Party/Customer substation?	
8.	Earth potential rise calculated using the correct earth fault current/ground return current?	
9.	substation touch and step voltage plots?	
10.	substation touch/step voltage compliance using the correct fault clearance time?	
11.	Third Party/Customer substation touch/step voltage compliance?	
12.	Earthing electrodes and conductors correctly rated?	
13.	HOT/COLD classification?	
14.	If HOT, 430V/1150V or 650V/1700V plot?	
15.	If HOT, voltage not transferred to external LV Third Party/customers?	
16.	If HOT, are any LV systems and gas/oil transmission pipelines etc. within the zone of influence safe?	
17.	Electrode surface area calculation?	
18.	Fence correctly earthed?	
	Drawing items	
19.	Earthing drawing matches earthing report?	
20.	Perimeter electrode ring buried at 0.6 metres or mesh buried in floor?	
21.	Minimum 2.4 metre earth rods on each corner?	
22.	Duplicate earth connection between perimeter electrode ring and substation earth bar?	
23.	Rebar connected?	
24.	All equipment bonded (duplicate where required)?	
25.	Chippings used?	
26.	Additional earthing laid with cable?	
27.	Earth bar location?	
28.	Ancillary metalwork bonded?	
29.	GIS HF grounding connected to Main Grid?	
30.	Earthing tape embossed PGCB ?	
31.	Warning labels?	

8. Batteries, Chargers and DC Switchgear

8.1 Scope

These clauses describe the General Technical Requirements for Batteries, Chargers and DC switch-gear for use in substations for 110V DC power for switchgear operations, protection, control, alarms, indications, and emergency lighting.

The equipment to be supplied, installed and commissioned is shown on bid drawings of this specification.

8.2 References

8.2.1 IEC Standards

- IEC 60051 Direct acting indicating analogue electrical measuring instruments and their accessories.
- IEC 60146 Semiconductor converters
- IEC 62040 Uninterruptible Power Systems (UPS)
- IEC 61000-6 EMC / Safety
- IEC 60529 Degree of protection provided by enclosures
- IEC 60439 Low voltage switchgear and control gear assemblies (BS EN 60439)
- IEC 60623 Vented nickel cadmium prismatic rechargeable single cells

MARKING CE EMC IEC EN 61000-6-2, IEC EN 61000-6-4 SAFETY IEC EN 50178, IEC EN 62040-1 TEST AND PERFORMANCE IEC EN 62040-3 NORTH AMERICAN STANDARDS UL 1564 “Industrial Bat

8.2.2 British Standards

- BS EN 60269 Cartridge fuses for voltages up to and including 1000 V AC and 1500 V DC.
- BS 381C Specification for colours for identification coding and special purposes.
- BS 5634 Method of Test for Potassium Hydroxide.
- BS 6231 Specification for PVC insulated cables for switchgear and control gear wiring.

8.3 Design Requirements

8.3.1 General

Batteries shall be located in separate mechanically ventilated rooms, which will be provided with sinks and water supplies. Storage facilities will be provided for electrolyte, distilled water and maintenance equipment.

The voltage measured at the main distribution switchgear shall not vary by more than plus 10 percent or minus 5 percent of the nominal voltage under all charging conditions when operating in accordance with the requirements of this Section.

Two 100% duty batteries shall be connected to duplicate 100% duty chargers, having boost and float facilities, in such a way that either charger can be disconnected without interrupting the output of the other charger or the battery.

The complete equipment shall preferably be a Manufacturer's standard but any departure from this specification shall be subject to the approval of the Engineer. The Battery Charger with Panel & Battery shall be of Europe/USA/Japan Origin or other eligible countries with equivalent quality.

8.4 Batteries

8.4.1 Type of Battery

The battery shall be of the high performance Nickel Cadmium pocket plate type complying with IEC 60623 and shall be designed for a minimum life expectancy of 25 years.

Battery cases shall be of high impact translucent plastic or annealed glass and shall be indelibly marked with maximum and minimum electrolyte levels. The design of the battery shall permit the free discharge of the gases produced during the normal operating cycle, whilst excluding dust. Spray arresters shall be included.

The electrolyte shall be free from impurities and the Potassium Hydroxide used shall comply with BS 5634. Dilution of the alkaline electrolyte and topping up of cells shall be carried out using distilled water only.

A complete set of test and maintenance accessories, suitably boxed, shall be provided for each battery.

A syringe hydrometer and a durable instruction card shall be included in each set.

Cells shall be numbered consecutively and terminal cells marked to indicate polarity.

Cells shall be permanently marked with the following information:

- Manufacturer's reference number and code
- Year and month of manufacture
- Voltage and nominal capacity at the 2, 3 and 5 discharge rate

The electrolyte capacity and general design of the cells shall be such that inspection and maintenance, including topping up of the electrolyte, shall be at intervals of not less than twelve months.

8.4.2 Initial Charge and Test Discharge

The initial charge, test discharge and subsequent re-charge of the battery must be carried out under continuous supervision. Resistors, instruments, leads, and the other apparatus will be necessary for the initial charge, test discharge and subsequent recharge of the battery.

8.4.3 Battery Duty

Each battery shall have sufficient capacity to supply the following continuous and intermittent loads for the periods specified, with the chargers out of service.

Standing DC loading for protection, control, emergency lighting indications and alarms for five (5) hours. This loading shall be determined from all equipment to be supplied on this Contract. In addition, the future circuit requirements estimated on the same basis as the present requirements.

At the end of five (5) hours the battery shall have sufficient capacity to complete the operations listed below.

(a) Two closing operations on all circuit breakers (including future) supplied by the battery.
(b) Two tripping operations on all circuit breakers (including future) supplied by the battery. Where busbar protection is provided, it shall be assumed that all circuit breakers in any one busbar protection zone trip simultaneously.
(c) Charging of DC motor wound circuit breaker closing springs (where applicable) to enable the closing operations to be carried out.
(d) At the end of these duties, the battery voltage shall not have dropped such that the voltage at the battery terminals falls below 95 % of the nominal system voltage when supplying the standing load.
(e) In addition, the voltages at the terminals of all components in the system (e.g. relays, trip and closing coils) shall not be outside of the individual voltage limits applying to them.

While sizing the battery, following additional aspect shall be considered:

(a) The DC system voltage variation shall be considered +15% & -10% at distribution board. The final voltage at load end shall be less than -10%.
(b) A margin of 10% shall be allowed for derating of this battery over its life time of 25 years. However, if designed for lower lifetime, aging factor may be considered as low as 15%.
(c) A sufficient design margin shall be considered. However, if the standard size is sufficiently higher (i.e.10-15%) than the calculated one, such margin may be relaxed.
(d) Temperature correction factor & capacity factor

All quantities derived in this manner shall be quoted in the Tender, but shall not be used for ordering materials until specifically approved by the Engineer. Detailed calculations, and loading characteristics on which these are based, shall be submitted to the Engineer at an early stage.

8.4.4 Location of Batteries

The batteries shall be housed in a ventilated battery room. The charging equipment and distribution switchboards shall be housed in a separate room.

Battery rooms shall be dimensioned and the ventilation system designed to cater for the installation of 48V communications batteries together. Suitable outgoing feeders shall also be provided on the station AC distribution boards to supply these future DC systems.

The floor of the battery room shall be coated with a suitable electrolyte resistant protective coating. The floor shall be fitted with a drain and shall have sufficient slope to prevent any major electrolyte spillages from entering into other areas.

No ducts or any other items shall penetrate the floor or create a means whereby spillage can drain away apart from the drain provided for this purpose.

8.4.5 Battery Mounting Connections and Accessories

Batteries shall be placed on timber boards mounted in double tiers on steel stands of robust construction and treated with acid resisting enamel or gloss paint to BS 381C No.361. The cells shall be arranged so that each cell is readily accessible for inspection and maintenance and it shall be possible to remove any one cell without disturbing the remaining cells. The stands shall be mounted on insulators and be so dimensioned that the bottom of the lower tier is not less than 300mm above the floor.

Alternatively, batteries may be mounted in a similar manner on treated hardwood stands.

Batteries shall be supplied and erected complete with all necessary connections and cabling. Connections between tiers, between end cells and between porcelain wall bushings shall be by PVC cables arranged on suitable racking or supports. Before jointing, joint faces shall be bright metal, free from dirt, and shall be protected by a coating of petroleum jelly. Terminal and inter-cell connections shall be of high conductivity corrosion free material.

Cartridge fuses shall be provided in both positive and negative leads, positioned as close to the battery as possible and shall be rated for at least three times the maximum battery discharge current at the highest operating voltage. The two fuses shall be mounted on opposite ends of the battery stand or rack in an approved manner. These fuse links shall comply with BS 88 Clause DC. 40 and shall be bolted in position without carriers.

Warning labels shall be fitted to warn personnel of the danger of removing or replacing a fuse whilst the load is connected and that fuses should not be removed immediately following boost charge due to the possible ignition of hydrogen gas.

Fuses between the battery and charger shall be located adjacent to the battery in a similar manner to that described above. A warning label shall be placed on the charging equipment indicating the location of these fuses and the fact that they should be removed to isolate the charger from the battery.

It shall not be possible to leave the battery disconnected (by means of switches or removal or operation of fuses) without some local and remote indication that such a state exists.

One set of miscellaneous equipment, including two syringe hydrometers, one cell-testing voltmeter, two cell-bridging connectors, two electrolyte-pouring funnels, two electrolyte thermometers, battery instruction card for wall mounting, electrolyte airtight containers, labels, tools and other items necessary for the erection and correct functioning and maintenance of the equipment, shall be provided for each station.

8.5 Control and Charging Equipment

Each battery charging equipment shall comply with the requirements of IEC 62040), shall be of the IGBT-controlled with PWM (Pulse Width Modulation) and high-frequency transformer, automatic constant voltage type with current limit facilities and shall be suitable for supplying the normal constant load, at the same time maintaining the battery to which it is connected in a fully charged condition.
All the equipment for each charger shall be contained in a separate ventilated steel cubicle. The charger cubicles shall normally be mounted immediately adjacent to the DC distribution panel to form a board and shall be of matching design colour and appearance.

Where their ratings permit, chargers shall preferably be designed for operation from a three phase 415V supply. Chargers shall maintain the float charge automatically for all DC loads between 0 and 100%, irrespective of variations in the voltage of the ac supply within the following limits:

- Frequency variation: 47 to 51 Hz
- Voltage variation: ± 15%

The mains transformer shall be of a suitable rating and design. Clearly marked off-circuit tappings shall be provided on the primary windings and change of tapping shall be by means of easily accessible links. The transformer shall be of the natural air-cooled type capable of operating continuously at full load on any tapping with the maximum specified ambient temperature.

All rectifiers and semi-conducting devices employed in the charger shall be of the silicon type. They shall be adequately rated, with due regard to air temperature within the charger enclosure, for the maximum ambient temperature.

The rating of the charger on float charge shall be equal to the normal battery standing load plus the recommended finishing/trickle charge rate for the battery.

Each charger shall also incorporate a boost charge feature which shall, after having been started, provide an automatically controlled high charge rate sufficient to restore a fully discharged battery to the fully charged state within the shortest possible time without excessive gassing or any form of damage to the battery. The boost charge shall be initiated manually or automatically upon detection of a significant battery discharge. An adjustable timer shall be provided to automatically switch the charger to the float condition after the correct recharge period. Design shall consider Load shall be connected to the charger during boast charge.

Should the AC supply fail while a battery is on boost charge, the switching arrangements shall automatically revert the charger to float charge status and then reconnect the battery to the distribution board.

The output voltage regulator shall be adjustable for both float and boost charge modes, within limits approved by the Engineer, by means of clearly marked controls located inside the cubicle.

Although it is not intended that the charger be operated with the battery disconnected, the design of the charger shall be such that with the battery disconnected the charger will maintain the system voltage without any damage to itself and with a ripple voltage no greater than 2.0% rms of the nominal output voltage.

The charger shall automatically adjust the charging current from a value not less than the battery capacity divided by 5 hours to a minimum value of not more than the battery capacity

divided by 100 hours. The charging circuitry shall be so designed that the failure of any component will not give a situation which will cause permanent damage to the battery by overcharging.

Each charger shall have a float charge maximum current rating sufficient to meet the total standing load current on the dc distribution board plus a battery charging current equal numerically to 20% of the battery capacity at the 5 hour rate.

Each charger shall be designed with a performance on float charge such that with the output voltage set at approximately 1.45 V per cell at 50% load and rated input voltage and frequency, the output voltage shall not vary by more than plus 3% to minus 2% with any combination of input supply voltage and frequency variation as stipulated in this specification and output current variation from 0-100% of rating.
Each charger shall be suitable for operating alone or in parallel with the other charger. When operating with both chargers, one charger shall be arranged to supply the standing load with the second charger in the quiescent standby mode.

Each charger shall also have a taper characteristic boost charging facility which shall be selectable by a float1boost charge selection switch and which will give boost charging of 1.60 -1.75 voltage per cell.

Each charger shall be designed with a performance on boost charge such that with rated input voltage and frequency the charger output shall not be less than its rating in Watts at 1.3 V and 1.65 V per cell, and also the output voltage shall be 1.60 - 1.75 V per cell over an output range of 0 - 100% of rating.

The boost charging equipment shall be capable of recharging the battery within six hours following a one hour discharge period.

In the event of the battery becoming discharged during an AC supply failure, the rate at which recharging commences shall be as high as possible consistent with maintaining the automatic charging constant voltage feature and with the connections remaining undisturbed as for normal service.

The charger shall have an automatic boost/quick charge feature, which shall operate upon detection of a significant battery discharge. When, after a mains failure, the AC supply voltage returns and the battery has been significantly discharged, the charger will operate in current limit. If the current limit lasts for more than a specified time and the charging current does not fall back to float level, the automatic high rate charge shall be activated.
An override selector switch shall be provided inside the charger unit to enable a first conditioning charge to be made, in line with the battery Manufacturer's recommendations, for batteries which are shipped dry and require forming at site.
A voltage dropper diode unit (typically called DVR module) shall be incorporated in the output circuit of each charger to limit the load voltage during boost charging of the battery. These

diodes shall be continuously rated to carry the maximum possible load current during boost charging. The diode unit shall not be in service in the normal float charging mode. Should the voltage stabilizer/ DVR unit fail in the boost charging mode, the charger shall automatically revert to the float mode.

An anti-paralleling diode shall be provided in each positive feed to the DC distribution board to prevent faults on one supply affecting the other. These diodes shall be continuously rated to carry the maximum possible discharge current likely to occur in service and a safety factor of 4 shall be used to determine the repetitive peak reverse voltage rating. The 12 t rating of the diodes shall be such that in the event of a DC short circuit, no damage to the diodes shall result.

Each charger shall be capable of sustaining, without damage to itself, a continuous permanent short circuit across its output terminals. The use of fuses, MCBs or other similar devices will not be acceptable in meeting this requirement.

Suitable relays shall be provided for each charger to detect failure of the incoming supply and failure of the DC output when in float charge mode. These relays shall operate appropriate indicating lamps on the respective charger front panel and shall have additional voltage free contacts for operating remote and supervisory alarms. These alarms shall be immune from normal supply fluctuations and shall not be initiated when any one charger is taken out of service.

The charger shall also be fitted with a device to de-energise the charger in the event of a DC output float over voltage.

Each charger shall be provided, as a minimum, with the following instrumentation, indication and alarm facilities:

- indicating lamps for the AC supply to the rectifier and DC supply from the rectifier.
- indicating lamps for float and boost charging operations.
- voltmeter -input voltage.
- voltmeter -output voltage.
- ammeter -output current.
- alarm -charger failure.
- alarm -mains failure.

The following battery alarms shall also be provided

- battery fuse failure
- diode assembly failure
- battery circuit faulty
- low DC voltage
- high AC voltage

- earth fault +ve
- earth fault -ve

Lamp test facilities shall be included.

A "charger faulty" alarm for each charger and a "battery faulty" alarm shall be provided in the substation control room and to the SCADA system where applicable.

Each battery charger shall be equipped with charge fail detection equipment to give local indication and remote alarm if the voltage from the charger falls below a pre-set level which will be lower than the nominal float charge voltage. Suitable blocking diodes shall be provided to prevent the battery voltage being supplied to the equipment and so prevent charge fail detection.

The device shall not operate on switching surges or transient loss of voltage due to faults on the AC system. The voltage at which the alarm operates shall be adjustable for operation over a range to be approved by the Engineer.

Each charger shall be equipped with a switch-fuse for the incoming AC supply and an off load isolator for the DC output.

Bidders shall include particulars with their tender on the method of adjustment included to compensate for ageing rectifier elements. The construction of the charger shall be such that access to all components is readily available for maintenance removal or replacement. Internal panels used for mounting equipment shall be on swing frames to allow for access to the charger interior.

8.6 Service Manual and Spare Card

Each set of battery charger shall be accompanied by a detailed service manual. The manual shall be such that easy trouble-shooting will be possible with it. The service manual shall cover the detailed diagram of each control card, IC number, clearly marked each circuit component like R,L,C, diode with their rating. The figures in the manual shall be Colourful, no black & white pictures are acceptable. The language of the Manual shall be simple English to facilitate easy understanding.
In case, the Contractor fails to provide service manual as stated above, they shall provide Spare control card for each charger. At-least 50% of total card used in a single charger shall be provided as spare. The components which are most likely to failure, as recommended by manufacturer and approved by Employer, shall be considered for spare. However, charger having sufficient successful field experience in PGCB system may be relaxed for spare card requirement subject to Employers Approval.

8.7 Distribution Switchboards

The switchboard shall comply with the requirements of BS 5468 (IEC.60439)

The distribution switchboard shall be of the cubicle type or otherwise incorporated in the cubicles for battery chargers. Double pole switches and fuses or switch fuses (miniature circuit breakers to BS 4752 or IEC 60157 may only be used if it can be shown that there will be no discrimination problems with sub-circuits) shall be fitted to the DC switchboard as required by substation services but, as a minimum requirement, that set out in the Schedule B of Requirements.

Distribution panels shall be mounted adjacent to the charger control panel and shall be of the cubicle type complying with the general requirements of cubicle type control panels. No equipment associated with the chargers shall be installed in the distribution board.

Distribution panels shall incorporate double-pole switches and fuses for each of the outgoing DC circuits and double-pole isolators for the incoming DC supplies The panel shall be provided with a voltmeter and centre zero ammeter on each incoming circuit.

A double pole switch or contactor shall be provided for the purpose of sectionalising the busbar.

A battery earth fault detecting relay, which will centre tap the system via a high resistance, shall be incorporated in the distribution panel.

A low voltage detecting device for the system shall be incorporated in the distribution panel. No-volt relays will not be accepted for these devices. The voltage setting shall be adjustable over an approved range.

In addition to any other requirements specified elsewhere, the battery earth fault detecting relays and low voltage devices shall each have three alarm contacts, one for local visual annunciation, one for the station control panel alarm indication and one for potential free contact for external supervisory alarms. A lamp test facility shall be provided.

Connections between the battery and the distribution cubicle shall be made in PVC insulated cable as required. Cable laid in runs where it may be subject to damage shall be protected by wire armouring, be sheathed overall and be cleated to walls as required.

Cable boxes or glands shall be provided as appropriate for all incoming and outgoing circuits of the distribution switchboard and associated battery chargers. Each circuit shall be suitably labelled at the front of the panel and at the cable termination where the terminals shall be additionally identified.

Charging and distribution switchboards shall be provided with an earthing bar of hard drawn high conductivity copper which shall be sized to carry the prospective earth fault current without damage or danger.

The cubicles for the chargers and distribution boards shall be of rigid, formed sheet metal construction, insect and vermin proof, having front facing doors allowing maximum access to the working parts, when open. The design of the cubicles for the chargers shall be such as to prevent the ingress of dust and minimise the spread of flames or ionised zones, shall be to IEC 60529 IP52, but at the same time shall provide all necessary ventilation and cooling. The design of the frames shall allow the clamping and holding of all chokes, transformers and similar sources of vibration, so that vibration will be minimised, satisfy relevant standards, and not limit the life of the equipment. The frame shall allow the fixing of lifting and so that the equipment remains properly mechanically supported whilst being transported, lifted and installed.

8.8 Insulation Monitoring System

8.8.1 General

The DC system is the heart of the Station protection system. Hence, it is important to know & monitor DC system healthiness. Normally station DC system are unearthed to overcome mal-functioning of Protection scheme during station fault condition.

The purpose of Insulation Monitoring is to aware the operator about the healthiness of Station DC system. The insulation monitor provides in advance, information for effective preventive maintenance thereby ensuring the availability of power supplies. It also prevents shock hazards in small and medium size low voltage power supply and distribution system.

Standard

- IEC 61557-8
- IEC 60364-4-41,
- IEC 62557-8: 1998-05

8.8.2 Principle

An insulation monitoring device will detect and signal an impermissible deterioration in insulation. Basic principle of station DC Insulation Monitoring System is when the system becomes grounded the voltage across a resistor will drop .

The DC-IM superimposes a measuring signal, generated by signal generator. On the occurrence of an incipient insulation fault, the measuring circuit between system and earth closed via the fault RF causing a voltage drop across the measuring resistance, which is processed and evaluated by electronic circuitry. If the voltage drop exceeds the set value proportional to insulation resistance, an alarm is given. The signal has a DC component which is used to charge the system capacitance, thereby ensuring that the signal goes through the incipient fault.

The nature of the measuring signal is very important as it should not affect operation of devices such as switched mode power supplies, computers, variable frequency drives etc. Further, the harmonics and other disturbances created by these devices, presence of filters connected to the system should not affect the measurement of the insulation fault.

The DC-IM shall be EMC to work in the harsh environment of Substation. It shall be able to withstand High voltage that may come during the service period.

An insulation fault should be eliminated as quickly as possible before a second insulation fault can occur on a different live conductor, as this would cause the system to fail. An insulation monitoring device must be designed to indicate the first occurrence of a live mass or earth fault; it must trigger an audible or visual signal.

8.8.3 Construction

Complete Insulation Monitoring for DC system shall be provided. Latest Technology shall be used for insulation Monitoring. The system can be standalone or integrated. Superimposition of measuring DC voltage & “AMP” measurement method

Normally integrated system shall be supplied with the contract. In case of integrated type, the system shall be placed inside the DCDB. Relays, contractor etc. shall be equipped with the system. DC control cable of 400V insulation shall be used. No Fan or coolers shall be considered in the design.

The system shall be capable of communicating with the Station SAS for signalling of DC fault.

8.8.3.1 Main Circuit

The main circuit shall consist of Power supply connection, R-L circuit for DC smother etc. The Device shall use station DC supply.

8.8.3.2 Control Circuit

Microprocessor based Control circuit shall be provided.

8.8.3.3 Fault Locator

The Device shall indicate the location of fault in the DC feeder.

8.8.3.4 HMI

Built-in HMI with high-class button or touch screen based shall be provided.

8.8.3.5 Alarm

The Device shall initiate alarm during occurrence of a fault in the DC system. It shall also send signal to the SAS for easy monitoring of the operator.

8.8.3.6 Fuse

Most insulation monitoring devices are connected to the system to be monitored via two connecting wires.

In principle, any type of fuse protection for an insulation monitoring device must be considered as line protection. According to IEC 60364-4-43, fuse protection is always required if the current carrying capacity is reduced by a decrease in cable cross section, a change in cable installation method, a change in conductor insulation or a change in the number of conductors.

The supply voltage terminals must be fitted with overcurrent releases for short-circuit protection. A 6A fuse shall be used for overload & short circuit protection. Fuse protection also makes it easier to access devices for service operation.

8.9 Labelling

All relays, instruments and control devices, and each unit of the equipment, shall be provided with a label. All labels and lettering shall be of sufficient size to provide easy reading from the normal operating or maintenance positions and shall consist of black lettering on a white background. All warning and danger labels shall have white lettering on a red background. Labels shall be of the non-corrodible type and lettering shall be of motorway script or similar. If plastic labels are used, these shall be laminated to avoid warping.

8.10 Special Tools

The Contractor shall provide a complete set of all special tools and services necessary for the erection and maintenance of the complete equipment.

8.11 Inspection and Testing

Inspection and testing during manufacture and after installation on site shall be in accordance with Section 15 of this specification.

APPENDIX

Appendix Batteries, Chargers and DC Switchgear

A. NI-CAD Battery

SL. No.	Description	
1	Installation	: Indoor
2	Cell type	: Ni-cd
3	Voltage (Normal)	: 1.2 volts per cell
4	Float voltage	: 1.40-1.42 volt/cell
5	Equalizing voltage	: 1.55 - 1.65 volt/cell
6	Capacity in AH at 20°C	: 150AH @ 5 Hr (for 48V DC)
6	No. of cells per Battery unit	: Not less than 94 nos. for 110V Not less than 42 nos. for 48V
7	Ambient temperature	: 40°C
8	Positive plate	: Tubular
9	Negative plate	: Pasted
10	Type of container	: Plastic polymer
11	ECV	: 1.11 V/Cell
12	Sp. gravity of electrolyte	: 1.19 ± 1%
13	Sp. gravity of electrolyte (Charged)	: 1.23 ± .010 at 20°C
14	Vent plug	: Anti-corrosive & fire proof
15	Cell condition	: Pre-charged.
16	Battery stand	: Steel frame of step type
17	Standard	: IEC or equivalent

B. Battery Charger

SL. No.	Description	48V	110V
	A) GENERAL		
1	Installation	:Indoor	:Indoor
2	Rectifier type	:IGBT controlled	:IGBT controlled
3	Rated D.C. voltage	:48V ±5%	:110V ±5%
4	Rated output current	:120 Amps	:150 Amps
5	Charging mode	:Both constant current & constant voltage	:Both constant current & constant voltage
6	High Voltage Insulation	: 1000 V AC for 1 minute between input to output and input to ground	: 1000 V AC for 1 minute between input to output and input to ground
7	Insulation resistance	:10 MW with 500V DC for 1minute	:10 MW with 500V DC for 1minute
8	Cooling system	:Self & natural air cooled.	:Self & natural air cooled.
9	Relative humidity	:Up to 98%	:Up to 98%
10	Ambient temperature	:45°C (max.)	:45°C (max.)
11	Noise level	:65 dB (max)	:65 dB (max)
12	Altitude	:1000 m	:1000 m
13	Applicable Standard	:IEC or equivalent.	:IEC or equivalent.
	B) TECHNICAL DATA		
	A.C. INPUT		
1	Voltage	:415 Volts	:415 Volts
2	Phase	:3 Phase	:3 Phase
3	Frequency	:50±5% Hz	:50±5% Hz
4	Input AC voltage variation	:±5%	:±5%
5	Power factor (Full range)	:0.8	:0.8
6	Efficiency (Full load)	:85%	:85%
7	Charge Characteristics	: Constant current / Constant voltage (During float charge)	: Constant current / Constant voltage (During float charge)

SL. No.	Description	48V	110V
8	Current limitation	:110%	:110%
	D.C. OUTPUT		
1	Voltage	:48±5% volt	:110±5% volt
2	Ripple Voltage (Full load)	:±3%	:±3%
3	Charge modes (3 level)	:Charge, Float charge& Boost charge.	:Charge, Float charge& Boost charge.
4	Float Voltage (adjustable)	:1.42 volt/cell	:1.42 volt/cell
5	Boost Voltage (adjustable)	:1.53 volt/cell	:1.53 volt/cell

9. LV AC Distribution Switchgear

9.1 Scope

These clauses describe the General Technical Requirements for LVAC switchboards for supplies to "Substation Services" including outdoor switchyard lighting and control building services (Section 13). All cable shall be FRLS type.

9.2 References

- IEC 60044-1 Current transformers
- IEC 60044-2 Voltage transformers
- IEC 60044-5 Instrument transformers
- IEC 60269 Low voltage fuses
- IEC 60439-1 Specification for low voltage switchgear and control gear assemblies.
- IEC 60644 Specification for high-voltage fuse links for motor circuit applications.
- IEC 60898 Electrical accessories – Circuit breakers for overcurrent protection for household and similar installations.
- IEC 60947-1 Low-voltage switchgear and control gear -General
- IEC 60947-2 Low-voltage switchgear and control gear -Circuit breakers
- IEC 60947-3 Low-voltage switchgear and control gear -Switches, disconnectors and fuse combination units.
- IEC 60947-4 Low-voltage switchgear and control gear –Electromechanical contactors and motor starters.

9.3 SwitchboardDesign

9.3.1 General

Main switchboards and MCB sub-distribution boards for substation and building supplies will be constructed to IEC 60439, (BS EN 60439) in accordance with the following:

The classification of the main switchboards shall be:

(a) The external design of switchboards shall be of the multi- tier, multi-cubicle type.
(b) Installation shall be indoors.
(c) Switchboards shall be free standing and fixed to the floor.
(d) Enclosures degree of protection shall be not less than IP42.

(e) Switchboards shall be of metal clad construction.
(f) All instrumentation and metering shall be fixed to a hinged lockable compartment.
(g) Switchboards and all associated equipment shall be suitable for use on a 415/230 volt, three phase, four wire, 50 Hz system having the neutral solidly earthed.
(h) Each circuit shall be clearly labelled to show the destination of the associated cable and the "ON" and "OFF" positions of the switches.
(i) Distribution boards for exterior use shall be galvanised, weatherproof and to category EP55 degree of protection.

The equipment shall be of the single busbar type with circuit equipment housed in separate compartments.

Where two or more incoming circuit breakers are provided at substations, these shall be mechanically and electrically interlocked to prevent more than one circuit closing at the same time.

The enclosures of all switchboards shall be dustproof and vermin proof. Access doors shall be mounted using concealed hinges. All removable covers shall be fitted with captive screws. Anti-condensation heaters with control switches shall be provided on switchboards. They shall be suitable for a tropical climate.

9.3.2 Rating

Incoming supplies to all switchboards shall be protected at the point of supply. All switchboards shall be suitably rated for a prospective short-circuit breaking capacity of 15 kA at 415V for three seconds.

9.3.3 Busbars

Busbars shall be capable of carrying the full rated current continuously without exceeding the maximum temperature specified in IEC 60439 under site ambient conditions.

Busbars shall be of copper, individually covered with a heat resistant phase coloured PVC. Busbar links between panels shall not be used. Neutral busbars shall have the same cross sectional areas as the phase busbars. Busbars shall be of the same current rating throughout their length and shall be capable of extension at both ends with the minimum disturbance to the busbar and cubicle enclosure.

9.3.4 Busbar and Circuit Shutters

For draw-out equipment shutters shall be provided over busbar and circuit orifices to close automatically and positively when the equipment is isolated or withdrawn. Means shall be

provided for padlocking the sets of shutters. Busbar orifice shutters shall be painted signal red and labelled 'BUSBAR' in white letters. Circuit orifice shutters shall be painted lemon yellow.

One blanking cover of each size shall be provided to prevent access to a circuit compartment when the equipment has been completely withdrawn from the panel.

9.3.5 Circuit Labels

Approved type title labels are to be fitted externally on the front cover of each distribution board giving details of the points controlled by each circuit. The circuit list shall be typed or printed stating the location of the equipment served, rating of the protective unit and the circuit loading. The lists shall be mounted on the inside of the cover door and shall be protected by an acrylic sheet slid into a frame over the circuit list, the list and cover to be easily removable to permit circuit modifications.

9.4 Circuit Breakers

All MCB and MCCB circuit breakers shall be high speed fault limiting, thermal/magnetic type with quick break, trip free mechanisms which prevent the breaker being held in against overloads or faults, shall comply with IEC 60947 (BS EN 60898 and be fitted with overcurrent releases of both thermal and instantaneous type. Short circuit performance shall be to IEC 60947.

Where circuit breakers incorporate thermal overload protection and short-circuit protection, their set-tings shall be subject to agreement with the Engineer.

Tripping arrangements shall be such as to ensure simultaneous opening of all phases. Arc extinction shall be by deionising arc chutes.

Circuit breakers on the incoming circuits shall have facilities for locking in the "off" position.

The fault interrupting capacity of the circuit breaker shall not be less than that of the switchboard itself, or if this is not the case, back up fuses shall be included.

9.5 Switch Fuses

Each switch-fuse unit shall be housed in a separate metal compartment and provided with a hinged metal door, interlocked with the switch mechanism so that:

(a) The door cannot be opened whilst the switch is closed.

(b) The door, on opening, automatically locks the switch in the "off' position. Facilities shall be incorporated to allow for the deliberate release of this interlock for maintenance purposes, should it be desired to observe the switch in operation.

An insulating barrier shall be fitted to segregate the fuses and neutral link from the switch and the connections of the latter shall be effectively shielded by an inner metal screen when the compartment door has been opened to obtain access to the fuses.

The switch-fuses may be either of the combination fuse-switch type or of the type with the switch and fuse in separate units. In either case, interlocking shall be provided to prevent access to the fuses until the associated switch is opened and provision shall be made for padlocking the switch in the "on" and "off' positions.

The switch shall have a quick make and quick break action, independent of the speed at which the switch handle is operated, and shall be entirely suitable for switching the inductive loads associated with motor circuits.

9.6 Oil Filtration Socket Outlet and Plug

The contract shall include heavy-duty weatherproof three phase and neutral interlocked switched socket outlets and plugs suitable for supplying the transformer oil filtration units.

9.7 Inspection and Testing

Inspection and testing during manufacture and after installation on site shall be in accordance with Section 16 of this specification.

SECTION 10 A

BUILDINGS AND CIVIL ENGINEERING WORKS (FOR OUTDOOR GIS AND AIS)

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SECTION 10 A

BUILDINGS AND CIVIL ENGINEERING WORKS (FOR AIS)

10A.1 GENERAL

This section covers all earth work, foundations and buildings associated with the project together with site preparation, roads, surfacing, cable trenches and tunnels, boundary walls, guard houses, foul and storm drainage and water supply.

10A.1.1 Scope of Work

The Tender must cover all requirements of the tender documents and any other items not specifically mentioned but which are necessary for the satisfactory design, construction, operation and maintenance of all substations to the satisfaction of the Employer. No additional costs will be considered for any items which have been overlooked but which are essential for the proper completion of the project in every respect. The detail scope of work for specific sub-stations is described in Schedule A of the bidding document.

The work includes but not limited the design, detailing, construction and maintenance of the following:

(i) Performance of site survey and subsoil investigation

(ii) Site preparation including retaining walls or site slope protection, cutting or filling up to the level specified in 10A.1.4 and levelling as well as compaction.

(iii) Foundations for all equipment to be installed in outdoor switchyards, control buildings and any other building required for the project

(iv) Complete buildings consisting of structural reinforced concrete frames, brick walls, concrete roof and floor slabs.

(v) Road including access road with a culvert or sufficient drainage pipes and roadways within sites, surfacing the entire area within site boundary and surface water drainage.

(vi) Cable trenches, cable tunnels, cable ducts and pipe ducts.

For all substations and for individual rooms in substations suitable nameplates, signs and labels shall be provided to ensure identification, safe operation of plant and warning of danger. The text, which shall be both in Bangla and English, shall be approved by the Employer. The substation sign board(s) shall be 3 mm, Aluminum sheet powder coated and the text (Bangla

& English) shall be UV resistant, PGCB logo on a separate circular plate to be fixed at the centre of sign board. The inscriptions shall be engraved with colored lettering. All nameplates, signs and labels shall be non-deteriorating and non-warping under aggressive weather conditions and shall be guaranteed for a minimum period of 10 years. Plates, etc., will be securely attached using bolts and nuts or screws; adhesive will not be permitted.

Included in the scope of work is the detailing, construction and maintenance of the following items which shall generally be constructed to the Employer's standards but full working drawings shall be prepared by the Bidder:

(a) guardhouse, sentry post, car port, pump house and chain linked fence

(b) boundary wall and entrance gate

(c) Property line demarcation

(d) septic tank and soak well

(e) water supply tube well and plumbing installations

(f) underground and overhead water storage tank

(g) surface water, foul and storm drainage

(h) air conditioning and ventilation

(i) lighting, small power, external floodlighting, emergency lighting and fire protection

Guardhouse, sentry post, car port and chain linked fence as stated in item (a) shall be designed as per enclosed drawing.

Boundary wall and entrance gate stated in item (b) shall be designed as per enclosed drawings.

A drawing of septic tank and soak well as in item (d) above has been enclosed. The contractor shall construct septic tank and soak well following that drawing along with specifications provided in clause 10A.3.3 of the document.

10A.1.2 Bidder to satisfy himself as to all conditions

The Bidder shall assess:

(i) access conditions at site, plus ground condition and ground bearing capacity

(ii) transport costs, materials costs and restrictions of availability of supply of materials locally

(iii) importation restrictions and delay due to customs controls

(iv) restrictions imposed by existing equipment on sequence of construction, access *etc.*

(v) restrictions caused by cable laying and overhead line Bidders

(vi) ground conditions and temporary works required to provide support during excavation

(vii) adjacent distribution substation and their adjacent area of authority if any

(viii) availability of permanent bench mark at site

10A.1.3 Way leaves, Land Purchase and Planning Permission

The Employer will be responsible for the purchase of all land within the permanent site boundary and the purchase of all land required to the base of the fill of any batter slopes. The Employer will also be responsible for obtaining land to provide a permanent single access to site from a nearby road or waterway.

During the construction period the Bidder shall be responsible for maintaining this access road in a reasonable condition by reinstating damage caused by his construction traffic and Employer's traffic.

Should the Bidder require more than one single access to a site or require additional land for construction activities outside the permanent site boundary, he shall be responsible for the purchase or way leave of the required land.

The Employer will be responsible for applying for planning permission. The Bidder shall be responsible for completing the approved site survey and the approved site layout plan, together with the approved architectural elevations of all facades of any buildings, by the key date given in the programme so that the Employer may use these drawings to apply for planning permission.

10A.1.4 Site Survey Drawings

For each site the Bidder shall prepare a survey at 1:200 scale showing existing ground levels on a maximum 10 meter grid and details of all features above and below the ground within the site boundary and up to 15 meters beyond it by the key date stated in the programme. Levels shall be related to bench marks clearly indicated on the plan. The plan shall be submitted to approval by the Engineer and the approved substation building plinth levels shall be given on site plan. The Bidder shall propose the building floor level to the Engineer. The Final Ground/formation Level (FGL) of the site will be 500mm above the crown of the nearest public road or 500mm above the Highest Flood Level (HFL) whichever is greater. If the site is located within/adjacent to an existing switchyard/substation of the employer/other organization, then FGL of the site should be determined same as mentioned above but should not be less than the FGL of existing switchyard/substation. For bay extension within an existing switchyard, FGL of new bay shall be same as the FGL of existing bay. All building plinth level will be 600mm above the FGL.

10A.1.5 Earth Works

Fill where required shall be carried out by the Bidder. Source of fill material and Retaining wall shall be planned and approved by the Employer. The Bidder shall be responsible for providing a level or uniform sloping site to suit his substation layout design. The final ground/formation levels (i.e. the level below the brick surfacing) shall be stated on the site survey plan to be prepared by the Bidder.

10A.1.6.1 Engineer's and Employer's Accommodation/Surveying Equipment

On each major site the Contractor shall provide an office of approx size 5 x 8m equipped with desk, one executive chair, two visitor chairs, one multipurpose shelf, light, fan and air

conditioner, toilet with wash basin *etc.* for the sole use of the Employer's Engineer and his inspectors. Similar facilities are to be provided for the supervision consultant of the Employer.

10A.1.6.2 Surveying Equipment

The Contractor shall loan his surveying instruments with surveyor to the Engineer and his staff when required. Instrument checks shall be carried out at monthly intervals. The specifications and user manuals of the instruments shall be submitted by the Bidder to the Employer.

10A.1.7 Programme

The Bidder's programme shall at Bid stage define the following key dates. Where drawings are to be submitted for approval, they shall be submitted at least 28 working days before the key dates to allow for the Engineer to comment and his comments to be incorporated in the drawings:

1 Issue of approved site survey drawing within the site boundary and up to 15 meters beyond it complete with soil levels and floor levels

2 Issue of approved electrical layout drawings

3 Completion of Site Investigation field work

4 Issue of approved Site Investigation Final report

5 Completion of loading tests on a foundation on fill site and any other site where settlement is likely to be a problem

6 Issue of approved drawings required for Planning Permission

7 Issue of a full complete set of civil building drawings

8 Construction start date

9 Date access will be given for:

   i) Installation of equipment in Buildings

   ii) Installation of outdoor plant

10 Construction finish date

The drawing programme shall ensure that complete set of approved civil building drawings will be issued at least 14 days before construction start, in accordance with the Project Requirements.

The Construction programme shall be expressed in an 'S' curve for the whole project, with the percentage (of the total value of work in the schedules) each month.

10A.1.8 Monthly Progress Certificates/Progress Reports

In accordance with the Project Requirements the Bidder shall submit agreed progress certificates before the seventh day of the next month. These certificates shall state the percentage

completion of each item in the schedules and shall state the overall percentage completion. An updated 'S' curve shall be submitted with the progress certificates.

10A.1.9 Temporary Facilities

The Bidder shall provide all temporary buildings, workshops, reinforcement, cement and lime stores and latrines required for his use. The Bidder shall agree the location of these buildings with the Engineer, after submitting a drawing showing their proposed location.

When a Bidder is placed in possession of a site, or part of a site, he shall erect temporary fencing immediately to protect the site until the boundary wall shall be erected.

10A.1.10 Site Supervision

Although the civil and building works may be let as a sub-contract to an approved local Bidder, the main Bidder shall ensure that an expatriate supervisor in his direct employ is continuously available at site during construction. This supervisor shall have at least a working command of spoken English and be able to read, understand and discuss specifications and drawings.

The Bidder shall notify the Employer and Engineer in writing of major field works three days before the work starts for the activities as described below:

i) subsoil investigation

ii) every concrete pour and foundation casting

10A.1.11 Designs and Drawings

The Bidder shall obtain the Engineer's approval for the use of all design codes and standards before design work starts. The Bidder shall supply one copy of all of codes for employer's Engineer. If non-English equivalent National codes are adopted, the Bidder shall supply English translations of these Codes to the Engineer.

One copy of calculations along with all soft (software, excel sheet) copies shall be submitted together with drawings. To avoid possible misunderstandings, calculations will not be approved separately from drawings.

The Bidder shall generally submit a complete set of drawings with all soft copies (AutoCAD drawing) of each item sequentially for approval after initially getting the electrical layout and section approved. Where possible, drawings shall be standardized and general drawings shall be issued covering several sheets.

The Bidder shall provide a co-ordination plan at scale 1:200 showing busbar sizes, structure types, foundation types, cable trenches, roads, ducts, buildings, boundary walls, earthing, drainage and all services in this Contract.

10A.2 REFERENCES

10A.2.1 General

The design and construction shall conform to the latest edition of the relevant Codes and Standards. Any proposed substitution for the listed Standards by an equivalent Standard will be

subject to approval by the Engineer. Relevant Standards include, but are not limited to, those listed in sub section 10A.2.2 below.

10A.2.2 Design and Construction Standards

BS12	Portland Cement
BS EN 124	Gully and Manhole tops for vehicular and pedestrian areas
BS 812	Testing aggregates
BS 882	Aggregates from natural sources for concrete
BS 1377	Methods of test for soils for civil engineering purposes
BS 1722: Part 10	Anti-intruder fences
BS 1881	Testing concrete
BS 2853	Design and testing of overhead runway beams
BS 3148	Methods of test for water for making concrete
BS 3921	Clay bricks
BS 4449	Steel bars for the reinforcement of concrete
BS 5262	External renderings
BS 5395	Stairs, ladders and walkways
BS 5572	Sanitary pipework
BS 5628	Code of practice for use of masonry
BS 5930	Code of practice for site investigations
BS 6031	Code of practice for earthworks
BS 6367	Code of practice for drainage of roofs and paved areas
BS 6399: Part 1	Code of practice for dead and imposed loads
BS 6399: Part 2	Code of practice for wind loads
BS 6465	Sanitary installations
BS 6651	Code of practice for protection of structures against lightning
BS 6700	Design, installation, testing and maintenance of services supplying water for domestic use
BS 8004	Code of practice for foundations
BS 8005	Sewerage
BS 8100	Lattice towers and masts
BS 8102	Code of practice for protection of structures against water from the ground
BS 8110	Structural use of concrete
BS 8206	Lighting for buildings
BS 8215	Code of practice for design and installation of damp-proof courses in masonry
BS 8290	Suspended ceilings
BS 8301	Code of practice for building drainage

10A.3 DESIGN

10A.3.1 Architectural and Structural Requirements of Buildings

All new buildings shall be designed to be architecturally pleasing in appearance and to withstand the tropical climate with minimal maintenance.

Architectural plan and all elevations of buildings shall be agreed before other detail plans are prepared.

Air conditioning units shall be provided in rooms listed in Section 13. Air conditioned rooms shall have a false ceiling such that the overall thermal transmittance of the roof shall be below 0.45

Watts/m^2˚C. The false ceiling shall be made from non-combustible materials, and shall be easily removable to provide easy access to small power cables.

Control room building and switchyard panel room shall be reinforced by a reinforced concrete frame which shall be capable of resisting a horizontal earthquake force of 0.1G. An external concrete open staircase shall be provided up to panel room floor. An internal concrete staircase shall be provided up to the roof. The roof shall be a flat insitu concrete slab designed for 2.5 kN/m^2 live load. For other buildings shall be designed as per latest BNBC.

The roof shall be waterproofed with lime terracing 2:2:7 lime, shurki (powdered brick) and brick chips 0.75" down, which shall be beaten in accordance with local practice or with any other approved water proofing system. The entire roof area shall be laid in one continuous operation. For lime terracing waterproofing system the minimum compacted thickness of terracing shall be 25mm at the low points of the roof with a 1:150 slope to those points formed by a layer of terracing of increasing thickness. Once laid, the terracing shall be covered with a layer of bitumen emulsion and the edge of the terracing shall be protected against erosion into the downpipes. Downpipes shall be of 100mm diameter uPVC pipe placed outside the wall but shall be enclosed in a facing brick buttress. There shall be at least one downpipe per 100m^2 of roof. The Bidder shall guarantee the roof against leaks for a period of 3 years from the Taking over Certificate date. The roof shall project at least 450mm beyond the face of all walls or 150mm beyond the face of all columns whichever is greater to form a sunshade and rain shelter to the walls below. The upper surface of this projection shall be sloped and a drip provided.

The main entrance to all buildings shall be shaded, either by a projection of the roof over the entrance veranda or by a separate roof at a lower level. This area of roof shall also be lime terraced and drained by rainwater pipes.

The roof parapet wall shall be about 1.0 meter high with an in situ concrete coping of 75mm with *dpc* below it. Where facing bricks are used below the roof level, they shall also be used above roof level. An architectural feature shall be provided by panels of open decorative block work (Mirpur ceramics or similar approved) to ensure good air circulation over the roof. Minimum three open decorative blocks of size 1000mm X 500mm should be provided on each side in solid portions of parapet wall.

The head of each downpipe shall be fitted with an enlarged hopper of 200mm and purpose made cast iron grill set into a recess in the roof projection.

All external walls of main control room building/SPR shall be minimum 230mm first class brickwork plus one layer of Mirpur Ceramics or similar approved facing bricks. External walls of other buildings shall be minimum 230mm first class brickwork plus one layer of Mirpur Ceramics or similar approved facing bricks or rendered with cement render and painted as required by the architectural plan. The internal walls shall also be generally of minimum 115mm thick first class brickwork. Internal walls and ceiling outside & inside of false ceiling shall all be rendered and receive one sealer coat plus two finishing coats of emulsion paint. Externally, rendered walls shall receive primer plus two finishing coats of acrylic external quality paint or similar approved.

Particular attention must be given in the design of buildings and layouts to fire prevention and safety of personnel at all times. Buildings housing switchgear and control equipment shall be

designed as far as practicable to exclude pollution under all likely weather conditions. Fire-proof or flame-retarding materials are to be used for floor, wall and ceiling finishes. Where areas are designed as having a fire resistance rating then materials shall be shown to have passed approved standard tests for that class of fire resistance.

The minimum height of ground floor of two story control room building shall be 3.0 meter and the minimum height of first floor control room shall be 4.0 meter. False ceiling should be provided in the control room floor. In the switchgear rooms, minimum 1 meter clearance shall be provided over the switchgear to the underside of the roof slab but the Bidder shall provide a greater clearance if it is required to remove equipment. The clearance maybe reduced below down stand beams provided no equipment is required to be removed from the top of the switchgear. All rooms in any building in a story shall be of same height.

The false ceiling shall be made from non-combustible materials, and shall be easily removable to provide easy access to small power cables. Suspended ceilings, with acoustic tiling and incorporating lighting and air-conditioning fixtures shall be used in corridors, offices, toilet, control and SCADA rooms of the buildings and as per schedule of finishes.

In main control room building, all structures shall be designed to carry the loads imposed by the structure itself, together with minimum floor live load (including stairs) of 5.0kN/m2 (minimum) or in accordance with an approved standard or code of practice. The roof shall be designed for 2.5 kN/m^2 live load.

If the ground floor contain any machine or any equipment, then this floor should be considered as beam supported slab.

All doors opening outwards from the buildings shall be provided with panic latches or bolts which override any locking device, for escape in the event of fire. All doors shall be provided with overhead door closures of adequate capacity. Door labels incorporating electrical hazard warning in Bangla and English shall be fixed to each entry door. Vision panels shall be provided to frequently used doors.

Window openings shall be fitted with protruding concrete sunshades above and at the sides of the openings.

The domestic water supply system shall include all plumbing, underground pipework, high and low level storage tanks, valves, fittings and pumps (including the provision of a standby pump) for the provision of a pressurized water supply system for the static water tank and all buildings within the compounds.

On completion of the installation and prior to putting to use, the system shall be sterilized in accordance with an approved Code of Practice.

The Bidder shall be responsible for the provision and installation of a water supply serving the substation buildings. Every cistern, sink, basin, etc., shall be provided with as stop-cock in the supply pipe adjacent to the fitting. Each basin, sink and shower unit is to be provided with both hot and cold water. Provision shall be made for connection to the drinking water supply.

Each Toilet shall be provided with 1 no. western type WC, 1 no. wash-hand basin, 1 no. wall mounted mirror, 1 no. towel rail *etc.* all necessary fittings and accessories shall be provided.

Minimum capacity of the crane is mentioned in the price schedule. If the maximum lifting weight is more than half of crane capacity, then the crane capacity shall be twice times of maximum lifting weight. No additional payment shall be made in this regard.

Battery rooms shall be supplied with sink and drainer & exhaust fans (if no air conditioning).

The Bidder shall provide the fire/heat detector and portable fire extinguishers for main control building and local control houses. The fire extinguishers shall be of the dry chemical type suitable for the protection against Class A; B; C; fires. Each fire fighting units should be clearly marked as to its type and method of operation and of refillable-type cylinder. The details of installation for the fire/heat detector and portable fire extinguishers shall be provided to the Employer for an approval.

10A.3.2 Ground Conditions, Foundations and Site Investigation

(a) Fill Sites

The Bidder shall impose the site layout on the survey to check for uneven depth of fill below any foundation and where uneven depth of fill exists his foundation proposals shall restrict final differential settlement to a 1 in 400 slope.

If a fill site has not been exposed to one wet season before foundation work starts, the Bidder shall flood the site to a depth of 50mm for 10 days (Not required on hydraulic fill sites). This requirement is because silty sands will generally compact to a denser condition on first time flooding.

On all fill sites the Bidder shall pipe rainwater from down pipes down to paddy level and shall prevent water ponding in open foundations and backfill all foundations as soon as possible.

When a filled site is handed over to the Bidder, the Bidder shall become responsible for maintaining the entirety of the fill in good condition, including all better slopes.

(b) Unfilled Sites

Original delta levels are generally below road level. Therefore most sites are historically fill sites but fill settlement can sensibly be considered complete, where fill is over 3 years old.

(c) Site Investigation

Detailed methodology for subsoil investigation shall be submitted before implementing the subsoil investigation. All laboratory tests shall be done at the test facility approved by the Employer.

The Bidder may appoint a sub Bidder to carry out the site investigation but all work and all lab work shall be witnessed by one of his Geo-technical engineer who shall countersign all recorded data.

1 borehole should be counted for every 600 square meter of proposed project area and provided on suitable points. At least three additional boreholes should be provided for

control building and switchyard panel room building or any other building. For boundary wall/retaining wall additional boreholes shall be provided on in each corner point and at a maximum 50m interval point. Additional boreholes may also be required where uneven fill depth is encountered. The number and location of boreholes shall be approved with the site survey drawing showing existing ground levels specified in the section 10A.1.4. The boreholes shall be located to an accuracy of ± 0.5m and shall be located to site layout considering existing obstacles at the field.

Boreholes shall be a minimum of 25 metres depth or twice building footing width or upto the level where the foundation/pile will be rest whichever is greater. All boreholes shall be backfilled with compacted sand.

Borehole log together with a summary of all required laboratory tests is required to be prepared. Soil test locations are required to be indicated on the geographical map.

In each borehole the following tests shall be carried out:

- Standard Penetration tests at 1.5 metre intervals.
- Undisturbed samples shall be taken at around 1.5 meters, 3.0 metres and 4.5 metres depth for unfilled site; 1.5 metres, 3.0 meters, 4.5 meters and 7.5 meters depth for filled site and tested by unconfined compression tests.
- One dimensional consolidation tests shall also be carried out on undisturbed samples taken at 1.5, 3 & 4.5 meters depth. The samples shall be saturated and the range of applied pressure shall fully reflect the in-situ conditions. Graphs showing void ratio (e) and applied pressure shall be submitted along with the Coefficient of Compressibility for the range of loading anticipated. Mv shall be in m^2/MN and shall be recorded at each stress increment. The coefficient of consolidation, cv, shall be given in m^2/year.
- Particle size analysis shall be carried out for each stratum and specific gravity, moisture content, liquid limit and plastic limit determined.
- Ground water level shall be determined by dipping the boreholes for 24 hours. Where collapse of the boreholes occurs, casing shall be used and left in until the water level remains constant for two days.
- In cohesive soils a vane test to BS 1377: Part 9 shall be carried out at three different depths. The Bidder shall check the sensitivity of soil and ground water at each site to concrete and take all measures necessary to ensure the long term durability of concrete.

The Bidder shall give the Engineer the requisite period of notice prior to commencing the geotechnical investigation at the field. The field sheets of each bore log shall be signed by the geo-technical engineer of Bidder and representative of the Engineer. The signed field sheets shall be include in site investigation report.

(d) Site Investigation Report

The site investigation and analysis of the data in a final report giving full details of foundation proposals shall be completed at each site by the programmed date. During site

investigation, Geographical map shall be prepared indicating the locations of soil test.

The report shall be submitted by the key date at each site given in the programme. The Bidder shall submit 3 copies of the report to the Engineer. The report shall propose full details of foundations and loading thereon and shall provide estimates of likely settlements and differential settlements. The report shall be the work of the Bidder's own foundation engineers.

If the Bidder uses a local site investigation Bidder, he shall appoint one of his geo-technical engineer to oversee the entire operation and each piece of data shall be countersigned by this person.

Where estimated settlement exceeds 25mm, the Bidder shall construct one foundation at an early stage and test load this foundation to confirm settlement predictions.

(e) Foundations

Regardless of the result of soil investigation report, the foundations of Main Control Building, gantry structures and auto-transformers shall be provided with piles. Others buildings foundation shall be provided with shallow or pile foundation as per soil condition. All earth retaining walls shall be RCC. Based on site and soil conditions, boundary walls with/without RCC retaining wall may be designed with pile foundation or shallow foundation. But, if width of footing perpendicular to wall exceeds 3000mm, then pile foundation must be provided for boundary walls (refer to enclosed drawing). Stability of surrounding & underlying soil and settlement of the wall foundation must be ensured by the contractor.

Piles shall be concrete (cast-in-situ or precast) complying with BS 8004. For structural design of cast in situ piles, guidelines provided in **Annexure 10A.1** should be followed. One working piles shall be randomly selected by the employer for pile load test in accordance with BS 8004. One working pile of control building and one of auto-transformers at each site shall be compression load tested and one working pile of gantry tower foundation at each site shall be uplift load tested to 100% of design load in accordance with BS 8004.

Other foundations of outdoor equipment shall be provided shallow/deep as per subsoil investigation report, settlement test as well as plate bearing test. In case of shallow foundation for outdoor equipment the bearing capacity of proposed soil level shall be checked by the Plate Bearing Test.

For shallow foundations the minimum depth of foundations shall be 1.5m.

All formations shall be hand rammed or mechanically compacted before placing 75mm minimum thickness of Class B concrete blinding, within 24 hours of bottoming excavation, which blinding shall project 75mm minimum distance beyond all footings. Each footing shall be inspected by the Engineer. Where soil condition is poor (on fill sites or already filled sites) or where the Bidder leaves foundations exposed and soil conditions deteriorate, one of the following measures shall be carried out as agreed with the Engineer:

i) Blinding depth and projection shall be increased as necessary.

ii) Soft soil shall be removed and replaced with compacted filling sand with the top 300mm (Minimum) consisting of sand and khoa (brick chips) in 2:3 ratio with 95% level of compaction.

The cost of this work shall be borne by the Bidder.

The Bidder shall propose the allowable bearing pressure for all foundations based on soil strength parameters only and shall not be increased while wind loads exceeds 25% of dead load as well as shall not exceed 125kN/m^2. Between column footings all walls, including all internal walls, shall be provided with a reinforced concrete strip footing of minimum dimension 800mm wide by 250mm deep placed at the same level as column footings and linked structurally to the footings. Column footings shall be tied at foundation/grade beam level and also floor level by beams to every adjacent column in both orthogonal directions.

The deepest parts of any foundations shall be completed first. All foundations shall be completed and backfilled, including all cable tunnel and cable trench work inside buildings, before walls are raised above floor levels. All other foundations shall be backfilled within 7 days of completing concreting.

All exposed concrete and the outer surfaces of cable trenches and cable tunnels shall receive three coats of bitumastic paint before backfilling to reduce ingress of water. The Concrete surface shall be ground smooth and all air holes *etc.* filled (rubbed down with a cement slurry) before painting.

The Bidder shall monitor settlement of all foundations each month and report this settlement to the Engineer until settlement has reduced to less than 1.5mm in 3 months.

The tops of all foundations shall terminate 200 mm above site average finished surface level. All exposed edges shall have 20 mm x 20 mm chamfers.

Excavation shall only be carried out when the ground water table is at least 1000mm below foundation level. The excavation shall be kept dry during the construction period by providing sumps and pumps as required. During the rainy season, shelters shall be erected over all open excavations. For dewatering, slurry wall with required specific gravity may be used.

Excavations shall be adequately supported or formed to ensure stability of the sides and prevent any damage to the surrounding ground or structures. The design of suitable sheet piling and/or timbering for excavation shall be in accordance with the recommendations of BS 8004 Section 5.

When the Contractor requested shall submit details of his temporary support to the Employer.

Excavation shall not be carried out below or adjacent to existing building foundations until under-pinning and shoring have been completed by the Contractor.

The Contractor shall not permit water to accumulate in any excavation unless otherwise agreed. Any water whether arising from the excavation or draining into shall be drained or

pumped to an approved location well clear of the excavation area in a manner that does not cause erosion, silting or contamination of existing drains and watercourses. Before the method of ground water lowering is selected, adequate knowledge of the ground and water conditions has to be obtained from the results of a soil investigation and/or information

The Contractor shall take adequate steps to prevent adjacent ground from being, adversely affected by loss of fines in any de-watering process.

Any over excavation shall be filled with Class B concrete.

All backfill shall be compacted to 95% maximum dry density as defined by BS 1377 test method part 4, 2.5 kg rammer.

Before starting foundation work the Bidder shall clear all sites of trees, tree roots, shrubs, debris, surplus soil, and any buildings.

Foundations shall be designed to resist uplift, assuming the water table is at ground level and the weight of soil resting on a foundation is that included within a 15˚ frustum.

10A.3.3 Drainage

The entire surface within boundary walls shall be of uniform sloping site, sloping at 1 in 500 minimum slope to open channels around the entire perimeter. These channels shall be designed for a rainfall intensity of 60mm per hour. Outside the boundary wall the Bidder shall be responsible for drainage up to 20 metres from the wall and will at some sites need to construct outlets with suitable erosion protection down to paddy level.

The concrete wall of cable trenches shall project at least 50mm. above brick paving level to prevent run off entering the cable trench. The floors of all cable trenches/tunnels shall be sloped to soak well as described in 10A.3.18.

The cable trenches will thus form barriers to surface water drainage. If the cutoff area exceeds 30m^2 it shall be drained by constructing Water Catchment Pits (WCP) with a 200mm minimum diameter uPVC pipe to the boundary drain. The Bidder's drainage design shall avoid all ponded water to avoid forming a mosquito breeding ground.

All drainage pipework within buildings shall be uPVC type, generally of 100mm diameter or as per requirement. Floor drains shall be placed in each battery room and toilet.

External pipework shall be 150mm. minimum diameter uPVC pipes at a minimum depth of invert of 300mm. Where pipes, including existing pipes alongside site, are less than 400mm above adjacent foundations they shall be surrounded in concrete. Where required, drainage pipes shall be kept below cables, allowing 1.1 m cover to top of pipes.

Manholes shall be of brick construction with minimum 450mm x 450mm clear openings and airtight RCC/ductile iron covers to BS EN 124. Manholes shall be located at each change of direction. Minimum fall on all pipelines shall be 1 in 150. Manholes shall not be located in roads.

The Bidder shall be responsible for all negotiations with local authority/WASA where a connection to a public sewer is proposed. Where high water levels in public sewers may cause

effluent to back up into a site, no return valves shall be fitted. The Bidder shall provide all protection required to existing sewers and shall deepen foundations, including boundary wall foundations, where required to ensure all foundations are below adjacent sewers. The Bidder shall draw longitudinal sections of all pipelines.

Septic tank and soak well for Main Control Building shall be constructed as per provided drawings. The septic tank shall be located at least 15 meters from buildings/ water pumps. The pipe network for septic tank should be designed considering self cleansing velocity. Inspection pits should be provided at regular intervals. Other buildings shall have septic tanks designed for the required number of users. All foul drains shall be vented by a vent pipe to above roof level. The inner surface of all manholes and septic tanks shall be painted with 2 coats of bitumastic paint to protect it against sulphate attack. The septic tank shall have access holes directly over the inlet pipes and outlet pipes. Where public sewers exist alongside a site, the Bidder shall connect directly to the foul sewer, provided effluent from the sewer is treated.

The Bidder shall construct the drainage first to ensure that at no stage is rainwater ponded on any part of the site. All rainwater shall be able to run off the site or shall be immediately pumped off site by the Bidder. The Bidder shall complete all necessary drains before casting any roof and large concrete area which will create large run off. The condensate drains for the air conditioning shall also be connected to the drainage. Bottom of drain shall be sloped at 1:300 minimum.

If a town's water supply is unreliable, the roof rain water shall be collected in an underground tank of standard Employer's design.

10A.3.4 Surfacing

For the whole of the switchyard outdoor equipment area the ground shall be surfaced with gravel or other readily available local materials as approved by the electrical design. Gravels/other materials shall be clean, thoroughly washed when necessary, and free from clay, soil or contaminating material and shall be graded from 20 - 45mm except needed otherwise, laid and lightly compacted to a finished thickness of 175mm or as required by electrical calculations. Below the gravel/other material layer there shall be a 75mm brick layer with cement mortar (1:6), laid over a 75mm level of fine sand spread over the finished fill site.

Landscaping in the vacant space of substation area shall be done with acceptable tree plantation, flower gardens and turfing.

The substation plot, outside of the designated switchgear equipment areas, shall be turfed. Turf shall be of good quality, free from weeds and other impurities. Samples of the turf which is proposed to use shall be submitted to the Engineer for his approval. The turfs shall be laid to even surfaces on a bed of plastic/vegetable soil of 150mm thickness, which shall be raked and consolidated to provide a suitable bed.

On sloping surfaces the Bidder shall provide and fix wooden pegs to retain turfs.

All areas to be surfaced shall first be treated with a total weed killer in accordance with the manufacturer's instructions. Weed killer shall only be applied in dry weather when there is no risk of it being washed out to adjacent agricultural areas.

10A.3.5 Roads

Access road from outside the site boundary to connect to any adjacent public road and all roads within the site boundary shall be provided by the Bidder. The road surface shall be finished by concrete paving or equivalent. All roads shall be of reinforced slabs of minimum 150mm thickness fitted with construction joints at distances not exceeding 6.0m. Paving schedule and methodology shall be approved by the Employer. The extent of roads required is shown approximately on Bid drawings but the scope of the work may change. Road layout shall generally permit vehicles to turn easily to avoid having to reverse out. Road layout shall be designed by the Bidder. The bidder shall visit the sites and assess all practical requirements like culvert design & construction, removal of any obstacles, permission from local authorities etc. for access road. All necessary works shall be the bidder's responsibilities.

The width (between the outer edges of kerbs) of access road from outside the site boundary to connect to any adjacent public road shall be 6.0 meter. Width (between the outer edges of kerbs) of all roads within the site boundary shall be generally 6.0 meter transformer, 4.5 meter & 3.0 meter for sub road and 1.5 meter for walkway.

The road edge shall be formed by Class B concrete kerb 250mm wide by 400mm deep, placed over one layer of bricks laid flat. The road shall be a Class A concrete slab of minimum 150mm deep at each edge with 1:50 inward slope and stiff broom concrete finish reinforced with 10mm bars at 250mm centres longitudinally and 10mm bars at 250mm centres transversely placed 80mm below the upper surface. Expansion and contraction joins shall be detailed on site plans. Expansion joints shall be filled with hot bitumen & sand (2:1) sealant. Below the slab shall be a layer of polythene 0.5mm thick laid over one layer of 1st class bricks laid on edge in herringbone fashion in and on cement mortar (mortar designation iv) laid over one layer of 1st class bricks laid flat in and on a layer of sand laid on insitu soil which shall be compacted as agreed with the Engineer. If the soil is clay a 75mm drainage layer of broken bricks shall additionally be placed over the soil.

The radius of the road edge at corners shall not be less than 3 metres and 1.2 metres either side of the road shall be kept clear of obstacles. Bollards or raised kerbs shall be provided where required to protect items alongside a road from vehicles. Ducts shall be provided below roads for all services in this Contract and for all future services.

Where mortar designations are referred to see BS 5628 Mortar designation iv is 1 cement: 2 Lime: 8 to 9 sand.

At each new substation site a two bay hard standing car port, complete with sun shades, is to be provided adjacent to the control building.

10A.3.6 Water Supply

The Bidder shall be responsible for providing a water supply both for construction and for operation of the completed sites. If a town's water supply is not available, the Bidder shall install a deep tube well of 40mm minimum diameter and 100m minimum depth with necessary pumps including all fittings, pipes *etc.* as required. But in that case guideline specified by WHO for drinking water is required to be satisfied. The Bidder shall supply and commission power supplies and all pumps required by tube wells.

If a town's water supply is available, the Bidder shall be responsible for making all necessary arrangements with local authority/WASA to connect a supply. If the pressure in the supply is inadequate to supply the roof tank continuously, the Bidder shall install a 1800 litre low level tank and pumps. This tank shall be below ground with a 200mm minimum air void around the tank to protect it from contamination. The pump control panel shall be located in the building. Water levels shall be controlled by float switches but the panel shall provide also for manual operation.

The supply shall be connected to a 2000 litre food graded plastic tank. This tank shall be raised 400mm clear of the line terracing on four brick piers of minimum 350mm square. All supplies in buildings shall be fed from the roof tank. The supply to the tank shall have a valve at waist height. The tank shall have an overflow returning to the location of this valve. No pipes shall pass through the roof directly over any room. Pipework shall be routed up the outside of the building and return pipes shall return down the outside of the building before entering through the wall. Pipework shall be CPVC secured by clamps at 1.5 metre intervals and painted with alkyd paint to match walls. All pipes should be concealed by brickworks on vertical walls.

10A.3.7 Plumbing and Sanitary Fittings

The Bidder shall prepare a drawing of all plumbing and building drainage for each building. Sanitary fittings and plumbing materials shall generally be of approved local manufacture.

In main control building each toilet shall have a single western WC. Each toilet outlet shall be vented by a 100mm diameter uPVC vent pipe passing up the outside of the building to 2500mm above roof level. Beside each toilet shall be placed a low level tap. Main control Building toilets shall also have a wash basin and cold and hot water shower with 10gallon capacity geyser for each toilet. Toilets and showers shall have all walls tiled upto the bottom of false celling.

Every tap and cistern shall have stop cocks in the supply pipe. One external tap shall be provided on each building. Battery rooms shall be provided with a stainless steel sink of approximate dimensions 900 x 600 x 200mm with a draining board to one side. The battery room floor drain shall be connected to the foul drainage. All floor drains shall have P traps.

Mirrors shall be installed over toilet wash basins. Care shall be taken in orientation of toilets to avoid offending religious sensitivities. Toilets shall generally be orientated North South where possible. Each shower shall have a wall on two sides and a porcelain shower tray sunk into the floor. Soap dishes shall be provided beside each shower.

Only foul water from WC pans shall be connected to septic tanks. All other water shall flow to surface water drains.

10A.3.8 Building Floors

All topsoil containing roots shall be removed and the insitu soil compacted before placing backfill. All backfill, including the backfill to column footings, below the floor shall be sand. The floor and all cable trenches shall be made of Class A concrete. The ground floor slab shall have a minimum 125mm thick reinforced Class A concrete furnished with non-skid floor tiles and shall rest on the compacted fill. Below the slab shall be placed a layer of polythene 0.5mm and a layer of sand khoa (2:3) compaction of minimum100mm thick, hand rammed to a smooth upper surface.

All cables from cable trenches shall enter the building over grade beam level, no cable trench shall be allowed into main control room building. Where power cables traverse a building to reach a switchgear room on the far side they shall generally be contained within cable tray.

All sand backfill shall be compacted to 95% optimum density and shall be tested. The fill within a building, above ground level, shall not be placed until all backfill outside the building is completed. All floor slabs shall have a damp proof membrane of 0.5mm thickness.

Wherever required, control building shall have a ramp at a slope of approximately 1 in 7.5, of 1.5m minimum width with a Concrete Class A slab of min depth 125mm with a stiff brush concrete surface finish, or other agreed non slip surface.

All floors (including verandahs) except for cable basement, GIS room, control room and battery roomshall have 25mm homogeneous floor tiles topping. All external steps where public access is given to buildings shall have marble tiles toppings. Elsewhere, concrete surfaces shall be used for all external floors/steps. Verandahs shall have a minimum 1:50 slope to shed rainwater away from buildings. Concrete floors and steps shall also be treated with 3coats of Lithurin or other approved concrete dust proofer.

Verandahs shall have a minimum shed of 1:50 slope to rainwater away from buildings.

If floor tiles are not adequately durable to withstand switchgear movement when rolled out to the maintenance position, then galvanized steel chequered plates shall be inserted in the floor to resist the abrasion from switchgear wheels.

10A.3.9 Cable Basement

Ground floor of the control room building shall be used as cable floor.

10A.3.10 Battery Room Floors

Battery rooms shall have a concrete floor sloping to a cast iron floor drain. The concrete surface shall be treated with Nitocote epoxy resin coating (Nitoflor primer plus two coats of Nitocote in accordance with manufacturer's instructions), or similar approved material, to ensure resistance to battery electrolyte. There shall be no cable trenches in battery rooms. Cable entrances through the floor shall be protected by a raised plinth 50mm high around the opening with the annulus around the cable sealed after installation.

10A.3.11 Control Room Floors

No raised floor except for panel installation shall be used.

10A.3.12 Site Clearance, Obstructions and Adjacent Structures

The Bidder shall be responsible for clearance of:

(1) Trees, shrubs and any vegetation including the extraction of all roots and compaction of backfill where roots have been extracted.

(2) The removal of all buildings, sheds or any other structures above or below ground including the removal of any septic tanks, drains or other underground services.

(3) The removal of any existing surfacing, roads, foundations or any other obstruction.

All material cleared away by the Bidder shall be the property of the Employer and shall be removed by the Bidder to a site in the Project area upon instructions of the Employer. The Employer may remove any buildings or structures himself from sites before the commencement of site works.

Where an existing service, existing equipment or adjacent building is to be retained, the Bidder shall take all necessary measures to protect the item concerned from damage and shall be responsible for ensuring that no movement of foundations occurs during or after completion of construction.

Any existing electrical equipment/cables which have to be modified or repositioned shall be included in the works at no extra cost. Any buried gas or water main services which require to be diverted shall be deviated by the Employer at his cost. However, where it is possible to retain these existing services and build new structures around them, the Bidder shall take all necessary measures to build in the service at no extra cost.

10A.3.13Guard Houses, Boundary Walls, Fences and Entrance Gates

The guard house serves for control of entrance. The gatekeeper shall be able to watch the area before and behind the guard house. The guard house shall be provided with toilet, water supply facilitates. Small power and lighting facilitates are to be provided in the Guard Houses.

The Contractor shall base his design of boundary walls and gates following bid drawing and subsoil investigation report. Where sites are within existing Employer's boundary walls, the Contractor shall construct a permanent chain linked fence 1.5m high in accordance with BS 1722 part 10 or similar approved.

10A.3.14 Windows

Even natural light shall be provided by windows to illuminate all areas of buildings. Window area shall be about 6% of floor area to limit solar heat gain. Tops of windows shall generally be minimum 2100mm from floor level but toilet windows may be higher. The bottom of windows shall be generally at least 0.45 metres above floor level. Each window shall be provided with a sunshade projecting about 350mm from the wall above and at the upper sides of the window. Few windows shall be placed on south facing walls. Windows shall be spaced to give a wide view of the switchyard.

Windows shall have single glazing with 6mm thick glass, reinforced with wire mesh where windows are placed in or over doors.

Window frames shall be anodised aluminium minimum thickness 1.5mm.

Glass panels shall be placed over doors to provide natural light to internal corridors and rooms where required.

External cills shall have a sloping tile or similar detail with drip.

The Bidder shall prepare a window schedule for each building.

The schedule shall clearly indicate both fixed and opening windows.

The Control and Switchgear rooms in particular shall have opening windows to allow adequate ventilation. Approved quality of MS grill shall have to be provided to all windows. All MS grill will be painted with one coat of red oxide primer and minimum two coats of approved quality synthetic enamel paint.

10A.3.15Doors

Internal doors and door frames shall be anodised aluminium. Main Entrance/Exit doors and door frames shall be steel or anodised aluminium.

The minimum size of the structural openings for doors shall be 1550mm wide for double doors and 930mm wide for single doors. Door height shall generally be 2100mm but switchgear and control rooms shall have a removable transom and removable panel over the door or a taller door to provide a total height of about 2100mm. All door sizes and widths shall be adequate to get in and get out all equipment and future equipment.

All external doors shall have weather boards, hydraulic closers and cabin hooks to hold the door open. External doors shall open inwards, except for switchgear room doors which must open outwards and be fitted with panic release latches.

Each wooden door leaf shall have minimum four 150mm heavy iron hinge. Door furniture shall be of approved local manufacture and shall generally be of brass. All corridor doors, external doors and rest room (toilet) doors shall be fitted with hydraulic closers. Door stops shall be fitted where required. Door frames shall generally be set 200mm off a wall junction to enable the door to open fully through 90˚.

All external doors shall be shaded by either the roof canopy of minimum 350mm or a separate precast concrete canopy over the top and the upper sides of a door.

The Bidder shall prepare a schedule of all doors and all door furniture for each building.

10A.3.16Brickwork

Brickwork shall be designed to BS 5628. External panels of brickwork shall be checked for wind pressure calculated in accordance with BS 6399 for a wind speed of 160 kph 3 second gust.

Bricks shall be first class bricks from approved manufacturers. 10 bricks shall be tested in accordance with BS 3921 to determine water absorption and crushing strength, which shall exceed 20N/mm^2. Mortar shall generally be mixed at a ratio of 1:5 (cement : sand).

All brick panels shall be tied to the concrete frame of approved design.

Facing bricks shall be approved quality and size from Mirpur ceramics or similar approved. Facing bricks shall be tied back to the main wall of control room building/SPR. External walls shall be 230mm thick brickwork, rendered internally and clad externally with facing bricks or rendered as required by the architectural plan.

Bricks shall be compacted down onto a full bed of mortar. Vertical joints shall be completely filled with mortar. Joints shall be raked out about 10mm deep where walls are to be rendered.

Brick walls shall be constructed so that tops of all meeting walls are about the same level. Only 18 courses per day shall be laid. New work shall be protected from sunlight and drying winds for 4 days.

Lime and cement for all brickwork shall be stored in a dry building with a raised dry floor.

Reinforcement by mild steel rods shall be provided where required by the design. Additionally openings over 500mm. wide shall be reinforced for 2 courses above and below the opening, minimum two 8mm bars per course extending 300mm beyond the opening both sides where possible.

All exposed brickwork shall be rendered and painted where not faced with facing bricks.

10A.3.17Expansion Joints, Joint Fillers and Sealants

Not used.

10A.3.18Cable Trenches in Switchyards

Cable trench sizes shall be standardised. Layout drawings shall be submitted for each substation showing layout and size of trenches. No trench shall cross a road; power cables shall be placed in ducts of minimum 150mm diameter with bell-mouthed ends. Ducts shall extend 1500mm minimum beyond the edge of roads. Spare ducts shall be installed for likely future development.

Floors and walls of trenches shall be constructed of Class A reinforced concrete of minimum 150mm thickness, with the external surface painted with two coats of bitumastic paint. Walls and covers shall protrude at least 70mm above site finish level and the top of the wall shall be flat with no rebate. Floors shall be sloped at 1: 150 minimum slope to brick soakaways placed at the side of trench; the volume of each soakaway shall be 2.5m^3 per 150m^2 of trench.

Covers shall be of reinforced concrete Class A. Each cover weigh less than 55 kg. The minimum depth shall be 70mm, with down stand ribs along each side providing a minimum overall depth of 100mm. The ends of the cover shall overhang the wall by 15mm and in the centre of each end there shall be a hand hole of minimum size 100mm by 20mm high. This hole shall allow air to ventilate the trench so that heat built up in the trench shall be reduced. No gaps larger than 5mm shall be left between adjacent covers so that the cables are always shaded. Cover slabs shall sit squarely and uniformly on the trench walls without the need for bedding or shims. Because portable fire extinguishers will be rolled over and along trenches, each cover shall be capable of resisting a 250kg point load at mid span. The Bidder shall provide ramps up to the edge of covers in several locations, as agreed on site, to enable the wheeled extinguisher to mount the covers. Longitudinal edges may be inclined at 10˚ to the vertical, thus creating a larger gap at the bottom of adjacent slabs, again to reduce heat build-up. The upper surface of covers shall have a stiff broom non slip concrete finish. All sharp edges shall be stoned smooth. Outer edges shall be chamfered.

Longitudinal fire separation walls and transverse fire separation walls as required by the cable section, may be of brick or reinforced concrete.

10A.3.19Cable Trenches in Local Control Building/SPR

No cable trench shall be allowed into main control room building, all cables from cable trenches shall enter the main control room building over grade beam level.

Inside local control building/SPR, entry of cable trenches may be permitted. The base and walls of the trench shall be of reinforced Class A concrete of minimum thickness 110mm with the outside face painted with 2 coats of bitumastic paint. Cable trays may be supported by Unistrut P3300 inserts, or similar approved, or drilled anchor bolts.

The building layout shall minimise trench lengths. Where power cables pass through a building to reach the far side, this shall generally be in a tunnel section. The Bidder shall be responsible for providing all trenches and ducts in a building, including ducts for outgoing power cables up to the site boundary and including any pulling pits required.

Trench covers shall be sheets of composite board, PERMALI YA 729 or similar approved, consisting of wood fibres impregnated and compacted in synthetic resin, or a computer flooring composite board. The weight of each cover shall be restricted to about 30 kg. The upper surface shall be skid resistant. Deflection shall be limited to 1/250 of span under a load of 3kN/m^2. Only one thickness of board shall be used to standardize the edge support detail. The recess to receive the cover shall be protected by steel or brass on the vertical edge and bedding surface. Covers shall fit snugly around all cables. Where cables enter the building, all ducts/trenches shall be sealed. Fire/oil barriers shall be required to separate hazardous equipment. The ends of all ducts entering trenches shall be bell-mouthed.

Any beams used to support large span covers shall be removable. All metal work shall be painted as specified in the paint section.

All covers shall bed down evenly. Full detailed fabrication drawings shall be provided for all covers.

10A.3.20Rainwater Pipes

Down pipes shall be 100mm minimum diameter placed on the outside of walls but enclosed in a brick buttress of facing bricks. One downpipe shall be provided for each 100m^2 of roof area. The head of the downpipe shall be enlarged to 200mm diameter and a purpose made cast iron grill provided over the head. This grill shall be sited in a recess in the roof slab projection.

The foot of the pipe shall have a 90˚ bend and water shall be discharged into either:

i) a small open channel conveying the water to the boundary channel

ii) a pipeline conveying the water off the site. Rainwater shall not be connected to the septic tank or allowed to discharge directly onto switchyard paving.

10A.3.21Switchyard Foundations

The tops of all foundations shall be set at the same level, which shall be raised above the Finished Switchyard Level (FSL) for the purpose of preventing surface water coming into contact with the equipment structures and holding-down bolts. The distance between the Finished Switchyard Level (FSL) and the top of foundations shall be at least 200mm. All exposed concrete surfaces shall be painted with an acrylic weather proofer or bituminous paint, and flat areas shall

be sloped to shed water. No base shall permit ponding of water in any way, and free drainage shall also be possible from all areas inside any grouting.

Bases shall generally be of Class A reinforced concrete.

Bases shall have all recesses for cables and earthing detailed on drawings. The drawings shall clearly show the orientation of each base and the location of all recesses. Where new foundations are adjacent to existing foundations; the Bidder shall be responsible for verifying the extent of the existing foundation and ensuring its stability.

For anchorage design of switchyard foundations shear force, vertical accelerations, overturning moments and torsion due to mass eccentricities of the equipment for the earthquake load of 0.1G are required to be considered. Mild steel ductile bolts and headed studs cast-in-place anchor bolts shall be used. Thick plate washer is required to be welded to the equipment base plate. Normal washers shall be used under a nut in all cases.

10A.3.22Transformer Bases

The transformer base, together with its surrounding bund shall form a raft to distribute the load from the transformer over the entire area within the bund wall. The bund shall extend at least 700mm beyond any part of the transformer and its radiators. The level of the top of the bund and the skids shall be 200mm above general switchyard level. Skids shall extend to the edge of the bund. Where separate transformer cooler banks are provided, the cooler banks shall also be protected by the bund.

50mm below the top of the wall shall be placed a layer of stone 225mm deep set on a galvanised grill painted with two coats of bitumastic paint. The effective volume of the bund below the stone shall equal 125% of the total volume of oil in the transformer and its radiators.

Rainwater will tend to collect in the bund. To evacuate rainwater a fixed submersible pump controlled by sensors and switches (Aqua Sentry or equal) shall be provided at each bund with power supplies and drainage manhole conveniently located. The bund water control system shall differentiate between water and oil to ensure that the pump will not be activated while oil is present in the bund.

The transformer base and the bund shall be founded a minimum 1.0 metres below Finished Ground Level (FGL).

The skid walls shall be at least 600mm wide. RCC piles shall be provided below each jacking point to lift the transformer. Top level of jacking pad should be at the same level of skid wall. Steel plates shall be inserted at the top of jacking pad.

The entire concrete surface of the bund and the transformer base which is not buried shall receive two coats of bitumastic paint. Skids shall receive 3 coats of bitumastic paint before being cast in.

Carriage way is required to be provided with rail connected to all transformer bases. Transformer shall be anchored in such a manner so that it can prevent the movement of transformer for 0.2G ground acceleration.

10A.3.23Blast Walls

The Bidder shall construct blast walls to reduce the risk of fire spreading from each three phase transformer unit to an adjacent transformer unit or control building. If the clear distances of transformer from GIS control room building less than the transformer height, then a blast wall should be provided between the transformer and the GIS control room building. Blast walls shall also be constructed to resist impact forces causing from a transformer explosion damaging adjacent equipment.

The height of the blast walls for transformers shall be 500mm higher than the tops of transformer or 500mm higher than the height of the tops of the HV bushing (whichever is higher) and 300mm wider at both sides than the width of transformer. The minimum thickness of blast walls shall be 200mm.

The blast wall will be constructed with Class A reinforced concrete with all exposed edges chamfered, Surface of wall will fare faced concrete and painted as the colour of transformer body.

10A.3.24Paints and Painting

All paints shall be of approved makes and colours and proven suitability for the prevailing climate and shall be approved by the Engineer. All surfaces for painting shall be cleaned down prior to being painted and rubbed down to a smooth finish.

All externally exposed concrete and render of the control buildings, boundary walls,blastwalls and guard posts shall be painted with a fungicide, Snowcem primer and two coats of Snowcem. All exposed facing bricks and Snowcern painted surfaces shall be treated with one coat of clear silicone (5%) water proofing solution.

All exposed parts of foundations, the outer faces of cable trenches and cable tunnels shall be painted with three coats of bitumastic paint.

All ungalvanized metalwork shall receive two coats of red oxide paint at least 4 days before installation and shall receive two finishing coats of paint after installation, each coat being of different colour. Surface preparation before painting shall be SA 2.5 or an agreed rust convertor acid shall be used. All galvanized steel, boundary wall wire supports, cranebeams, baseplates and holding down bolts and concrete plinths shall receive two coats of bitumastic paint. Galvanized steel shall not be painted until the surface has weathered.

Internal walls when fully dry shall have the surface rubbed down with sandpaper and be painted with a sealer and 2 finishing coats of plastic emulsion paint before equipment is installed. A further finishing coat shall be applied after completion of installation.

One day shall be allowed for drying of each coat before the next coat is applied.

The interior of all septic tanks and manholes carrying foul sewage shall receive two coats of bitumastic paint.

10A.3.25Furniture

The Bidder shall supply a complete set of tables, chairs, stools, desks, benches, storage shelves and drawing cabinets as described in the Project Requirements, Volume I with layout top, for drawing examination, lockable cabinets for spares and test equipment and key boxes in each

control building. These shall generally be of steel of local manufacture and shall be of robust durable construction. In each rest room (toilet) two couches, approximately 900mm wide by 1900mm long with back rests against the wall, shall be provided.

The full details and specification of these materials shall be agreed before purchase. The Bidder shall arrange for a list of items to be handed over to the Employer, who will sign for receipt of a complete set as stated on the list.

10A.3.26Concrete

Only two class of concrete shall be used. Class A shall be used for all structural work, piling and for all foundations which are not unreinforced massive blocks. Class B concrete shall be used for blinding, pipe surround and unreinforced or nominally reinforced concrete. Road slabs and floor slabs all shall be reinforced Class A concrete.

	Class A	**Class B**
Minimum Cement Content	360kg/m^3	170kg/m^3
Maximum Water Cement ratio	0.55	-
Coarse Aggregate type brick	Well graded crushed stone chips	Jhama
Maximum Coarse aggregate size	20mm (40mm for piling)	25mm
Method of Batching batching	Volume batching	Volume
Minimum Characteristic of Trial		
Minimum at 28 days	30N/mm^2	-
Minimum characteristic strength		
of trial mix at 7 days	14N/mm^2	-
Minimum characteristic strength		
of works cubes at 28 days	20N/mm^2	-
Slump Range	30 -100mm	50mm min
Slump for concrete placed	100-200mm	-
below water in piling		

It should be noted that minimum specified cement content will produce significantly stronger concrete. The Bidder's design shall be based on a 28 day crushing strength of minimum 20N/mm^2. Design shall be in accordance with this Contract and BS 8110 or other agreed standard.

For all types of foundation work mild steel of minimum characteristic strength 415 N/mm^2 shall be used and minimum reinforcement required for pedestals and foundation bases shall be 0.5% and 0.13% of gross cross sectional area respectively.

Minimum cover to rebars shall be 60mm where concrete is in contact with backfilled soil against a shuttered face, 75mm where concrete is cast against soil, and 38mm for all above ground concrete. In detailing bars which traverse a member, a reduction of 5mm shall be made for a bent bar and 10mm for a straight bar to ensure adequate cover. Exposed ends of sunshades and roof projection shall have 70mm minimum cover.

All concrete design shall ensure easy access for vibrators of 50mm. minimum diameter. Because of the slowness of concreting using local methods of transport, congested reinforcement details and shapes which are difficult to concrete should not be used. The location of all cold joints shall be agreed in writing with the Engineer and all joint surfaces shall be scabbled. All joints shall be horizontal or formed against vertical stop ends. Shear key shall be provided in joints. All cold joints shall be indicated on drawings. Roof slabs shall generally be cast in one continuous operation. Where curing compounds are used to protect exposed surfaces from solar radiation and improve moisture retention, they shall be subject to the approval of the Employer. This is a **Hold Point**.

10A.3.27Concrete Reinforcement

The Bidder may use locally available mild steel bars from approved sources or import steel bars to any agreed standard. No bar or stirrup shall be smaller than 8mm diameter to ensure adequate rigidity during concreting.

If locally purchased bars are used, bending tests and tensile tests shall be carried out to ensure the bars meet the design standard adopted and weight per unit length shall be tested regularly.

Bar bending lists shall generally be shown on drawings, where possible with a diagrammatic representation of each bar to ensure clarity and ease site communication. The Engineer will not systematically check the accuracy of every bar on bar lists when approving drawings. The Bidder shall therefore arrange to check all bar lists. Drawings shall detail all chairs and ties and include these on bar lists.

Bars shall be tied at every intersection and the ends of tie wire bent away from concrete surfaces.

Anti crack bars shall be provided at changes in slab or wall thickness and at the corners of every rectangular opening.

10A.3.28External Render

All brickwork which is not faced with facing bricks shall be rendered. Concrete columns and walls shall be rendered and painted in accordance with BS 5262 with a 3mm spatterdash coat a 12mm undercoat followed by a 9mm finishing coat. Surface preparation shall be as described in BS 5262. Joints shall be provided in all render where brickwork panels abut concrete columns and grade beams, as required by BS 5262.

A mix type II or III shall generally be used. The finishing coat shall be weaker than the undercoat.

The tops of all foundation blocks and all protruding concrete foundations shall also be rendered where required by the Engineer.

PVA Bonding agents shall not be used because of the risk of early drying in the tropics. All concrete surfaces to be rendered shall have the entire surface scabbled and brushed with a stiff brush to remove all loose material. The surface of the undercoat shall be roughened to ensure bonding of the finishing coat.

All render once completed shall be kept continuously damp for 10 days, after which if shall be treated with a fungicide. Any existing backgrounds shall be treated with a fungicide and all growth cleaned after 5 days of contact with the fungicide.

10A.3.29Goalposts

In each outdoor switchyard with live conductors crossing roads the Bidder shall erect a permanent goalpost at the edge of the danger area with red and white metal warning boards hanging down from the goalpost to warn high vehicles of the overhead danger. This structure shall conform and match those supporting structures in Section 11 of this Contract for the high voltage switchgear.

10A.3.30Lifting Beams (Not required for this contract)

Deleted.

10A.3.31Stairs

Except where indicated otherwise in the schedules, all single/multi story buildings shall have internal/external staircase up to the roof; the minimum staircase clear width shall be 2.5metre and the maximum slope about 30˚, all detail being designed in accordance with BS 5395. These staircases shall be enclosed. The design shall allow free circulation of air over the treads and through the risers. Non slip nosings shall be provided.

Main control building shall have one internal and one external staircase, which shall have a minimum clear width of 2.5metre with a maximum slope of 30˚, all detailed in accordance with BS 5395. External staircases shall not be enclosed but shall be completely protected against rain by roof projections; steps shall be open with non slip nosings. Internal staircases shall have homogeneous floor tiles with non-slip nosings. All staircases shall be provided with stainless steel railings (38mm dia. for vertical railing & 50mm dia for horizontal railing).

All roofs which are not accessible by stairs shall be provided with a galvanised steel fixed ladder.

10A.4 CONCRETE WORKMANSHIP

10A.4.1 General

At all stages in the production, mixing, placing and curing of concrete, the work will be inspected by the Engineer's representative. If any material, dimension or practice is not at least equal to the standards set out herein, it shall be rejected and alternatives compliant with the said standards, and in addition to the satisfaction of the Engineer, shall be implemented.

10A.4.2 Aggregates

Coarse aggregate shall be capable of passing through a 20mm sieve and be retained on a 5mm sieve. Fine aggregate shall be not larger than 5mm and not smaller than 0.06mm and shall be sharp in texture.

All aggregates shall be free of harmful quantities of organic impurities, clay, silt, salt or unsound particles. The amount of clay, silt and fine dust present in aggregate, whether as coatings or separate particles, may not be more than:

15% by weight in crushed sand 3% by weight in natural or crushed gravel sand 1% by weight in coarse aggregate.

If the Engineer considers that any aggregate which the Bidder proposes to use contains an excess of fine particles or any harmful substances, the Bidder shall either replace the aggregate or, at his option and entirely at his expense, institute a series of approved tests at an approved laboratory to determine the nature and extent of the fine particles and harmful substances. Following receipt by the Engineer of the results of the analysis and tests, he will advise the Bidder in writing whether the proposed aggregate may or may not be used. The Engineer's decision in this respect shall be final.

Tests to determine the extent of impurities or fine particles shall include (but shall not be restricted to) the relevant tests specified in BS 882:1992, ASTM. C40-79 (Colormetric test) and ASTM. C33-82.

10A.4.3 Sampling

At least four weeks before he envisages first receiving aggregate from any source the Bidder, in the presence of the Engineer, shall obtain samples for testing. Samples shall be taken in accordance with the procedure quantities laid down in BS 812 and shall be subjected to those tests which the Engineer considers necessary to demonstrate the soundness of the material.

Such tests shall be carried out in an approved manner at the Bidder's expense and may include the manufacture, both in the laboratory and at site, of test cubes or cylinders to determine crushing strength.

10A.4.4 Grading

The Bidder shall ensure that his offer includes the full cost of obtaining and transporting suitably graded stone aggregates to site.

Grading of aggregates should, together with the required minimum cement content and water cement ratio, ensure adequate durability, density and characteristic strength of the finished concrete. The Bidder shall submit in writing to the Engineer the makeup of the mix he proposes to use, together with the grading analysis for the particular material and any details concerning his or others' experience with the use of aggregate obtained from the same source.

10A.4.5 Cement

Ordinary Portland Cement shall comply with BS 12A. The Bidder may obtain cement, bagged or in bulk, from any approved source in Bangladesh but shall always submit sufficient samples from each delivery, as required by the Engineer, to ensure that all cement complies with the minimum

requirements of BS 12A. All cement shall be stored in a weather tight shed at least 300mm off the floor to prevent the moisture. Regular checks shall be made on the weight of cement in each bag.

10A.4.6 Water

All water used in the preparation of concrete for foundations shall be potable water, *i.e.,* clean, fit for drinking and free from all earth, vegetable matter and alkaline substances, whether in solution or in suspension, and shall comply with BS 3148.

10A.4.7 Reinforcing

Where reinforcing is specified in any foundation design, it shall comply with BS 4449 or an approved similar standard. Before any reinforcing is used, the Bidder shall provide the Engineer with a certified mill certificate, verifying its grade and quality, and proof test such samples as the Engineer considers necessary. All reinforcement shall be clean and free from loose mill scale, dust, loose rust and paint, oil or any other coating which in the opinion of the Engineer may destroy or reduce bond.

10A.4.8 Storage

The Bidder shall ensure that all the materials he provides for the preparation of concrete shall be stored in a manner which prevents contamination by dust, clay, water or any other harmful material.

Heaps of coarse and fine aggregate shall be separated by at least one metre.

Where aggregate is tipped directly onto the ground, the bottom 20cm of the heaps shall not be used. Bagged cement shall be protected from rain, mixing water or damp soil during storage/transport. Cement from accidentally split or damaged bags shall not be used.

Where the Engineer considers it necessary, special precautions shall be taken to ensure that aggregate stored on site shall remain dust free. Such precautions may include the bagging of aggregate at the pit if sites are adjacent to dusty roads or if heavy rain is liable to wash out fine material or saturate the aggregate to an extent which might influence the water content of a mix.

Where the Bidder establishes central depots for receiving cement prior to despatch to individual sites, he shall ensure that the cement storage areas are sufficiently raised above the surrounding ground to prevent contamination of the cement by surface water. The material from which storage plinths are made shall be approved by the Engineer.

10A.4.9 Design Mix

Prior to ordering any aggregate the Bidder shall inform the Engineer of the source(s) of his aggregates and deliver samples to the Engineer. The Bidder will authorise at an approved laboratory tests to show the sieve analyses, relative densities, moisture content and specific gravity of the samples of aggregate from each source. At least four test specimens of concrete shall be mixed at an approved laboratory and tested after 7 and 28 days.

Depending on the moisture content of the samples of aggregate the Bidder will report to the Engineer on the expected water/cement ratio and the aggregate/cement ratio of concrete to be produced on site.

Following the successful testing of the laboratory samples the Bidder shall make trial mixes at site (from which he will take at least 4 test specimens) using the proportions advised to the Engineer (and in the presence of the Engineer) and using the equipment he intends to use in the normal day to day manufacturing of concrete. The minimum 28 day crushing strength of any such test specimen shall be not less than 20 N/mm^2.

After successful testing of the test specimens made at site, the Engineer may then approve the source(s) of aggregate and the mix design.

No changes to the approved mix design will be permitted unless the type or source of aggregate differs from those already tested, in which case further tests at both the laboratory and at site will be made.

Any concrete placed which does not conform to the approved mix designs, shall be removed and replaced by the Bidder at his own cost.

10A.4.10Mixing and Placing of Concrete

Proportions of aggregates and cement and the quantity of water for each batch of concrete shall be closely monitored by an experienced mixer operator. Aggregate shall preferably be weight batched but, where this is not possible, volume batching shall be permitted, provided that the net volumes of the loading equipment are approved by the Engineer. Containers for measuring quantities of water shall be clearly marked and only approved quantities of water shall be used in the manufacture of concrete.

Mechanical mixers shall be in good condition and well maintained. After loading, the constituent parts of the concrete shall be mixed together for a period of not less than two minutes or 30 revolutions of the barrel, whichever is the greater. For mixers with a capacity greater than $1.5m^3$ these periods may be increased if the Engineer so requires.

When the constituents are adequately mixed, the fresh concrete shall be discharged from the mixer and placed in the foundation with the minimum of delay. Chutes shall be used to ensure that fresh concrete is not dropped by more than 1.5 metres.

No concrete shall be placed until all form work, installation of parts to be embedded, and preparation of surfaces involved in the placing have been approved. No concrete shall be placed in or through water, except with the written permission of the Engineer, and the method of

depositing such concrete shall be approved by the Engineer. Concrete shall not be placed in running water and shall not be subjected to the action of running water until after the concrete has hardened for seven days. All surfaces of forms and embedded materials that have become encrusted with dried mortar or grout from concrete previously placed, mud or other foreign material, shall be cleaned of all such refuse before the surrounding or adjacent concrete is placed. Immediately before placing concrete, all surfaces of foundations upon or against which the concrete is to be placed shall be free from standing water, mud and other foreign matter. The surfaces of concrete which have set, and against which new concrete is to be poured, shall be thoroughly cleaned to remove all foreign material and laitance, and be saturated with water immediately before placing concrete. Concrete shall be deposited continuously and as rapidly as possible until the unit being poured is complete. If for any reason the work is stopped before

completing the unit of operation, a construction joint shall be installed in accordance with the instructions of the Engineer. Concrete shall be so deposited as to maintain, until the completion of a unit, a plastic surface approximately horizontal.

The method and equipment used for transporting concrete shall be such that concrete having the required composition and consistency will be delivered as near as practical to its final position without segregation or loss of slump. All concrete mixing and placing equipment and methods shall be subject to approval by the Engineer. Concrete placement will not be permitted when, in the opinion of the Engineer, weather conditions or other pertinent factors prevent proper placement and consolidation.

Bidders are reminded that, as a minimum standard, the following series of inspections should be carried out by the Bidder before concreting can begin:

1 Formwork coated with mould oil and correct in type, quantity and condition

2 Centre lines of template to coincide at the centre peg

3 Formwork to be well strutted and correctly located

4 Vibrator to be in working order

5 Mixer to be in working order

6 There is provision to maintain continuous mixing and pouring, by hand if necessary, in the event of a mixer breaking down

7 Where necessary, re-bar is on site ready bent and complete with tie wire, stirrups and concrete or plastic preformed spacer packs

8 A reliable level is at hand

9 There is sufficient aggregate, cement and water to complete the pour

10 Excavations are safe and not cluttered around the top edges

11 The mixer barrel is clean, and the paddles are complete and in place and the barrel will rotate at the speed specified by the Manufacturer

12 A suitable chute is in place

13 Both an air thermometer and concrete thermometer are on site

14 There is a large quantity of hessian sacking at hand

Where any of the above items are not complied with, the Engineer may suspend concreting pending their implementation.

10A.4.11Testing of Concrete

Samples shall be taken and tested in accordance with BS 1881. Testing shall be carried out by an approved laboratory, who shall arrange to immediately notify the Bidder and the Employer in writing of any cube failure. Failed cubes shall be kept for reference.

Concrete for the test specimens shall be taken at the point of deposit. To ensure that the specimens are representative of the concrete, a number of samples shall be taken from different

points. Each sample shall be large enough to make one test specimen and shall be taken from one point in the work.

The tests specimens shall be stored at the site at a place free from vibration, under damp sacks for 24 hours ± 1/2 hour, after which time they shall be removed from the moulds, marked and stored in water at a temperature of 10˚ to 21˚C until the test date. Specimens which are to be sent to a laboratory for testing shall be packed for transit in damp sand or other suitable damp material, and shall reach the laboratory at least 24 hours before test. On arrival at the laboratory, they shall be similarly stored in water until the date of the test.

One compression plate of the testing machine shall be provided with a ball seating in the form of a portion of a sphere, the centre of which coincides with the central point of the face of the plate. Test specimens shall be placed in the machine in such a manner that the load is applied to the sides of the specimen as cast.

Cube strengths for concrete are to be not less than 14N/mm^2 within seven days after mixing and 20N/mm^2 within 28 days after mixing.

One cube shall be tested at 7 days to obtain an indication of the concrete strength. The remaining three cubes shall be tested at 28 days and the average of their strengths shall be calculated. Should the average of the cube strengths fall below the specified 28 days cube strength, the Engineer may order the affected concrete to be removed and replaced at the Bidder's expense, or the Engineer may allow the Bidder to take a cylinder for further testing in accordance with BS 1881, if Schmidt Hammer readings indicate below strength concrete.

The diameter of the cylinder shall be not less than three times the size of the maximum aggregate and its length will be at least double the diameter, after allowing for preparation and facing prior to the test. Both a report and compression test will be completed for the sample in accordance with BS 1881. Only one such test will be permitted from any one sample and if the crushing strength of the sample is in excess of that required by the design the Engineer may, after the Bidder has made suitable repairs to the part disturbed by taking the sample, accept the concrete.

10A.4.12Formwork

Formwork shall conform to the shape, lines and dimensions of the concrete as called for on the Plans and shall be sufficiently strong to carry the dead weight of the concrete without undue deflection or bulging, and sufficiently tight to prevent leakage of mortar. It shall be properly braced and tied together so as to maintain position and shape. Members used in forms at exposed surfaces shall be dressed to uniform thickness and shall be free from loose knots or other defects. Joints in forms shall be horizontal or vertical. At all unexposed surfaces and rough work, undressed timber may be used. Timber reused in shutters shall have nails withdrawn and surfaces to be in contact with concrete thoroughly cleaned before being reused. Formwork shall not be disturbed until a minimum of 48 hours has passed from time of placement and concrete has hardened sufficiently to support any construction loads that may be imposed. When stripping forms, metal wedges or tools shall not be used to pry panels loose. If wedging is necessary, it shall be done with wood wedges lightly tapped to break adhesion. All columns and beams will have exposed edges chamfered 20 mm x 20mm. Formwork stripping time should be as per standard code and practice.

10A.4.13Reinforcing Steel

Steel reinforcing bars shall be positioned in the concrete at the places shown on the drawings, or where reasonably directed by the Engineer.

Before reinforcing bars are placed in position, surfaces shall be cleaned of heavy flaky rust, loose mill scale, dirt, grease and all foreign matter. Once in position, reinforcing bars shall be maintained in a clean condition until they are completely embedded in concrete. Reinforcing bars shall have at least the minimum concrete cover shown on the drawings. Reinforcing bars shall be accurately placed and secured in position, such that they will not move during placing of concrete. Precast concrete block spacers may be used for supporting reinforcing bars.

10A.4.14Consolidation of Concrete

Concrete shall be consolidated to maximum practical density, without segregation, by vibration so that it is free from pockets of coarse aggregate and closes against all surfaces and embedded materials. Vibration of concrete in structures shall be by electric or pneumatic-driven immersion type vibrators of 50mm minimum diameter, operating at speeds of at least 8,000rpm when immersed in concrete. The vibrator shall be inserted vertically at close enough intervals so that the zones of influence overlap. The vibrator shall be inserted to the full depth of the layer being treated and withdrawn slowly. When concrete is being placed in layers, the tip of the vibrator shall extend approximately 100mm. into the underlying layer. Vibrators shall not be used to move concrete horizontally. Care shall be exercised to avoid over-vibration of the concrete and direct contact between the vibrator and reinforcing shall be avoided.

10A.4.15Curing of Concrete

For foundations where excavations are to be backfilled immediately following the striking of shutters, the concrete is to be thoroughly wetted before backfilling commences. Where shutters are to be struck and backfilling of the excavation is not to take place immediately, the concrete is to be covered with wetted hessian sacking and be enclosed in polythene sheeting to avoid rapid drying of the concrete. Curing period should be as per ACI 308R-01 guidelines.

10A.4.16Hot Weather Concreting

In hot weather the following additional precautions shall be taken.

(a) In hot weather suitable means shall be provided to shield the aggregate stockpiles from the direct rays of the sun or to cool the mixing water/aggregates to ensure that the temperature of the concrete when deposited shall not exceed 32˚C.

(b) In hot dry weather suitable means shall be provided to avoid premature stiffening of concrete placed in contact with hot dry surfaces. Where necessary the surfaces, including reinforcement, against which the concrete is to be placed shall be shielded from the rays of the sun and shall be sprayed with water to prevent excessive absorption by the surfaces of water from the final concrete.

10A.5 WORKMANSHIP OF ALL OTHER MATERIALS

This specification only describes concrete work in detail. All other materials workmanship shall be in accordance with an agreed standard. Before starting any new item of work the Bidder shall submit samples of the materials to the Engineer for approval in writing and the method of installation shall also be approved. The first item of any type to be installed shall be inspected and checked in detail by the Engineer before other items are constructed.

10A.6 Land development work:

10A.6.1 Land development work shall be carried out by dredged filling material or by carried earth/filling sand using the following methods or any other suitable method:

(a) Land development by dredge filling material:

Land development by dredge filling materials means dredging by cutter suction dredger for collection and direct pumping of dredged fill materials by 18" dia. or more cutter suction dredgers from the pre-selected river bed through pipe line to the proposed fill site in wet and liquefied condition. The dredged material will be placed at site directly and excess water will be removed out of the site. Spreading and compaction of fill material will be carried out in layers. The layer thickness shall be determined on the quality of dredged fill material. Each layer should be compacted to a minimum of 95% optimum density as defined by the Proctor Test.

(b) Land development by carried earth/filling sand:

The responsibility of selecting proper location of collection of fill materials (such as earth/viti sand) will rest on the contractor, subject to the approval of the employer. The contractor shall obtain prior necessary permission from the concerned owner/authority paying royalties, all taxes, duties etc. as per prevailing Govt. / semi Govt. / Autonomous organization rule with the intimation to employer for collecting the required fill material. In this case mini suction dredger can be used to collect fill material from nearby river. The crops compensation resulting from the damage of crops during pipe line installation and any other activities shall be paid by the contractor and the cost deem to be included in the price. All fill shall be compacted in layers not exceeding 150mm deep to a minimum of 95% optimum density as defined by the Proctor Test.

10A.6.2 The quoted rates are inclusive of all the costs for supply of materials and hire charges for equipment and accessories etc. required to execute the works by the Contractor.

10A.6.3 Before land filling, The Contractor has to construct necessary dyke/embankment for protection the developed land.

10A.6.4 The rates are inclusive of all the royalties, taxes, VAT, octroi etc. to be paid to Govt. & semi-Govt. Organization or to any person for the earth borrowed from.

10A.6.5 If the Contractor uses the land beyond the control of the Employer, the cost/hire charges, octroi etc. so required will be paid by the Contractor for carrying, laying & installation of equipment, tools & pipes etc. over that land.

10A.6.6 The Contractor is responsible to obtain the permission/approval from the competent authority for the works as mentioned in clause no. 4 & 5 above.

10A.6.7 The Contractor shall execute the pre-work measurements jointly with the representative of Employer for the area to be filled prior to start the land development work.

10A.6.8 The Contractor, along with his bid shall furnish the detailed procedure of whole works with a list of manpower, tools & equipment required to execute the same. He shall, if the proposal is by dredged filling also show in the drawing location of the river bed to be dredged and the route of pipe lines from the dredging point to the filling area.

10A.6.9 The Contractor shall clean and remove the unspecified & the unsuitable materials which do not mix with the earth at his own cost and responsibility.

The work may be increased or decreased as per site requirement and no extra price escalation by the contractor for such increase of work shall be entertained.

10A.6.10 The Contractor will arrange the testing of the samples of the fill materials & compaction tests of developed areas by Laboratory approved by employer. The cost of any or all such tests shall be borne by the Contractor.

10A.6.11 The Contractor shall protect & maintain all the materials, equipment etc. against any theft or damage etc. at his own cost until the final executed works are handed over to the Employer.

10A.6.12 After 30 days of completion of the land development work, the contractor will arrange the joint survey (Post-work measurement) along with the employer representative. The quantity of land development shall be calculated by the contractor and checked by the employer according to this joint post-work measurement and the pre-work measurement taken prior to start the work (as mentioned in clause no.7). The rates in the schedule are inclusive of all surveys/pre & post-work measurements.

10A.6.13 The security of the equipment and materials used and the safety of the personnel engaged in the work shall be at the risk and responsibility of the Contractor.

10A.7 Fire Extinguisher:

10A.7.1 Control Room/Communication Room/Battery Rooms:

These rooms shall be protected by portable CO_2 fire extinguisher system. The system shall consist of all equipment required for directing the CO_2 gas discharge at a fire including, but not limited to, CO_2 cylinders and necessary piping, a flexible hose along with a jet nozzle. The effective reach of CO_2 gas jet release shall be sufficient to fight small fires that could develop in a control room area. Fire extinguishers shall be placed at strategic locations as per instruction of project engineer. The quantity of extinguisher at each new/up gradation AIS & GIS substation given in Table-1.

10A.7.2 Outdoor Switchyard/Cable Room:

These areas shall be protected by portable dry type ABC powder fire extinguisher system. The system shall consist of all equipment required for directing the dry ABC powder discharge at a fire including, but not limited to, a wheel carriage(only for 15kg capacity) loaded with potable cylinders and necessary piping and a flexible hose along with a jet nozzle & pressure gauge. The extinguisher material shall be non-explosive, non-hazardous, non-corrosive, non toxic. The effective reach of jet release shall be sufficient to fight small fires that could develop in an outdoor switchyard, cable room & store room area. Fire extinguishers shall be placed at strategic locations as per instruction of project engineer. In addition sand buckets also shall be provided with a metal frame for hanging buckets and shall be placed at locations directed by project engineer. The quantity of extinguisher at each new substation given in Table-1.

Table-1: The quantity of fire extinguisher shall be provided at each new substation as follows:

Sl No	Description	Quantity
1	CO_2 Type: 3kg 5kg	 5Nos. 5 Nos.
2	ABC dry powder type: 5kg 8kg 15kg(including wheel carriage)	 6 Nos. 4 Nos. 3 Nos.
3	Sand bucket with metal frame	One(1)set with 5 buckets

ANNEXURE-10A.1

DETERMINATION OF DEPTH OF FIXITY, LATERAL DEFLECTIONAND MAXIMUM MOMENT OF LATERALLY LOADED PILES

10-1. DETERMINATION OF LATERAL DEFLECTION AT THE PILEHEAD AND DEPTH OF FIXITY

10.1.1 The Iong flexible pile, fully or partially embedded, is treated as a cantilever fixed at some depth below the ground level (see Fig. 2).

10-1.2 Determine the depth of fixity and hence the equivalent length ofthe cantilever using the plots given in Fig. 2.

Where $T = (\frac{EI}{K_1})^{(\frac{1}{5})}$

(k_1 is a constants given below, E is the Young's modulus of the pile material in kg/cm2 and I is the moment of inertia of the pile cross-section in cm^4).

Note: Fig. 2 is valid for long flexible piles where the embedded length Le is ≥ 4R or 4T.

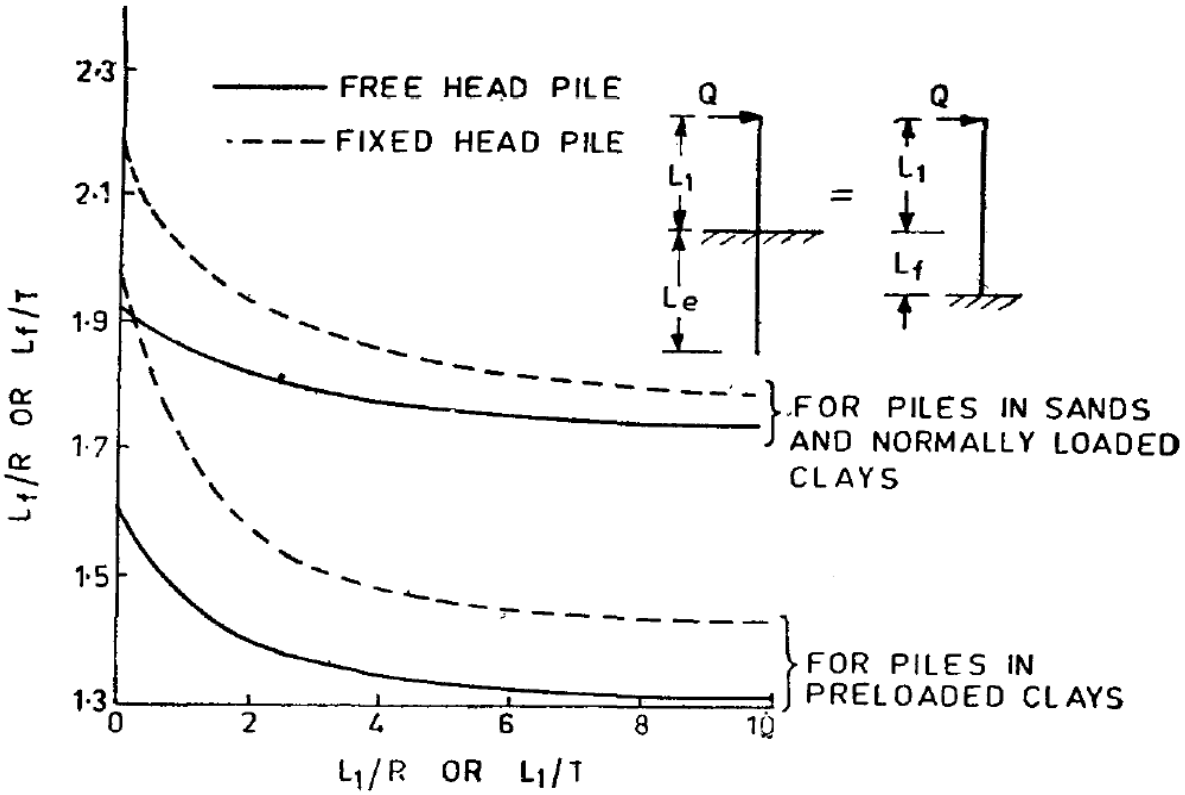


FIG. 2 DETERMINATION OF DEPTH FIXITY

K_1 is the constant of modulus of horizontal subgrade reaction, maximum value of k_1 may be considered as 0.525 Kg/cm^3.

10.1.3 Knowing the length of the equivalent cantilever the pile head deflection (Y) shall be computed using the following equations:

$$Y = \frac{Q(L_1 + L_f)^3}{3EI}$$

……for free head pile

$$= \frac{Q(L_1+L_f)^3}{12EI}$$

……..for fixed head pile

Here,

Y in cm

Q is the lateral load in kg

10.2. DETERMINATION OF MAXIMUM MOMENT IN THE PILE

10.2.1 The fixed end moment (M_F) of the equivalent cantilever is higher than the actual maximum moment (M) of the pile. The actual maximum moment is obtained by multiplying the fixed end moment of the equivalent cantilever by a reduction factor, m given in Fig. 3. The fixed end moment of the equivalent cantilever is given by:

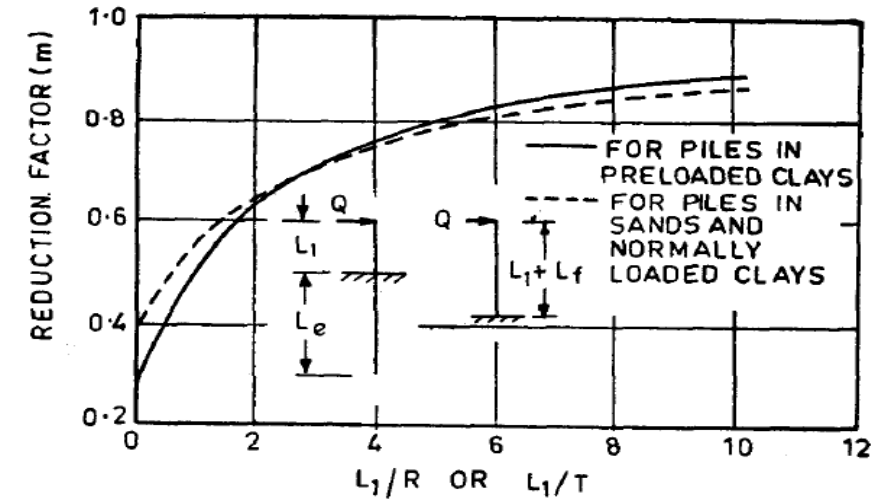
$M_f = Q(L_1$ +L_f)

……for free head pile

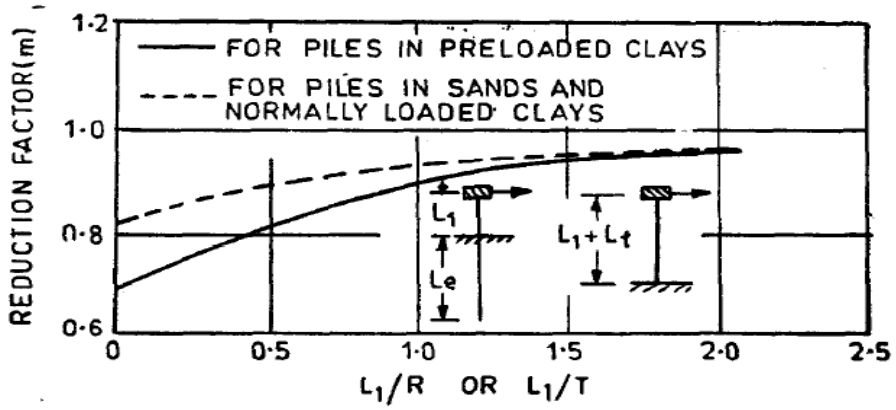
$$= \frac{Q(L_1+L_f)}{2}$$

……..for fixed head pile

The actual maximum moment (M) = m (M_f)



3A FOR FREE HEAD PILE



3B FOR FIXED HEAD PILE

FIG. 3 DETERMINATION OF REDUCTION FACTORS FOR COMPUTATION OF MAXIMUM MOMENT IN PILE

10.2.2 Reinforcement of upper section of pile should be provided upto 1.25x L_f depth

SECTION 10B
BUILDING AND CIVIL ENGINEERING WORKS (FOR INDOOR GIS)

SECTION10B

BUILDING AND CIVIL ENGINEERING WORKS (FOR INDOOR GIS)

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SECTION 10B

BUILDING AND CIVIL ENGINEERING WORKS (FOR INDOOR GIS)

10B.1 GENERAL

Under this Section the Contractor will be responsible for the design and construction of all civil engineering and building works and services for new indoor/outdoor GIS substation.

10B.1.1 Scope of Work

The Tender must cover all requirements of the tender documents and any other items not specifically mentioned but which are necessary for the satisfactory design, construction, operation and maintenance of all substations to the satisfaction of the Employer. No additional costs will be considered for any items which have been overlooked but which are essential for the proper completion of the project in every respect. The detail scope of work for specific sub-stations is described in Schedule A of the bidding document.

The work includes but not limited the design, detailing, construction and maintenance of the following:

a) Site survey and subsoil investigation.
b) Site preparation including ~~retaining walls or~~ site slope protection, cutting or filling up to the level specified in 10B.1.4 and leveling as well as compaction.
c) Road including access road with a culvert or sufficient drainage pipes and roadways within sites, surfacing the entire area within site boundary and surface water drainage.
d) Foundations for all equipment to be installed in outdoor switchyards, control building, indoor switchgear and any other building required for the project.
e) GIS and control building (complete building consisting of structural reinforced concrete frames, brick walls, concrete roof and floor slabs) with cable celling room.
f) Motorized door for GIS entrance.
g) Floor finishing: Homogeneous floor tiles cable floor, GIS room floor & control room floor, Nitocote epoxy resin coating in battery room.
h) Cable trenches, cable tunnels, cable ducts and pipe ducts.
i) Water supply and plumbing installations.
j) Surface water and foul drainage.
k) Boundary wall and entrance gate.
l) Property line demarcation.
m) Air conditioning and ventilation.
n) Lighting, small power, external floodlighting, emergency lighting and fire protection.

For all substations and for individual rooms in substations suitable nameplates, signs and labels shall be provided to ensure identification, safe operation of plant and warning of danger. The text, which shall be both in Bangla and English, shall be approved by the Employer. The substation sign board(s) shall be 3 mm, Aluminum sheet powder coated and the text (Bangla & English) shall be UV resistant, PGCB logo on a separate circular plate to be fixed at the center of sign board. The inscriptions shall be engraved with colored lettering. All nameplates, signs and labels shall be non-deteriorating and non-warping under aggressive weather conditions and shall be guaranteed for a minimum period of 10 years. Plates, etc., will be securely attached using bolts and nuts or screws; adhesive will not be permitted.

Included in the scope of work is the detailing, construction and maintenance of the following items which shall generally be constructed to the Employer's standards but full working drawings shall be prepared by the Contractor:

a) Septic tank and soak well.
b) Underground and overhead water storage tank.
c) Guard house, sentry post, car port, pump house and chain linked fences.

Guardhouse, sentry post, car port, chain linked fence, Septic tank and soak well shall be designed as per enclosed drawing.
The Bidder shall state which approved local building contractor(s) he proposes to employ to carry out the work.

10B.1.2 Contractor to satisfy himself as to all conditions

The Contractor shall assess:

a) access conditions at all sites, plus ground conditions and ground bearing capacity
b) transport costs, materials costs and restrictions of availability of supply of materials locally
c) importation restrictions and delay due to customs controls
d) restrictions imposed by existing equipment on sequence of construction, access *etc.*
e) restrictions caused by cable laying, equipment and line contractors
f) ground conditions and temporary works required to provide support during excavation
g) adjacent distribution substation and their adjacent area of authority if any
h) availability of permanent bench mark at site

10B.1.3 Way leaves, Land Purchase and Planning Permission

The Employer will be responsible for the purchase of all land within the permanent site boundary and the purchase of all land required to the base of the fill of any batter slopes. The Employer will also be responsible for obtaining land to provide a permanent single access to site from a nearby road or waterway.

During the construction period the Bidder shall be responsible for maintaining this access road in a reasonable condition by reinstating damage caused by his construction traffic and Employer's traffic.

Should the Bidder require more than one single access to a site or require additional land for construction activities outside the permanent site boundary, he shall be responsible for the purchase or way leave of the required land.

The Employer will be responsible for applying for planning permission. The Bidder shall be responsible for completing the approved site survey and the approved site layout plan, together with the approved architectural elevations of all facades of any buildings, by the key date given in the programme so that the Employer may use these drawings to apply for planning permission.

10B.1.4 Site Survey Drawings

For each site the Contractor shall prepare a survey at 1:200 scale showing existing ground levels on a maximum 10 meter grid and details of all features above and below the ground within the site boundary and up to 15 meters beyond it by the key date stated in the programme. Levels shall be related to bench marks clearly indicated on the plan. The plan shall be submit to approval by the Employer and the agreed substation building floor levels shall be given on each site plan. The Contractor shall propose the building floor level to the Employer. The Final Ground/formation Level (FGL) of the site will be 500mm above the crown of the nearest public road or 500mm above the Highest Flood Level (HFL) whichever is greater. If the site is located within/adjacent to an existing switchyard/substation of the employer/other organization, then FGL of the site should be determined same as mentioned above but should not be less than the FGL of existing switchyard/substation. For bay extension within an existing switchyard, FGL of new bay shall be same as the FGL of existing bay. All building plinth level will be 600mm above the FGL.

10B.1.5 Earth Works

Fill where required shall be carried out by the Bidder. Source of fill material and Retaining wall shall be planned and approved by the Employer. The Bidder shall be responsible for providing a level or uniform sloping site to suit his substation layout design. The final ground/formation levels (FGL) (i.e. the level below the brick surfacing) shall be stated on the site survey plan to be prepared by the Bidder.

10B.1.6.1 Engineer's and Employer's Accommodation/Surveying Equipment

On each major site The Bidder shall provide an office of approx size 5m x 8m equipped with desk, one executive chair, two visitor chairs, one multipurpose shelf/office almirah, light, fan and air conditioner, toilet with wash basin *etc.* for the sole use of the Employer's Engineer and his inspectors. Similar facilities are to be provided for the supervision consultant of the Employer.

10B.1.6.2 Surveying Equipment

The Bidder shall loan his surveying instruments to the Engineer and his staff when required. Instrument checks shall be carried out at monthly intervals. The specifications and user manuals of the instruments shall be submitted by the Bidder to the Employer.

10B.1.7 Programme

The Bidder's programme shall at Bid stage define the following key dates for each site. Where drawings are to be submitted for approval, the bidder shall be submitted at least 28 working days before the key dates to allow for the Engineer to comment and his comments to be incorporated in the drawings:

a) Issue of approved site survey drawing within the site boundary and up to 15 meters beyond it complete with soil levels and floor levels
b) Issue of approved electrical layout drawings
c) Completion of Site Investigation field work
d) Issue of approved Site Investigation Final report
e) Completion of loading tests on a foundation on each fill site and any other site where settlement is likely to be a problem
f) Issue of approved drawings required for Planning Permission
g) Issue of a full complete set of civil building drawings
h) Construction start date
i) Date access will be given for:
- Installation of equipment in Buildings
- Installation of outdoor plant
j) Construction finish date

The Bidder's programme shall outline the number of sites he proposes to build at any time and shall show the order of completion of sites and how crews will move from site to site. This information shall be used to establish the number of expatriate site supervisors required.

The drawing programme shall ensure that complete set of approved civil building drawings will be issued at least 14 days before construction start at any site, in accordance with the Project Requirements.

The Construction programme shall be expressed in an 'S' curve for the whole project, with the percentage (of the total value of work in the schedules) given for each site each month. The overall percentage completion of the project each month shall also be given.

10B.1.8 Monthly Progress Certificates/Progress Reports

In accordance with the Project Requirements the Contractor shall submit agreed progress certificates for each site before the seventh day of the next month. These certificates shall state the percentage completion of each item in the schedules and shall state the overall percentage completion of each site and that site's contribution to overall project percentage completion. An updated 'S' curve shall be submitted with the progress certificates.

10B.1.9 Temporary Facilities

The Bidder shall provide all temporary buildings, workshops, reinforcement, cement and lime stores and latrines required for his use. The Contractor shall agree the location of these buildings with the Employer, after submitting a drawing showing their proposed location.

The Bidder is placed in possession of a site, or part of a site, he shall erect temporary fencing immediately to protect the site until the boundary wall shall be erected.

10B.1.10 Site Supervision

Although the civil and building works may be let as a sub-contract to an approved local contractor, the main contractor shall ensure that an expatriate supervisor in his direct employ is continuously available at each site during construction. This supervisor shall have at least a working command of spoken English and be able to read, understand and discuss specifications and drawings.

The Bidder shall notify the Employer in writing of every subsoil investigation, concrete pour and foundation casting three days before the work starts. This is a **Hold Point**.

10B.1.11 Designs and Drawings

The Bidder shall obtain the Engineer's approval for the use of all design codes and standards before design work starts. The Bidder shall supply one copy of all of codes for employer's Engineer. If non-English equivalent National codes are adopted, the Bidder shall supply English translations of these Codes to the Engineer.

One copy of calculations along with all soft (software, excel sheet) copies shall be submitted together with drawings. To avoid possible misunderstandings, calculations will not be approved separately from drawings.

The Bidder shall generally submit a complete set of drawings with all soft copies (AutoCAD drawing) for each substation for approval after initially getting the electrical layout of each substation approved. Where possible, drawings shall be standardized and general drawings issued covering several sites.

For each substation The Bidder shall provide a co-ordination plan at scale 1:200 showing structure types, foundation types, cable trenches, roads, ducts, buildings, boundary walls, earthing, drainage and all services in this Contract.

10B.2 REFERENCES

10B.2.1 General

The design and construction shall conform to the latest edition of the relevant Codes and Standards. Any proposed substitution for the listed Standards by an equivalent Standard will be subject to approval by the Employer. Relevant Standards include, but are not limited to, those listed in sub section 10B.2.2 below.

10B.2.2 Design and Construction Standards

BS 12 Portland Cement

BS EN 124 Gully and Manhole tops for vehicular and pedestrian areas

BS 812 Testing aggregates

BS 882 Aggregates from natural sources for concrete

BS 1377 Methods of test for soils for civil engineering purposes

BS 1722: Part 10 Anti-intruder fences

BS 1881 Testing concrete

BS 2853 Design and testing of overhead runway beams

BS 3148 Methods of test for water for making concrete

BS 3921 Clay bricks

BS 4449 Steel bars for the reinforcement of concrete

BS 5262 External renderings

BS 5395 Stairs, ladders and walkways

BS 5572 Sanitary pipework

BS 5628 Code of practice for use of masonry

BS 5930 Code of practice for site investigations

BS 6031 Code of practice for earthworks

BS 6367 Code of practice for drainage of roofs and paved areas

BS 6399: Part 1 Code of practice for dead and imposed loads

BS 6399: Part 2 Code of practice for wind loads

BS 6465 Sanitary installations

BS 6651 Code of practice for protection of structures against lightning

BS 6700 Design, installation, testing and maintenance of services supplying water for domestic use

BS 8004 Code of practice for foundations

BS 8005 Sewerage

BS 8100 Lattice towers and masts

BS 8102 Code of practice for protection of structures against water from the ground

BS 8110 Structural use of concrete

BS 8206 Lighting for buildings

BS 8215 Code of practice for design and installation of damp-proof courses in masonry

BS 8290 Suspended ceilings

BS 8301 Code of practice for building drainage

10B.3 DESIGN

10B.3.1 Architectural and Structural Requirements of Buildings

All new buildings shall be designed to be architecturally pleasing in appearance and to withstand the tropical climate with minimal maintenance.

Architectural plan and all elevations of buildings shall be agreed before other detail plans are prepared.

The general layouts of buildings are to be maintained as shown, but minor modifications may be made to provide buildings wholly suitable for the equipment being provided by the contractor to satisfy the requirements of other parts of the Specification.

Indoor GIS building and switchyard panel room shall be designed to have reinforced concrete frames, with infill panel walls of reinforced concrete or brick which shall be capable of resisting a horizontal earthquake force of 0.2G. For other buildings shall be designed as per latest BNBC.

All external walls of control room building/SPR shall be minimum 230mm first class brickwork plus one layer of Mirpur Ceramics or similar approved facing bricks. External walls of other buildings shall be minimum 230mm first class brickwork plus one layer of Mirpur Ceramics or similar approved facing bricks or rendered with cement render and painted as required by the architectural plan. The internal walls shall also be generally of minimum 115mm thick first class brickwork. Internal walls and ceiling outside & inside of false ceiling shall all be rendered and receive one sealer coat plus two finishing coats of emulsion paint. Externally, rendered walls shall receive primer plus two finishing coats of acrylic external quality paint or similar approved.

Internal partition shall be fire barriers rated for minimum 1 hour and of approved material/design. Internal walls shall all be rendered and receive one sealer coat plus two finishing coats of emulsion paint of approved colour.

All brickwork shall be tied into the concrete frame. Externally, rendered walls shall receive primer plus two finishing coats of PEP acrylic external quality paint or similar approved. At least two air bricks shall be provided to each room in which staff work/rest.

Substation buildings shall be designed to withstand pressure due to internal arcing or arrangement shall be made for pressure release in such an event by providing wall dampers. Parameters considered in the building design shall be subject to PGCB's approval.

Particular attention must be given in the design of buildings and layouts to fire prevention and safety of personnel at all times. Buildings housing switchgear and control equipment shall be designed as far as practicable to exclude pollution under all likely weather conditions. Fire-proof or flame-retarding materials are to be used for floor, wall, door and ceiling finishes. Where areas are designed as having a fire resistance rating then materials shall be shown to have passed approved standard tests for that class of fire resistance.

All floor slabs shall be constructed of reinforced concrete supported on reinforced concrete beams. Floor finishes will be designed to provide high impact and abrasion resistance. The finishes shall be in accordance with the schedule of finishes.

Electric overhead traveling crane(s) shall be provided in the 400kV, 230 kV and 132 kV GIS switchgear room to facilitate erection and maintenance of the equipment

The minimum height of ground floor shall be 3.0 meter. The height of control rooms shall provide about 1 meter clearance over the top of the cabinets/equipments to the underside of the false ceiling and any fittings suspended from ceilings shall be the criteria governing room heights. In the switchgear rooms, about 1 meter clearance shall be provided over the switchgear to the underside of the roof slab but the Contractor shall provide a greater

clearance if it is required to remove equipment. The clearance may be reduced below down stand beams provided no equipment is required to be removed from the top of the switchgear.

Rooms shall have walls and roof slabs adequately insulated. Maximum thermal transmittance values for all rooms shall be 0.7 watts/m^2/°C for walls and 0.57 for roofs. Air conditioning units shall be provided in rooms listed in Section 13. Air conditioned rooms shall have a false ceiling such that the overall thermal transmittance of the roof shall be below 0.45 Watts/m^2/°C. The false ceiling shall be made from noncombustible materials, and shall be easily removable to provide easy access to small power cables. Suspended ceilings, with acoustic tiling and incorporating lighting and air-conditioning fixtures shall be used in corridors, offices, toilet, control and communication rooms of the buildings and as per schedule of finishes

In main control room building, all structures shall be designed to carry the loads imposed by the structure itself, together with minimum floor live load (including stairs) of 5.0kN/m2 (minimum) or in accordance with an approved standard or code of practice. In GIS floor if converted UDL of machine loading exceeds 5.0KN/m2, then that value should be used instead of 5.0KN/m2 as live load. The roof shall be designed for 2.5 kN/m^2 live load.

If the ground floor contains any machine or any equipment, then this floor should be considered as beam supported slab.

All doors opening outwards from the buildings shall be provided with panic latches or bolts which override any locking device, for escape in the event of fire. All doors shall be provided with overhead door closuers of adequate capacity. Door labels incorporating electrical hazard warning in Bangla and English shall be fixed to each entry door. Vision panels shall be provided to frequently used doors.

Window openings shall be fitted with protruding concrete sunshades above and at the sides of the openings.

Roofs to the main buildings shall be insitu reinforced concrete slab and shall be insulated and waterproofed. The roof shall be waterproofed with lime terracing 2:2:7 lime, shurki (powdered brick) and brick chips 0.75" down, which shall be beaten in accordance with local practice. The entire roof area shall be laid in one continuous operation. The minimum compacted thickness of terracing shall be 25mm at the low points of the roof with a 1:150 slope to those points formed by a layer of terracing of increasing thickness. Once laid, the terracing shall be covered with a layer of bitumen emulsion and the edge of the terracing shall be protected against erosion into the downpipes. Downpipes shall be 100mm diameter uPVC pipe placed outside the wall but shall be enclosed in a facing brick buttress. There shall be at least one downpipe per 100m^2 of roof. The Contractor shall guarantee the roof against leaks for a period of 3 years from the Taking over Certificate date. The roof shall project at least 450mm beyond the outer face of all walls or 450mm beyond the outer face of all columns whichever is greater to form a sunshade and rain shelter to the walls below. The upper surface of this projection shall be sloped and a drip provided. A steel ladder shall be provided to permit easy access to the roof of stair case and to the lift machine room opening. Roof mounted equipments (if any) shall be covered by approved screens for better elevation/aesthetics.

The head of each downpipe shall be fitted with an enlarged hopper of 200mm and purpose made cast iron grill set into a recess in the roof projection.

The roof parapet wall shall be about 1.0 meter high with an insitu concrete coping (minimum 75mm) with *dpc* below it. Where facing bricks are used below the roof level, they shall also be used above roof level. An architectural feature shall be provided by panels of open decorative block work (Mirpur ceramics or similar approved) to ensure good air circulation over the roof. Minimum three open decorative blocks of size 1000mmX500mm should be provided on each side in solid portions of parapet wall.

The domestic water supply system shall include all plumbing, underground pipework, high and low level storage tanks, valves, fittings and pumps (including the provision of a standby pump) for the provision of a pressurized water supply system for the static water tank and all buildings within the compounds.

On completion of the installation and prior to putting to use, the system shall be sterilized in accordance with an approved Code of Practice.

The Bidder shall be responsible for the provision and installation of a water supply serving the substation buildings. Every cistern, sink, basin, *etc.*, shall be provided with a stop-cock in the supply pipe adjacent to the fitting. Each basin, sink and shower unit is to be provided with both hot and cold water. Provision shall be made for connection to the drinking water supply.

Each Toilet shall be provided with 1 no. western type WC, 1 no. wash-hand basin, 1 no. wall mounted mirror, 1 no. towel rail etc. all necessary fittings and accessories shall be provided.

Battery rooms shall be supplied with sink and drainer & exhaust fans (if no air conditioning).

The main entrance to all buildings shall be shaded, either by a projection of the roof over the entrance verandah or by a separate roof at a lower level. This area of roof shall also be lime terraced and drained by rainwater pipes.

Minimum capacity of the crane is mentioned in the price schedule. If the maximum lifting weight is more than half of crane capacity, then the crane capacity shall be twice times of maximum lifting weight. No additional payment shall be made in this regard.

10B.3.2 Cable Basement

Not used.

10B.3.3 Cable Tunnels and Cable Trenches

The Contractor is responsible for all civil works required for the installation of cables.

Main structure of cable tunnel is reinforced concrete and shall be designed enough bearing capacity caused by some parts of cable tunnel are under heavy equipment. Cable tunnel is used for power cables from Transformer to GIS building and so on.

All cable runs in buildings shall be arranged within the ground floor.

10B.3.4 Ground Conditions, Foundations and Site Investigation

(a) Fill Sites

The Bidder shall impose the site layout on the survey to check for uneven depth of fill below any foundation and where uneven depth of fill exists his foundation proposals shall restrict final differential settlement to a 1 in 400 slope.

If a fill site has not been exposed to one wet season before foundation work starts, the Bidder shall flood the site to a depth of 50mm for 10 days (Not required on hydraulic fill sites). This requirement is because silty sands will generally compact to a denser condition on first time flooding.

On all fill sites the Bidder shall pipe rainwater from down pipes down to paddy level and shall prevent water ponding in open foundations and backfill all foundations as soon as possible.

When a filled site is handed over to the Bidder, the Bidder shall become responsible for maintaining the entirety of the fill in good condition, including all better slopes.

(b) Unfilled Sites

Original delta levels are generally 4 meters below road level. Therefore most sites are historically fill sites but fill settlement can sensibly be considered complete, where fill is over 3 years old.

(c) Site Investigation

Detailed methodology for subsoil investigation shall be submitted before implementing the subsoil investigation. All laboratory tests shall be done at the test facility approved by the Employer.

The Bidder may appoint a sub Bidder to carry out the site investigation but all work and all lab work shall be witnessed by one of his Geo-technical engineer who shall countersign all recorded data.

1 borehole should be counted for every 600 square meter of proposed project area and provided on suitable points. At least three additional boreholes should be provided for control building and switchyard panel room building or any other building. For boundary wall/retaining wall additional boreholes shall be provided on in each corner point and at a maximum 50m interval point. Additional boreholes may also be required where uneven fill depth is encountered. The number and location of boreholes shall be approved with the site survey drawing showing existing ground levels specified in the section 10B.1.4. The boreholes shall be located to an accuracy of $\pm$ 0.5m and shall be located to site layout considering existing obstacles at the field.

Boreholes shall be a minimum of 25 meters depth or twice building footing width or upto the level where the foundation/pile will be rest whichever is greater. All boreholes shall be backfilled with compacted sand.

Borehole log together with a summary of all required laboratory tests is required to be prepared. Soil test locations are required to be indicated on the geographical map.

In each borehole the following tests shall be carried out:

- Standard Penetration tests at 1.5 meter intervals.

- Undisturbed samples shall be taken at around 1.5 meters, 3.0 meters and 4.5 meters depth for unfilled site; 1.5 meters, 3.0 meters, 4.5 meters and 7.5 meters depth for filled site and tested by unconfined compression tests.

- One dimensional consolidation tests shall also be carried out on undisturbed samples taken at 1.5, 3 & 4.5 meters depth. The samples shall be saturated and the range of applied pressure shall fully reflect the insitu conditions. Graphs showing void ratio (e) and applied pressure shall be submitted along with the Coefficient of Compressibility for the range of loading anticipated.

- Particle size analysis shall be carried out for each stratum and specific gravity, moisture content, liquid limit and plastic limit determined.

- Ground water level shall be determined by dipping the boreholes for 24 hours. Where collapse of the boreholes occurs, casing shall be used and left in until the water level remains constant for two days.

- In cohesive soils a vane test to BS 1377: Part 9 shall be carried out at three different depths. The Contractor shall check the sensitivity of soil and ground water at each site to concrete and take all measures necessary to ensure the long term durability of concrete.

Prior to commencement, the Contractor shall submit to the Engineer detailed schedules for the site survey and soil investigation. This is a **Hold Point**.

(d) Site Investigation Report

The site investigation and analysis of the data in a final report giving full details of foundation proposals shall be completed at each site by the programmed date. During site investigation, Geographical map shall be prepared indicating the locations of soil test.

The report shall be submitted by the key date at each site given in the programme. The Bidder shall submit 3 copies of the report to the Engineer. The report shall propose full details of foundations and loading thereon and shall provide estimates of likely settlements and differential settlements. The report shall be the work of the Bidder's own foundation engineers.

If the Bidder uses a local site investigation Bidder, he shall appoint one of his geo-technical

engineer to oversee the entire operation and each piece of data shall be countersigned by this person.

Where estimated settlement exceeds 25mm, the Bidder shall construct one foundation at an early stage and test load this foundation to confirm settlement predictions.

(e) Foundations

Regardless of the result of soil investigation report, the foundations of GIS Control Building, gantry structures and auto-transformers shall be provided with piles. Others buildings foundation shall be provided with shallow or pile foundation as per soil condition. All earth retaining walls shall be RCC. Based on site and soil conditions, boundary walls with/without RCC retaining wall may be designed with pile foundation or shallow foundation. But, if width of footing perpendicular to wall exceeds 3000mm, then pile foundation must be provided for boundary walls (refer to enclosed drawing). Stability of surrounding & underlying soil and settlement of the wall foundation must be ensured by the contractor.

Piles shall be concrete (cast-in-situ or precast) complying with BS 8004. For structural design of cast in situ piles, guidelines provided in **Annexure 10B.1** should be followed. One working piles shall be randomly selected by the employer for pile load test in accordance with BS 8004. One working pile of control building and one of auto-transformers at each site shall be compression load tested and one working pile of gantry tower foundation at each site shall be uplift load tested to 100% of design load in accordance with BS 8004.

Other foundations of outdoor equipment shall be provided shallow/deep as per subsoil investigation report, settlement test as well as plate bearing test. In case of shallow foundation for outdoor equipment the bearing capacity of proposed soil level shall be checked by the Plate Bearing Test.

For shallow foundations the minimum depth of foundations shall be 1.5m.

All formations shall be hand rammed or mechanically compacted before placing 75mm minimum thickness of Class B concrete blinding, within 24 hours of bottoming excavation, which blinding shall project 75mm minimum distance beyond all footings. Each footing shall be inspected by the Engineer. Where soil condition is poor (on fill sites or already filled sites) or where the Bidder leaves foundations exposed and soil conditions deteriorate, one of the following measures shall be carried out as agreed with the Engineer:

i) Blinding depth and projection shall be increased as necessary.
ii) Soft soil shall be removed and replaced with compacted filling sand with the top 300mm (Minimum) consisting of sand and khoa (brick chips) in 2:3 ratio with 95% level of compaction.

The cost of this work shall be borne by the Bidder.

The Bidder shall propose the allowable bearing pressure for all foundations based on soil strength parameters only and shall not be increased while wind loads exceeds 25% of dead load as well as shall not exceed 125kN/m^2. Between column footings all walls, including all internal walls, shall be provided with a reinforced concrete strip footing of minimum dimension 800mm wide by 250mm deep placed at the same level as column footings and linked structurally to the footings. Column footings shall be tied at foundation/grade beam and floor level by beams to every adjacent column in both orthogonal directions.

The deepest parts of any foundations shall be completed first. All foundations shall be completed and backfilled, including all cable tunnel and cable trench work inside buildings, before walls are raised above floor levels. All other foundations shall be backfilled within 7 days of completing concreting.

All exposed concrete and the outer surfaces of cable trenches and cable tunnels shall receive three coats of bituminous paint before backfilling to reduce ingress of water. The Concrete surface shall be ground smooth and all air holes *etc.* filled (rubbed down with a cement slurry) before painting.

The Contractor shall monitor settlement of all foundations each month and report this settlement to the Engineer until settlement has reduced to less than 1.5mm in 3 months.

The tops of all foundations shall terminate 200 mm above site average finished surface level. All exposed edges shall have 20 mm x 20 mm chamfers.

Excavation shall only be carried out when the ground water table is at least 1000mm below foundation level. The excavation shall be kept dry during the construction period by providing sumps and pumps as required. During the rainy season, shelters shall be erected over all open excavations. For dewatering, slurry wall with required specific gravity may be used.

Excavations shall be adequately supported or formed to ensure stability of the sides and prevent any damage to the surrounding ground or structures. The design of suitable sheet piling and/or timbering for excavation shall be in accordance with the recommendations of BS 8004 Section 5.

When the Contractor requested shall submit details of his temporary support to the Employer.

Excavation shall not be carried out below or adjacent to existing building foundations until under-pinning and shorings have been completed by the Contractor.

The Contractor shall not permit water to accumulate in any excavation unless otherwise agreed. Any water whether arising from the excavation or draining into shall be drained or pumped to an approved location well clear of the excavation area in a manner that does not cause erosion, silting or contamination of existing drains and watercourses. Before the method of ground water lowering is selected, adequate knowledge of the ground and water conditions has to be obtained from the results of a soil investigation and/or information

The Contractor shall take adequate steps to prevent adjacent ground from being, adversely affected by loss of fines in any de-watering process.

Any over excavation shall be filled with Class B concrete.

All backfill shall be compacted to 95% maximum dry density as defined by BS 1377 test method part 4, 2.5 kg rammer.

Before starting foundation work the Contractor shall clear all sites of trees, tree roots, shrubs, debris, surplus soil and any buildings.

Foundations shall be designed to resist uplift, assuming the water table is at ground level and the weight of soil resting on a foundation is that included within a 15° frustum.

10B.3.5 Fire Criteria

The Contractor shall make provision in the design of the building structure for minimum periods of fire resistance in accordance with "The British Building regulations 1985 - Part B - Fire - B2/3/4 Fire Spread.

The minimum periods of fire resistance (hours) shall be related to the maximum dimensions, *i.e.,* height, floor area or cubic capacity, of buildings or compartments of buildings.

For calculating the maximum dimensions the following definitions shall apply: -

(a) "Area", in relation to a building, means the area calculated by reference to its finished internal faces:

(b) "Basement" means a story of which the floor is at any point more than 1.2 meters below the finished surface of the ground adjacent to it.

(c) "Floor area" means the aggregate area of every floor in a building or extension, calculated by reference to the finished internal faces of the walls enclosing the areas, or if at any point there is no such wall, by reference to the outermost edge of the floor.

(d) "Height" means the height of the building measured from the mean level of the ground adjoining the outside of the external walls of the building to the level of half the vertical height of the roof of the building, or to the top of the walls or of the parapet, if any, whichever is the higher.

To restrict the spread of fire, certain walls and floors shall be designated as fire compartment barriers. Fire compartment barriers shall provide complete barrier-to spread of smoke heat and other products of combustion. The barriers shall have a rating of 2 hours minimum. All openings in walls/floors for entry/exit of cables shall be sealed with approved fire sealant rated for minimum 2 hours.

10B.3.6 Drainage

The entire surface within boundary walls shall be of uniform sloping site, sloping at 1 in 300 minimum slope to open channels around the entire perimeter. These channels shall be designed for a rainfall intensity of 60 mm per hour. Outside the boundary wall the Bidder shall be responsible for drainage up to 20 metres from the wall and will at some sites need to construct outlets with suitable erosion protection down to paddy level.

The concrete wall of cable trenches shall project at least 50mm above brick paving level to prevent run off entering the cable trench. The floors of all cable trenches/tunnels shall be sloped to soak well as described in 10B.3.21.

The cable trenches will thus form barriers to surface water drainage. If the cut off area exceeds 30m^2 it shall be drained by constructing Water Catchment Pits (WCP) with a 200mm minimum diameter uPVC pipe to the boundary drain. The Bidder's drainage design shall avoid all ponded water to avoid forming a mosquito breeding ground.

All drainage pipework within buildings shall be uPVC type, generally of 100mm diameter or as per requirement. Floor drains shall be placed in each battery room and toilet.

External pipework shall be 150mm minimum diameter uPVC pipes at a minimum depth of invert of 300mm. Where pipes, including existing pipes alongside site, are less than 400mm above adjacent foundations they shall be surrounded in concrete. Where required, drainage pipes shall be kept below cables, allowing 1.1 m cover to top of pipes.

Manholes shall be of brick construction with minimum 450mm x 450mm clear openings and airtight RCC/ductile iron covers to BS EN 124. Manholes shall be located at each change of direction. Minimum fall on all pipelines shall be 1 in 150. Manholes shall not be located in roads.

The Bidder shall be responsible for all negotiations with local authority/WASA where a connection to a public sewer is proposed. Where high water levels in public sewers may cause effluent to back up into a site, non-return valves shall be fitted. The Bidder shall provide all protection required to existing sewers and shall deepen foundations, including boundary wall foundations, where required to ensure all foundations are below adjacent sewers. The Bidder shall draw longitudinal sections of all pipelines.

Septic tank and soak well for Main Control Building shall be constructed as per provided drawings. The septic tank shall be located at least 15 meters from buildings/ water pumps. The pipe network for septic tank should be designed considering self cleansing velocity. Inspection pits should be provided at regular intervals. Other buildings shall have septic tanks designed for the required number of users. All foul drains shall be vented by a vent pipe to above roof level. The inner surface of all manholes and septic tanks shall be painted with 2 coats of bitumastic paint to protect it against sulphate attack. The septic tank shall have access holes directly over the inlet pipes and outlet pipes. Where public sewers exist alongside a site, the Bidder shall connect directly to the foul sewer, provided effluent from the sewer is treated.

The Bidder shall construct the drainage first to ensure that at no stage is rainwater ponded on any part of the site. All rainwater shall be able to run off the site or shall be immediately pumped off site by the Bidder. The Bidder shall complete all necessary drains before casting any roof and

large concrete area which will create large run off. The condensate drains for the air conditioning shall also be connected to the drainage. Bottom of drain shall be sloped at 1:300 minimum.

If a town's water supply is unreliable, the roof rain water shall be collected in an underground tank of standard Employer's design.

10B.3.7 Surfacing

For the whole of the switchyard outdoor equipment area the ground shall be surfaced with gravel or other readily available local materials as approved by the electrical design. Gravels/other materials shall be clean, thoroughly washed when necessary, and free from clay, soil or contaminating material and shall be graded from 20 - 45mm except needed otherwise, laid and lightly compacted to a finished thickness of 175mm or as required by electrical calculations. Below the gravel/other material layer there shall be a 75mm brick layer with cement mortar (1:6), laid over a 75mm level of fine sand spread over the finished fill site.

Landscaping in the vacant space of substation area shall be done with acceptable tree plantation, flower gardens and turfing.

The substation plot, outside of the designated switchgear equipment areas, shall be turfed. Turf shall be of good quality, free from weeds and other impurities. Samples of the turf which is proposed to use shall be submitted to the Engineer for his approval. The turfs shall be laid to even surfaces on a bed of plastic/vegetable soil of 150mm thickness, which shall be raked and consolidated to provide a suitable bed.

On sloping surfaces the Bidder shall provide and fix wooden pegs to retain turfs.

All areas to be surfaced shall first be treated with a total weed killer in accordance with the manufacturer's instructions. Weed killer shall only be applied in dry weather when there is no risk of it being washed out to adjacent agricultural areas.

10B.3.8 Roads

Access road from outside the site boundary to connect to any adjacent public road and all roads within the site boundary shall be provided by the Bidder. The road surface shall be finished by concrete paving or equivalent. All roads shall be of reinforced slabs of minimum 150mm thickness fitted with construction joints at distances not exceeding 6.0m. Paving schedule and methodology shall be approved by the Employer. The extent of roads required is shown approximately on Bid drawings but the scope of the work may change. Road layout shall generally permit vehicles to turn easily to avoid having to reverse out. Road layout shall be designed by the Bidder. The bidder shall visit the sites and assess all practical requirements like culvert design & construction, removal of any obstacles, permission from local authorities etc. for access road. All necessary works shall be the bidder's responsibilities.

The width (between the outer edges of kerbs) of access road from outside the site boundary to connect to any adjacent public road shall be 6.0 meter. Width (between the outer edges of kerbs)

of all roads within the site boundary shall be generally 6.0 meter transformer, 4.5 meter & 3.0 meter for sub road and 1.5 meter for walkway.

The road edge shall be formed by Class B concrete kerb 250mm wide by 400mm deep, placed over one layer of bricks laid flat. The road shall be a Class A concrete slab of minimum 150mm deep at each edge with 1:50 inward slope and stiff broom concrete finish reinforced with 10mm bars at 250mm centres longitudinally and 10mm bars at 250mm centres transversely placed 80mm below the upper surface. Expansion and contraction joins shall be detailed on site plans. Expansion joints shall be filled with hot bitumen & sand (2:1) sealant. Below the slab shall be a layer of polythene 0.5mm thick laid over one layer of 1st class bricks laid on edge in herringbone fashion in and on cement mortar (mortar designation iv) laid over one layer of 1st class bricks laid flat in and on a layer of sand laid on insitu soil which shall be compacted as agreed with the Engineer. If the soil is clay a 75mm drainage layer of broken bricks shall additionally be placed over the soil.

The radius of the road edge at corners shall not be less than 3 metres and 1.2 metres either side of the road shall be kept clear of obstacles. Bollards or raised kerbs shall be provided where required to protect items alongside a road from vehicles. Ducts shall be provided below roads for all services in this Contract and for all future services.

Where mortar designations are referred to see BS 5628 Mortar designation iv is 1 cement: 2 Lime: 8 to 9 sand.

At each new substation site a two bay hard standing car port, complete with sun shades, is to be provided adjacent to the control building.

10B.3.9 Water Supply

The Bidder shall be responsible for providing a water supply both for construction and for operation of the completed sites. If a town's water supply is not available, the Bidder shall install a deep tube well of 40mm minimum diameter and 100m minimum depth with necessary pumps including all fittings, pipes *etc.* as required. But in that case guideline specified by WHO for drinking water is required to be satisfied. The Bidder shall supply and commission power supplies and all pumps required by tube wells.

If a town's water supply is available, the Bidder shall be responsible for making all necessary arrangements with local authority/WASA to connect a supply. If the pressure in the supply is inadequate to supply the roof tank continuously, the Bidder shall install a 1800 litre low level tank and pumps. This tank shall be below ground with a 200mm minimum air void around the tank to protect it from contamination. The pump control panel shall be located in the building. Water levels shall be controlled by float switches but the panel shall provide also for manual operation.

The supply shall be connected to a 2000 litre food graded plastic tank. This tank shall be raised 400mm clear of the line terracing on four brick piers of minimum 350mm square. All supplies in buildings shall be fed from the roof tank. The supply to the tank shall have a valve at waist height. The tank shall have an overflow returning to the location of this valve. No pipes shall pass through

the roof directly over any room. Pipework shall be routed up the outside of the building and return pipes shall return down the outside of the building before entering through the wall. Pipework shall be CPVC secured by clamps at 1.5 meters intervals and painted with alkyd paint to match walls. All pipes should be concealed by brickworks on vertical walls.

10B.3.10 Plumbing and Sanitary Fittings

The Bidder shall prepare a drawing of all plumbing and building drainage for each building. Sanitary fittings and plumbing materials shall generally be of approved local manufacture.

In main control room building each toilet shall have a single western WC. Each toilet outlet shall be vented by a 100mm diameter uPVC vent pipe passing up the outside of the building to 2500mm above roof level. Beside each toilet shall be placed a low level tap. Main control Building toilets shall also have a wash basin and cold and hot water shower with 10 gallon capacity geyser for each toilet. Toilets and showers shall have all walls tiled upto the bottom of false celling.

Every tap and cistern shall have stop cocks in the supply pipe. One external tap shall be provided on each building. Battery rooms shall be provided with a stainless steel sink of approximate dimensions 900 x 600 x 200mm with a draining board to one side. The battery room floor drain shall be connected to the foul drainage. All floor drains shall have P traps.

Mirrors shall be installed over toilet wash basins. Care shall be taken in orientation of toilets to avoid offending religious sensitivities. Toilets shall generally be orientated North South where possible. Each shower shall have a wall on two sides and a porcelain shower tray sunk into the floor. Soap dishes shall be provided beside each shower.

Only foul water from WC pans shall be connected to septic tanks. All other water shall flow to surface water drains.

10B.3.11 Substation Building Floors

All topsoil containing roots shall be removed and the insitu soil compacted before placing backfill. All backfill, including the backfill to column footings, below the floor shall be sand. The floor and all cable trenches shall be made of Class A concrete. The ground floor slab shall have a minimum 125mm thick reinforced Class A concrete furnished with non-skid floor tiles and shall rest on the compacted fill. Below the slab shall be placed a layer of polythene 0.5mm and a layer of sand khoa (2:3) compaction of minimum 100mm thick, hand rammed to a smooth upper surface.

All cables from cable trenches shall enter the building over grade beam level, no cable trench shall be allowed into main control room building. Where power cables traverse a building to reach a switchgear room on the far side they shall generally be contained within cable tray.

All sand backfill shall be compacted to 95% optimum density and shall be tested. The fill within a building, above ground level, shall not be placed until all backfill outside the building is completed. All floor slabs shall have a damp proof membrane of 0.5mm thickness.

Each control building shall have a ramp at a slope of approximately 1 in 7.5, of 1.5m minimum width with a Concrete Class A slab of min depth 125mm with a stiff brush concrete surface finish, or other agreed non slip surface.

All floors (including verandahs) except for GIS room and battery room shall have 25mm homogeneous floor tiles topping. All external steps where public access is given to buildings shall have marble tiles toppings. Elsewhere, concrete surfaces shall be used for all external floors/steps. Verandahs shall have a minimum 1:50 slope to shed rainwater away from buildings. Concrete floors and steps shall also be treated with 3coats of Lithurin or other approved concrete dust proofer.

Verandahs shall have a minimum shed of 1:50 slope to rainwater away from buildings.

If floor tiles are not adequately durable to withstand switchgear movement when rolled out to the maintenance position, then galvanized steel chequered plates shall be inserted in the floor to resist the abrasion from switchgear wheels.

10B.3.12 Cable Basement and GIS Room Floors

No cable basement shall be used. Cables shall enter into the building through ground floor. GIS room shall have a concrete floor finished by 25mm cement screed in composite method of construction. To avoid cracks, joint of adequate size are to be made at suitable points. Screed shall correspond with expansion joints in floor slab. Additional screed joints like sawn joints, additional expansion joint etc. shall be avoided. To improve the resistance to abrasion and to reduce dust accumulation, the screed shall be coated with synthetic resin based paint unless specified otherwise.

10B.3.13 Control Room Floor

No raised floor except for panel installation shall be used.

10B.3.14 Battery Room Floors

Battery rooms shall have a concrete floor sloping to a cast iron floor drain. The concrete surface shall be treated with Nitocote epoxy resin coating (Nitoflor primer plus two coats of Nitocote in accordance with manufacturer's instructions), or similar approved material, to ensure resistance to battery electrolyte. There shall be no cable trenches in battery rooms. Cable entrances through the floor shall be protected by a raised plinth 50mm high around the opening with the annulus around the cable sealed after installation.

10B.3.15 Site Clearance, Obstructions and Adjacent Structures

The Contractor shall be responsible for clearance of:-

(1) Trees, shrubs and any vegetation including the extraction of all roots and compaction of backfill where roots have been extracted.

(2) The removal of all buildings, sheds or any other structures above or below ground including the removal of any septic tanks, drains or other underground services.

(3) The removal of any existing surfacing, roads, foundations or any other obstruction.

All material cleared away by the Contractor shall be the property of the Employer and shall be removed by the Contractor to a site in the Dhaka area upon instructions of the Employer. The Employer may remove any buildings or structures himself from sites before the site is handed over to the Contractor.

Where an existing service, existing equipment or adjacent building is to be retained, the Contractor shall take all necessary measures to protect the item concerned from damage and shall be responsible for ensuring that no movement of foundations occurs during or after completion of construction.

Any existing electrical equipment/cables which have to be modified or repositioned shall be included in the works at no extra cost. Any buried gas or water main services which require to be diverted shall be deviated by the Employer at his cost. However, where it is possible to retain these existing services and build new structures around them, the Contractor shall take all necessary measures to build in the service at no extra cost.

10B.3.16 Guard Houses, Boundary Walls, Fences and Entrance Gates

The guard house serves for control of entrance. The gatekeeper shall be able to watch the area before and behind the guard house. The guard house shall be provided with toilet, water supply facilitates. Small power and lighting facilitates are to be provided in the Guard Houses.

The Contractor shall base his design of boundary walls and gates following bid drawing and subsoil investigation report. Where sites are within existing Employer's boundary walls, the Contractor shall construct a permanent chain linked fence 1.5m high in accordance with BS 1722 part 10 or similar approved.

10B.3.17 Windows

Even natural light shall be provided by windows to illuminate all areas of buildings. Window area shall be about 6% of floor area to limit solar heat gain. Tops of windows shall generally be minimum 2100 mm from floor level but toilet windows may be higher. The bottom of windows shall be generally at least 0.45 metres above floor level. Each window shall be provided with a

sunshade projecting about 350mm from the wall above and at the upper sides of the window. Few windows shall be placed on south facing walls. Windows shall be spaced to give a wide view of the switchyard.

Windows shall have single glazing with 6mm thick glass, reinforced with wire mesh where windows are placed in or over doors.

Window frames shall be anodised aluminium minimum thickness 1.5mm.

Glass panels shall be placed over doors to provide natural light to internal corridors and rooms where required.

External cills shall have a sloping tile or similar detail with drip.

The Bidder shall prepare a window schedule for each building.

The schedule shall clearly indicate both fixed and opening windows.

The Control and Switchgear rooms in particular shall have opening windows to allow adequate ventilation. Approved quality of MS grill shall have to be provided to all windows. All MS grill will be painted with one coat of red oxide primer and minimum two coats of approved quality synthetic enamel paint.

10B.3.18 Doors

Internal doors and door frames shall be anodized aluminium. Main Entrance/Exit doors and door frames shall be steel.

External doors shall be of aluminium. Fire rated doors shall be in accordance with NFPA 80 and shall be of standard construction. Doors shall be dust-proofed by use of neoprene or other approved seals.

The minimum size of the structural openings for doors shall be 1550mm wide for double doors and 930mm wide for single doors. Door height shall generally be 2100mm but switchgear and control rooms shall have a removable transom and removable panel over the door or a taller door to provide a total height of about 2100mm. All door sizes and widths shall be adequate to get in and get out all equipment and future equipment.

All external doors shall have weather boards, hydraulic closers and cabin hooks to hold the door open. External doors shall open inwards, except for switchgear room doors which must open outwards and be fitted with panic release latches.

Each wooden door leaf shall have minimum four 150mm heavy iron hinges. Door furniture shall be of approved local manufacture and shall generally be of brass. All corridor doors, external doors and rest room (toilet) doors shall be fitted with hydraulic closers. Door stops shall be fitted where required. Door frames shall generally be set 200mm off a wall junction to enable the door to open fully through 90°.

All external doors shall be shaded by either the roof canopy of minimum 350mm or a separate precast concrete canopy over the top and the upper sides of a door.

The Bidder shall prepare a schedule of all doors and all door furniture for each building.

For the GIS entrance gate at GIS room, the gate shall be electrical motorized horizontal or vertical door. Before commencement of installing, the contractor shall submit a detailed drawings and specifications of motorized door for Employer's approval. This is a **Hold Point**.

10B.3.19 Brickwork

Brickwork shall be designed to BS 5628. External panels of brickwork shall be checked for wind pressure calculated in accordance with BS 6399 for a wind speed of 160 kph 3 second gust.

Bricks shall be first class bricks from approved manufacturers. 10 bricks shall be tested in accordance with BS 3921 to determine water absorption and crushing strength, which shall exceed 20N/mm^2. Mortar shall generally be mixed at a ratio of 1: 5 (cement: sand).

All brick panels shall be tied to the concrete frame of approved design.

Facing bricks shall be of Mirpur ceramics or similar approved. Facing bricks shall be tied back to the main wall of GIS control room building/SPR. External walls shall be 230mm thick brickwork, rendered internally and clad externally with facing bricks or rendered as required by the architectural plan.

Bricks shall be compacted down onto a full bed of mortar. Vertical joints shall be completely filled with mortar. Joints shall be raked out about 10mm deep where walls are to be rendered.

Brick walls shall be constructed so that tops of all meeting walls are about the same level. Only 18 courses per day shall be laid. New work shall be protected from sunlight and drying winds for 4 days.

Lime and cement for all brickwork shall be stored in a dry building with a raised dry floor.

Reinforcement by mild steel rods shall be provided where required by the design. Additionally openings over 500mm wide shall be reinforced for 2 courses above and below the opening, minimum two 8mm bars per course extending 300mm beyond the opening both sides where possible.

All exposed brickwork shall be rendered and painted where not faced with facing bricks.

10B.3.20 Expansion Joints, Joint Fillers and Sealants

Not used.

10B.3.21 Cable Trenches in Switchyards

Cable trench sizes shall be standardized. Layout drawings shall be submitted for each substation showing layout and size of trenches. No trench shall cross a road; power cables shall be placed in ducts of minimum 150mm diameter with bell-mouthed ends. Ducts shall extend 1500mm minimum beyond the edge of roads. Spare ducts shall be installed for likely future development.

Floors and walls of trenches shall be constructed of Class A reinforced concrete of minimum 150mm thickness, with the external surface painted with two coats of bitumastic paint. Walls and covers shall protrude at least 50mm above site finish level and the top of the wall shall be flat with no rebate. Floors shall be sloped at 1:150 minimum slope to brick soakaways placed at the side of trench; the volume of each soakaway shall be 2.5m^3 per 150m^2 of trench.

Covers shall be of reinforced concrete Class A. Each cover weight less than 55 kg. The minimum depth shall be 70mm, with down stand ribs along each side providing a minimum overall depth of 100mm. The ends of the cover shall overhang the wall by 15mm and in the centre of each end there shall be a hand hole of minimum size 100mm by 20mm high. This hole shall allow air to ventilate the trench so that heat built up in the trench shall be reduced. No gaps larger than 5mm shall be left between adjacent covers so that the cables are always shaded. Cover slabs shall sit squarely and uniformly on the trench walls without the need for bedding or shims. Because portable fire extinguishers will be rolled over and along trenches, each cover shall be capable of resisting a 250kg point load at mid span. The Contractor shall provide ramps up to the edge of covers in several locations, as agreed on site, to enable the wheeled extinguisher to mount the covers. Longitudinal edges may be inclined at 10˚ to the vertical, thus creating a larger gap at the bottom of adjacent slabs, again to reduce heat build-up. The upper surface of covers shall have a stiff broom non slip concrete finish. All sharp edges shall be stoned smooth. Outer edges shall be chamfered.

Longitudinal fire separation walls and transverse fire separation walls as required by the cable section, may be of brick or reinforced concrete.

10B.3.22 Rainwater Pipes

Down pipes shall be 100mm minimum diameter placed on the outside of walls but enclosed in a brick buttress of facing bricks. One downpipe shall be provided for each 100m^2 of roof area. The head of the downpipe shall be enlarged to 200mm diameter and a purpose made cast iron grill provided over the head. This grill shall be sited in a recess in the roof slab projection.

The foot of the pipe shall have a 90° bend and water shall be discharged into either:

i) a small open channel conveying the water to the boundary channel

ii) a pipeline conveying the water off the site. Rainwater shall not be connected to the septic tank or allowed to discharge directly onto switchyard paving.

10B.3.23 Switchyard Foundations

The tops of all foundations shall be set at the same level, which shall be raised above the Finished Switchyard Level (FSL) for the purpose of preventing surface water coming into contact with the equipment structures and holding-down bolts. The distance between the Finished Switchyard Level (FSL) and the top of foundations shall be at least 200mm. All exposed concrete surfaces shall be painted with an acrylic weather proofer or bituminous paint, and flat areas shall be sloped to shed water. No base shall permit ponding of water in any way, and free drainage shall also be possible from all areas inside any grouting.

Bases shall generally be of Class A reinforced concrete.

Bases shall have all recesses for cables and earthing detailed on drawings. The drawings shall clearly show the orientation of each base and the location of all recesses. Where new foundations are adjacent to existing foundations; the Bidder shall be responsible for verifying the extent of the existing foundation and ensuring its stability.

For anchorage design of switchyard foundations shear force, vertical accelerations, overturning moments and torsion due to mass eccentricities of the equipment for the earthquake load of 0.1G are required to be considered. Mild steel ductile bolts and headed studs cast-in-place anchor bolts shall be used. Thick plate washer is required to be welded to the equipment base plate. Normal washers shall be used under a nut in all cases.

10B.3.24 Transformer Bases

The transformer base, together with its surrounding bund shall form a raft to distribute the load from the transformer over the entire area within the bund wall. The bund shall extend at least 700mm beyond any part of the transformer and its radiators. The level of the top of the bund and the skids shall be 200mm above general switchyard level. Skids shall extend to the edge of the bund. Where separate transformer cooler banks are provided, the cooler banks shall also be protected by the bund.

50mm below the top of the wall shall be placed a layer of stone 225mm deep set on a galvanised grill painted with two coats of bitumastic paint. The effective volume of the bund below the stone shall equal 125% of the total volume of oil in the transformer and its radiators.

Rainwater will tend to collect in the bund. To evacuate rainwater a fixed submersible pump controlled by sensors and switches (Aqua Sentry or equal) shall be provided at each bund with power supplies and drainage manhole conveniently located. The bund water control system shall differentiate between water and oil to ensure that the pump will not be activated while oil is present in the bund.

The transformer base and the bund shall be founded a minimum 1.0 metres below Finished Ground Level (FGL).

The skid walls shall be at least 600mm wide. RCC piles shall be provided below each jacking point to lift the transformer. Top level of jacking pad should be at the same level of skid wall. Steel plates shall be inserted at the top of jacking pad.

The entire concrete surface of the bund and the transformer base which is not buried shall receive two coats of bitumastic paint. Skids shall receive 3 coats of bitumastic paint before being cast in.

Carriage way is required to be provided with rail connected to all transformer bases. Transformer shall be anchored in such a manner so that it can prevent the movement of transformer for 0.2G ground acceleration.

10B.3.25 Blast Walls

The Bidder shall construct blast walls to reduce the risk of fire spreading from each three phase transformer unit to an adjacent transformer unit or control building. If the clear distances of transformer from GIS control room building less than the transformer height, then a blast wall should be provided between the transformer and the GIS control room building. Blast walls shall also be constructed to resist impact forces causing from a transformer explosion damaging adjacent equipment.

The height of the blast walls for transformers shall be 500mm higher than the top most part of transformer or 500mm higher than the height of the tops of the HV bushing (whichever is higher) and 300mm wider at both sides than the width of transformer. The minimum thickness of blast walls shall be 200mm.

The blast wall will be constructed with Class A reinforced concrete with all exposed edges chamfered, Surface of wall will fare faced concrete and painted as the colour of transformer body.

10B.3.26 Paints and Painting

All paints shall be of approved makes and colours and proven suitability for the prevailing climate and shall be approved by the Engineer. All surfaces for painting shall be cleaned down prior to being painted and rubbed down to a smooth finish.

All externally exposed concrete and render of the buildings, boundary walls and guard posts shall be painted with a fungicide, Snowcem primer and two coats of Snowcem. All exposed facing bricks and Snowcem painted surfaces shall be treated with one coat of clear silicone (5%) water proofing solution.

All exposed parts of foundations, the outer faces of cable trenches and cable tunnels shall be painted with three coats of bitumastic paint.

All ungalvanized metalwork shall receive two coats of red oxide paint at least 4 days before installation and shall receive two finishing coats of paint after installation, each coat being of different colour. Surface preparation before painting shall be SA 2.5 or an agreed rust convertor acid shall be used. All galvanized steel, boundary wall wire supports, crane beams, base plates and holding down bolts and concrete plinths shall receive two coats of bitumastic paint. Galvanized steel shall not be painted until the surface has weathered.

Internal walls when fully dry shall have the surface rubbed down with sandpaper and be painted with a sealer and 2 finishing coats of plastic emulsion paint before equipment is installed. A further finishing coat shall be applied after completion of installation.

One day shall be allowed for drying of each coat before the next coat is applied.

The interior of all septic tanks and manholes carrying foul sewage shall receive two coats of bitumastic paint.

10B.3.27 Furniture

The Contractor shall supply a complete set of tables, chairs, stools, desks, benches, storage shelves and drawing cabinets as described in the Project Requirements with layout top, for drawing examination, lockable cabinets for spares and test equipment and key boxes in each building. These shall generally be of steel of local manufacture and shall be of robust durable construction. In each rest room (toilet) two couches, approximately 900mm wide by 1900mm long with back rests against the wall, shall be provided.

The full details and specification of these materials shall be agreed before purchase. The Contractor shall arrange for a list of items to be handed over to the Employer, who will sign for receipt of a complete set as stated on the list.

10B.3.28 Concrete

Only two grades of concrete shall be used. Class A shall be used for all structural work, piling and for all foundations. Class B concrete shall be used for blinding, pipe surround and unreinforced or nominally reinforced concrete. Road slabs and floor slabs shall all be Class A reinforced concrete.

	Class A	Class B
Minimum Cement Content	360kg/m^3	170kg/m^3
Maximum Water Cement ratio	0.55	-
Coarse Aggregate type	Well graded crushed stone chips	Jhama brick
Maximum Coarse aggregate size	20mm (40mm for piling)	25mm
Method of Batching	Volume batching	Volume batching
Minimum characteristic strength of trial mix at 28 days	30N/mm2	-
Minimum characteristic strength of trial mix at 7 days	14N/mm2	-
Minimum characteristic strength of works cubes at 28 days	20N/mm2	-

Slump Range	30mm min-100mm max
50mm min	
Slump for concrete placed below water in piling	150mm min

It should be noted that minimum specified cement content will produce significantly stronger concrete. The Contractor's design shall be based on a 28 day crushing strength of minimum 20N/mm^2. Design shall be in accordance with this Contract and BS 8110 or other agreed standard.

For all types of foundation work mild steel of minimum characteristic strength 415 N/mm^2 shall be used and minimum reinforcement required for pedestals and foundation bases shall be 0.5% and 0.13% of gross cross sectional area respectively.

Minimum clear cover to re-bars shall be 60mm where concrete is in contact with backfilled soil against a shuttered face, 75mm where concrete is cast against soil, and 38mm for all above ground concrete. In detailing bars which traverse a member, a reduction of 5mm shall be made for a bent bar and 10mm for a straight bar to ensure adequate cover. Exposed ends of sunshades and roof projection shall have 70mm minimum cover.

All concrete design shall ensure easy access for vibrators of 50mm minimum diameter. Because of the slowness of concreting using local methods of transport, congested reinforcement details and shapes which are difficult to concrete should not be used. The location of all cold joints shall be agreed in writing with the Engineer and all joint surfaces shall be scrabbled. All joints shall be horizontal or formed against vertical stop ends. Shear key shall be provided in joints. All cold joints shall be indicated on drawings. Roof slabs shall generally be cast in one continuous operation. Where curing compounds are used to protect exposed surfaces from solar radiation and improve moisture retention, they shall be subject to the approval of the Employer. This is a **Hold Point**.

10B.3.29 Concrete Reinforcement

The Contractor may use locally available mild steel bars from approved sources or import steel bars to any agreed standard. No bar or stirrup shall be smaller than 8mm diameter to ensure adequate rigidity during concreting.

If locally purchased bars are used, bending tests and tensile tests shall be carried out to ensure the bars meet the design standard adopted and weight per unit length shall be tested regularly.

Bar bending lists shall generally be shown on drawings, where possible with a diagrammatic representation of each bar to ensure clarity and ease site communication. The Engineer will not systematically check the accuracy of every bar on bar lists when approving drawings. The Contractor shall therefore arrange to check all bar lists. Drawings shall detail all chairs and ties and include these on bar lists.

Bars shall be tied at every intersection and the ends of tie wire bent away from concrete surfaces.

Anti crack bars shall be provided at changes in slab or wall thickness and at the corners of every rectangular opening.

10B.3.30 External Render

All brickwork which is not faced with facing bricks shall be rendered. Concrete columns and walls shall be rendered and painted in accordance with BS 5262 with a 3mm spatter dash coat a 12mm undercoat followed by a 9mm finishing coat. Surface preparation shall be as described in BS 5262. Joints shall be provided in all render where brickwork panels abut concrete columns and grade beams, as required by BS 5262.

A mix type II or III shall generally be used. The finishing coat shall be weaker than the undercoat.

The tops of all foundation blocks and all protruding concrete foundations shall also be rendered where required by the Engineer.

PVA Bonding agents shall not be used because of the risk of early drying in the tropics. All concrete surfaces to be rendered shall have the entire surface scabbled and brushed with a stiff brush to remove all loose material. The surface of the undercoat shall be roughened to ensure bonding of the finishing coat.

All render once completed shall be kept continuously damp for 10 days, after which if shall be treated with a fungicide. Any existing backgrounds shall be treated with a fungicide and all growth cleaned after 5 days of contact with the fungicide.

10B.3.31 Lifting Beams (Not used)

In substation buildings a galvanized steel lifting beam shall be provided for hoisting equipment to all upper floors. The beam shall be fixed permanently in place and shall project the required distance from the building to lift the largest equipment from road transport. Beams shall be designed in accordance with BS 2853 and deflection shall be limited to 1/900th of span. An approved (Morris of Loughborough 190 Series with Morris 164 travelling trolley or similar approved) hand chain hoist with hand geared travel and travelling trolley of capacity to suit the heaviest equipment or future equipment shall be provided on each beam. The chains shall reach to lorry level and provision shall be made to hang up the chains to one side when not in use.

Inward opening doors shall close around the beam and be shaped to a close fit.

10B.3.32 Stairs

Except where indicated otherwise in the schedules, all single/multi-storey buildings shall have internal/external staircase up to the roof; the minimum staircase clear width shall be 2.5metre

and the maximum slope about 30˚, all detail being designed in accordance with BS 5395. These staircases shall be enclosed. The design shall allow free circulation of air over the treads and through the risers. Non slip nosing shall be provided.

GIS building shall have one internal and one external staircase for fire escape, which shall have a minimum clear width of 2.5metre with a maximum slope of 30˚, all detailed in accordance with BS 5395. External/fire staircases shall be enclosed and shall be completely protected against rain by roof projections; steps shall be open with non-slip nosing. All staircases shall have homogeneous floor tiles with non-slip nosing. All staircases shall be provided with stainless steel railings (38mm dia. for vertical railing & 50mm dia. for horizontal railing). In GIS building, provision for a lift of capacity of 6 persons should be provided.

All roofs which are not accessible by stairs shall be provided with a galvanized steel fixed ladder.

10B.4 CONCRETE WORKMANSHIP

10B.4.1 General

At all stages in the production, mixing, placing and curing of concrete, the work will be inspected by the Engineer's representative. If any material, dimension or practice is not at least equal to the standards set out herein, it shall be rejected and alternatives compliant with the said standards, and in addition to the satisfaction of the Engineer, shall be implemented.

10B.4.2 Aggregates

Coarse aggregate shall be capable of passing through a 20mm sieve and be retained on a 5mm sieve. Fine aggregate shall be not larger than 5mm and not smaller than 0.06mm and shall be sharp in texture.

All aggregates shall be free of harmful quantities of organic impurities, clay, silt, salt or unsound particles. The amount of clay, silt and fine dust present in aggregate, whether as coatings or separate particles, may not be more than:

15% by weight in crushed sand
3% by weight in natural or crushed gravel sand
1% by weight in coarse aggregate.

If the Engineer considers that any aggregate which the Contractor proposes to use contains an excess of fine particles or any harmful substances, the Contractor shall either replace the aggregate or, at his option and entirely at his expense, institute a series of approved tests at an approved laboratory to determine the nature and extent of the fine particles and harmful substances. Following receipt by the Engineer of the results of the analysis and tests, he will advise the Contractor in writing whether the proposed aggregate may or may not be used. The Engineer's decision in this respect shall be final.

Tests to determine the extent of impurities or fine particles shall include (but shall not be restricted to) the relevant tests specified in BS 882:1992, ASTM. C40-79 (Color metric test) and ASTM. C33-82.

10B.4.3 Sampling

At least four weeks before he envisages first receiving aggregate from any source the Contractor, in the presence of the Engineer, shall obtain samples for testing. Samples shall be taken in accordance with the procedure quantities laid down in BS 812 and shall be subjected to those tests which the Engineer considers necessary to demonstrate the soundness of the material.

Such tests shall be carried out in an approved manner at the Contractor's expense and may include the manufacture, both in the laboratory and at site, of test cubes or cylinders to determine crushing strength.

10B.4.4 Grading

The Contractor shall ensure that his offer includes the full cost of obtaining and transporting suitably graded stone aggregates to site.

Grading of aggregates should, together with the required minimum cement content and water cement ratio, ensure adequate durability, density and characteristic strength of the finished concrete. The Contractor shall submit in writing to the Engineer the makeup of the mix he proposes to use, together with the grading analysis for the particular material and any details concerning his or others' experience with the use of aggregate obtained from the same source.

10B.4.5 Cement

Portland Composite Cement shall comply with BS 12. The Contractor may obtain cement, bagged or in bulk, from any approved source in Bangladesh but shall always submit sufficient samples from each delivery, as required by the Engineer, to ensure that all cement complies with the minimum requirements of BS 12. All cement shall be stored in a weather tight shed at least 300mm off the floor to prevent the moisture content. Regular checks shall be made on the weight of cement in each bag.

10B.4.6 Water

All water used in the preparation of concrete for foundations shall be potable water, *i.e.,* clean, fit for drinking and free from all earth, vegetable matter and alkaline substances, whether in solution or in suspension, and shall comply with BS 3148.

10B.4.7 Reinforcing

Where reinforcing is specified in any foundation design, it shall comply with BS 4449 or an approved similar standard. Before any reinforcing is used, the Contractor shall provide the Engineer with a certified mill certificate, verifying its grade and quality, and proof test such

samples as the Engineer considers necessary. All reinforcement shall be clean and free from loose mill scale, dust, loose rust and paint, oil or any other coating which in the opinion of the Engineer may destroy or reduce bond.

10B.4.8 Storage

The Contractor shall ensure that all the materials he provides for the preparation of concrete shall be stored in a manner which prevents contamination by dust, clay, water or any other harmful material.

Heaps of coarse and fine aggregate shall be separated by at least one meter.

Where aggregate is tipped directly onto the ground, the bottom 20cm of the heaps shall not be used. Bagged cement shall be protected from rain, mixing water or damp soil during storage/transport. Cement from accidentally split or damaged bags shall not be used.

Where the Engineer considers it necessary, special precautions shall be taken to ensure that aggregate stored on site shall remain dust free. Such precautions may include the bagging of aggregate at the pit if sites are adjacent to dusty roads or if heavy rain is liable to wash out fine material or saturate the aggregate to an extent which might influence the water content of a mix.

Where the Contractor establishes central depots for receiving cement prior to dispatch to individual sites, he shall ensure that the cement storage areas are sufficiently raised above the surrounding ground to prevent contamination of the cement by surface water. The material from which storage plinths are made shall be approved by the Engineer.

10B.4.9 Design Mix

Prior to ordering any aggregate the Contractor shall inform the Engineer of the source(s) of his aggregates and deliver samples to the Engineer. The Contractor will authorize at an approved laboratory tests to show the sieve analyses, relative densities, moisture content, and specific gravity of the samples of aggregate from each source. At least four test specimens of concrete shall be mixed at an approved laboratory and tested after 7 and 28 days. The contractor shall be entirely responsible for the control of the quality of concrete mixed and placed. Before the commencement of any concrete design mix, the Contractor shall submit to the Engineer the details of the material used, source of the supply, storage and quality control requirements, including preliminary trail mixes and works' tests. This is a **Hold Point**.

Depending on the moisture content of the samples of aggregate the Contractor will report to the Engineer on the expected water/cement ratio and the aggregate/cement ratio of concrete to be produced on site.

Following the successful testing of the laboratory samples the Contractor shall make trial mixes at site (from which he will take at least 4 test specimens) using the proportions advised to the Engineer (and in the presence of the Engineer) and using the equipment he intends to

use in the normal day to day manufacturing of concrete. This is a **Hold Point**. The minimum 28 day crushing strength of any such test specimen shall be not less than 20N/mm2.

After successful testing of the test specimens made at site, the Engineer may then approve the source(s) of aggregate and the mix design.

No changes to the approved mix design will be permitted unless the type or source of aggregate differs from those already tested, in which case further tests at both the laboratory and at site will be made.

Any concrete placed which does not conform to the approved mix designs, shall be removed and replaced by the Contractor at his own cost.

10B.4.10 Mixing and Placing of Concrete

Proportions of aggregates and cement and the quantity of water for each batch of concrete shall be closely monitored by an experienced mixer operator. Aggregate shall preferably be weight batched but, where this is not possible, volume batching shall be permitted, provided that the net volumes of the loading equipment are approved by the Engineer. Containers for measuring quantities of water shall be clearly marked and only approved quantities of water shall be used in the manufacture of concrete.

Mechanical mixers shall be in good condition and well maintained. After loading, the constituent parts of the concrete shall be mixed together for a period of not less than two minutes or 30 revolutions of the barrel, whichever is the greater. For mixers with a capacity greater than 1.5m^3 these periods may be increased if the Engineer so requires.

When the constituents are adequately mixed, the fresh concrete shall be discharged from the mixer and placed in the foundation with the minimum of delay. Chutes shall be used to ensure that fresh concrete is not dropped by more than 1.5 meters.

No concrete shall be placed until all form work, installation of parts to be embedded, and preparation of surfaces involved in the placing have been approved. No concrete shall be placed in or through water, except with the written permission of the Engineer, and the method of depositing such concrete shall be approved by the Engineer. Concrete shall not be placed in running water and shall not be subjected to the action of running water until after the concrete has hardened for seven days. All surfaces of forms and embedded materials that have become encrusted with dried mortar or grout from concrete previously placed, mud or other foreign material, shall be cleaned of all such refuse before the surrounding or adjacent concrete is placed. Immediately before placing concrete, all surfaces of foundations upon or against which the concrete is to be placed shall be free from standing water, mud and other foreign matter. The surfaces of concrete which have set, and against which new concrete is to be poured, shall be thoroughly cleaned to remove all foreign material and laitance, and be saturated with water immediately before placing concrete. Concrete shall be deposited continuously and as rapidly as possible until the unit being poured is complete. If for any reason the work is stopped before completing the unit of operation, a construction joint shall be installed in accordance with the instructions of the Engineer. Concrete shall be so

deposited as to maintain, until the completion of a unit, a plastic surface approximately horizontal.

The method and equipment used for transporting concrete shall be such that concrete having the required composition and consistency will be delivered as near as practical to its final position without segregation or loss of slump. All concrete mixing and placing equipment and methods shall be subject to approval by the Engineer. Concrete placement will not be permitted when, in the opinion of the Engineer, weather conditions or other pertinent factors prevent proper placement and consolidation.

Bidders are reminded that, as a minimum standard, the following series of inspections should be carried out by the Contractor before concreting can begin:

1 Formwork coated with mold oil and correct in type, quantity and condition

2 Centre lines of template to coincide at the center peg

3 Formwork to be well strutted and correctly located

4 Vibrator to be in working order

5 Mixer to be in working order

6 There is provision to maintain continuous mixing and pouring, by hand if necessary, in the event of a mixer breaking down

7 Where necessary, re-bar is on site ready bent and complete with tie wire, stirrups and concrete or plastic preformed spacer packs

8 A reliable level is at hand

9 There is sufficient aggregate, cement and water to complete the pour

10 Excavations are safe and not cluttered around the top edges

11 The mixer barrel is clean, and the paddles are complete and in place and the barrel will rotate at the speed specified by the Manufacturer

12 A suitable chute is in place

13 Both an air thermometer and concrete thermometer are on site

14 There is a large quantity of hessian sacking at hand

Where any of the above items are not complied with, the Engineer may suspend concreting pending their implementation.

10B.4.11 Testing of Concrete

Samples shall be taken and tested in accordance with BS 1881. Testing shall be carried out by an approved laboratory, who shall arrange to immediately notify the Contractor and the Employer in writing of any cube failure. Failed cubes shall be kept for reference.

Concrete for the test specimens shall be taken at the point of deposit. To ensure that the specimens are representative of the concrete, a number of samples shall be taken from different points. Each sample shall be large enough to make one test specimen and shall be taken from one point in the work.

The tests specimens shall be stored at the site at a place free from vibration, under damp sacks for 24 hours + 1/2 hour, after which time they shall be removed from the molds, marked and stored in water at a temperature of 10 to 21°C until the test date. Specimens which are to be sent to a laboratory for testing shall be packed for transit in damp sand or other suitable damp material, and shall reach the laboratory at least 24 hours before test. On arrival at the laboratory, they shall be similarly stored in water until the date of the test.

One compression plate of the testing machine shall be provided with a ball seating in the form of a portion of a sphere, the center of which coincides with the central point of the face of the plate. Test specimens shall be placed in the machine in such a manner that the load is applied to the sides of the specimen as cast.

Cube strengths for concrete are to be not less than $14N/mm^2$ within seven days after mixing and $20N/mm^2$ within 28 days after mixing.

One cube shall be tested at 7 days to obtain an indication of the concrete strength. The remaining three cubes shall be tested at 28 days and the average of their strengths shall be calculated. Should the average of the cube strengths fall below the specified 28 days cube strength, the Engineer may order the affected concrete to be removed and replaced at the Contractor's expense, or the Engineer may allow the Contractor to take a cylinder for further testing in accordance with BS 1881, if Schmidt Hammer readings indicate below strength concrete.

The diameter of the cylinder shall be not less than three times the size of the maximum aggregate and its length will be at least double the diameter, after allowing for preparation and facing prior to the test. Both a report and compression test will be completed for the sample in accordance with BS 1881. Only one such test will be permitted from any one sample and if the crushing strength of the sample is in excess of that required by the design the Engineer may, after the Contractor has made suitable repairs to the part disturbed by taking the sample, accept the concrete.

In addition to cube sampling, 30% of concrete pours shall be tested by Schmidt Hammer. The Contractor is to pay for all remedial work and testing. Readings shall be taken at locations agreed with the Engineer and shall be witnessed by the Engineer. At least 15 readings shall be taken such that, after discarding the highest and lowest, some 12 readings remain from which the mean shall be calculated. Readings shall be restricted to the middle third of a beam,

slab or column and shall not be closer than 50mm to an edge or closer than 50mm to any other readings. Immediately on completion of hammer testing, the concrete surface shall be painted to seal it with two coats of snowcem primer.

10B.4.12 Formwork

Formwork shall conform to the shape, lines and dimensions of the concrete as called for on the Plans and shall be sufficiently strong to carry the dead weight of the concrete without undue deflection or bulging, and sufficiently tight to prevent leakage of mortar. It shall be properly braced and tied together so as to maintain position and shape. Members used in forms at exposed surfaces shall be dressed to uniform thickness and shall be free from loose knots or other defects. Joints in forms shall be horizontal or vertical. At all unexposed surfaces and rough work, undressed timber may be used. Timber reused in shutters shall have nails withdrawn and surfaces to be in contact with concrete thoroughly cleaned before being reused. Formwork shall not be disturbed until a minimum of 48 hours has passed from time of placement and concrete has hardened sufficiently to support any construction loads that may be imposed. When stripping forms, metal wedges or tools shall not be used to pry panels loose. If wedging is necessary, it shall be done with wood wedges lightly tapped to break adhesion. All columns and beams will have exposed edges chamfered 20 mm x 20mm. Formwork stripping time should be as per standard code and practice.

10B.4.13 Reinforcing Steel

Steel reinforcing bars shall be positioned in the concrete at the places shown on the drawings, or where reasonably directed by the Engineer.

Before reinforcing bars are placed in position, surfaces shall be cleaned of heavy flaky rust, loose mill scale, dirt, grease and all foreign matter. Once in position, reinforcing bars shall be maintained in a clean condition until they are completely embedded in concrete. Reinforcing bars shall have at least the minimum concrete cover shown on the drawings. Reinforcing bars shall be accurately placed and secured in position, such that they will not move during placing of concrete. Precast concrete block spacers may be used for supporting reinforcing bars.

10B.4.14 Consolidation of Concrete

Concrete shall be consolidated to maximum practical density, without segregation, by vibration so that it is free from pockets of coarse aggregate and closes against all surfaces and embedded materials. Vibration of concrete in structures shall be by electric or pneumatic-driven immersion type vibrators of 50mm minimum diameter, operating at speeds of at least 8,000rpm when immersed in concrete. The vibrator shall be inserted vertically at close enough intervals so that the zones of influence overlap. The vibrator shall be inserted to the full depth of the layer being treated and withdrawn slowly. When concrete is being placed in layers, the tip of the vibrator shall extend approximately 100mm into the underlying layer. Vibrators shall not be used to move concrete horizontally. Care shall be exercised to avoid over-vibration of the concrete and direct contact between the vibrator and reinforcing shall be avoided.

10B.4.15 Curing of Concrete

For foundations where excavations are to be backfilled immediately following the striking of shutters, the concrete is to be thoroughly wetted before backfilling commences. Where shutters are to be struck and backfilling of the excavation is not to take place immediately, the concrete is to be covered with wetted hessian sacking and be enclosed in polythene sheeting to avoid rapid drying of the concrete. Curing period should be as per ACI 308R-01 guidelines.

10B.4.16 Hot Weather Concreting

In hot weather the following additional precautions shall be taken.

(a) In hot weather suitable means shall be provided to shield the aggregate stockpiles from the direct rays of the sun or to cool the mixing water/aggregates to ensure that the temperature of the concrete when deposited shall not exceed 32°C.

(b) In hot dry weather suitable means shall be provided to avoid premature stiffening of concrete placed in contact with hot dry surfaces. Where necessary the surfaces, including reinforcement, against which the concrete is to be placed shall be shielded from the rays of the sun and shall be sprayed with water to prevent excessive absorption by the surfaces of water from the final concrete.

10B.5 WORKMANSHIP OF ALL OTHER MATERIALS

This specification only describes concrete work in detail. All other materials workmanship shall be in accordance with an agreed standard. Before starting any new item of work the Contractor shall submit samples of the materials to the Engineer for approval in writing and the method of installation shall also be approved. The first item of any type to be installed shall be inspected and checked in detail by the Engineer before other items are constructed.

The contractor shall submit to the Engineer a comprehensive method statement giving sequential details of his proposed installation method and include his intended program. The method of statement shall include the following details, but not limited;

(a) Method of excavation and dealing with water
(b) Method of pre-heating, welding and site bending of reinforcement
(c) Method of placing of concrete
(d) Method of curing and protecting the concrete
(e) Method of backfilling and compacting
(f) Method of floor finishing
(g) Method of motorized door for GIS entrance
(h) Reinstatement of working areas
(i) Quality control procedure
(j) Site safety procedure

This is a **Hold Point**.

10B.6 Land development work :

10B.6.1 Land development work shall be carried out by dredged filling material or by carried earth/filling sand using the following methods or any other suitable method:

(c) Land development by dredge filling material:

Land development by dredge filling materials means dredging by cutter suction dredger for collection and direct pumping of dredged fill materials by 18" dia. or more cutter suction dredgers from the pre-selected river bed through pipe line to the proposed fill site in wet and liquefied condition. The dredged material will be placed at site directly and excess water will be removed out of the site. Spreading and compaction of fill material will be carried out in layers. The layer thickness shall be determined on the quality of dredged fill material. Each layer should be compacted to a minimum of 95% optimum density as defined by the Proctor Test.

(d) Land development by carried earth/filling sand:

The responsibility of selecting proper location of collection of fill materials (such as earth/viti sand) will rest on the contractor, subject to the approval of the employer. The contractor shall obtain prior necessary permission from the concerned owner/authority paying royalties, all taxes, duties etc. as per prevailing Govt. / semi Govt. / Autonomous organization rule with the intimation to employer for collecting the required fill material. In this case mini suction dredger can be used to collect fill material from nearby river. The crops compensation resulting from the damage of crops during pipe line installation and any other activities shall be paid by the contractor and the cost deem to be included in the price. All fill shall be compacted in layers not exceeding 150mm deep to a minimum of 95% optimum density as defined by the Proctor Test.

10B.6.2 The quoted rates are inclusive of all the costs for supply of materials and hire charges for equipment and accessories etc. required to execute the works by the Contractor.

10B.6.3 Before land filling, The Contractor has to construct necessary dyke/embankment for protection the developed land.

10B.6.4 The rates are inclusive of all the royalties, taxes, VAT, octroi etc. to be paid to Govt. & semi-Govt. Organization or to any person for the earth borrowed from.

10B.6.5 If the Contractor uses the land beyond the control of the Employer, the cost/hire charges, octroi etc. so required will be paid by the Contractor for carrying, laying & installation of equipment, tools & pipes etc. over that land.

10B.6.6 The Contractor is responsible to obtain the permission/approval from the competent authority for the works as mentioned in clause no. 4 & 5 above.

10B.6.7 The Contractor shall execute the pre-work measurements jointly with the representative of Employer for the area to be filled prior to start the land development work.

10B.6.8 The Contractor, along with his bid shall furnish the detailed procedure of whole works with a list of manpower, tools & equipment required to execute the same. He shall, if the proposal is by dredged filling also show in the drawing location of the river bed to be dredged and the route of pipe lines from the dredging point to the filling area.

10B.6.9 The Contractor shall clean and remove the unspecified & the unsuitable materials which do not mix with the earth at his own cost and responsibility.

The work may be increased or decreased as per site requirement and no extra price escalation by the contractor for such increase of work shall be entertained.

10B.6.10 The Contractor will arrange the testing of the samples of the fill materials & compaction tests of developed areas by Laboratory approved by employer. The cost of any or all such tests shall be borne by the Contractor.

10B.6.11 The Contractor shall protect & maintain all the materials, equipment etc. against any theft or damage etc. at his own cost until the final executed works are handed over to the Employer.

10B.6.12 After 30 days of completion of the land development work, the contractor will arrange the joint survey (Post-work measurement) along with the employer representative. The quantity of land development shall be calculated by the contractor and checked by the employer according to this joint post-work measurement and the pre-work measurement taken prior to start the work (as mentioned in clause no.7). The rates in the schedule are inclusive of all surveys/pre & post-work measurements.

10B.6.13 The security of the equipment and materials used and the safety of the personnel engaged in the work shall be at the risk and responsibility of the Contractor.

10B.7.1 Fire Extinguisher:

10B.7.1 Control Room/Communication Room/Battery Rooms:

These rooms shall be protected by portable CO_2 fire extinguisher system. The system shall consist of all equipment required for directing the CO_2 gas discharge at a fire including, but not limited to, CO_2 cylinders and necessary piping, a flexible hose along with a jet nozzle. The effective reach of CO_2 gas jet release shall be sufficient to fight small fires that could develop in a control room area. Fire extinguishers shall be placed at strategic locations as per instruction of project engineer. The quantity of extinguisher at each new/upgradation AIS and GIS substation given in Table-1.

10B.7.2 Outdoor Switchyard/Cable Room :

These areas shall be protected by portable dry type ABC powder fire extinguisher system. The system shall consist of all equipment required for directing the dry ABC powder discharge at a fire including, but not limited to, a wheel carriage(only for 15kg capacity) loaded with potable cylinders and necessary piping and a flexible hose along with a jet nozzle & pressure gauge. The extinguisher material shall be non-explosive, non-hazardous, non-corrosive, non toxic. The effective reach of jet release shall be sufficient to fight small fires that could develop in an outdoor switchyard, cable room & store room area. Fire extinguishers shall be placed at strategic locations as per instruction of project engineer. In addition sand buckets also shall be provided with a metal frame for hanging buckets and shall be placed at locations directed by project engineer. The quantity of extinguisher at each new substation given in Table-1.

Table-1: The quantity of fire extinguisher shall be provided at each new substation as follows:

Sl No	Description	Quantity
1	CO_2 Type: 3kg	5Nos.

	5kg	5 Nos.
2	ABC dry powder type: 5kg 8kg 15kg(including wheel carriage)	 6 Nos. 4 Nos. 3 Nos.
3	Sand bucket with metal frame	One(1)set with 5 buckets

ANNEXURE-10B.1

DETERMINATION OF DEPTH OF FIXITY, LATERAL DEFLECTIONAND MAXIMUM MOMENT OF LATERALLY LOADED PILES

10-1. DETERMINATION OF LATERAL DEFLECTION AT THE PILEHEAD AND DEPTH OF FIXITY

10.1.1 The Iong flexible pile, fully or partially embedded, is treated as a cantilever fixed at some depth below the ground level (see Fig. 2).

10-1.2 Determine the depth of fixity and hence the equivalent length of the cantilever using the plots given in Fig. 2.

Where $T = (\frac{EI}{K_1})^{(\frac{1}{5})}$

(k_1 is a constants given below, E is the Young's modulus of the pile material in kg/cm2 and I is the moment of inertia of the pile cross-section in cm^4).

Note: Fig. 2 is valid for long flexible piles where the embedded length Le is ≥ 4R or 4T.

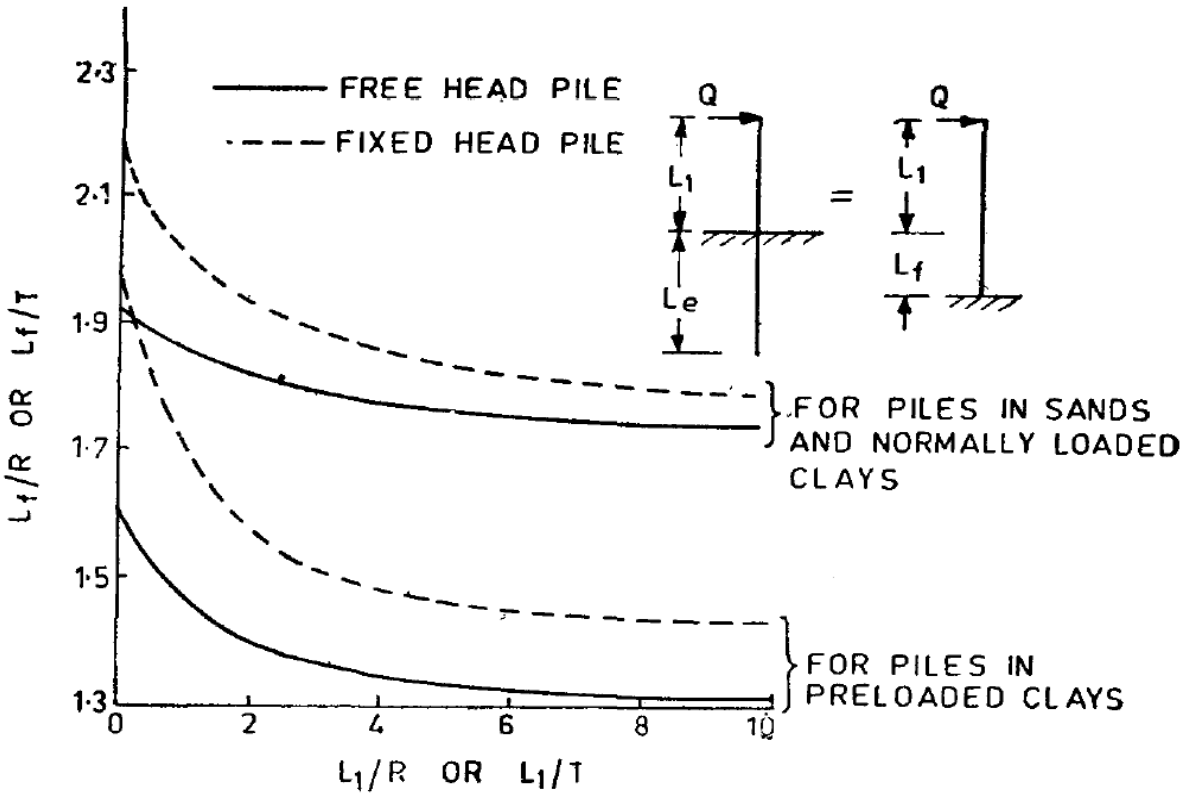


FIG. 2 DETERMINATION OF DEPTH FIXITY

K_1 is the constant of modulus of horizontal subgrade reaction, maximum value of k_1 may be considered as 0.525 Kg/cm^3.

10.1.3 Knowing the length of the equivalent cantilever the pile head deflection (Y) shall be computed using the following equations:

$$Y = \frac{Q(L_1 + L_f)^3}{3EI}$$

……for free head pile

$$= \frac{Q(L_1+L_f)^3}{12EI}$$

……..for fixed head pile

Here,

Y in cm

Q is the lateral load in kg

10.2. DETERMINATION OF MAXIMUM MOMENT IN THE PILE

10.2.1 The fixed end moment (M_F) of the equivalent cantilever is higher than the actual maximum moment (M) of the pile. The actual maximum moment is obtained by multiplying the fixed end moment of the equivalent cantilever by a reduction factor, m given in Fig. 3. The fixed end moment of the equivalent cantilever is given by:

$M_f = Q(L_1$ +L_f)

……for free head pile

$$= \frac{Q(L_1+L_f)}{2}$$

……..for fixed head pile

The actual maximum moment (M) = m (M_f)

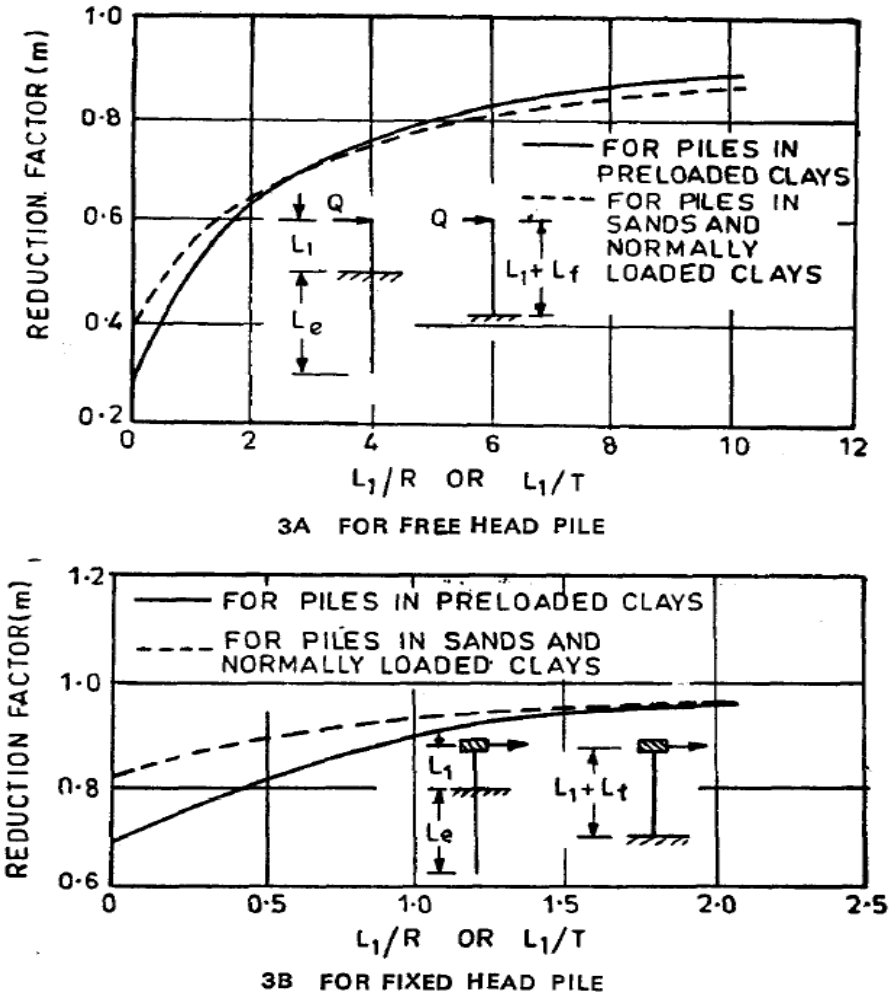


FIG.,3 DETERMINATION OF REDUCTION FACTORS FOR COMPUTATION OF MAXIMUM MOMENT IN PILE

10.2.2 Reinforcement of upper section of pile should be provided upto 1.25x L_f depth

SECTION 11

SUPPORTING STRUCTURES FOR OUTDOOR EQUIPMENT

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SECTION 11

SUPPORTING STRUCTURES FOR OUTDOOR EQUIPMENT

11.1 SCOPE

Where specified structures shall be provided under this contract for supporting the conductors, busbars, insulators, isolating switches, circuit breakers, current and voltage transformers, surge arresters, line traps, coupling capacitors, sealing ends or cable boxes and cables where necessary and other items of plant generally as shown on the relevant drawings. Facilities shall also be provided where specified for the termination of the incoming transmission lines.

All structure designs shall be such as to facilitate inspection, painting, maintenance, repairs and operation with the continuity of supply being the prime consideration.

11.2 STRUCTURE ARRANGEMENT

The arrangement of the high level structures supporting conductors and/or busbars shall be either lattice structures primarily composed of angle sections, or low visual impact A-frame type structures primarily composed of welded hollow or composite sections. Angle, hollow or composite sections shall be either steel or Aluminium as specified. For lattice structures a fully triangulated system of bracings shall preferably be adopted. For A-frame structures the primary connections between major components shall be bolted, for ease of transportation and erection.

Low level support structures shall be either lattice structures primarily composed of angle sections or 'moment' type structures primarily composed of welded hollow or composite sections.

The design and arrangement of supporting structures shall be subject to approval by the Engineer.

The type of arrangement of high level structures and acceptable materials for both high and low level structures shall be as specified in the Schedule of Technical Requirements.

11.3 DESIGN

11.3.1 General

The supporting structures shall be designed to ensure that the specified minimum phase, earth and section clearances are maintained under all conditions. Where applicable special attention shall be paid to the design of the line termination structures to ensure minimum phase clearance is obtained for the complete range of angles of entry specified.

The strength and rigidity of structures shall be such that the alignment of the equipment which they carry shall not be affected by the static and dynamic loads to which the structures are subjected.

For the purposes of design all high level structures shall be considered as terminal structures. For multi-bay continuous structures, central columns shall be designed for the most onerous condition of adjacent bays being loaded or unloaded. For the purposes of design of line termination gantries, highest/maximum loaded gantry column should be identified from the line gantry layout and that same gantry should be designed for all line termination gantries.

The assumptions made in the overall structural design especially in the load transfer between the gantry beam and column shall be adequately reflected in the design and detailing of the beam-column connection.

11.3.2 Assumed Loading Combinations

The supporting structures shall be designed to resist the ultimate applied loading, determined in accordance with the following load combinations:

Load Combination 1 - Design Wind, Coincident Temperature, (Ice)

(a) The wind pressure specified in the Schedule of Technical Requirements Appendix 11 of this Section, applied to the projected area of all conductors and electrical equipment;

(b) The wind pressure specified in the Schedule of Technical Requirements applied to the projected area of all members of the windward face of structure;

(c) Where appropriate the conductor and/or earthwire tensions or busbar forces, including due allowance for both horizontal and vertical deviations /inclinations;

(d) Self weight of the equipment and structure;

(e) When stated in the Schedule of Technical Requirements the effects of the specified radial ice thickness shall be taken into account in the determination of the wind area of

the conductor, earthwire, busbar, electrical equipment and the supporting structure, the conductor and earthwire tensions and the self weight of the equipment and the structure.

The wind directions considered shall include transverse, longitudinal and if appropriate 45˚ to the major axis of the structure.

Load Combination 2 - Still Air, Short Circuit, Minimum Temperature or Maximum Operating Temperature

(a) Conductor and/or earthwire tensions or busbar forces including the dynamic affects calculated in accordance with IEC 865-1.

(b) Self weight of the equipment and structure;

Unless agreed to the contrary, the "resultant spring constant" (s) of both supports of one span for strained conductors shall be taken as 10^7 N/m for steel structures.

(f) Load Combination 3 - Still Air, Seismic, Coincident Temperature (Ice)

(a) Conductor and/or earthwire tensions or busbar forces;

(b) Seismic forces;

(c) Self weight of the equipment and structure;

(d) When stated in the Schedule of Requirements the effects of the specified radial ice thickness.

Seismic forces shall be applied as a static horizontal force transversely and alternatively longitudinally to the major axis of the structure, and shall be equal in value to the seismic coefficient stated in the Schedule of Technical Particulars multiplied by the self weight of the conductor, earthwire, busbar, electrical equipment and structure, and applied at the centre of gravity of the equipment and structure as appropriate.

(g) Load Combination 4 - Still Air, Erection, Coincident Temperature

(a) Conductor and/or earthwire tensions or busbar forces;

(b) Self weight of the equipment and structure.

For erection conditions any one complete phase conductor bundle or busbar or earthwire shall be assumed not to be erected in any one span.

11.3.3 Line Termination Structures

For details of the incoming transmission line phase conductor and earthwire details, and angles of entry reference should be made to the Schedule of Technical Requirements & relevant drawings.

11.3.4 Partial Load Factors

The partial load factors to be applied to the loading combinations determined in accordance with Clause 11.3.2 shall be as specified in the Schedule of Technical Requirements.

11.3.5 Wind Loading

The reference wind pressure to be adopted for the design of the outdoor supporting structures shall be based upon the value specified in the Schedule of Technical Requirements. The reference wind pressure q_{ref} N/m2 at a height of 10m above ground level shall be subjected to variation for height and shape of the structure or equipment under consideration to give the total wind load.

The total wind load on the structure or equipment surface shall be determined from the expression:

The total wind load on the structure or equipment surface shall be determined from the expression:

$$F_w = q \left[\frac{H}{10}\right]^{2\alpha} C_{shp} W_A$$

where Fw = The calculated total wind load on the structure or equipment:

q_{ref} = reference wind pressure

H = Height to top of the panel under consideration

α = power law index

Cshp = aerodynamic shape factor

WA = windward face area of the structure or equipment

The aerodynamic shape factor Cshp shall be as specified:

Flexible conductors	1.0	
Earth wires	1.2	
Tubular busbars $Re < 4.1 \times 10^5$	1.2	[1]
$4.1 \times 105 < Re < 8.2 \times 105$	0.6	

Support insulators, porcelain for apparatus or cap & pin insulator strings	1.2	[2]
Flat truss structures consisting of profiles	1.6	
Square & rectangular lattice towers & supports consisting of profiles	2.8	
Sharp edged structures & components other than above	2.0	
Flat truss structures consisting of tubes	1.2	
Square & rectangular lattice towers & supports consisting of tubes	2.1	

Notes: [1] Re = Reynolds Number

[2] Based on external diameter of insulator.

11.3.6 Equipment and Conductor Terminations

All supporting structures shall be provided with such holes, bolts and fittings as may be necessary to accommodate insulators, isolating switches and other equipment provided under the Contract.

Where incoming transmission lines and/or conductors and/or earthwires are terminated at structures with tension sets, approved shackle or swivel attachments shall be provided. To facilitate maintenance and erection, additional attachment points shall be provided adjacent to the main termination attachment. The supply and connection of the incoming transmission line will be undertaken under a separate contract.

Structures required to support cable sealing ends shall be provided with arrangements for supporting the cables. Attachment holes for the connection of earthwire bonds shall be provided adjacent to the earthwire attachment point. Attachment holes for the connection of the substation earthing grid shall be provided on the vertical face of the structure, approximately 300mm above the top of concrete. Foundation holding-down bolts shall not be used for the attachment of earth connections.

11.3.7 Safety and Access Requirements

To facilitate safe inspection and maintenance all supporting structures which cannot be maintained from ground level shall be provided with climbing facilities, inter-circuit screens, guards etc in appropriate positions as agreed with the Engineer.

All members inclined at 40˚ or less to the horizontal, shall be designed to resist a mid-point load of 1.5 kN, with no other loading being considered.

Where specified step bolts of an approved type shall be fitted to supporting structures at not more than 450 mm centres starting as near as practicable to the base and continuing to within 1m below the top of the structure. It shall be noted on the erection drawings that all step bolts are to be removed after construction for a distance of 2.0m above ground level. Adequate clearance shall be provided between the step bolts and any obstructions which might interfere with their use. Step bolts shall not be less than 16mm diameter, project not less than 150mm, and be fixed with nut, washer and nut.

Where specified ladders of an approved type generally in accordance with the requirements of BS 4211, 450mm wide and 350mm rung spacing shall be fitted to supporting structures. They shall be incorporated into the structure either integrally or separately. Where specified cage protection or fall arrest systems shall be fitted to the ladder. Means shall be provided to prevent unauthorised access of ladders.

Intercircuit screens shall be provided where necessary to prevent access between adjacent circuits on multi-bay structures. Inter-circuit screens shall be fabricated from a 50mm x 50mm mesh formed from 3mm diameter galvanised steel wire.

All structures shall be fitted with identification/notice plates as appropriate.

11.3.8 Structural Design

The allowable ultimate unit stresses used in the determination of the nominal member strength of supporting structures shall be based on the following:

Lattice steel structures	ANSI/ASCE 10-90
Steel A frame or moment structures	BS 5950
Aluminium structures	BS 8118: Part I

Partial factors to be applied to member nominal strength determined in accordance with the above stated codes shall be as specified in the Schedule of Technical Requirements. For ANSI/ASCE 10-90 the appropriate reference stress levels shall be based on the values specified in BS 5950.

The maximum allowable slenderness ratios shall not exceed the following:

Steel /Aluminium

For column or support leg members, beam chords	120
For other load bearing compression members	200
For secondary (redundant bracings)	250
For tension only members	350

Members shall be of such shape, size and length to preclude damage or failure from vibration or stress reversal, including the detailing of connections.

Minimum member thickness and diameter of bolts shall be as specified in the Schedule of Technical Requirements

Holding down bolts shall be used to connect the structures to their foundations. The design of holding down bolts shall make adequate provision for combined axial and shear forces.

The nuts of all bolts attaching conductors, busbars or earthwire tension sets etc, shall be locked with a locknut. No screwed threads shall form part of a shearing plane between members, and bolts shall not project more than 10mm beyond the nut.

11.3.9 Design Submissions

The Bidder shall submit all design calculations & drawings (with all soft/software copies) and method statements as required. All sets of calculations shall be complete, bound, properly titled and given a unique drawing number. An agreed system of identification of the structure design reference, fabrication drawings and substation general arrangement drawings shall be used.

Calculations shall contain a Design Information sheet, derivation of all applied loadings including sag and tension and dynamic tension calculations, the design load for each member group under the critical loading case, member size, slenderness ratio, allowable load, end connection detail and foundation load schedule. Codes or standard references should be quoted and where computer programs are used, a full explanation in the English language shall be provided to assist the Engineer's approval of the calculation.

11.4 MATERIALS

All steel shall comply with BS EN 10025 or BS EN 10210 as appropriate and shall be suitable for all usual fabrication processes including hot and cold working within the specified ranges.

The Bidder must take due cognisance of the minimum ambient temperature, quality of steel, charpy impact value and stress relieving.

The quality of finished steel shall be in accordance with BS EN 10163. All steel shall be free from blisters, scale, lamination, segregation's and other defects. There shall be no rolling laps at toes of angles or rolled in mill scale.

Hot rolled steel plate 3mm thick or above shall be in accordance with the requirements of BS EN 10029.

Bolts and nuts shall be ISO Metric Black Hexagon to BS 4190 and shall be threaded ISO Metric

Course Pitch to BS 3643: Part 2, Tolerance Class 7H/8g. Only one grade of steel shall be used per bolt diameter. Washers shall be in accordance with BS 4320 Grade E and BS 4464 Type B as appropriate.

Consumables used in metal arc welding shall be in accordance with the relevant standard.

All materials for aluminium. structures shall be in accordance with BS 8118: Part 2.

11.5 WORKMANSHIP

The Bidder shall submit panel assembly (fabrication) drawings which shall show all materials in place, complete with all fabrication and connection details. A complete tabulation listing all pieces, bolts, nuts, washers etc shall also be shown on the drawings. The Bidder shall make changes to the fabrication details which the Engineer determines necessary to make the finished structure conform to the requirements and intent of the specification.

The Bidder shall submit a detailed Method Statement of his proposed fabrication procedures including quality control procedures to ensure satisfactory assembly and erection, interchangeability of similar members, accuracy of dimensions, position and alignment of holes.

All welding shall be carried in accordance with BS 5135 for steel structures and BS 8118 Part 2 for aluminium structures. All members shall be stamped on before galvanising or other protective coatings, using characters 10mm high and shall be clearly legible after galvanising.

11.6 PROTECTIVE TREATMENT

Unless otherwise specified after fabrication, all structural steelwork, including bolts, nuts and washers shall be hot dipped galvanised to meet the requirements of BS 729. Bolt threads shall be cleaned of surplus spelter by spinning or brushing. Dies shall not be used for cleaning threads other than on nuts. Nuts shall be galvanised and tapped 0.4mm oversize and threads shall be oiled.

Excessively thick or brittle coatings due to high levels of silicon or phosphorous in steel, which may result in an increased risk of coating damage and/or other features that make the final product non-fit-for purpose shall be cause for rejection. Protective treatment for aluminiurn shall be in accordance with the requirements of BS 8118.

Galvanising thickness and aluminium protection procedure shall be as specified in the Schedule of Technical Requirements

11.7 QUALITY CONTROL

11.7.1 General

Routine tests on raw materials and fabricated individual members shall be undertaken in accordance with BS EN 10025, BS EN 10210 and BS 8118 as appropriate.

All steel ex-mills or received from merchant's stock shall be marked to identify the cast or casts from which it was rolled in accordance with Section 9 of BS EN 10025 and Section 10 of BS 102 10, and shall be covered by the appropriate (mill) certificate. The optional impact test BS EN 10210 option 1.6 for quality JO is required.

The material grades or alloy categories of individual pieces of steel/aluminium shall be capable of positive identification at all stages of the fabrication process.

Bolts and nuts shall be covered by the appropriate test certificate to prove compliance with BS 4190.

11.7.2 Welding

Unless specified to the contrary all structural welds shall be undertaken using approved welding procedures in accordance with BS EN 288. All welders shall be tested to the requirements of BS EN 287.

All welding shall be subject to a non-destructive testing (NDT) programme, which shall include visual, ultrasonic and magnetic particle testing as appropriate. Visual inspection shall be in accordance with BS 5289, ultrasonic to BS 3923 and magnetic particle to BS 6072. Acceptance criteria shall be in accordance with BS 5135, except for porosity and BS 8118: Part 2. All welds especially butt welds must be continuous to ensure a pickle-tight connection when galvanised.

The Bidder's NDT programme shall be submitted to the Engineer for approval prior to the commencement of fabrication.

11.7.3 Check Erection

Prototype structures shall be check erected in order to verify the accuracy of detailing and fabrication.

The degree of check erection shall be sufficient to verify not only the main structure, but all auxiliary steelwork. Sufficient blocking and support shall be provided to prevent distortion and overstressing of members to ensure proper fit. Assembly shall be accomplished without extraordinary effort to align bolt holes, or to force pieces into position. Bolt holes shall not be reamed or enlarged. Any damage to protective coatings during check erection if the check erection is undertaken on coated structures, shall be recoated at the fabricator's cost.

11.7.4 Galvanising

Tests on galvanised members and components shall be carried out at the works to ensure compliance with the requirements of BS 729.

11.7.5 Tolerances

The fabrication tolerances after galvanising for steel members, which are not to be considered cumulative shall be as follows:

(a) On linear dimensions of nominal sections as per BS 4, BS 4848, BS EN 10024, BS EN 10034 & BS EN 10056-2.

(b) On overall length of member ± lmm

(c) On centres of holes ± lmm

(d) On groups of holes ± 2mm

(e) On back-gauges ± lmm

(f) On corresponding holes in opposite faces of a member ± lmm

(g) On specified hole diameter on the punch side (in the black), ± 0.3%

or when drilled -0mm

(h) Taper on the punched holes as measured between the specified hole diameter on the punch side and the hole diameter on the die's side (in the black) ± l.0mm

(i) On specified bends, open and closed flanges ± 0.02%

The pennitted tolerances for straightness after galvanising shall not exceed an offset of 1: 1000.

Tolerances for aluminium structures shall be in accordance with BS 8118: **Part 2.**

11.8 ERECTION

The Bidder shall when requested provide the Engineer with a Method Statement detailing his proposed erection methods. Due cognisance shall be taken of the relevant parts of BS 5531 and current health and safety legislation.

All structural members stored on site shall be kept clear of the ground where possible. Contact with substances likely to attack the protective coatings shall be avoided and all members kept in a clean and tidy condition. Care shall be taken to prevent damage/deterioration of any protective coating during transportation, storage and erection. Unless otherwise agreed damaged members shall be replaced. The renovation of damaged areas of protective coatings shall be carried out using techniques agreed with the Engineer.

The Bidder shall ensure that the structures are not strained or damaged in any way during erection. Structures shall be erected vertically within a tolerance at the top, or the centre of the beam of 0.5% of the overall structure height before equipment installation or conductor/busbar stringing.

APPENDIX TO SECTION 11

Line	Description			
1.	Structure Arrangement [clause 11.2] High Level Low Level Primary Material		Lattice or A-Frame Lattice or Moment Steel	
2.	**Load Combination 1** [clause 11.3.2]		Structures only	Structures Busbars etc.
	Wind pressure at above G.L. q_{ref}	kN/m^2	3.54	1.21
	Power Law factor	α	0	0.095
	Coincident temperature	˚C	5	
	Radial ice thickness	mm	0	
	Density of ice	kg/m3	-	
	Load Combination 2			
	Minimum temperature	˚C	5	
	Maximum operating temperature	˚C	80	
	Load Combination 3			
	Seismic coefficient		0.1g	
	Coincident temperature	˚C	5	
3.	**Line Termination Structure** [clause 11.3.3]		**Phase**	**Earthwire**
	Conductor Designation		Finch	7 x 4.0
	Type		ACSR	GSW
	Number of sub-conductors		2	-
	(All of the above three shall be finalized during execution)			
	Maximum working tension per Phase (132kV)	kN	14	4.5
	Maximum working tension per Phase (230kV)	kN	20	5.0
	Maximum working tension per Phase (400kV)	kN	40	5.0
	Wind pressure	kN/m2	1.40	1.76
	Radial ice thickness	mm	0	0

Line	Description		
	Maximum downlead span m	75	75
	Maximum angle of entry horizontal deg.	45	45
	Vertical deg.	0-30	0-30
	Low duty tension set wind area m2	0.7	-
	Mass kgs	100	-
4.	**Partial Load Factors** [clause 11.3.4]	**Steel**	**Aluminium**
	Load Combination 1	1.35	N/A
	2	1.0	N/A
	3	1.0	N/A
	4	1.5	1.5

Line	Description		
5.	**Safety and Access Requirements** [clause 11.3.7]	**High Level**	**Low Level**
	Step bolts	YES	NO
	Ladders:	YES	NO
	Cage protection	NO	NO
	Fall arrest system	NO	NO
6.	**Partial Material Factors** [clause 11.3.8]		
	Steel	0.85	
	Aluminium	-	
	Foundations	0.76	
7.	**Minimum Member Thickness** [clause 11.3.8]	**Steel**	**Aluminium**
	Main member mm	6.0	
	Other bracing members mm	5.0	
	Secondary (redundant) members mm	5.0	N/A
	Plates mm mm	6.0	
	Bolt diameters mm	16.0	
	Minimum thickness specified shall apply to both hot rolled and hollow sections		
	Minimum angle size mm	45x45x5	
8.	**Protective Treatment** [clause 11.6]		
	Galvanising thickness µm	85	N/A
	Protection procedure	BS 729	No

Line	Description		

12. National Load Dispatch Centre (NLDC)

For the SCADA facilities required for any Power Station or Substation at the National Load Dispatch Centre (NLDC) the following provisions shall be made:

12.1 General scope

The power system of Bangladesh is operated from NLDC SCADA/EMS system which is operated from Main & Backup Master Station situated at two different locations. The system is being in operation after successful installation & commissioning by M/S Areva T&D Ltd. (Now M/S GE T&D Ltd.) since 2010.

The SCADA/EMS system of NLDC is based on “e-terra platform” developed by AREVA T & D (Now owned by GE).

In order to the SCADA/EMS, tele-control & tele-metering facilities required for new Power Station or Substation to NLDC, the complete design, supply, delivery, installation, testing & commissioning of new hardware and software, extension of the existing equipment, necessary adjustment, adaptation, modification, integration and configuration of new and existing equipment in NLDC, shall be provided for integration of new power station or substation along with required modifications in existing power station or substations, which are in the scope of the work of the Contractor, under this contract.

All required electrical quantities digital (Status, Control, Alarms etc.) and analog (Measured Data for any bay i.e. MW, MVAR, kV, Amp) data shall be transmitted to NLDC through the RTU or the Industrial Gateway of the station automation system (SAS for Substations) using IEC 60870-5-104 protocol, integrated with the NLDC after the successful testing and commissioning.

Necessary CT, VT arrangements shall be facilitated for analog measurements. All the analog values should be floating type and frequency dead band should be zero. Scaling of all the field analog values shall be done at field.

Digital Status of the equipment’s, Events & Alarms for the network connected to the grid are to be monitored & archived from NLDC. Therefore, potential free auxiliary contacts are required whereas data should be time stamped at field.

All Circuit Breakers, motorized disconnecting switches, tap changer, etc. are required to be monitored and controlled from NLDC though the RTU/Industrial Gateway. Therefore, necessary arrangements should be made to access those devices from NLDC along with local remote control switch.

Necessary Cabling and interfacing between the RTU/Industrial Gateway and the communication equipment are to be done by the contractor. The scope also includes the supply of any hardware (if any) required for the completion of NLDC Integration. Other works/activities which are not explicitly mentioned but are required for the NLDC integration shall be included in the scope of works.

The Integration of proposed RTU/Industrial Gateway for data communication with existing NLDC SCADA/EMS system at NLDC, Bangladesh is the scope of Contractor. Necessary modification in the hardware and software along with database and display at NLDC master station and backup station to accommodate all the new system extended with this contract are also in the scope of work.

12.1.1 Industrial Gateway for New Substation

The RTU/Industrial Gateway for SCADA integration with NLDC shall be 02 (two) in number and shall be configured as Master and Hot Standby. One Gateway will report to Main NLDC and other Gateway will report to BACKUP NLDC simultaneously. Both the RTU/Industrial Gateway shall be capable of reporting to both NLDC Master Station (with two communication terminal server simultaneously through VLAN Network) & Backup Station (through Routed Network) at the same time.

In case of local station using SAS, the Industrial Gateway shall be physically separated device from SAS servers and provision of access shall be made from both local and remote location. SAS Servers and Gateway shall be configured to get the data directly from the BCU through switches for independent operation. Data Flow between SAS and Gateway shall not be occurred.

In case of existing RTU/Industrial Gateway data shall be interfaced to new RTU/Industrial Gateway or existing one as per NLDC requirements. Redundant power supply & control cards along with sufficient spares shall be provided for uninterrupted operation.

The RTU/Industrial Gateway shall be compatible with IEC 61850 for connection interface at station level and IEC 60870-5-104 protocol for connection interface with NLDC for SCADA integration.

The RTU/Industrial Gateway shall be configured according to provided signal list from NLDC as per approved SLD of the new station, communication parameter, IP address and station address.

Connectivity from the RTU/Industrial Gateway to the Communication Equipment at respective Substation along with Communication Equipment, Switch and Front End Server at both main & backup master station shall be provided.

For time synchronization properly configured GPS is required.

In order to ensure cyber security properly configured hardware firewall shall be used between the RTU/Industrial Gateway to communication equipment (SDH and PDH equipment).

The RTU/Industrial Gateway shall have adequate capacity to cater to the future extension of substation.

Maintenance tools for configuration and O&M purpose (necessary hardware, software, spare parts & accessories) shall be supplied.

12.1.2 Extension for the New Substations

Extension and modification in existing system of NLDC is under the scope of the contractor for two (2) new substations, which shall integrate and ensure updating NLDC SCADA/EMS system for smooth & reliable power system operation.

12.2 Training

Necessary trainings are in the scope of the contractor for regular operation and maintenance of the RTU/Industrial Gateway along with SAS as well as emergency restoration procedure. RTU/Industrial Gateway along with SAS configuration training shall also be given for the respective vendor equipment with protocol for the integration to NLDC.

The number of trainees, duration and allowance shall be according to Chapter 1.3 of this volume.

12.3 Integration Works

For the proper Integration of New Substations with the NLDC, at least the following works shall be done at NLDC Main & Backup Master Station using the existing NLDC SCADA/EMS System (based on the software of e-terra Platform by GE) for all the New Substations.

Pre-Database Works:

- Confirmation of Approved Hardware Architecture with sufficient redundancy and proper Cyber Security.
- Preparation of Signal List as per approved SLD for all the New Station and Far-End Stations.
- Confirmation of RTU/Industrial Gateway Configuration Parameter and Information.

- Collection of Network, Generation Parameter and related data for SCADA/EMS Modelling.

Database Modelling, Updatation and On lining Works:

(a) SCADA Database Modeling as per field information and data
(b) RTU/Industrial Gateway Database Modeling
(c) RTUTOP file Creation and Import
(d) SCADA Verification
(e) Network Parameterization and Network Database Modeling
(f) Network Verification
(g) Network-SCADA Mapping
(h) Generation Parameterization and Generation Database Modeling
(i) Network-Generation Mapping
(j) Hydro Database Verification
(k) DTS Database Modeling
(l) DTS-Network, DTS-Generation, DTS-Hydro Verification
(m) DTS Database Validation
(n) Alarm Database Modeling & Validation
(o) Data communication path creation for both Master station and Standby station
(p) Configuration & Updatation of communication network manager platform
(q) Database Updatation and On lining both for NLDC Main & Backup Master Station
    i) On-lining of all databases in SCADA/EMS & Communication Front End Servers
    ii) IP/VLAN configuration on Polling Servers (Communication Front End) and Switches as well as Network Management Servers.
    iii) Compilation and On-lining of all the related displays on WEB servers.

Post Online Works:

(a) RTU/Gateway Configuration and Updatation. Configuring the Gateway according to the requirements. (Required Signals with IEC address, IEC Protocol, data communication parameters, RTU/Gateway IP, NLDC Master/Backup Station IP etc.)
(b) Field data confirmation by local test at site
    i) Verification of all Analog Measurements and checking limit, dead band, polling time
    ii) Verification of Digital Signal Status (open/close, in between, invalid)
    iii) Verification of Alarms, Events etc.
    iv) Verification of Control and Interlock

Fault Rectification and Tuning of Data:

(a) End-To-End Test shall be carried out in Master station and in Standby station in NLDC
   i) Verification of all analog measurements
   ii) Verification of all digital signals and controls
   iii) Verification of displays including single line, popup, alarms etc.
   iv) Verification of communication line for redundancy
   v) Verification of continuous and complete integration of the RTU/Gateway

(b) Tuning of Power system application for all available network and generation applications in SCADA/EMS server including AGC and DTS (Dispatcher Training Server)

The following activities are also in contractor's scope of work:

(a) Collection of required network and generation data for modeling of the network data-base
(b) All required works both in NLDC and at the site

Adaptation work and configuration of the NLDC will mainly consist of:

(a) Modeling the new Substations/Power Stations and new bays of existing Substations.
(b) Configuration of communication network manager platform to display the single line diagrams, statuses, alarms, measurements of the new substations and new bays
(c) Creation/Modification and update of database at respective SCADA/EMS servers at master/backup station
(d) Creation of associate display and modification of existing displays wherever required
(e) Point to point test

12.4 Required Information for NLDC SCADA integration

12.4.1 Signal List

12.4.1.1 Busbar

(a) **Analog Input**: kV, Hz.

(b) Digital Input (Single Point):
   i) Protection Class-3 Trip (Bus bar Trip),
   ii) Voltage Status.

12.4.1.2 Bus-Coupler

(a) **Status Digital (Single Point):**
- i) Remote/ Local Switch for Circuit Breaker.
- ii) Bay Fault.
- iii) Breaker Fault (Spring Charge, SF6 Low).
- iv) Protection Class-2 (Over current, Earth fault).

(b) **Status Digital (Double Point, Single Physical Address):**
- i) Circuit Breaker Open/Close.
- ii) Isolator Open/Close.
- iii) Earth Switch Open/Close.

(c) **Control Digital (Double point, Single Physical Address):**
- i) Circuit Breaker Open/ Close.
- ii) Motorized Isolator Open/ Close.

12.4.1.3 Line/Feeder

(a) **Analog Input:** MW, MVAR, Amperes, kV**.**

(b) **Status Digital (Single Point):**
- i) Remote/ Local Switch for all Circuit Breaker.
- ii) Bay Fault (VT fail for Transmission Line).
- iii) Breaker Fault (Spring Charge, SF6 Low).
- iv) Protection Class-1 (Distance, Differential).
- v) Protection Class-2 (Over current, Earth fault).
- vi) CB Auto Re-close.
- vii) CB Auto Reclosed Blocked.

(c) **Status Digital (Double Point, Single Physical Address):**
- i) Circuit Breaker Open/ Close.
- ii) Isolator Open/ Close.
- iii) Earth Switch Open/ Close.

(d) **Control Digital (Double point, Single Physical Address):**
- i) Circuit Breaker Open/ Close.
- ii) Motorized Isolator Open/ Close.

12.4.1.4 Transformer

(a) **Analog Input:** MW, MVAR, Amperes, kV at both sides, Tap Position Indication (TPI).

(b) **Status Digital (Single Point):**
- i) Remote/ Local Switch for all Circuit Breakers.

ii) Bay Fault (DC Fail for Transformer Panel).
iii) Breaker Fault (Spring Charge, SF6 Low).
iv) Protection Class-1 (Distance, Differential).
v) Protection Class-2 (Over current, Earth fault).
vi) Transformer Alarm (Buchholz Alarm, Oil Level Low).
vii) Transformer Trip (Buchholz Trip, PRD Trip)
viii) Transformer Temperature Alarm (Oil Temp Alarm, Winding Temperature).
ix) Transformer Temperature Trip (Oil Temp trip, Winding Temperature trip).
x) Tap Changer Alarm.
xi) Tap changer trip.
xii) Tap changer high limit.
xiii) Tap changer low limit.

(c) **Status Digital (Double Point, Single Physical Address):**
i) Circuit Breaker Open/ Close.
ii) Isolator Open/ Close.
iii) Earth Switch Open/ Close.
iv) Tap Changer SCADA/ Station Control.

(d) **Control Digital (Double point, Single Physical Address):**
i) Circuit Breaker Open/ Close.
ii) Motorized Isolator Open/ Close.
iii) Tap Changer Raise/ Lower.

12.4.1.5 Generator (if needed)

(a) **Analog:**
Frequency, Volts, MW, MVAR, Amperes, Real Power Setting, Water Inflow/ Fuel Flow, Reservoir Water Level, Fuel Tank Level

(b) **Status Digital (Single Point)**
i) Local/Remote Switch for CB & BI
ii) Local/Remote Switch for Generator
iii) Bay Fault
iv) Protection Class 1 Trip
v) Protection Class 2 Trip
vi) Protection Class 3 Trip
vii) Synchronizing in progress
viii) Turbine Trip
ix) Generator Trip
x) Generator Transformer Trip
xi) Generator Transformer Fault
xii) Generator unit Stopping
xiii)

xiv) Generator unit Available
xv) Generator unit Running
xvi) Generator unit Stopped
xvii) AGC Mode Status (ON/OFF)
xviii) AGC Status Faulty
xix) Load freq. control on/off switch
xx) Power set on/ off switch
xxi) Load freq. control unit fault

(c) **Status Digital (Double Point, Single Physical Address)**
i) Circuit Breaker Open/Close
ii) Isolator switch open/ Close
iii) Earth Switch Open/Close

(d) **Control Digital (Single Point)**
i) AGC Mode On Request
ii) AGC Mode Off Request

(e) **Control Digital (Double Point, Single Physical Address)**
i) Circuit Breaker Open /Close
ii) Generator Unit Start/ Stop
iii) Raise/ Lower MW Set Point Pulse

(f) **Control Analog:** Real Power Set Point

12.4.1.6 Substation Common Alarm

(a) **Status Digital (Single Point)**
i) Control Disable Switch
ii) RTU Fault Alarm
iii) Station Communication Alarm
iv) Main Substation LVAC Power Supply
v) Station DC Fault Alarm
vi) Communication DC Fault Alarm
vii) Check Synchronizing Over-ride

12.4.1.7 For HVDC additional Signal Requirement (if needed)

(a) **Status Digital (Single Point)**
i) Frequency Control Active,
ii) Frequency control enabled
iii) Power oscillation damping enabled,
iv) AC yard control at pole control,

v) AC yard control at SAS control

(b) **Filter & Reactor**

(c) **Analog:** MVAR

(d) **Status Digital (Double Bit, Single Physical Address)**
i) Circuit Breaker Open/Close
ii) Earth Switch Open/Close

(e) **Converter**

(f) **Analog:** Pole MW, Pole MVAR, Total MW, Total MVAR

(g) **Control Analog:** Real Power Set Point

12.4.2 Network Parameters

Line length, Line Conductor type, Short Circuit data for Zero sequence (%R, %X, % of full charging Susceptance) etc.

12.4.3Generation Parameters (if needed)

Generator Type, Fuel Type, Heat-Rate Curve, Incremental Heat Rate Curve, Capability Curve, Droop Settings, Raise/Lower Pulse Setting, Operating Range (Capmin, Capmax, Ecomin, Eco-max, LFCmin, LFCmax) etc.

12.5 Interfaces

This contract includes Industrial grade Gateway to the NLDC. The Gateway shall have adequate capacity (minimum 25% additional spare point with license) to cater to the future extensions of substation. The cabling between the Gateway and the communication equipment shall be provided under this contract as well.

In case of Windows operating system based Gateway, at least the following shall be included: USB port, VGA port, HDD/flash memory ad one spare, TFT monitor, mouse, key board, etc. Hard disc shall be at least 50 % free and CPU loading maximum of 30 % at any condition.

If the gateway is firmware-based, then two (2) control cards are required.

Gateways also shall have eight (8) LAN ports and redundant power supply. There should be GPS facilities for time synchronization. Cyber security has to be ensured at field SCADA interface level. Supported protocol shall be IEC 60870-5-104, 61850 & MODBus etc.

At the existing substations, extensions of the existing gateway or RTU shall be provided and included in the contract price.

12.6 Detailed Description of the Scope of Supply for SCADA, Control & Monitoring System

(a) Overall Scope of Work and Supply

The SCADA system will be based on:

i) The communication with the NLDC shall be via the supplied gateway for Control and Monitoring System of the substation.
ii) Industrial gateway shall be implemented at each involved substation for remote monitoring & control from the National Dispatch Centre. It shall provide all the necessary control and monitoring facilities for 400kV& 230kV Level, 132 kV level, 33 kV level and auxiliaries.
iii) All necessary adaptation work and configuration of the existing SCADA platform of the NLDC to integrate the Substations and the new bays shall be provided.
iv) For 132kV, 230kV& 400kV Level, all feeders shall be controlled via SCADA, whereas, for 33kV Level.
v) All necessary equipment, including required numbers of BCU and panels shall be provided under the scope of the project

(b) General Principle and Description of SCMS

The substation control and monitoring system shall have distributed client/server architecture. It shall consist of:

i) The BCU equipment, which will be installed at the bay level,
ii) The substation level equipment, to be installed in the control room,
iii) A redundant communication network between station level and bay level for data exchange to limit the number of cables and ensure extension of the system. The exchange of information between distributed single bay unit and central substation control level shall be performed through redundant fibre optic wires. The communication network shall be based on the following architecture:
    - One optical double-ring LAN with protection and BCU,
    - One UPT CAT 5 redundant LAN at substation level.

The station level equipment will be power supplied from the two independent AC sources:

i) One from the AC station auxiliaries 230 V AC 50 Hz,

ii) The second one from a UPS,
iii) An automatic change over shall prevent supply interruption.

In the event of loss of supply or disconnection for any reason, the system shall reboot automatically (without loss of stored information) and will update statuses of all devices when the power supply re-covers. The updating process shall not inhibit control functions.

The substation control level must support future expansion of substation control system, having a 25% of resources as minimum.

At bay level, all control functions, data acquisition interlocking functions shall be done in the bay control devices within the bay level equipment. Each feeder shall be equipped with an individual bay control device.

For the data acquisition of substation auxiliaries, information (LV/MV switchgear, station battery, charger, UPS etc.,) a local RTU (or BCPU) shall be provided and installed in the control building. The bay control devices shall be connected to the station level via a redundant optical fibre communication link.

The bay level equipment shall comprise at least the following elements:

i) Bay control unit (BCU). Bay computer shall be separate unit (not incorporated in the protection unit).
ii) Input / output modules for digital and analogue signals,
iii) Communication with protection equipment and analogue signals,
iv) Redundant optical fibre communication with substation level or ring bus communication,
v) Backup mimic panel for maintenance control and measurements. One two position switch shall be provided on control panel:

- Local: Only local control is enabled, the interlocking function is on bay level only, no synchronization,
- Remote: Only remote control is enabled.
- In both cases, all the data must be transmitted to the higher level (NLDC),

vi) Communication port for operation / maintenance from a laptop computer.

Bay control units shall be supplied from 110 V DC.

In the event of loss of supply or disconnection for any reason, the system shall reboot automatically (without loss of stored information) and will update statuses of all devices when the power supply re-covers. The updating process shall not inhibit control functions. There should not be any loss of data due to the loss of auxiliary supply.

It shall be taken into consideration that additional bay control units can be added to the system, without disturbance of the system, for future expansion. A provision of 20% in bay units' expansion is required, as well as a provision of 10% in I/O signals, within each bay.

Control and supervision of the system will be possible from different levels:

i) NLDC,
ii) Substation control level from the operator workstation,
iii) Bay control level.

On all levels, a correct interlocking will be ensured which provides the highest safety for staff and equipment. On the substation control level, the interlocking is managed by the microprocessor-based system, on the bay level it is performed by hard wiring.

The substation control system shall follow the specifications of IEC family 61850, 60870-5-101/104, 60870-5-102 and 60870-5-103. It is an obligatory requirement that the same Manufacturer supplies equipment and software for both the substation control and supervision system and the protection system.

(c) Scope of Work and Supply at new Substations

The substation control system refers to the station level and bay level controls. The station level control equipment shall include the following:

(d) Station Level:

i) Arrangement of the all bays
ii) 2 (two) independent station computers operating on a main and hot standby basis,
iii) 2 (two) operator workstations including 2 x 21" colour monitors for each operator (complete with appropriate desk and chair).
iv) The second operator workstation shall have the capability to be used as Employer's Representative workstation,
v) Two (2) numbers of independent SCADA Gateways
vi) Black & white A 4 laser printer,
vii) Colour A 3 laser printer,
viii) Common bay control unit for monitoring auxiliary power supply and all other equipment on a substation level (telemetry, telecommunication, HVAC, fire protection, etc.),
ix) Satellite clock, which should run on SNTP protocols. The satellite clock will provide the reference time to the comprehensive Substation Control and Monitoring System and protection re-lays through IEC61850 substation LAN.,

The satellite clock system will be complete with GPS receiver, antenna and time synchronisation ports.

x) Interface for laptop computer for maintenance, information transfer and emergency HMI,

xi) Non-fail power supply system,

xii) Communication network equipment (substation local area network, field communication net-work, optical couplers, etc.),

xiii) Optical connection for data exchange with the NLDC.

xiv) Configuration of the new/existing gateway.

The station computers in the substation must be separate machines from the station HMI (operator workstation) and should be located in the control panels, and not on the control desk with the HMI.

(e) Bay Level:

The control system of the bay level at substation shall be carried out with microprocessor based Bay Control Unit (BCU) control system. All BCUs shall be provided with IEC 61850 Edition 2 communication ports.

The connections between BCUs and the station level shall be based on redundant fibre optic links. These communication ports will be used for control, indication and alarm systems to the substation automation system and SCADA. The BCU shall be provided for all:

i) 400kV, 230 kV and 132 kV transmission line bays,

ii) 400/230/33 kV and 400/132/33kV power transformers,

iii) 400kV, 230 kV and 132 kV busbars

iv) 33kV feeders (BCU and panels) and Auxiliaries.

A bay control unit (BCU) shall provide the following:

i) Control for each individual circuit / bay with a LCD mimic and user interface for control and monitoring of the circuit / bay,

ii) Interface for protection devices that cannot directly interface with the substation control system local area network,

iii) Interface for laptop computer for maintenance, information transfer and emergency HMI,

iv) Interlocking functions (soft and hard wired).

Station level control functions shall include the following:

i) Control of all switching devices,

ii) Real-time indication of events and alarms,

iii) Display of analogue values and high / low limit checking,
iv) Display of historical values,
v) Data archiving,
vi) Disturbance monitoring and analysis,
vii) Trend display,
viii) Protection and control relay setting information,
ix) Protection relay fault and disturbance records,
x) Time synchronization,
xi) Interlocking function to prevent unsafe operator action (display message if operator attempts an inappropriate action),
xii) Self-check and diagnostic,
xiii) Manual data setting by the operator, including:
xiv) Hand dressed data entry,
xv) Control inhibit setting,
xvi) Alarm inhibit setting,
xvii) Maintenance tag setting,
xviii) High / low limit setting.
xix) Remote access to substation control system from SCADA system using a TCP / IP link.

All peripheral devices that constitute the substation automation system should be supervised and monitored by Control through IEC 61850 or any other compatible protocol.

(f) Scope of Work and Supply at existing Substation (if needed)

The existing SCMS shall be extended to integrate the new feeders.

The BCU shall be provided, with IEC 61850 Edition 2 communication ports, for each feeder.

The connections between BCUs and the station level shall be based on redundant fibre optic links. These communication ports will be used for control, indication and alarm systems to the substation automation system and SCADA.

A bay control unit (BCU) shall provide the following:

i) Control for each individual circuit / bay with a LCD mimic and user interface for control and monitoring of the circuit / bay,
ii) Interface for protection devices that cannot directly interface with the substation control system local area network,
iii) Interface for laptop computer for maintenance, information transfer and emergency HMI, Inter-locking functions (soft and hard-wired).

All necessary optical/Ethernet switches shall be provided to connect the new BCUs to the station level of SMS.

All necessary adaptation work shall be provided.

The signal list will follow the same rules as for new substations.

(g) Engineering Services

i) General

The engineering services shall be provided by the Contractor to the extent and detail necessary for a turnkey project. They shall include drawings, instructions and all other technical documents required allow the Contractor to build, erect, commission, operate and maintain the substation systems, even if these are not specifically mentioned in these Technical Requirements.

ii) Design Services

The Contractor shall design in detail the general layout of the SCADA and substation control system, based on the preliminary design and modifications agreed. This general layout shall be submitted to the Employer / Employer's Engineer for approval and comments. It shall also include all detailed structural drawings, detailed descriptions and reports required to permit an exact understanding of the solution adopted.

Once the general layout is approved, the Contractor shall include the following as a minimum requirement:

- Design of all works required for the implementation and extension of the SCADA and substation control system,
- General layouts for the SCADA and substation control system,
- Engineering of SCADA and substation control system,
- All necessary calculations.
- These engineering services shall also include:
- Design reports,
- Complete drawings of all systems,
- Integration in existing SCADA system.

13. Lighting, Small Power and Ventilation

13.1 Scope

This section of the specification includes for the interior and exterior lighting, small power and ventilation systems.

Whenever practicable, fixtures shall be sourced locally. All lamps, fittings, plugs, sockets and general accessories of the same size and types shall be similar and interchangeable throughout the installation.

The lighting and small power equipment and installation shall comply with other sections of this Specification as appropriate.

All civil works associated with this section of the works shall be deemed to be included as part of the works in this section. No additional payments will be made for such requirements.

The requirements of this section of the works are subject to the Main Conditions and Specifications laid down in other sections of the Bid Document. All cable shall be FRLS type.

13.2 References

British Standards

- BS 7671 Code of Practice Regulations for Electrical Equipment in Buildings 15th Edition.
  Institution of Electrical Engineers
- BS 6004 Specification for PVC insulated cables (non-armoured) for electric power and Lighting
- BS 6346 Specification for PVC insulated cables for electricity supply
- BS 6500 Specification for insulated flexible cords and cables
- BS 6121 Mechanical cable glands
- BS EN 60947 Specification for control gear for voltages up to and including 1000V AC and 1200V DC
- BS 4533 Luminaries
- BS 3677 Specification for high-pressure mercury vapour lamps
- BS 1363 Specification for 13A fuse plugs and switched and unswitched socket outlets

- BS 1362 Specification for general purpose fuse links for domestic and similar purposes (suitable for use in plugs)
- BS 4568 Specification for steel conduit and fittings with metric threads of 150 form forelectrical installation
- BS 4066 Test on Electric cable under fire conditions
- BS 4434 Specification for safety aspects in the design construction and installation of refrigerating appliances and systems
- BS 5970 Code of Practice for thermal insulation of pipework and equipment
- BS 848 Fans for general purposes
- BS 6540 Method of test for atmospheric dust spot efficiency and synthetic dust weight arrestance
- BS 2871 Specification for copper and copper alloys: tubes
- BS 1470 Specification for wrought aluminium and aluminium alloys for general engineering purposes, plate, sheet and strip
  Institution of Heating and Ventilation, Engineers Guide to Current Practice
  American Society of Heating Refrigeration and Air Conditioning, Engineers Recommendations
  Heating and Ventilation, Contractors Association of U.K., Specification DW/121

13.3 Defects Liability Period

The Contractor shall be responsible for the efficient and good working of the installations comprising this section of the Specification for the agreed period as set out in the Specification document.

13.4 Approvals

The Contractor shall submit to the Engineer for approval copies of all his calculations forming the basis for the designs of the specified systems, which shall be shown on the working drawings, also to be submitted for approval.

Any approvals shall not, however, relieve the Contractor of his contractual responsibilities which include obtaining local authority approvals for electrical wiring installations.

13.5 Lighting Requirements

The lighting installations shall be designed to give the standard service illuminations and shall incorporate emergency lighting where indicated. Control rooms, relay rooms,

telecommunications equipment rooms, offices and stores shall have the service illumination measured at 850 mm above finished floor level. All other areas shall have the service illumination measured at floor level.

The installations shall also meet the limiting glare index requirements as set out in the specified codes of practice. This section of work gives proposals for the types of lighting fittings to be used in the area, type of control to be employed, number of socket outlets and the types of mounting expected to be suitable for the respective areas. Where discharge and fluorescent light sources are to be used in areas containing rotating or reciprocating machinery, the fittings shall be allocated between the 3 phase and neutral in such a manner as to avoid stroboscopic effects. When 3 phase lighting installations are to be used, contactor switching controlled by pushbuttons located in the area to be illuminated is preferred.

In all rooms and corridors having two entrances the lighting installation shall have two way switching, the switches being located in appropriate positions adjacent to the entrances.

Emergency lighting shall be arranged to illuminate all stairways, exits and entrances and provide some illumination in operational areas within the control building and the switchyard, e.g. circuit breaker and transformer locations.

Security lighting shall be installed around the perimeter walls illuminating the external area and shall be controlled from the gatehouse. The level of illumination for security lighting shall be measured at a distance of 3 metres outside the boundary wall.

13.6 Schedule of Design Requirements

The lighting system shall include provision for ease of erection, maintenance, cleaning, lamp replacement and future extension. Lamp replacement and maintenance should, unless otherwise approved, be possible without necessitating outages on main plant items.

Lighting apparatus shall be of top quality, designed to ensure satisfactory operation and service life under all variations of load, frequency and temperature. Sodium discharge lighting shall be used for road and security lighting. Switchyard floodlighting shall use 500W Halogen lamps unless otherwise specified.

Key to Abbreviations:

- L Local switches
- S1, S2 etc. Socket outlets or fused spur circuits
- P.B Pushbutton for remote control
- T.S Time switch control

- C Ceiling mounted
- W Wall mounted
- P Pole or earth mast mounted
- M Recessed modular mounting
- D Suspended
- F Flush installation
- S Surface installation
- A Automatic on mains failure.
- BH Behind ceiling diffuser.

13.7 Coding Systems

The Contractor shall, when preparing drawings showing the respective designs, use a code to identify each lighting fitting and socket outlet.

The code shall comprise letters and figures so compiled that the following information can be readily identified:

(a) The lighting distribution board to which the fitting or socket outlet is connected.
(b) If connected to the normal supplies or to the emergency DC supplies.
(c) The circuit number and phase of the distribution board to which the fitting is connected.
(d) The sequence of the fitting in a particular circuit.

13.8 Distribution Boards

The distribution boards and all component parts shall be manufactured and tested in accordance with the latest standards and designed to suit the fault level of the transformers supplied. The Contractor shall demonstrate by calculation that this has been complied with.

Each, current carrying component shall be so designed that under continuous rated full load conditions in the climatic conditions at Site the maximum total temperatures permitted under the relevant Standards are not exceeded.

Each distribution board shall have a rustproof metal case of sheet steel with either a galvanised or enamelled finish. The colour of the enamel finish shall match the colour of other switchgear. The metal casing is to be provided with a number of knock-outs or other approved form of cable entries, corresponding to the circuit capacity of the distribution board, and a suitable screened brass earthing stud.

Busbars, including neutral bar, shall be of high conductivity copper supported to withstand all normal and fault condition stresses.

All busbars, neutral bars and primary conductors are to be PVC sleeved in respective phase and neutral colours.

Distribution boards for exterior use shall be galvanised and weatherproof.

Neutral bars shall have an appropriate number of ways relative to the size of the board. They shall have a rating not less than that of the associated phase busbars.

The metal surface adjacent to any live part and all spaces between phases shall be protected by barriers of fireproof insulation material.

The distribution boards shall be either single pole or triple pole and neutral types and shall be equipped with means to provide overcurrent protection to each circuit. This protection may comprise an HRC fuse or a miniature circuit breaker, both of which shall be removable without exposing live connections.

Fuse bases and bridges, where used, shall be of an approved non- hygroscopic insulation suitable for the receipt of HRC fuses.

Residual current circuit breakers shall be incorporated to protect all lighting circuits, socket outlets and supplies to appliances, etc. These shall comply with the requirements of the main electrical part of this Specification.

The current rating of the busbars in each distribution board is not to be less than the sum of maximum current rating of all outgoing circuits. The neutral connection for each circuit is to be direct to the neutral busbar.

Title labels of an approved type and inscriptions are to be fitted externally on the front cover of each distribution board giving details of the points controlled by each circuit. The circuit lists shall be typed or printed stating the location of the equipment served, rating of the protective unit and the circuit loading. The lists shall be mounted on the inside of the cover door and shall be protected by an acrylic sheet slid into a frame over the circuit lists. The lists and cover are to be easily removable to permit circuit modifications.

The cables feeding the distribution boards will be connected directly to the incoming isolator or neutral bar as appropriate, unless otherwise indicated by the Specification.

Switch fuse units or isolators connected on the incoming side of a distribution board shall be mechanically attached to the board with solid copper electrical connections between the units. A suitable insulated barrier is to be supplied to prevent copper or carbon dust released under fault conditions passing from one unit to the other.

Distribution boards for use on the direct current system shall be double pole types equipped with adequately rated fuses.

Mixed capacity boards shall be employed and all contactors and time switches associated with the respective outgoing circuits shall be accommodated within the distribution board.

13.9 Miniature Circuit Breakers

Miniature circuit breakers shall comply with the requirements of the main electrical part of this Specification.

13.10 Cables

Cables shall be XLPE insulated, single wire armoured and PVC sheathed overall and be manufactured and tested in accordance with the requirements of BS 5467, 600/1000V grade or equivalent. The outer sheath shall be coloured black and incorporate flame retardant characteristics to meet the requirements of BS 4066 and IEC 60332. Jute fillings will not be permitted. Cables shall comply with the requirements of the cable section of this Specification.

Flexible type cables for pendant cords and final connections to fixed apparatus are to be butyl or silicone rubber insulated and sheathed, manufactured and tested in accordance with the requirements of BS 6500, 300/500V or 300/300V grade as applicable.

The conductor is to comprise multi-strands of 0.25 mm wire. The number of strands are to be not less than 30 and in all cases of a number suitable for the protection rating of the respective circuits.

All cables used for lighting and small power shall have copper conductors.

The Contractor is to select conductor sizes for the respective final circuits to meet the following conditions:

(a) That the minimum conductor size for lighting circuits is to be 1.5 mm2 and for socket outlets 2.5 mm2.
(b) That the size is to be adequate for the current to be carried as set out in the cable Manufacturer's specification.
(c) That the size is sufficient to keep the voltage drop in the phase and neutral conductor to the farthest lighting or power point, under normal full load conditions, to within the final circuit limit specified in BS7671. Diversity will not be allowed.

13.11 Cable Terminations

Terminations for cables shall comprise compression type glands with armour and bonding clamps to meet the requirements of Type E1 to BS 6121, or equivalent, and are to be designed to secure the armour wires, to provide electrical continuity between the armour and the threaded fixing component of the gland and to provide watertight seals between the cable outer sheath and gland and between the inner sheath and threaded fixing component. The glands are to project at least 10 mm above the gland plate to avoid moisture collecting in the cable crutch.

Earth bond terminal attachments are to be provided.

Terminations for rubber insulated cables are to comprise compression type glands where the function of the gland is to secure the outer sheath of the cable, in accordance with the requirements of Type A2 to BS 6121 or equivalent. A watertight seal is to be provided between the outer sheath and the gland. Only one cable is to be terminated in each gland.

13.12 Sealing and Drumming

Immediately after the works tests, both ends of all cables shall be sealed against the ingress of moisture, dirt and insects and the end projecting from the drum shall be adequately protected against mechanical damage during handling and shall be fitted with a pulling eye bonded to cores, sheath and armours.

13.13 Conduit

All wiring shall be installed in screwed heavy gauge welded steel conduit or heavy gauge PVC conduit, at the discretion of the Engineer. No conduit less than 20 mm diameter will be permitted.

- Surface mounted - steel - Switch rooms, battery rooms, i.e. painted blockwork
- Flush mounted - PVC - Relay control rooms which have a decorative finish.

Steel conduits shall be manufactured in accordance with BS 4568, Part 1 or equivalent, heavy gauge screwed and welded Class B and shall be galvanised. Conduit fittings are to be manufactured of good quality galvanised malleable cast iron and of small circular pattern to BS4568, Part 2 or equivalent, withinternally tapped spouts minimum length 21 mm. threaded to the correct length at intersections, tees, draw throughs and stop-ends.

Conduit fittings of PVC shall be of the plain bore pattern suitable for a push-on compression type joint-and shall be sealed with a hard setting vinyl cement to prevent ingress of vermin, water, dust, etc. Inspection bends, solid or normal bends, elbows or tees are not to be used except with the approval of the Engineer.

Conduit runs shall, wherever possible, be concealed in ceilings, voids and walls, chases etc., and in rooms of secondary importance (with back outlet entries to switch boxes etc. especially on fair faced brickwork) otherwise the conduits shall be securely fixed to the surface of walls using heavy cast distance saddles. Where plastered finishes are called for, buried conduit systems shall be provided.

Where the system of wiring is concealed, the 'loop-in' system of conduit shall be used and the 'looping-in' boxes shall conform to BS 31, Class B3.

A separate insulated earth conductor, coloured green and yellow, shall be run in PVC conduits and such facilities shall be provided at all terminal points.

Wherever the installation is specified as being flame-proof, the conduit runs entering these areas shall have a barrier box inserted in the run immediately before the conduit passes into the flame-proof area. All conduit work inside the flame-proof area shall be carried out with solid drawn galvanised conduit and all conduit fittings, sockets and accessories shall be galvanised and certified suitable for Group 1 hazard. At the completion of the wiring all machine faces on accessories shall be thoroughly cleaned and greased, prior to the screwing or bolting of all accessory cover plates into their final flame-proof secure position.

The ends of all steel conduits shall be reamered to remove all burrs or sharp edges after the screw threads have been cut. All dirt, paint or oil on the screw threads, the conduit, sockets and accessories must be removed prior to erection. All conduits shall be swabbed through prior to installation of cables.

The ends of the conduit shall butt solidly in all couplings. Where they terminate in fuse-switches, distribution boards, adaptable boxes or non-spouted switch boxes, they shall be connected thereto by means of smooth bore male brass bushes, compression washers and sockets. All exposed threads and all bends shall be painted with an aluminium spirit paint after erection.
All conduit and accessories, after being installed, shall be examined and all parts where the surface has been chipped or scratched shall be painted.

All conduits shall be kept 80 mm clear of water, gas and other services. Should this prove impracticable, then they shall be properly bonded by means of pipe clamps or other device ensuring mechanically sound, electrically continuous connection.

The method of installing PVC conduit and fittings shall conform strictly to the Manufacturer's recommendation. These recommendations shall be submitted when seeking approval to the system pro-posed. In general the clauses dealing with steel conduit shall apply.

PVC tube not exceeding 25 mm in diameter shall be bent cold by means of the appropriate spring and the tube shall be saddled as quickly as possible after bending. When bending larger sizes of tube, the tube must be heated in an approved manner until it is pliable. A 90˚ bend shall have a radius of not less than five times the outside diameter of the tube.

Joints between conduits and conduit fittings shall be watertight and shall be made by means of a solvent adhesive as recommended by the Manufacturer. Care shall be taken to ensure that the tube is clean and free from damp and grease and in particular dust, mould and oil.

The Contractor shall provide PVC tube ends and flexible covers to prevent ingress of concrete grout into the tubing and boxes.
All bends are to be made on Site to suit conditions and not more than two right angle bends will be permitted without the interposition of a draw box. No tees, elbows, sleeves, either of inspection or solid type, will be permitted. Generally long straight conduit runs from point to point shall have draw boxes installed at maximum intervals of 10 metres.

Deep boxes or extension rings on standard circular conduit boxes shall be used where necessary in order to bring the front of each box flush with the surface of the ceiling or wall. Where conduits are laid direct on the shuttering of the reinforced slab construction, conduit extension rings or deep boxes shall be used to raise the run of conduit to between the top and bottom reinforcing. Galvanised draw wires or other approved types shall be provided where conduits are not to be wired on completion or are to be wired by others.

All draw boxes and junction boxes shall be of ample size to permit the cables being drawn in and out. They shall be made of malleable iron or PVC approved type and the jointing surface machined to ensure a dust tight joint. All circular boxes shall be provided with long spouts internally threaded incorporating a shoulder for the proper butting of the conduit and a solid brass earth terminal tapped and screwed into the base of the box.

All conduit boxes shall be screwed on or in walls, ceilings etc. by countersunk wood screws of appropriate size. Holes in boxes shall be adequately countersunk to ensure the complete recession of the fixing screws. All inspection and draw-in boxes shall be provided with covers fixed by round head brass screws.

Where surface conduit is specified, it shall be fixed by means of distance saddles and shall terminate in raised back pattern conduit boxes. Surface conduits shall not be bent or set to enter accessories, and where they turn through walls back outlet boxes shall be provided. Conduits shall be fixed at 1200 mm centres on vertical runs and 900 mm apart on horizontal runs.

Vertical conduit runs shall have saddles at 300 mm maximum from their points of emergence from floors or ceilings and the remaining saddles shall be fixed consistent with the

requirements of spacing and appearance. Saddles shall be fixed on each side of every bend at 300 mm maximum from the point of intersection of the centre line conduit.

Conduits in ceiling cavities shall be supported independent of the suspended ceiling.

Where conduits cross expansion joints, the Contractor shall allow for the installation of expansion couplers at the positions of the expansion joint and at fight angles to it. He shall provide a bonding earth wire between each terminal fitted in the nearest conduit box each side of the coupler.
All flexible metallic tubing shall be galvanised watertight pattern fitted with sweated brass adaptors.

External earth conductors, wrapped around the tubing, shall be provided.

Where conduits are laid in slab floor etc., the Contractor shall arrange for a competent person to be in attendance whilst the concrete pouting or screeding operation is being carried out, in order to avoid damage being caused to the conduits and also to ensure that the conduit work is in sound condition, properly and efficiently maintained during this installation period.

Particular care should be taken when setting out conduit runs to outlet points where they are to be fitted to furniture, kitchen fittings, etc. The Contractor shall ascertain exact details of the furniture and fittings construction in order that all conduit work shall wherever possible be concealed.
Conduits installed in chases of walls and floors shall be firmly secured by wrought iron pipe hooks or crampets and these fixings shall in themselves be sufficient to hold the conduits in place. Conduits installed in chases shall be painted with one coat of bitumastic paint before erection and a further coat shall be applied to all accessible surfaces including the hooks and the crampets after erection.

Recessed conduits buried in plaster shall permit a full 6mm. depth of cover over its entire length. Provision shall be made for the tapping of condensed moisture.

Care shall be taken to prevent water, dirt or rubbish entering the conduit system during erection.

Screwed metal caps or plugs shall be used for protecting open ends.

All conduit systems shall be erected completely with all conduit accessories connected. They shall then be offered for inspection and approval by the Engineer before any cables are installed. Conduit boxes shall be fixed to the structure of the building independently of the conduit.
Where a conduit is exposed to different temperatures (either by surrounding air conditions or by virtue of the surrounding medium with which it is in contact) at any particular time, the section of the conduit at the higher temperature shall be isolated from the section at the lower temperature by means of a conduit box filled with an approved permanently plastic compound,

after completion and testing of all wiring. Such a condition would arise if a conduit running in a warmed building is run to exterior points.

Where galvanised conduit is specified, all conduit, accessories, switch boxes and all associated apparatus used in the installation must also be galvanised. Galvanised conduit shall be used when mounted outside a building, installed in floor chases subject to dampness or accidental flooding, or buried in the ground. Conduit systems shall be weatherproof when erected outside a building. Exposed conduit threads shall be given a coat of zinc rich paint.

Conduit buried in the ground shall be wrapped with PVC self-adhesive tape half lapped. The taping shall be extended for a distance of 150 mm beyond the point where the conduit emerges from the ground. Joints in galvanised conduit systems shall be made watertight using lead, aluminium paint and hemp and/or gaskets. The joints shall be partially screwed up before the paint and hemp are applied to maintain continuity.

All adaptable boxes shall be grey iron pattern unless otherwise specified. Where adaptable boxes are fitted flush, the cover plates shall be heavy gauge metal with 12 mm overlap on all sides. The internal depth of a box shall be not less than 40 mm.

Covers shall be secured by a screw at each comer and by additional screws as necessary to provide a maximum spacing of 300 mm between adjacent screws. Fixing screws shall be brass (round or cheese head).

Covers for boxes shall be of the same material as the box. For boxes mounted in weatherproof situations, the cover shall have a machined surface around the perimeter mating with a similar machined surface on the box and shall be complete with a gasket.

Every flush outlet box to which a luminaire pull cord switch or similar is to be fitted, shall be equipped with an approved type of break joint ring.

13.14 Cable Trunking

Where trunking is specified it shall be constructed of 1.65 mm minimum thickness zinc coated mild steel or PVC and shall have a removable cover throughout its length with centre screw latch fixings.

Trunking shall be rigidly fixed and supplied complete with purpose manufactured fittings, connectors, dividers, flanges, cable retaining clips, racks and copper earth continuity links. As an alternative, if approved, a proprietary brand of heavy duty plastic trunking may be acceptable. When submitting details for approval, full installation instructions as recommended by the Manufacturer shall be included in the details.

All cables installed in trunking shall be labelled and identified in an approved manner. Clips shall be at 600 mm from centres. Vertical cable trunking shall be fitted with cable pin racks arranged to avoid any strain on the cables.

All trunking shall be rust proofed, primed and painted and fixed at intervals not greater than 1,000 mm.

13.15 Cable Trays

Cable trays, where required as part of the Contract supply, are to be the perforated galvanised sheet type.

Trays are to have upturned edges and be of a width suitable for the number of cables to be supported and are to be supplied with purpose- made galvanised steel brackets suitable for mounting from the building structure. External cable trays shall be provided with covers.

Where site cutting of trays or support bracket steelwork is unavoidable, recutting bare steel shall be protected with two coats of an approved zinc rich paint immediately after cutting.

13.16 Cable Jointing

The Contractor shall be responsible for the sealing and jointing of all cables supplied and installed as part of this Section of the Contract. Straight jointing of cables is not permitted without the written consent of the Engineer.

13.17 Contactors

Contactors shall comply with BS 5424 or equivalent and shall be of the electrically held-in types contained in heavy gauge sheet steel cases suitable for panel mounting. Each contactor shall be continuously rated and suitable for thirty inductive switching operations per hour.

13.18 Switches and Pushbuttons

Switches shall be rated for 15 amps, shall be single pole types and be provided with an earth terminal. Switches shall be one way, two-way or intermediate as required and, where mounted together, they shall be fitted in a common box.
Switches for use in areas designated for surface installation shall be quick-make-quick-break fixed grid industrial types mounted in galvanised malleable iron boxes with protected dolly and arranged where necessary for multi-gang switching.

Switches for use in areas designated for flush installation shall be micro-break types fixed to white plastic cover plates and mounted in galvanised steel flush type boxes.

Switch-boxes shall be galvanised and fitted with screwed stainless steel front plates having a 6 mm overlap minimum for flush installations. They shall be suitably barriered and labelled where two phases are connected in the same box.

Switches mounted externally shall be of weatherproof pattern to IP55 level fitted with machined box and cover joint, brass operating handles, neoprene weathertight seals and external fixing feet.

Where DC emergency lighting circuits are to be switched, double-pole quick make, quick break switches with pillar type terminals and earthing straps shall be provided.

Switches shall be mounted 1.4 m above finished floor level.

Pushbutton switches shall either be flush or surface types contained in galvanised steel boxes and be single pole rated for 5 Amps. Pushbuttons shall be made of non-hygroscopic material, be non-swelling and so fitted as to avoid any possibility of sticking.

The terminals for all switches shall be adequate to accommodate 2 conductors, each a minimum of 1.5 mm^2 in area.

13.19 Lighting Fittings

Illustrations and/or samples of all lighting fittings which the Contractor proposes to purchase shall be submitted to the Engineer for approval before issuing any sub-orders.

Lighting fittings for interior and exterior use are to be manufactured and tested in accordance with the appropriate sections of BS 4533, IEC 60162 or equivalent and together with all components are to be suitable for service and operation in the tropical climate stated.

Each fitting is to be complete with all lampholders, control gear, internal wiring, fused terminal block, earth terminal and reflectors or diffusers as specified. The design of each fitting is to be such as to minimise the effect of glare and such that the ingress of dust, flies and insects is prevented, where open type fittings are used it is to be impossible for insects to become lodged therein.

The control gear for use with fluorescent lamps is to be quick or resonant start type without starters.

Chokes are to be impregnated and solidly filled with polyester resin, or other approved high melting compound, are to be manufactured to restrict the third harmonic content to less than 17% of the uncorrected current value, and are to be silent in operation.

The built-in ballast units shall comply with IEC 60082 and shall include radio interference suppressors and capacitors to correct the fitting power factor to a minimum of 0.85 lagging. Control gear noise levels shall be minimal.

Fittings shall be supplied complete with closed end vitreous enameled metal reflectors or totally enclosed opal plastic diffusers, which shall be fully interchangeable.

Dispersive reflector fittings suitable for mercury bulb fluorescent or tungsten filament lamps shall be of heavy gauge sheet steel finished vitreous enamel. They shall be fitted with anti-vibrators and arranged for conduit box mounting, direct or pendant, on galvanised ball and socket dome type lids.

Bulkhead fittings shall have cast bases tapped for conduit entry, hinged bezels, heat resisting prismatic glasses fitted with neoprene gaskets and porcelain lamp holders. Circuit cable shall not be connected direct to bulkhead fittings but shall terminate in a fixed base connector mounted in a conduit box adjacent to the fitting. Final connections to each fitting shall be carried out with silicone rubber covered cable. All bulkhead fittings shall be watertight pattern.

Internal connections are to comprise stranded conductors not less than 0.75 mm^2 covered with heat resistant insulation to the requirements of BS 6500 or equivalent. All internal wiring is to be adequately cleated to the fitting casing with an approved form of cleat. The finish of fittings for interior use is to be impervious to deterioration by atmospheric reaction. Fittings for exterior use shall have a vitreous enamel, natural aluminium or galvanised finish according to the Manufacturer's standard product.

Lamp holders as applicable are to be suitable for the lamp specified.

Lighting fittings are to be of the type description as generally set out in the schedule appended to this section of the Specification. The type references used are to be repeated in the Schedules and on the drawings.

13.20 Fluorescent Lamps

Not used

13.21 Requirement of LED Lighting

13.21.1 Introduction

Lighting is an important parameter for a well working environment. Now a days power saving is a challenge with increasing demand of power . So, there is an emphasis on saving power. In this case LED lighting is taking place of tradition lighting like Fluorescent light, compact fluorescent light etc. In this section there will be discussion on standard requirement of LED Lighting in the interior & exterior of substation. When required by Schedule of Requirement, LED design shall comply with the following requirement.

13.21.2 LED lighting standards

- IEC (International Electrotechnical Commission) (60061-1,2, 6100-3-2)
- ANSI (American National Standard Institute) - Establishes definitions of solid state lighting de-vices and components. It also provides a common terminology.
- IESNA (Illuminating Engineering Society of North America) - Provides procedures for reproducible measurements of photometry, color and electrical characteristics of solid state lighting products.
- UL (Underwriters Laboratories) - Writes safety standards for LED products including drivers, controllers, arrays, packages and modules.
- NEMA (National Electrical Manufacturers Association) - makes recommendations for mechanical, thermal and electrical interfaces between luminaires.

13.21.3 Design Considerations

The lighting system shall include provision for ease of erection, maintenance, cleaning, lamp replacement and future extension. Lamp replacement and maintenance should, unless otherwise approved, be possible without necessitating outages on main plant items.

The following basic criteria shall be considered —

(a) Operating Voltage

The LED driver must have the capability of operating voltage from 85-265 V AC voltage range. Within this range the driver should be capable of driving LED load properly.

(b) Total luminous flux

There is a standard luminous flux in various places like control room, battery room, staircase etc. and it is necessary to maintain proper lux.

(c) CCT (Correlated Color Temperature)

There is a recommendation for Correlated Color Temperature (CCT) is to be 6000-6500K that is daylight in nature. As there will be control room, office room, battery

room etc. 'daylight CCT' is necessary here. For beautification purpose there may be used warm light or accent lighting. In Roadway in substation there may be used daylight or warm light.

(d) CRI (Color Rendering Index)

CRI is one of the important factors in lighting. The bidder must ensure that CRI should be greater than 80. Higher the value of CRI, the better the visualization. So higher CRI is recommended here.

(e) Power Factor:

The power factor the LED lighting should be greater than 0.9. The bidder must ensure that p.f. and the driver must contain power factor correction circuitry.

(f) Total Harmonic Distortion:

Total harmonic distortion (THD) is a very important factor in substation. As very high frequency switching happens in the driver the THD is little a bit high in LED lighting but now the trend is changing. Well sophisticated driver is available now. In this case according to IEC 61000-3-2 standard the maximum permissible harmonic current is given:

But it is desirable have THD not more than 15% and It is strongly recommended.

According to IEC61000-3-2	
Harmonic Order (h)	Maximum harmonic current permitted (calculated in 1% compared to fundamental magnitude)
2	2
3	30*(power factor)
5	10
7	7
9	5
$11 < h \leq 39$ (odd only)	3

(g) Chromaticity Coordinates (x,y and u',v')

According to the standard IES LM-79-08 the chromaticity index of shall have color rendering values of X = 0.335 and Y= 0.342 (i.e., Color 2) on the CIE chromaticity scale. Basically the bidder has to ensure that the color temperature should be daylight type and in accordance with there should be matching of chromaticity coordinates x,y.

(h) Thermal stabilization

The LED lighting should be thermally stable. The bidder has to ensure that the light can sustain both at high and low temperature. The heat generated inside diffuser or driver level, the temperature should be as low as possible. Thermal test report should be properly documented. These Shall be tested for at least 3,000 hours with data collection at a minimum of every 1,000 hours

(i) Driver efficiency

The LED driver which has AC to DC converter should have the efficiency of 90% or above. The driver should contain PFC (Power factor control) system inside it.

(j) Current of voltage controlled LEDs

Current of voltage controlled LEDs should be in permissible level so that the heat generated and loss can be minimum. As there is variation in drive current according to various driver, in this case the bidder should be aware of the current level in driver of LED.

(k) Efficacy

The efficacy of LED is very good now. The bidder should have the higher efficacy and must be greater than 100 Lumen per Watt. Higher efficacy is recommended. Here the efficacy must not be less than 97percent after 10, 000 hours of use.

(l) Luminous intensity

The bidder must ensure that the LED lights, tubes have proper luminous intensity which is needed to maintain the standard lux and have to have the proper technical documents that can ensure the validity.

(m) Zonal lumen summation

The bidder must have the knowledge of zonal lumen summation or calculation that is by the lighting fixture how much area can be covered.

(n) Outdoor Specifications

For outdoor lighting in substation the lighting should have appropriate wattage and appropriate lux mentioned. The pole and circuit connection should be constructed in proper way.

The Ingress Protection (IP) should be at least IP65. Higher IP or protection from dust, water, shower should have higher priority at outdoor.

(o) Maintenance

The LED lighting should be of low maintenance product. The bidder should include terms and conditions about maintenance of LED lighting what the bidder provides.

(p) Lifetime

The lifetime is very important for LED lighting. The bidder must ensure that the lighting should have the lifetime of at least 3years, or having a lifetime of at least 30,000 hours. With this lifetime the efficacy must be above 97% within 10,000 hours.

13.21.4 Additional information to be included

(a) Description of LED sources

There should be of data that how much LEDs are on the LED chip. There must be sufficient number of LEDs that is required to maintain required lumen what the bidder says. The LEDs may be in series or parallel connection. The number may be varied according to Lumen produced.

(b) Description of auxiliary equipment

The bidder has to highlight if any auxiliary equipment is needed like battery setup, fixture, diffuser setup etc. But it is desirable to have dimming control if needed any time.

(c) Ambient conditions including airflow, temperature and relative humidity

The LED lights should be capable of sustain at ambient airflow, temperature(25C-55C) and relative humidity and the bidder must be liable of taking all of considerations according to the location of substation.

13.21.5 LED Technology

(a) **SMD: Surface Mounted Device LED**

This LED light chip is compact (flat design), versatile and incredibly popular today. It consists of a circuit board with LED's (light emitting diodes) directly attached to the surface. SMD lights can be found in many bulbs and can be used for colour-changing bulbs.

(b) **COB: Chip-on-Board LED**

In contrast to the SMD technology, COB LED lights package multiple LED chips together, instead of spreading the LEDS on the surface. This makes COB lights brighter than SMD bulbs (lumen per watt ratio). COB lights shine bright, but cannot change colour like SMD bulbs. No Ceramic PCB Engine shall be used for COB, rather Aluminium PCB shall be used for COB LED.

(c) **DOB: Driver-on-Board LED**

This new LED technology is often used for downlights, solving the problem of needing a separate LED driver. Unlike other non-DOB bulbs, the DOB technology used by ECO Lights uses an AC current instead of AC converted to DC. It makes downlights more reliable, energy efficient and reduces the heat a LED light can produce.

13.21.6 LED Fittings

(a) **Edison LED Screw Cap Bulbs - E27, E14**

These are made of metal and heat resistant PBT plastic (polybutylene terephthalate, [C12H12O4]n, melting point 200°C, plasticity at 125°C). It meets European electrical regulations and have CE certification.

The small Edison screw (E14) has nine threads per inch, or about 2.8 mm per thread. The diameter is 14 mm.

The medium Edison screw (E27) has seven threads per inch, or about 3.6 mm per thread.

The diameter is 27 mm.

Edison (E27) LED bulbs are energy efficient and last long, keeping maintenance costs at an all-time low. The Edison bulb can also be found in other bulbs, such as the Edison LED filament bulb and Edison cap corn bulbs. The cap is versatile and universally used.

(b) **Bayonet Bulbs - B22, B15, SBC**

The Bayonet bulb can easily be identified with its special bayonet cap fitting. They are similar to the Edison LED bulbs, the only difference is the base.
The Bayonet Bulbs screw (B15) has no threads. Its diameter is 15 mm. The Bayonet Bulbs screw (B22) has no threads. Its diameter is 22 mm.

(c) **Edison LED Filament Bulbs**

These are used for filament bulb.

(d) **Floodlights (including PIR floodlights)**

Normally used for Outdoor lighting . They uses Latest LED COB/ SMD technology with classic

Aluminium housing. The housing is Pure die-casting aluminium housing. They can be also

Ultra slim die cast aluminium housing with powder coated surface for corrosion resistance.

They are typically used for streetlights or Outdoor switchyard or GIS Hall, as floodlights are capable of producing a huge amount of lighting. The light shall be of minimum IP65.

PIR stands for Passive InfraRed sensor. PIR floodlights are floodlights with a built-in motion sensor technology. This LED Floodlight with P.I.R shall be equipped with a 4th wire.

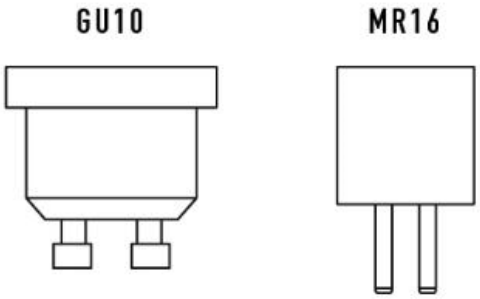
(e) **Spotlights (GU10, MR16)**

Spotlights are very popular for decorative use and strong accent lighting. Spotlights can have a different base, such as GU10 and MR16. The number stands for the distance between the pins, in millimetres.

GU bulbs feature a twist-lock mechanism, which is the main difference between popular GU10 and MR16 bulbs. The GU10 bulb will run at 240 volts (which is the same voltage as supplied by the mains power supply), while MR16 bulbs run on just 12 volts.

Unlike GU bulbs, MR16 bulbs do not need to be twisted. This shall have Die-Cast Aluminium housing with Fire rated and adjustable fittings for tilting.

Light fittings may be white and modern brushed chrome finish. The spots are made of high quality aluminium die cast fittings, with fire-rated cans and the junction box that has an anti-fire cotton seal for extra fire resistance and acoustic protection.



(f) **Downlight (COB, DOB, GU10) recessed**

Downlights illuminate spaces in a concentrated, 'diluted' way. Spotlights have a narrow beam which is used to play with light, creating a contrast between light and dark. Downlights, on the other hand, are not used for accent lighting, like spotlights or track lights. It gives soft, uniform lighting. Downlights provide basic lighting for space, such as a kitchen, entry or hallway.

COB LEDs are basically multiple LED chips (typically nine or more) bonded directly to a substrate by the manufacturer to form a single module. Since the individual LEDs used in a COB are chips and not traditionally packaged, the chips can be mounted such that they take up less space and the highest potential of the LED chips can be obtained. When the COB LED package is energized, it appears more like a lighting panel than multiple individual lights.

Being multi-chip packaged, the light emitting area of a COB LED can contain many times more light sources in the same area that standard LEDs could occupy resulting in a greatly increased lumen output per square inch.

(g) **Cabinet Lights**

(h) **LED Panels**

LED panel light supply is well known as long time. Stable cold mild source, epoxy resin, light physique. Drive energy requirements chip itself is lower than 0.5w, switching frequency necessities mandate larger than the 120hz, in order that while the prevalence frequency disturbance could be seen blinking. Minimum IP 42.

LED panel light shall be with Aluminum heat sink, No UV or RF interference, Patented heat sink and optical diffuser. No mercury, no ballast required, wide voltage and constant current design, solid state, high shock & vibration resistant, Mercury free, savings in energy consumption, quiet, no noise, no flickering. The products hall shall be in accordance with CE, UL and FCC testing standards.

(i) **LED Tube Bulbs**

Typical Fittings are

i) T5, T8 and T12
ii) UL Type A LED tube light – Ballast Compatible
iii) UL Type B LED tube light - Ballast Bypass
iv) UL Type C LED tube light - Remote Driver etc.

13.21.7 Safety considerations

(a) Compatibility of Lighting Systems

In the substation there may be traditional lighting system. The LED lighting should be compatible of working with both traditional system and new LED lighting system. For example, Traditional fluorescent tube has magnetic ballast system or electronic ballast system. In that case the bidder should take the responsibility of changing the system without changing the fixtures in some cases.

(b) Design Verification

The bidder should try to mention all the technical standard documents, safety documents and design verification documents.

(c) Electrical characteristic

It is desirable to have the documents of electrical characteristics of lighting, Driver efficiency, temperature characteristics etc.

(d) Environmental

The LED light or the product should be certified by ROHS, EnergyStar, CE for Energy Saving etc.

13.22 Socket Outlets and Fused Spur Outlets

Each socket outlet shall comply with the requirements of the BS 1363 or equivalent and shall be the interlocked shuttered and switched types arranged for surface or flush mounting in single or multi- gang units as appropriate.

Each fused spur outlet shall be equipped with double pole isolator, a fuse to BS 1362 or equivalent and where required front entry for flexible connection.

Each socket outlet and fused spur outlet shall be equipped with a galvanised metal box with earth terminal.

Each group of five socket outlets is to be provided with a matching fused plug top.

All socket outlets for exterior use shall be galvanised and weather- proof and be equipped with screwed dustproofed cap attached to the socket by means of a chain.

13.23 Time Switches

Time switches for use with lighting systems shall be the synchronous motor wound types protected by a suitably rated fuse for 230 volts operation with a nine hour reserve spring and are to be fitted with a twenty-four hour hand set dial, two "OFF" and two "ON" levers and manual operation pushbutton. The main contacts shall be rated for 20 Amps on a 230 Volt 50 Hz AC supply.

Time switches shall be suitable for mounting in the distribution boards supplying the circuits to be controlled.

13.24 Poles

Lighting poles shall be tapered, of hot dip galvanised steel with bituminous preservative inside and outside at the base and shall be approved by the Engineer.

Each pole shall be equipped with a base section compartment of 470 mm by 150 mm to house an inspection trap, lockable door, fused cut out, cable entry and terminations for both the incoming and outgoing power cables and secondary cables feeding the light sources.

Poles for substation lighting shall support the floodlights at 11m above ground level and poles for access roadway lights shall support the lanterns at 4.5m above ground level.

The Contractor shall ensure each pole is provided with foundations suitable for the ground conditions occurring at each site.

13.25 Interior Installations

Wiring for the lighting and socket outlet installations shall comprise PVC cables drawn into conduits attached to walls, structural or roof steelwork or ceilings as appropriate (see chapters **13.13** and **13.14)**.

Surface and flush type installations are required according to the particular area as indicated in the schedule appended to this section.

In areas where flush type installations are indicated the wiring shall be drawn into conduits buried under wall finishes or concealed above ceilings as appropriate.

All fixings shall be of a type approved by the Engineer and all metalwork used shall be galvanised. Fixings to structural steelwork shall be with purpose made brackets or clamps; the drilling of structural steelwork will not be permitted.

Cleats with two screw fixings shall be used for supporting conduits at not greater than 2m intervals.

All switchboxes, socket outlet boxes and items of a similar type shall be fixed with two screws or bolts.

Switches and pushbuttons for lighting circuits shall be mounted at 1400 mm above finished floor level.

Socket outlets shall be mounted 500 m above finished floor level but those for use with workshop benches shall be mounted 150 mm clear of the bench working surface.
Lighting fittings shall be attached to ceilings, walls, trunking or roof steelwork or suspended therefrom as appropriate.

Where fittings are to be suspended, rod type suspension units shall be employed.
Final connections to all suspended lighting fittings shall be with heat resistant flexible cable terminated in porcelain clad connectors in the ceiling or junction box which shall also terminate the main circuit cable. The cable length shall be such that the suspension unit supports the full weight of the lighting fittings.

Where recessed type lighting fittings are to be installed suspension units shall be used to prevent the weight of the fittings being applied to the suspended ceiling. It shall be possible to carry out maintenance from the underside of the fitting without disturbing the false ceiling. To facilitate this need the final connection to each fitting shall be with heat resistant flexible cable from a plug in type ceiling rose mounted above the false ceiling.

All cables not contained within conduit for their whole route shall be terminated with a cable gland.

Where lighting fittings are mounted direct on walls or ceilings, the main circuit cables may be connected into the fitting terminal block. Where terminal blocks do not exist within the lighting fitting, flexible heat resistant cable shall be used connected to a separate junction box.

Earth continuity shall be maintained throughout the entire wiring installation with separate insulated earth continuity conductors of adequate cross-section ultimately connected to a common earth terminal at the respective distribution board.

Within the interior installation adequate provision shall be made for connection to small ventilating fans, which are not energised from the central air conditioning control and starter panel.

Each and every trunking route shall be bonded across all joints with external copper bonding links supplied for the purpose.

13.26 Exterior Installation

Exterior substation lighting fittings shall be attached to substation walls at high level or pole mounted as appropriate. Security lighting round the perimeter wall/fence is to be provided.

When locating the floodlights for the switchyard lighting, the Contractor shall ensure that all floodlights are outside safety clearance for the high voltage switchgear at the particular location.
Cables to exterior lighting shall be laid direct in ground, laid in concrete trenches or cleated to buildings structures as appropriate to the route requirement. The cables shall be terminated at a cut-out located at the base of each support. Wiring between the cut-out and the control gear or lantern shall be with multicore cable run within poles or with cable drawn into galvanised steel conduit attached to the sup-porting structure.

13.27 Emergency Lighting

Emergency lighting shall comprise lighting fittings of the types indicated in the schedule appended to this section of the Specification.

The system shall be so arranged that on failure of the normal A.C. supplies to the lighting installation the emergency lighting system will automatically be switched on. Other than those of the "on demand" type, all emergency lighting shall be switched "off" 5 minutes after restoration of normal supplies. Each emergency lighting unit shall have a minimum 3 hour rating.

Sufficient fittings of Type E3 shall be provided in each room to enable the rooms and building to be evacuated safely.

In addition, in designated working areas emergency manually switched lighting, to give not less than 30 lux, shall be provided utilising type E4 fittings. Switches shall be labelled to the approval of the Engineer.

The security lighting scheme shall illuminate the area to 6 metres inside the perimeter wall to the lighting level specified.

13.28 Telephone System

A complete conduit/duct system shall be provided throughout the building to enable the telephone cables to be run to the proposed extension points. This includes telephone wiring to operators' desks and office in the control building.

Telephone instruments, the PABX and connections to PTT exchange lines shall be carried out by other Contractor.

13.29 Schedule of Lighting Fittings and Socket Outlets

All lighting schemes are to utilise fittings and lamp types which are available locally in Bangladesh to ensure that replacements are readily acceptable.

Lighting fittings described in this Schedule shall also meet the general requirements of the Clause for Lighting Fittings of this Specification.

• Type F1	Shall indicate a basic channel complete with control gear and lamp holders for one fluorescent lamp, equipped with an open ended metal reflector having upward light slots.
• Type F2	Shall indicate a fitting which shall comply generally with the description for Type Fl but be equipped for use with two lamps.
• Type F3	Shall indicate a recessed modular fitting suitable for mounting in a suspended ceiling and equipped with a clear prismatic controller. The metalwork and trim are to comprise a rigid welded unit so arranged as to be invisible when erected complete with controller. The fitting is to be equipped with a pre-wired removable gear tray and adjusting facilities to enable levelling relative to the ceiling to be carried out after erection. The assembly is to be complete with control gear and lamp holders for one 1500 mm long 65 watt fluorescent lamp
• Type F4	Shall indicate a fitting which shall generally comply with the description F3 but with an open type grid diffuser.
• Type F5	Shall indicate a dust-tight, weatherproof and vapour resistant fitting, having a grey polyester fibre glass reinforced chassis containing the control gear and having lamp holders for one 1500 fluorescent lamp. The fitting shall be complete with a vacuum formed acrylic diffuser

	which is secured to the body with injection moulded toggles and sealed with a neoprene gasket.
• Type F6	Shall indicate a weatherproof bulkhead fitting with a cast aluminium base and vandal resistant diffuser equipped with control gear and lamp holders for two fluorescent lamps
• Type E1	Shall indicate a self-contained, self-sustained (normally off) emergency lighting unit, complete with integral batteries and control gear, with the words "EXIT" in white letters on red background in English and Arabic. It shall be energised from the batteries under mains failure conditions. The mains failure device shall be sensed by an unswitched phase con-nection from the local lighting circuit.
• Type E2	Shall indicate a self-contained, self-sustained (normally off) wall mounted emergency lighting unit comprising a pilot light and two 100 watt spotlights complete with integral batteries and control gear. The pilot light shall be energised under mains failure conditions with manual "on demand" switches for the spotlights. The mains failure device shall be sensed by an unswitched phase connection from the local lighting circuit.
• Type E3	Shall indicate a self-contained, self-sustained (normally off) wall or ceiling mounted emergency lighting unit complete with integral batteries and control gear. The lamps shall be energised under mains failure conditions. The mains failure device shall be sensed by an unswitched phase connection from the local lighting circuit.
• Type E4	Shall indicate a 110V DC wall or ceiling mounted emergency lighting unit which shall be manually switched and be similar to type E3.
• Type H1	Shall indicate forward throw floodlight fitting comprising a sheet steel vitreous enamelled or spun aluminium reflector housing a 500 Watt Halogen lamp. The fittings to be complete with wall mounting bracket.
• type H2	Shall indicate a semi cut-off roadway and perimeter security lantern with housing manufactured from a one piece LM6 aluminium alloy casting enamelled white internally and equipped with reflector bowl of heat resisting glass, all suitable for housing the lamp holder and control gear for one 150 Watt sodium vapour lamp. The fitting to be equipped with pole arm suitable to give an outreach of 1 metre.
• Type S1	Shall indicate a 13 Amp single or double gang flush mounted switched socket outlet.
• Type S2	Shall indicate a 13 Amp single or double gang surface mounted switched socket outlet.
• Type S3	Shall indicate an ironclad one gang heavy duty 4 pole interlocked switched socket outlet with scraping earth connection suitable for use on a 400V 3 phase 4 wire 50 Hz for 125A. Each socket is to be

	supplied complete with cable box with 2 glands, suitable for terminating a PVCWPVC cable and shall be fitted with a screwed dustproof cap attached to the top of the socket by means of a chain. Matching plugs to be provided in each socket.
• Type S4	Shall indicate a 15 amp 3 phase 4 wire switched socket outlet with plug flush mounted.

13.30 Design for Lighting level

(a) The lighting distribution board shall be designed for operation in a 400 V, 3 phase, 4 wire, 50 Hz. neutral grounded system with a fault level of 15 kA at 400 V. The emergency lighting system operating from 220 V +/- 10% DC system shall be automatically placed into service in the event of loss of AC main supply.

(b) The overall maintenance factor shall be taken as 0.8 and 0.75 for different outdoor and indoor lighting systems respectively.

(c) The minimum lux level to average lux level ratio should not be less than 0.3 i.e. Emin/Eav> 0.3.

(d) **Measuring Units of Light Level - Illuminance**

Illuminance is measured in foot candles *(ftcd, fc, fcd)* or lux (in the metric SI system). A *footcandle* is actually *one lumen* of *light density per square foot*; *one lux* is *one lumen per square meter*.

1 lux = 1 lumen / sq meter = 0.0001 phot = 0.0929 foot candle (ftcd, fcd)
1 phot = 1 lumen / sq centimeter = 10000 lumens / sq meter = 10000 lux
1 foot candle (ftcd, fcd) = 1 lumen / sq ft = 10.752 lux

(e) The design calculation shall be made using software. Dialux is the preferable software.

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(f) **Schedule of Lighting Requirements**

i) **Indoor Areas**

Location	Service Illuminance (Lux)	Glare Index
Control relay room	350	19
Behind panels	100	-

Location	Service Illuminance (Lux)	Glare Index
Manger Room/Tea Room	350	19
Battery room	100	-
toilet	100	-
Corridors, stairs	100	22
GIS Hall	200	
Corridor	100	
Stairs	100	
ACDB- DCDB room / Store	150	
Tiffin room / Kitchen	150	
Maintenance room	150	
Conference room	350	

ii) **Outdoor Areas**

Location	Service Illuminance (Lux)	Glare Index
Switchyard floodlighting	30	-
Transformer compounds	120	-
Roadway lighting	30	-
Perimeter wall security	10	-
Control building exterior	15	-
Road within campus including		
colony area		

(g) The surface for lux measurement shall be at 0.5 m high from ground for Indoor and 1 m for outdoor Areas except transformer Yard. In case of Transformer compounds, surface at 1.5 m height from ground shall be considered for lux measurement.

13.31 Air Conditioning and Ventilation

13.31.1 Scope of Work

This Section of the works covers the design, supply, delivery, installation, commissioning and setting to work of the ventilating systems for the control building.

All ventilating systems shall be fully automatic in operation and shall be capable of maintaining internal conditions within the bands of temperature and humidity specified here after the substations are normally manned and allowance shall be made for at least four persons on site in the design.

13.31.2 Air Conditioning

The following areas shall be air conditioned:

(a) Office
(b) Control & Relay Protection room
(c) Telecommunication/SCADA/PLC room
(d) AC & DC Auxiliary Power Supply room (36kV GIS room)
(e) CAF (Compressed Air Foam) Supply room

Air conditioning shall be provided in the form of Air Cooled Split System Air Handling Units or cassette type Air Handling Units. The systems shall handle predominantly recirculated air with a controlled quantity of fresh air introduced either at each unit or independently via a separate supply and extract system. Supply air distribution ducts for the Control/Relay room shall be located in the false ceiling serving supply diffusers. Return (recirculated) air shall be drawn in through the front of each unit.

The cooling medium for the Cassette type System Air Handling Units shall be direct expansion provided by air cooled refrigeration condensing units located on the roof of the building or wall mounted on building exterior, and interconnected by refrigerant pipework to multi circuit direct expansion cooling coils.

Air conditioning system shall be thermostatically controlled to maintain internal conditions under continuous operation within the limits stated. Plant shall be arranged to facilitate maintenance and future replacement of equipment.

13.31.3 Mechanical Ventilation

Supply and extract ventilation shall be provided to serve the following areas:

(a) Battery Room
(b) Toilets (Extract only)
(c) Cable basement

Supply air handling plants shall consist of a sand trap fresh air intake louvre, insect screen, pre-filter, bag filter, electric air heater battery, fan and distribution ductwork.

The air intake shall not face the prevailing wind.

Extract ventilation shall be provided by means of wall mounting fans, roof extract units or ducted systems with louvered discharges to atmosphere. Individual extract fans shall be provided for Battery room and toilets.

Extract fans for battery room shall be corrosion resistant throughout, with a 4 mm PVC lining.

13.31.4 Basis for Design

(a) **External Design Conditions**

The external conditions for the calculation of duties for the mechanical services shall be with mean monthly, maximum and minimum values as below:

- Maximum ambient shade temperature: 40 °C
- Minimum ambient shade temperature: 4 °C
- Maximum daily average temperature: 35 °C
- Maximum annual temperature: 25 °C
- Relative humidity: maximum 100%, minimum 80%
- Solar radiation: 100 mW / m²

All plant and equipment installed externally, or which can be affected by external condition shall be capable of withstanding without damage or deterioration the effects of solar radiation, rain, wind, dust, sand storms or other weather phenomena prevalent in the area in which particular building is located.

(b) **Internal Design Conditions**

Air conditioning systems shall be capable of maintaining internal conditions in all air conditioned areas within the following bands or, if necessary for the satisfactory operation of the equipment housed, more stringent requirements:

- For substations 22+4 °C DB, 40 to 70% R.H

The following air change rates/hour shall be provided in mechanically ventilated area:

- Battery rooms 10
- Toilets 12 (extract only)
- Cable basement 6
- Other general areas 4

All air conditioning and ventilating systems shall be designed for continuous operation. Plant shall be arranged to facilitate maintenance and future replacement of equipment.

The Contractor shall calculate heat gains and losses under the specified conditions for each part of each building, taking into account solar radiation, thermal transmittance through roofs, walls, floors and windows, fresh air requirements, heat emission from installed e1ectrical equipment and lighting, personnel, infiltration and any other sources. The Contractor shall be responsible for determining the heat transfer coefficients for all materials used in building construction. In the event of any change in materials. design or method of building construction, the Contractor shall at all times be responsible for rechecking the design of all systems to ensure that they are capable of meeting the specified design requirements.

13.31.5 Air Cooled Condensing Units

The cooling medium for the air conditioning shall be direct expansion refrigeration provided by air cooled condensing units located externally.

The condensing units shall be of the fully packaged type requiring only site connection of refrigeration pipework, isolated electrical supply and input from the control system.
The individual item of refrigerant equipment shall be matched such that the required performance of the evaporator is achieved concurrently with the satisfactory operation of the compressor and adequate heat rejection at the condenser. Each system as a whole shall maintain the correct duty at the design ambient and operate at the maximum ambient conditions stated without exceeding the safe operational limits of any individual item of equipment and without causing any safety device to operate.

All electrical equipment, control, magnetic coils and solenoids shall be manufactured specifically for operation at the electrical characteristics specified herein and such items designed for any other characteristics shall not be used.

Air cooled condensing units and air handling units that are inter-connected on site with refrigerant piping shall all be supplied by the same Manufacturer.

The casings of the condensing unit shall be weatherproof and shall incorporate adequate access and inspection panels secured in place by rustproof fasteners.

The whole of the casing shall be treated for corrosion and weather resistance and ungalvanized mild steel shall not be used (even if painted). The unit shall be finished in not less than two coats of weather resistant finish, such as baked enamel of a light reflective colour.

The access panels shall be adequately sized for the service and removal of all working parts of l the unit. All panels shall be stiffened and supported to prevent flexing and drumming.

Electrical equipment shall he contained in a fully weatherproofed enclosure with internal division be-tween the power connections and equipment and the control connections and equipment.

13.31.6 Refrigeration Systems

Liquid lines shall be insulated where they are in direct sunlight or where they pass though non-air conditioned areas.

Suction lines shall be insulated over their entire length.

All insulation to refrigeration pipe work shall be of flexible, closed cell l foam phenolic rubber type with a temperature range of -40°C to +105°C. They shall have a thermal conductivity of 0.0375 w/m °C at 21°C and a water vapour transmission of less than 6.0 ng/Ns.

The thickness of insulation shall be in accordance with the following tables:

Location	Insulation Thickness for O.D.	Pipe Size Range
Suction Lines		
	6-10mm	12-22mm
Exposed to weather	13mm	19mm
In air conditioned spaces	9mm	19mm
In non-air conditioned spaces	9mm	9mm
Liquid Lines		
Exposed to weather and in non-air-conditioned spaces	9 mm	19 mm

The refrigerant used shall conform to BS 4334 Group 1 or equivalent and shall be non-explosive, non-combustive, non-toxic and non-irritating.

Packaged air conditioning plant items requiring interconnection with refrigeration piping on site shall be leak tested by the Manufacturers and delivered to site with a holding charge of refrigerant.

13.31.7 Console Air Conditioning Units

Console model room air conditioners shall be of the slim-line pattern and complete with 4-way adjustable grilles, heavy gauge zinc coated stove enamelled sheet steel casing with single or two colour decorative finish. Electrical-heaters shall not be fitted.

The casing and position shall be such as to protrude not more than 250 mm into the air-conditioned space and no external projection beyond the building line will be permitted other than the fixing of the condenser cooling air grille.

The units shall be extremely quiet ill operation, the noise level not being higher than 30 dB. All sections of the casing shall be acoustically and thermally insulated.

Compressors shall be of the fully hermetic type, fitted with resilient mountings and complete with thermal overload protection and starting relays.
Evaporators shall be manufactured of' copper tube with copper or aluminium fins mechanically bonded.

The evaporator fan shall be of double inlet, double width type and complete with continuously rated totally enclosed electric motor.

Filters shall be of the washable type, suitably positioned for easy access for cleaning.

Automatic control by means of an integral thermostat shall be provided, together with the safety control to prevent excessive cooling.

Motors shall be air-cooled and units shall be complete with internally mounted condenser cooling fans with totally enclosed motors.
Fresh air shall be introduced separately by means of a central fresh air plant, where these units are proposed to serve individual offices in a building.

Units shall be supplied as a whole and be suitable for easy removal and re-positioning should this be desired at a later date.

13.31.8 Ductwork

All sheet metal ducting shall be manufactured and installed in accordance with the Institution of Ventilation Engineers Guide to Current Practice Section B 16, the American Society of Heating, Refrigeration and Air Conditioning Engineers, or the Heating and Ventilating Contractors Association of United Kingdom Specification DW/142 or equivalent international standards for sheet metal ductwork for low velocity low pressure air system with air velocity of up to 10 m/s.

Ail ductwork and fittings serving hazardous areas, such as battery rooms where corrosive fumes are expected, shall be of rigid PVC materials.

13.31.9 Condensate Drains

Provision shall be made for condensate to be passed into the rainwater drainage system. Condensate drains must be routed directly into the drainage system or individual soakaways. Pipes discharging onto substation or building brick paving will not be permitted.

13.31.10 Extract Ventilation Units

This clause covers fan powered extract ventilation units for mounting in walls and windows, on roofs and in plant rooms.

Extract units shall incorporate propeller. aerofoil, axial, centrifugal or hybrid type fans which shall be constructed in accordance with the relevant sections of this Specification.

Roof units shall comprise a galvanised sheet steel base suitable for use as a weathering skirt, a mild steel fan/motor mounting frame and a spun aluminium cowl. The sheet steel base shall be constructed to support the fan/motor without distortion and where the fan is belt driven shall incorporate a rigid subframe for motor mounting. Fans shall be diaphragm mounted or fitted with a cylindrical casing de-signed for removal from the unit from inside or outside the building without disturbing the weathering skirt or cowl fixings. The cowl shall be weatherproofed and shall be hinge mounted to provide complete access to the fad/motor.

Lubricating points shall be extended to a convenient access point. Stainless steel nuts, bolts and washers shall be used for all fixings exposed to the weather.

13.31.11 Air Filters

All filter media hall be properly bonded and protected against filter fibre or particle migration. The direction of air flow shall be clearly marked on all filter panels and on installation frames.

Access to filters shall be through removal panels fitted with quick release fasteners and rubber sealing gaskets.

Each disposable panel filter system shall be provided with 4 complete spare sets for use during the commissioning period. These sets shall be in addition to any filter cells supplied as spares in accordance wit11 the general clauses of this specifications.

Filter performance shall, unless otherwise noted, be taken to mean the Overall Gravometric Efficiency against BS 6540:Part I Duct Test or equivalent.

Filter media of all types and sizes shall be supported in rigid peripheral frames with internal or external wire support of the media to ensure that the media shall not collapse under air flow. The holding frames shall incorporate accurately sized channel sections to provide a good fitting for the filters.

The type of washable and/or disposal panel filters shall be subject to the Engineer's approval.

13.31.12 Grilles and Louvres

Grilles shall be of aluminium construction and shall be fixed by means of subframe with spring clips or screw fixings.

The corners of front flanges of grilles and subframes shall be mitred and jointed to produce a clean unbroken appearance and visible aluminium sections shall be free from extrusion marks.

Front flanges shall be at least 30mm wide and shall incorporate a lip of at least 4.5 mm and a felt gasket. Blades shall be fixed at even centres with intermediate mullions giving support for blades of more than 550 mm long. Grille finish shall be anodised natural aluminium colour except where otherwise indicated.

All grilles shall be fitted with an opened blade damper for regulation purposes and shall be fitted with acoustically lined inlet plenums where necessary in order to comply with the acoustic limits of this Specification.

Outdoor air louvres shall be of all extruded aluminium construction fitted with opposed blade dampers in the connected ducting where necessary for air flow regulation, Movable blade louvres shall not be used.

Louvres shall be weatherproof and shall incorporate an aluminium wire mesh screen on the inside surface.

The dimensions of louvres for mounting in the building structure shall suit the concrete block or brick modules and shall be fixed to a hardwood frame.

13.31.13 Control Equipment

Each item of shall be provided with local isolation and/or emergency stop buttons to facilitate maintenance, inspection and emergency operation.

The control system shall be of the electronic type, capable of providing the degree of thermostatic control specified. The Contractor shall provide full wiring diagram of all control circuits giving terminal connection reference.

The control system shall incorporate all necessary safety interlocks for the successful operation of the mechanical plant and system. All of the individual control elements shall be provided by the same Manufacturer.

Temperature sensors shall be of the resistance type using nickel based elements and shall be accurate to $\pm$ 1ºC over the range of 0 ºC to 30 ºC. The sensor resistance shall be compatible with the measuring bridge of the matching control box.

13.31.14 Electrical Connections

All electrical power control cables and wiring associated with the air conditioning and ventilation systems, including all connections between control panels, valves, thermostats, sensing probes and other like items shall be supplied, installed and connected up as part of this Contract.

The cabling and wiring system shall comply with the requirements of the relevant clauses of this Specification and be either surface or flush installation as appropriate.

Cables and wiring shall comprise either PVCWPVC laid in cleats or trenches, or PVC drawn into galvanised conduits and trunking.

Final connections to electric motors and all other items of plant subject to movement and vibration shall comprise flexible cable in flexible conduit.

13.31.15 Manufacturers

Wherever possible all air conditioning and ventilating plant shall be selected from a single Manufacturer's product range and origin. Where this is not possible, because of practical or technical constraints. then the number of different sources of origin shall. be kept to a minimum. Local service facilities shall be available for the equipment proposed.

The Contractor shall provide, with his submission, illustrated technical literature covering all plant and equipment offered.

The preferable manufacturer are Hitachi, Mitsubishi, General & York.

13.31.16 Standards

All air conditioning and ventilation equipment shall conform to British Standards, Chartered Institution of Building Services or ASHRAE recommendations or other recognised International Standards.

13.31.17 Approval

The Contractor shall submit to the Engineer for approval copies of all his calculations forming the basis for the selection of all air conditioning and ventilating plant, plant selection details and full working drawings. Such approval shall not relieve the Contractor of his contractual responsibilities.

13.31.18 Maintenance

The Contractor shall be responsible for the maintenance of all installations covered by this section of the Specifications for the period stated elsewhere in the Specification.

13.32 Earthing and Bonding

All equipment being supplied under this Section shall be effectively bonded to ensure earth continuity throughout the system. Continuity may be provided by means of cable armouring but a separate earth continuity conductor shall be included with all wiring in conduits. No reliance shall be placed on metal to metal joints in conduits for earth continuity. The earth continuity conductors shall as far as possible

be in one continuous length to the furthest part of the installation from the controlling switchboard. The earth conductor shall connect all metal cases housing electrical equipment. The branches shall be connected to the main conductor by permanently soldered on mechanically clamped joints.

13.33 Testing and Commissioning

The Contractor shall be required to prove that the installed system meets the design requirements and Specification to the satisfaction of the Engineer.

14. Fibre-Optic Multiplexer Equipment for Communication and Protection

14.1 Scope of Specification

This specification describes the communication requirements for the transport of voice, data and protection signals between the new substations existing substations and the National Load Dispatching Centre (NLDC) in Rampura, including engineering, configuration, testing, installation, commissioning and training.

The scope of work is to connect the Substation Automation System to the existing communication sys-tem to be installed under this contract for securing the transport of voice, data and protection signals, complete system for new substations and extension and integration into the existing system for existing substations.

The scope of work is to connect REMOTE END substations, too. All necessary equipment, material and services shall be included in the contract price.

OPGW with 48 cores of optical fibre in 400kV, 230kV & 132kV Overhead Line will be installed by the transmission Line Contractor, but this optical fibre will be used for optical connection for current differential protection of the 400kV, 230kV & 132kV line.

All materials and equipment offered shall be brand new, from the Manufacturer's normal and standard construction, designed and manufactured according the latest technological methods.

For the purpose of standardisation of operating performance and facilities offered equipment shall be compatible with the existing ones.

For standardization of operation performance, facilities and spare requirements, the fibre optic multiplexer equipment for communication and protection to be supplied under this project shall consist of equipment which can totally be integrated into the existing telecommunication system in PGCB's net-work, including the telecommunication network management system. The fibre optic multiplexers presently used in PGCB’s network are:

- **ABB FOX 515/615, and**
- **Areva MSE 5001**

The Manufacturer of Telecommunication system – Fibre optic multiplexer equipment for communication and protection shall be the same as the existing system supplier : **ABB (CH/S)** or **GE (France/India).**

Only Manufacturer Authorization Letter is required to be submitted with the bid. Since, above mentioned manufacturers are approved, all other requirements mentioned in sub-clause 2.5 of Section 3 of Volume 1 are not required.

Any other Manufacturer of Telecommunication system shall have to fulfil the Qualification Criteria required in sub-clause 2.5 of Section 3 of Volume 1 of Tender documents.

14.2 Summary of Standards

The Equipment shall comply with the latest ITU-T recommendations for the plesiochronuous and synchronous hierarchies.

The equipment shall be KEMA type tested.

14.2.1 PDH Interfaces

The PDH interfaces shall conform to the following recommendations:

ITU

- ITU-T G.702 General aspects of digital transmission systems - Terminal equipment Digital hierarchy bit rates
- ITU-T G.703 Digital transmission systems - Terminal equipment - General Physical/electrical characteristics of hierarchical digital interfaces
- ITU-T G.704 Digital transmission systems - Terminal equipment - General Synchronous frame structures used at 1544, 6312, 2048, 8448 and 44 736 kbit/s hierarchical levels
- ITU-T G.706 General aspects of digital transmission systems - Terminal equipment- Frame alignment and cyclic redundancy check (CRC) procedures relating to basic frame structures defined in recommendation G.704
- ITU-T G.71 1 Pulse code modulation (PCM) of voice frequencies
- ITU-T G.712 Transmission performance characteristics of pulse code modulation channels

- ITU-T G.732 General aspects of digital transmission systems - Terminal equipment - Characteristics of primary PCM multiplex equipment operating at 2048 kbit/s
- ITU-T G.735 Characteristics of primary multiplex equipment operating at 2048 kbit/s and offering synchronous digital access at 384 kbit/s and/or 64 kbit/s
- ITU-T G.736 General aspects of digital transmission - Characteristics of a synchronous digital multiplex equipment operating at 2048 kbit/s
- ITU-T G.737 Characteristics of external access equipment operating at 2048 kbit/s and offering synchronous digital access at 384 kbit/s and/or 64 kbit/s
- ITU-T G-823 The control of jitter and wander within digital networks, which are based on the 2048 kbit/s hierarchy
- ITU-T G.826 Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate

14.2.2 Architecture of Optical SDH Interfaces

The architecture of optical SDH interfaces shall conform to the following recommendations:

ETS/EN

- ETS 300 147: Synchronous digital hierarchy multiplexing structure
- ETS 300 417: Transmission and Multiplexing (TM); Generic requirements of transport functionality of equipment
- ETS 300 417-1-1 / EN 300 417-1-1 V 1. 1.2: Generic Processes and Performance
- ETS 300 417-2-1 / EN 300 417-2-1 VI.1.2: SDH and PDH Physical Section Layer Functions
- ETS 300 417-3-1 / EN 300 417-3-1 V 1. 1.2: STM-N Regenerator & Multiplex Section Layer Functions
- ETS 300 417-4-1 / EN 300 417-4-1 V 1. 1.2: SDH Path Layer Functions

ITU

- ITU-T G.707 Network node interface for the synchronous digital hierarchy

- ITU-T G.783 Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks
- ITU-T G.803 Architecture of transport networks based on the synchronous digital hierarchy (SDH)
- ITU-T G.805 Generic functional architecture of transport networks
- ITU-T G.826 Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate
- ITU-T G.841 Types and characteristics of synchronous digital hierarchy (SDH) net- work protection architectures
- ITU-T G.957 Optical interfaces for equipment and systems relating to the synchronous digital hierarchy
- TU-T G.958 Digital line systems based on the synchronous digital hierarchy for use on optical fibre cables
- ITU-T M.2101.1 Performance limits for bringing into service and maintenance of international SDH paths and multiplex section
- ITU-T T.50 International Reference Alphabet (IRA) - Information technology 7bit coded character set for information interchange

14.2.3 Synchronisation and Timing of Optical SDH Interfaces

The synchronisation and timing of optical SDH interfaces shall conform to the following recommendations:

ETS/EN

- ETS 300 417-6-1 / EN 300 417-6-1 V 1. 1.2 Synchronisation Layer Functions
- ETS 300 462-1 / EN 300 462-1-1 V 1. 1. 1 Transmission and Multiplexing (TM); Generic requirements for synchronisation networks; Part 1: Definitions and terminology for synchronisation networks.
- EN 300 462-4-1 V1.1 Transmission and Multiplexing (TM); Generic requirements for synchronisation networks; Part 4-1: Timing characteristics of slave clocks suitable for synchronisation supply to Synchronous Digital Hierarchy (SDH) and Plesiochronous Digital Hierarchy (PDH) equipment

- ETS 300 462-5 / EN 300 462-5-1 V1.1.2 — Transmission and Multiplexing (TM); Generic requirements for synchronisation networks; Part 5: Timing characteristics of slave clocks suitable for operation in Synchronous Digital Hierarchy (SDH) equipment

ITU

- ITU-T G.813: — Timing characteristics of synchronous digital hierarchy (SDH) equipment slave clocks (SEC)

14.3 Abbreviations

- ADM — Add-drop multiplexed
- ALS — Automatic Laser Shutdown
- BIP — Bit Interleaved Parity
- CAP — Carrier-less Amplitude and Phase
- CAS — Channel Associated Signalling
- CRC — Cyclic Redundancy Check
- DTMF — Dual Tone Multi-Frequency
- EN — European Norm
- EOW — Engineering Order Wire
- ETS — European Telecommunications Standards
- GPS — Global Positioning System
- HDSL — High Density Subscriber Line
- IEC — International Electrical Commission
- IP — Internet Protocol
- ISDN — Integrated Services Digital Network
- ITU — International Telecommunication Union
- LAN — Local Area Network
- MCMI — Multi Coded Mark Inversion
- MS — Multiplex Section
- NE — Network Element
- NMS — Network Management System
- OS — Optical Section
- OSPF — Open Shortest Path First
- PDH — Plesiochronous Digital Hierarchy
- PPP — Point-to-Point Protocol
- RS — Regenerator Section

- SDH Synchronous Digital Hierarchy
- SNMP Simple Network Management Protocol
- SOH Section Overhead
- STM Synchronous Transport Module
- TCP Transmission Control Protocol
- TTI Trail Trace Identifier
- VC Virtual Container
- VF Voice Frequency

14.4 General Requirements

The digital multiplex equipment shall be universal, software-controlled, and provide various interface cards to connect tributary interfaces signals such as voice, teleprotection and data to aggregate inter-faces. On aggregate level 2Mbit/s and 8Mbit/s electrical interfaces complying with ITU-T recommendations G.703 / G.704 and 2Mbit/s HDSL interfaces shall be available. In addition, optical STM-1 aggregate interfaces on 155Mbit/s shall be available. All modules shall form an integrated part of a shelf.

The multiplexer shall provide means to drop and insert individual 64 kbit/s signals and allocate them to determined time slots in the 2Mbit/s streams. Path protection on 64 kbit/s and 2Mbit/s shall be sup-ported.

It shall be suitable for operation in substation with harsh environment with high electromagnetic interference, be highly reliable and provide secure communication for real time signals such as voice, SCADA, teleprotection and status/control signals.

The equipment offered shall already be working successfully in telecommunication networks operated by power utilities. It shall comply to the latest ITU-T standards and be able to be interconnected with telecommunication equipment.

Any equipment in the network shall be manageable from a control centre and there shall be means to supervise external/existing equipment as well.

As a minimum modules for the following user signals shall be available as plug-in units for the digital multiplexer:

- Analogue subscriber interface: subscriber and exchange side
- G.703, 64kbit/s data Interface
- X.24/V. 11 (RS-422), Nx 64kbit/s data interface
- V.24/V.28 (RS-232), data interface
- RS 232/485/422 dat interface

- Alarm collection interface
- Teleprotection command interface
- Binary signal (status and control) interface
- 2Mbit/s electrical interface for unframed signals acc. to ITU-T G.703 and framed signals acc. to G.703 and G.704.

Additionally, the equipment shall provide the following aggregate interfaces:

- STM-4 (622 Mbit/s) optical 1+1 interface for medium and long distances, with automatic laser shut down.
- STM-1 (155 Mbit/s) / STM-4 (622 Mbit/s) optical add-drop interface for medium and long distances, with automatic laser shut down
  - 2 Mbit/s electrical interface /
  - 2 Mbit/s HDSL interface

The equipment shall be equipped with a ringing generator for analogue subscriber interfaces.

14.5 General Conditions

The same equipment shall be used as a terminal, for through connections (transit, repeater) and as add-drop multiplexer (ADM) with integrated optical line modules.

First order multiplexing (2048 Mbit/s), second order multiplexing (8448 Mbit/s/s) and STM-1/STM-4 or STM-16 (for 400kV if any) multiplexer shall be integrated.

Conference for voice channels and point-multipoint function for data signals shall be possible.

The equipment shall be of fully modular design, based on a single cubicle.

14.5.1 Channel Capacity: Digital Cross Connection

The equipment shall be equipped with a redundant cross connection function with decentralised cross connection functions on each board.

The cross connect capacity shall be minimum 40x 2Mbit/s, or 200x 64kbit/s non-blocking.

14.5.2 Redundant Centralised Functions

The equipment shall be equipped with redundant circuits for all centralised functions.

14.5.3 Power Supply

The multiplex equipment shall operate at 48VDC +/- 15%. Redundant power-supply shall be supported.

14.5.4 ITU Compliance

The Equipment shall comply to the latest ITU-T recommendations for the plesiochronuous and synchronous hierarchies, such as:

G.702-704, G.706, G.711-714, G.732, G.735-737, G.742, G.826, G.823, Q-552

14.5.5 Electromagnetic Compatibility and Safety Regulations

The equipment shall comply with the EN50022, EN50082, IEC 801-2, IEC 801-6 and shall be conform-ant with CE.

14.5.6 Ambient Conditions

- Storage and transport: -40... +70˚C; 98% (no condensation)
- Operation: -5... +45˚C, humidity of max. 95% (no condensation)

14.5.7 Mechanical Construction

The equipment shall be of robust design. All tributary and aggregate units shall be integrated in the same shelf.

All connectors shall be accessible from the front.

14.5.8 Network Management System

The equipment shall be software programmable, by both a local craft terminal - preferably notebook and a centralised Network Management System (NMS).

Traffic through the multiplexer shall under no circumstances depend on Network Management System; i.e. the multiplexer has to operate without being connected to any management system.

The Network Management System shall be used to supervise & configure the tele-protection, PDH and SDH equipment.

14.5.9 1+1 Path Protection

The equipment shall protect communication channels. The protection shall be end to end from one interface (telephone or data) to the other. It shall switch automatically from the main channel to the standby channel. It shall be configurable whether the system switches back to the main channel (reversible switching) or not (non-reversible).

If a path has switched to its standby route because the main route is disturbed this shall be indicated with an alarm.

The switching shall be done within the multiplexer without using the network management system.

14.5.10 1+1 Section Protection

The equipment shall provide multiplexing section protection. It shall be possible to use two independent links: one as the main and the other as the standby. The system shall automatically switch to the standby connection and generate an alarm if the main connection is disturbed.

The switching shall be done within the multiplexer without using the Network Management System.

14.5.11 Network Topology

It shall be possible to build point to point, linear, ring, T, and meshed networks.

14.5.12 Synchronisation

The equipment shall be synchronisable with an external centralised clock, with connected 2048 Mbit/s signals and/ or with internal oscillator. The synchronisation shall be configurable and it shall be possible to distribute the synchronisation to other equipment as well.

The system shall have means to switch to select the synchronisation source as well as means to prevent the system from switching synchronisation loops. The equipment shall be capable select the synchronisation source by means of the SSM (Synchronisation Status Messaging) feature according to ITU-T G.704 or priority based.

14.5.13 Alarms

Each module shall supervise its functions and shall have an alarm-indication LED on its front. All alarms shall be collected by the NMS.

Each node shall be capable to collect up to 50 external alarms.

14.5.14 Test Loops

The equipment shall provide means to loop signals on 64kBit/s level as well as on 2Mbit/s level. It shall indicate an alarm if a loop is activated. It shall have the possibility to determine the time after which an activated loop is switched back.

14.5.15 Maintenance Facilities

Every Network Element shall have a built-in Signal Generator and Analyser to analyse communication paths. It must be possible to cross connect the Generator and Analyser to transmission channels and terminate the signal in other Network Elements. The configuration must be possible locally with the craft access terminal and remotely with the NMS or the craft access terminal.

It must be possible to loop-back signals locally and remotely using the craft access terminal or the NMS.

14.6 Requirements for Transport Level

14.6.1 SDH Aggregate Units

The interface shall be designed for use on single mode fibre at 1310nm and 1550nm
The following main functions shall be supported:

- Termination of the OS-, RS-, MS- and VC-4 layer
- Extraction and insertion of the SOH communications information through connections of VC-12 and VC-3

The following maintenance functions shall be supported:

- Status indications
- Loops
- Restart after ALS
- TTI monitoring
- BIP Error Insertion

The following SDH interfaces shall be available:

- STM-1/4 for 132kV & lower voltage level
- STM-4/16 for 230kV voltage level
- STM-16 for 400kV voltage level
- The number of optical port shall be as per field requirement

This interface shall provide Multiplex Section Protection (MSP): 1+1 Section Protection

- 2Mbit/s & 64kbit/s electrical interface
- The number of port shall be as per field requirement

14.6.2 HDSL Aggregate Units

2Mbit/s HDSL interface

The HDSL interface shall provide means to interconnect the multiplexer over two pairs of copper wire up to 12km using CAP modulation (Carrier-less Amplitude and Phase). It shall communicate either with another interface of the same type or with a remote desktop terminal.

2Mbit/s HDSL Desktop Terminal

This Terminal shall provide a HDSL interface to transmit 2Mbit/s over two pairs of copper over a distance up to 12 km. It shall be housed in a metallic indoor case. The following interfaces shall be avail-able:

- G.703, 2Mbit/s, 75 ohm
- G.703, 2Mbit/s, 120 ohm
- X.21/V 11, Nx 64kbit/s (N = 1 .. 32)
- V.35, Nx 64kBit/s (N = l.. 32)
- V.36 / RS485, Nx 64kbit/s (N = l.. 32)

LAN Connection:

l/0 base ethernet connection for e.g. router supporting LAN protocols: IP, IPX; routing protocols: RIP; WAN protocols: HDLC, PPP, frame relay (including RFC 1490). It shall inter-operate with Cisco, Well-fleet, 3Com etc. and be manageable locally, remotely, and with Telnet and SNMP. Two such desktop terminals shall be connectable to provide a 2Mbit/s link over two pairs of copper.

HDSL Repeater:

An HDSL repeater solution for distances longer than 12km shall be offered including a remote powering solution.

HDSL Line Protection:

The HDSL equipment shall (where necessary) be protected against influences of induced voltages up to 10 kV.

14.7 Tributary Units

14.7.1 Analogue Subscriber Interface

An interface with at least 10 subscribers as well as high-density analogue subscriber card with 60 sub-scribers shall be available. The ringing generator shall be integrated in the subscriber module interface. The ringer frequency shall be adjustable for 20Hz, 25Hz, and 50Hz. The following main functions shall are supported:

Downstream signalling:

- Ringing
- Metering
- Polarity reversal
- Reduced battery
- No battery

Upstream signalling:

- On/off-hook
- Pulse and DTMF dialling
- Flash impulse
- Earth key

General:

- Constant current line feeding
- Line test
- Permanent line checks
- CLIP (On-hook VF transmission)
- Metering after on-hook

14.7.2 Exchange Interface

This interface shall provide 12 interfaces to connect remotely connected analogue subscribers to an exchange. It shall provide the following functions:

- pulse dialling
- tone dialling (DTMF)
- earth key function
- metering function(12 kHz or 16 kHz)
- flash impulse
- polarity reversal

- indication of busy lines

The following parameters shall be configurable by software:

- input voice level -5 to +4 dBr
- output voice level -7.5 to -1 dBr
- metering pulse enable/disable
- signalling bit definition
- loop back of voice to the telephone

14.7.3 Party Line Telephone System (Engineering Order Wire)

An engineering order wire (EOW) facility shall be provided at each multiplexer. The EOW shall be con-figured as a party line and use in band DTMF signalling to call another EOW-Terminal. The terminal shall have an integrated DTMF decoder allowing to program a subscriber call number (LA digits), and two group call numbers (LA digits each).

14.7.4 V. 24N.28 RS232 Interface

It shall support the following bit rates:

- 0... 0.3 kbit/s transp. (V. 110)
- 0.6... 38.4kbit/s synchronous / asynchronous (V. 110).

Modules where each interface can be individually configured with 1+1 path protection shall be available.

14.7.5 V.11/X.24 Interface

This interface shall comply to the ITU-T X.24 recommendation for signal definition and to V. 11 for electrical characteristics.

It shall support the following bit rates:

- 48, 56, Nx 64 kbit/s (N = 1... 30) synchronous
- 0.6... 38.4kbit/s synchronous / asynchronous (X.30)

Modules where each interface can be individually configured with 1+1 path protection shall be available.

14.7.6 V.35 Interface

Modules where each interface can be individually configured with 1+1 path protection shall be available.

14.7.7 V.36 / RS 485 Interface

Modules where each interface can be individually configured with 1+1 path protection shall be available.

14.7.8 64 kbit/s Co-directional Interface

This interface shall comply with the ITU-T G.703 part 1.2.1 for co-directional data transfer. A module shall have at least 8 interfaces.

Modules where each interface can be individually configured with 1+1 path protection shall be available.

14.7.9 Ethernet Interface

There shall be a 10BaseT interface available with Router Bridge and FRAD Function available. The following specification shall be covered:

- Ethernet connection: 10baseT
- LAN protocols: IP, IPX
- Routing protocols: static IP route, OSPF2 V2
- WAN protocols: PPP, Frame Relay (including RFC 1490)

The interface shall be manageable locally, remotely, with the management system of the platform. The LAN interface shall support linear-, ring- and star-configurations. The WAN side shall support link capacities n*64kBit/s and 2Mbit/s.

14.7.10 Alarm Interface

This interface shall provide means to collect various alarms, which will be displayed, on the network management system. It shall be used to manage non-PDH equipment with the PDH network management system.

It shall have at least 24 binary inputs and at least 4 outputs, which can be switched by the network management system.

It shall be possible to connect an input to an output so that if an alarm occurs, the output contact will be switched.

It shall be possible to label an alarm. The label-text shall be read from the interface module so that it can be indicated on the network management system as well as on the local craft terminal.

14.7.11 Teleprotection Interface

The protection of the overhead lines shall be arranged as detailed in Section 5. Teleprotection equipment shall be provided for permissive tripping and direct tripping on the lines. The permissive tripping signals are required to operate circuit breaker trip relays in conjunction with the distance protection and directional earth fault relays. The direct tripping signals are required to operate remote circuit breaker tripping relays.

Technical Requirements

This interface shall provide means to transmit four bi-directional command channels. The signals shall be adjustable from 24 to 250VDC by means of software.

All inputs and outputs shall be isolated and with EMC immunity for harsh environment.

Security, dependability and transmission speed shall be selectable and programmable.

It shall be able to drop and insert commands, transfer commands as a transit station, it shall be possible to have AND- and OR-connections between commands.

The interface shall support T-nodes.

The teleprotection interface shall provide an integrated non-volatile event-recorder which shall be synchronisable either internally or by GPS or a command counter which counts trip commands.

The teleprotection interface shall provide means for signal delay measurement.
1+1 protection must be available; the switching shall be done within less than 10ms. The interface shall do automatic loop test every 60s.
Under no circumstances shall the interface cause trip-commands in case of power supply failure or when put in or out of service.

It shall be possible to synchronise all teleprotection interfaces with one GPS in one station. The GPS time shall be distributed over the teleprotection channel.

An 8-bit command addressing shall be used to prevent tripping if the signal is inadvertently re-routed through the telecommunication network.

14.7.12 Optical Protection Relays Interface

This interface shall have an optical port to connect protection relays for teleprotection to the multiplexer.

It shall operate on 800 -1300nm use MCMI line coding and be suitable for teleprotection relays.

14.7.13 Binary Contact Interface

- This interface shall provide means to transmit binary signals.
- The inputs and outputs shall be isolated.
- The inputs shall be suitable for 24VDC to 60VDC.
- Outputs shall be solid state relays.
- The interface shall provide a 24VDC short circuit proofed auxiliary power supply.
- It shall be able to drop and insert commands, transfer commands as a transit station, it shall be possible to have AND- and OR-connections between commands.
- The teleprotection interface shall provide an integrated event recorder, which shall be synchronisable either internally or by GPS.

14.7.14 2Mbit/s G.703 / G.704 Interface

- This interface shall comply with the ITU-T G.703 and G.704 recommendations.
- The interface module shall have at least four interfaces to be activated individually. It shall be possible to have 128 interface modules a multiplexer.
- In order to connect different equipment, the interfaces shall be available with the impedance of 120 ohms and 75 ohms.
- The interface shall support CRC-4 multi-frame according to ITU-T G.704 (enabled and disabled by software).
- The CAS signalling according to ITU-T G.704 table 9 shall be activated optionally.
- The interface shall be able to extract the 2.048 MHz clock, which can be used to synchronise the multiplex equipment.
- The interface module shall support 2Mbit/s loop-back of the incoming signal as well as the loop-back of the internal signals.

14.8 Telephone System

An IP phone facility shall be provided at each new substation. The IP phone shall be incorporated by IP connection from upstream substation through IP network in the operational telephone system which is controlled from the existing call manager at NLDC Dhaka. At least three IP telephone sets proper to above mentioned administrative telephone system shall be provided at each new substation.

New substations will become remote subscribers in the administrative telephone system. Facility for minimum 10 x 2W remote subscribers shall be provided and installed at the substation and the remote subscribers shall be connect with the nearest existing exchange of the existing telephone network.

Necessary cards required at the nearest exchange and its associated multiplexer shall be included in the contract price. At least three telephone sets proper to the above mentioned administrative telephone system shall be provide at each new substation

The trunk numbering plan shall be compatible with the present scheme in service in Bangladesh.

The telephone signalling (dialling) system shall be compatible with the present system.

An alarm system shall be provided to indicate traffic failure including blown fuses, loss of power supply, etc. In addition, contacts shall be provided to facilitate extension of the alarms to the telecontrol equipment.

14.9 Communications DC Power Supply Equipment

14.9.1 General

14.9.1.1 Basis of Design

The equipment shall comply with IEC 60146 and 60478.

The charger shall be of either the Thyristor-controlled type or of the SMPS type. The battery shall be nickel cadmium type - as detailed in a separate section of this Specification.

The design and selection of equipment and components shall be based on achieving a minimum lifetime of 20 years, when operating under the specified service conditions.

14.9.1.2 Operating Principle

The output of the charger shall, during normal operation, continuously supply the power requirements of the load whilst simultaneously maintaining the battery charge in the float charge mode. In the event of an interruption in the A.C. mains supply to the charger, the battery shall supply the load requirements for not less than the specified standby time - whilst maintaining the output voltage within permissible limits.

Upon restoration of the A.C. mains supply, the rectifier shall automatically resume supply of the load requirements whilst simultaneously recharging the battery at the float voltage.

14.9.2 Configuration

The power supply installation shall comprise two batteries and two charging sources. each charger shall be able to float charge both batteries as well as supplying the total load.

The total battery capacity shall be able to supply the total load (comprising the delivered load together with 25%. spare for future use) for at least 5 hours in the event of failure of the A.C. mains supply.

The D.C. power supply equipment is required to limit the output voltage to the load within plus 15% and minus 15% of the nominal value, provided these values do not exceed the voltage guarantee of the load equipment. The power supply output positive shall be earthed.

14.9.3 Charger

General requirement of this chapter can be referred to the chapter 8.5 of this volume.

14.9.3.1 General

The charger shall operate according to the constant voltage current limiting principle and shall incorporate a soft start feature to gradually accept load on initial energising.

The charger shall restart automatically upon restoration of the A.C. mains supply following a mains supply interruption, and recharge the battery at the float voltage.

The charger shall be suitable for operation in parallel with one or more chargers, and shall include a current sharing facility.

The charger shall be of sufficient output capacity for the application, parallel operation of chargers (where required) is for the purpose of redundancy and not to satisfy the output current requirements.

14.9.3.2 Charger Output

The output characteristic shall provide an output voltage regulation of ±1%, over the specified A.C. mains voltage and frequency range and for load changes 0-100%. The output voltage regulator shall be adjustable within limits approved by the Engineer and shall be so designed that special tools are not required for such adjustment. Compensation for battery temperature shall be provided.

The charger shall have protection against overloads or short circuits and shall limit the output current.

Recovery to a constant voltage characteristic shall occur automatically at the end of the overcurrent/short circuit.

14.9.3.3 Boost Charging

Both Auto & Manual boost charging shall be provided. A boost timer shall be included to prevent over-charging.

Operation of boost charging shall not disconnect the charger and battery from the load. The load shall be connected to DC charger during boost charging. However, provision may be applied so that, it shall not be possible for both chargers to be selected to boost charging at the same time, or for the load to become disconnected from both batteries and chargers simultaneously.

If the A.C. mains supply fails during boost conditions the two batteries shall be automatically connected in parallel by "no volt" contactors to the load.

It shall not be possible to connect a "boosted" battery to the load until its terminal voltage has fallen below the load equipment upper voltage limit.

14.9.3.4 Noise and Interference

To avoid unacceptable levels of electrical noise in the load equipment smoothing of the D.C. output is required. This shall achieve a psophometric noise level at the output, for loads between 0 and 100%, not exceeding the equivalent of 2 mV at a frequency of 800 Hz after weighting as specified by ITU-T (CCITT).
The relative harmonic content of the input current shall comply with the European Directive for EMC, the EN 60555-2 standard. In the case of SMPS chargers active power factor correction (i.e. boost for step up converter) shall be provided to control the power factor.

The production of radio frequency interference voltages shall not exceed the values of suppression grade "N", as defined in EN 55014/55015 - for Thyristor-controlled type chargers, and suppression grade "B" as defined in EN 55022 for SMPS type chargers.

The performance of the D.C. power supply equipment unit shall not be affected, or in any way degraded, by the use of the following when the severity of the electromagnetic radiation environment corresponds to Class 3, in accordance with IEC 801-3:

- private mobile radio operating in designated or planned radio frequency bands
- current cellular radio equipment
- future cellular equipment
- mobile data equipment.

It is the Contractor's responsibility to determine the radio frequency bands applicable in the locality.

14.9.3.5 Efficiency/Rating

The charger efficiency shall not be less than 85%.

All chargers supplied shall preferably have the same rating, or be in fixed multiples, to limit the number of different charger ratings.

14.9.3.6 Instruments, Controls and Alarms

The charger shall be equipped with the following:

- A.C. mains input circuit breaker
- D.C. output circuit breaker
- charger output current meter
- charger output voltage meter
- alarms for charge fail, D.C. volts high etc.

Each alarm shall be provided with local annunciation and two sets of potential free contacts, for connection to external alarm monitoring systems.

14.9.4 Battery

14.9.4.1 Type

Nickel-cadmium cells shall be of the pocket plate type in accordance with IEC 60623.

Cell containers shall be of the moulded plastic type, non-flame propagating and mechanically shock resistant. They shall provide for the electrolyte level to be viewed through the container material.

Cells shall be permanently marked with the following information:

- Sec-14: Fibre Optic Multiplexer
- Manufacturer's reference number and code
- year and month of manufacture
- voltage and nominal capacity at the 10 hour rate
- cell number.

14.9.4.2 Mounting

The batteries shall be mounted on metal stands, or racks, in a manner such that all the plates of each cell are visible for inspection, test and maintenance purposes. Stands or racks shall have a maximum of two tiers. In all cases adequate space must be left between the tiers for maintenance purposes and to permit the topping up of electrolyte. Stands or racks shall have a protective finish of not less than two coats of electrolyte resisting enamel or gloss paint. Alternatively, an epoxy resin sintered finish may be used.

At locations where the battery is not housed in a separate battery room the battery stand/rack shall be fitted with cladding. The cladding shall permit the free flow of air to the battery, and shall be removable for maintenance purposes.

Cell containers shall be accurately set up in alignment on the stand or rack with lead and/or rubber discs under the feet moulded on each container. Cell lids shall be so positioned that at least one topping up aperture is on the access gangway side of the cell and not obstructed by any inter-cell connecting arrangements.

14.9.4.3 Battery Main Fuses

Bolted cartridge fuses shall be provided in both positive and negative leads and positioned as close to the battery as possible and shall be rated at five times the charger float output rated current. A cartridge fuse shall be provided in the charger input lead to the negative pole of the battery and rated at twice the charger float output rated current. These fuses shall be mounted preferably on the end of the battery stand or rack. These fuse links shall comply with BS 88.

Class DC 40 or equivalent and shall be mounted in fuse carriers with an insulated barrier between the poles.

The cable or busbar to the battery shall be firmly supported at a point near the cell terminal pillar. Where two cables are used they shall be terminated one to either side of the terminal pillar. These cables shall be arranged as to allow some flexibility and to avoid any forces being applied to the cell terminal pillar.

14.9.4.4 Connections

The positive pole of each battery shall be connected to station earth via a single bolted link at the distribution cubicle. Low resistance inter-cell connectors shall be used. Connections between tiers of cells and between end cells and fuses shall be made with insulated copper rod which shall be of equivalent cross-section to the distribution busbars.

Connections from the battery fuses to the chargers and distribution cubicles shall be made with insulated cable of equivalent cross-section to the distribution busbars. The positive and negative terminals of each cell shall be clearly indicated. The positive and negative terminals of the complete battery shall be indicated by red and black marking respectively.

14.9.4.5 Capacity

The battery capacities shall be 200 ampere hours at the 10 hour rate.

14.9.5 D.C. Distribution and Instrumentation

14.9.5.1 General

The distribution section shall be designed for incoming and outgoing D.C. supplies as follows:

- Two independent supplies (including one for future use) incoming from the batteries and associated chargers. The battery negatives shall be connected to the distributed busbar through a single pole switch. The 48V battery positive shall be directly connected to the positive busbar.
- Each load equipment shall be connected to a distribution outlet. The use of teed supplies to more than one load equipment will not be permitted.
- Double pole miniature or moulded case circuit breakers to IEC 157 shall be supplied, fitted with auxiliary contacts which operate when the circuit breaker trips.

The MCBs shall be rated to meet the load requirements and shall be labelled with the destination of the load. Outgoing connections shall be brought to terminals, mounted in the cubicle, provided with strip connectors and cable lugs. The number of outlets shall cater for the quantity of load equipment items plus 50%, with a minimum of 10 outlets being provided, Space shall also be available for the installation of 10 extra outlets for future use.

14.9.5.2 Instruments and Alarms

Instrumentation shall comprise:

- battery ammeter (charge and discharge)
- battery voltage
- load current ammeter

- busbar voltage

An alarm indication shall be provided if the busbar voltage falls outside set limits.

The MCB auxiliary contacts and the high/low voltage alarm shall each provide local annunciation and two sets of potential free contacts, for connection to external alarm monitoring systems.

14.9.6 Housing

The above covers the mounting/housing for batteries.

A modular construction is preferred for the battery charger and D.C. distribution / instrumentation, with each unit comprising a single 19" or ETSI standard rack configuration, all mounted in a single cubicle.

The modular construction shall provide:

- simple plug in units for easy assembly and servicing
- individual battery charger unit removal in safety, without loss of output power to the load
- expansion of capacity at a later date

In the case of Contractors who do not offer a modular construction, separate cubicles are required for each charger and the D.C. distribution / instrumentation.

APPENDIX

Appendix Fibre-Optic Multiplexer Equipment for Communication and Protection

A. Fibre-Optic Multiplexer Equipment

Sl. No.	Description	Unit	Rating
1	**GENERAL**		
1.1	Type of multiplexer		SDH: ADM & PDH
1.2	Complying to ITU-T rec.		Yes
1.3	Transmission Capacity	Mbit/s	STM-4 & STM-16
1.4	Access capacity on 64 kbit/s	channels	Minimum 200
1.5	Access capacity on 2 Mbit/s	channels	Minimum 40
1.6	Redundant central processor		Shall be available
1.7	Digital cross connect function		Fully non-blocking
2	**Available AGGREGATES:**		
2.1	Optical aggregates (ITU-T G.957)		As per field requirement
3	**Available TRUNK INTERFACES:**		
3.1	HDB3, 2 Mbit/s interfaces per module	Nos.	Minimum 8
3.2	Complying to ITU-T rec.		G.703, transparent G.704, selectable
3.3	HDSL, 2Mbit/s interface: no of copper wires	Nos.	4 or 2
	Capacity on 2Mbit/s or on 1Mbit/s	ch	30 or 15
	Capacity selectable	ch/ pair of wire	30 / 2 pairs
			30 / 1 pair
			15 / 1 pair
4	**Available USER INTERFACES**		
4.1	**Voice interfaces for trunk lines:**		
4.1.1	1 + 1 com path protection, available for all		Yes
4.1.2	Analogue, 2wire with E&M :		
	Input lever	dBr	+6.5 ~ -12.5
	Output level	dBr	-1.0 ~ -20

Sl. No.	Description	Unit	Rating
4.1.3	Digital, 2Mbit/s CAS or PRI		
4.2	**Voice interfaces for remote subscriber:**		
4.2.1	2wire, subscriber side	dBr	-5 .. +4 / -7.5 .. -1
4.2.2	2wire, PABX side	dBr	-5 .. +4 / -7.5 .. -3
4.3	**Integrated teleprotection**		
4.3.1	**Interface for Commands:**		
4.3.1.1	Number of independent commands	Nos.	4
4.3.1.2	Transmission time max.	ms	6
4.3.1.3	Signal voltage	Vpeak	250
4.3.1.4	1 + 1 com path protection		Yes
4.3.2	**Interface(s) for Differential Protection:**		
4.3.2.1	Electrical interface: G.703	kbit/s	64
4.3.2.2	Optical Interface	kbit/s	Minimum 64
4.4	**Data: channels per module**		
4.4.1	1 + 1 com path protection, available for all		Yes
4.4.2	V.24/V.28 (RS-232) data interface	Nos.	4
4.4.3	V.11/X.24 (RS-422) data interface	Nos.	4
4.4.4	V.35/V.36 (RS-485) data interface		4
4.4.5	G.703: 64kbit/s	Nos.	8
4.4.6	Ethernet:10/100 BaseT	Nos.	1
	WAN capacity	Mbit/s	Min : 2X2Mbits/s
	Protocols		Min : IP
4.5	**Integrated alarm gathering module:**		
4.5.1	Number of external alarms per module	Nos.	Min. 20
4.5.2	Auxiliary power supply for ext. contacts		Yes
4.6	**Network Management System**		
4.6.1	Type/Name of configuration tool		
4.6.2	For fault / configuration management		Yes / yes

Sl. No.	Description	Unit	Rating
4.6.3	For local / remote operation		Yes / yes
4.6.4	Data communication network (DCN)		Ethernet/IP or Ethernet / OSI
4.7	**Ambient Conditions:**		
4.7.1	Storage: ETS 300 019-1-1, class 1.2	°C / % hum	-25 .. + 55 / class 1.2
4.7.2	Transport: ETS 300 019-1-2, class 2.2	°C / % hum	-25 .. + 70 / class 2.2
4.7.3	Operation: ETS 300 019-1-3, class 3.1E	°C / % hum	-5 .. +45 / class 3.1E
4.8	**Power Supply**		
4.8.1	Operation	VDC	48 / 60 (-15/+20%)
4.8.2	Fully redundant power supply		yes

B. Operation Telephone System (PABX)

Sl. No.	Description	Unit	Rating
1	**GENERAL**		
1.1	Type		IP PABX
1.2	Complying to ITU-T rec.		Yes
1.3	Analogue Trunk Connectivity		Yes
1.4	Digital Trunk Connectivity(E1/T1)		Yes
1.5	10/100 BaseT Ethernet Connection		Yes
1.6	No of Subscribers	Nos.	Up to 32
2	**Trunk Connectivity**		
2.1	Analogue Trunk		
2.1.1	- Loop Start/Ground Start(Via peripheral)		Yes
2.1.2	- E&M		Yes
2.1.3	- DID(Direct Inward Dial)		Yes
2.2	Digital Trunk		
2.2.1	- T1		Yes
2.2.2	- E1		Yes
2.2.3	- ISDN Connectivity using BRI/PRI		Yes
2.3	IP Trunk		
2.3.1	- 10/100 Mbps Ethernet(IEEE 802.3)		Yes
2.3.2	- TCP/IP, H.323, T.38(Switching)		Yes
2.3.3	- Voice Compressor : G.711, G729		Yes
2.3.4	- QoS(Quality of Signal) : 802.1		Yes
2.3.5	- SIP(Session Initiation Protocol): RFC 3261		Yes
3	**Main Features**		
3.1	Ring Back		Yes
3.2	Call Forwarding, park, waiting, pick-up		Yes
3.3	Call/Message waiting lamp		Yes
3.4	Hands Free operation		Yes

Sl. No.	Description	Unit	Rating
3.5	Speed Calling, Stored number redial		Yes
3.6	Account Code		Yes
3.7	Automatic Attendant, Auto Answer		Yes
3.8	Automatic Route Selection		Yes
3.9	Call-by-call Service, Call Duration Display		Yes
3.1	Call Transfer, Direct Outward Dialing		Yes
3.11	Hunt Group, Music on Hold		Yes
3.12	Night Service, Off-hook Alarm, Redial		Yes
4	**Network Management System**		
4.1	Type/Name of configuration tool		
4.2	For fault / configuration management		Yes / yes
4.3	For local / remote operation		Yes / yes
4.4	Data communication network (DCN)		Ethernet / IP or Ethernet / OSI
5	**Ambient Conditions:**		
5.1	Storage: ETS 300 019-1-1, class 1.2	°C / % hum	-25 .. + 55 / class 1.2
5.2	Transport: ETS 300 019-1-2, class 2.2	°C / % hum	-25 .. + 70 / class 2.2
5.3	Operation: ETS 300 019-1-3, class 3.1E	°C / % hum	-5 .. +45 / class 3.1E

15. Power Line Carrier, Teleprotection and Communication Equipment

15.1 Power Line Carrier Equipment

15.1.1 General

Power Line Carrier equipment shall be installed on the 400kV, 230kV and 132kV transmission networks associated with the project.

The carrier frequency range available is between 50 to 500 kHz.

Drawing shows the existing and planned arrangements of power line carrier system. All materials and equipment offered shall be brand new, from the manufacturer's normal and standard construction, designed and manufactured according the latest technological methods.

Existing power line carrier (PLC) and communication equipment which are of has been supplied by ABB, Switzerland. For the purpose of standardisation of operating performance and facilities offered equipment shall be compatible with the existing ones.

Equipment providing increased signalling capacity, based on digital techniques shall be offered satisfying the following requirements:

- the high frequency bandwidth requirements are no greater than the SSB type.
- the digital equipment will not affect analogue equipment in service on the same line.
- an applicable schedule of technical particulars and guarantees is prepared and included with the Bid.
- full details of in service installations are included.

Should equipment manufactured by a different supplier be proposed, Bidders are to verify that the equipment shall be fully compatible with existing system and equipment and provide evidence that the equipment has been successfully interfaced with the existing type and is in continuous commercial operation.

15.1.2 Carrier Frequency Allocation

The Contractor shall submit a comprehensive carrier frequency allocation plan which shall be subject to the approval of the Employer. Before approval however, the Contractor shall agree all carrier frequency plans and power output with the governing radio frequency licencing authority to ensure non-interference with Air Traffic Control, and Marine Navigation Beacons, etc.

15.1.3 Line Coupling

(a) General

The high voltage transmission system is a three phase 50Hz system solidly earthed with the following design parameter detailed elsewhere in this specification:

Nominal Voltage (kV)	400	230	132
Rated Max.Voltage (kV)	420	245	145
Symmetrical Short Circuit Current, 1 sec (kA)	63	50	40
Lightning Impulse Withstand Voltage (kVp)	1425	1050	650
Continuous Switchgear Rating (A)	4000	3150	2000

All current carrying equipment shall be capable of withstanding these conditions for a period of one second.

(b) Method of Coupling

Coupling of the carrier signals to the double circuit transmission lines shall be phase to phase by means of capacitor voltage transformers supplied under this contract.

The Contract shall include all line traps and mountings, coupling filters, conductor clamps, HF connections, matching transformers, HF cables and glands required to complete the HF installation at site.

(c) Line Traps

New line traps shall have at least the same continuous rating as the switchgear and shall be capable of withstanding the short circuit current for one second.

The preferred value of coil inductance is 1 millihenries although other values will be considered depending upon the Bidders frequency plan.

The line traps shall be broad band tuned by means of a tuning device, which shall preferably be arranged to permit interchange without removing the line trap. The ohmic resistance shall preferably be 600 ohms or greater.

The line trap shall have a protective device which utilises non-linear resistor type arrestors and the nominal discharge current shall be 10kA.

Bidders shall submit type test reports or be expected to demonstrate that their line traps satisfy the tests recommended in IEC publication 353 - Line Traps, with regard to temperature rise, short time current rating, protective discharge, and also the HF rejection bandwidth.

All line traps shall be provided with bird barriers and clearly visible rating plates which will include the following data:

i) Manufacturer's name
ii) Type
iii) Serial number
iv) Rated continuous current
v) Rated short time current with respect to time
vi) Rated coil inductance
vii) Total mass (kg)

whilst the tuning device shall be similarly marked detailing:

i) Manufacturers's name
ii) Type
iii) Serial number
iv) Frequency band(s) etc., in kilohertz
v) Rated protective level of the tuning device.

Line traps are to be mounted on capacitor voltage transformers, supplied under this Contract and Bidders shall detail the type of mounting and connecting plates available for the line conductor and busbar connections.

15.1.4 Capacitor Voltage Transformers

New capacitor voltage transformers (CVT) and lattice steel structures shall be provided suitable for mounting line traps on them.

The capacitor shall have a rated capacitance of not less than 6000pF at the working voltage, an impulse withstand voltage as specified and meet the insulation level and test voltage equivalents of IEC recommendation for each device (IEC Publication 358 - Coupling Capacitors and Capacitor dividers). Creepage distances will be 31 mm/kV (based on maximum phase to earth voltage).

Full technical details of the capacitor voltage transformers shall be provided in the Schedules of Guarantees and Technical Particulars.

15.1.5 HF Coupling Units

The high frequency coupling units shall be assembled in a sheet steel box or similar and be suitable for mounting on the pedestal support for the capacitor voltage transformer, or coupling capacitor. The filters are to be suitable for outdoor use in a hot dusty/humid climate and are to

have weatherproof door seals together with breather holes to avoid condensation. The units are to have an earthing switch which should preferably be interlocked with the box door/lid such that the latter cannot be opened unless the earth switch is closed to earth the device, and clear indication of the ON/OFF position of this switch should be indicated. The terminal of the filter which shall be connected directly to the substation earth shall be clearly designated.

The coupling device shall meet in full the safety and protection requirements of the IEC recommendation for such devices (IEC publication 481 - Coupling devices for power line carrier systems).

The tuning range of the coupling unit(s) shall be suitable for the HF carrier frequency allocations being provided on this Con-tract. Full details of the Bidder's proposals shall be submitted for approval by the Employer and appropriate Authority. The device shall be fitted with a rating plate clearly defining, but not limited to, the following data:

(a) Manufacturer's name
(b) Type
(c) Serial number
(d) Peak envelope power
(e) Available bandwidth or working range

Bidders shall be expected to demonstrate that their equipment complies with the following tests:

(a) Drain coil -measurement of impedance at power frequency

- current carrying capacity at power frequency 1 amp RMS continuous and 50 amps RMS for 0.2 seconds.

(b) Power frequency voltage tests on the isolation transformer of 5 kV RMS for one minute between each coil and earth, and between each coil and screen.
(c) Composite loss at several frequencies within the working range of the filter.
(d) Return loss at several frequencies within the working range of the filter.
(e) Impulse voltage test on each phase to phase filter, in accordance with Section 6 of IEC Publication 60.

The coupling filters detailed above shall be mounted on the CVT or CC pedestals, unless a waterproof housing is provided in the base of the coupling capacitor or CVT, at a height such that the external HV (primary) terminal on the coupling filter shall be at a minimum height of 2440mm above ground level.

Full technical details of the HF coupling units shall be provided in the Schedule of Technical Particulars.

15.1.6High Frequency Cable

Sufficient high frequency cable suitable to connect the coupling filters with the indoor PLC high frequency units shall be sup-plied. The cable shall preferably have a characteristic impedance of 75 ohms unbalanced or 150 ohms balanced depending upon the impedance of the coupling filters and the indoor equipment. The cable shall be PVC covered, steel wire armoured with a further outer sheath of PVC.

Bidders shall clearly show the make up of the cable, together with details of the cable mechanical and electrical characteristics.

Bidders shall also state the "short" time and continuous test voltages with which their cable complies.

15.1.7 Power Line Carrier High Frequency Unit

(a) **General**

The design and selection of equipment and components shall be based on achieving a minimum lifetime of 20 years when operating under the specified service conditions.

The design and performance requirements of the digital power line carrier equipment shall be equivalent or better than IEC 495.

The equipment to be provided shall be of the digital transmission signalling type, constructed on a modular basis with modules plugging into 19" (480 mm) shelves. The equipment shall be composed completely of solid state integrated circuits with a minimum of discrete components.

Equipment providing increased signalling capacity, based on digital techniques shall be offered satisfying the following requirements.

i) The high frequency bandwidth requirements are no greater than the SSB type
ii) The digital equipment will not affect analogue equipment in service on the same line.
iii) Full details of in service installations are included.

(b) **Information to be Submitted with the Bid**

The Bidder shall submit the following with the Bid:

i) a technical description, which shall include full details of the design, operation, construction, performance and maintenance aspects of the equipment.
ii) detail performance of the equipment .

iii) a proposed frequency plan.

(c) **Deleted**

(d) **Digital Carrier Terminal Equipment**

The equipment design shall be based on complete flexibility over the RF frequency spectrum and also in the selection of services to be transmitted. RF allocation shall be achieved with programmable synthesisers and easily tuned RF filters. The allocation of the frequency band and of the services to be transmitted shall be carried out by means of a laptop computer with suitable software installed, it shall be interactive so that programming/reprogramming can be readily carried out at the factory and also at site.

The combined bit stream (containing speech/data etc.) shall be suitably digitally modulated (e.g. QAM, or PSK etc.) and converted to the selected nominal carrier frequency band for transmission over the power line.

The nominal impedance at the carrier frequency output shall be 75 ohms (un-balanced) or 150 ohms (balanced). Provision shall be made for terminating the output in an appropriate dummy load. The return loss within the nominal carrier frequency band in the transit direction shall be not less than 10dB.

Bidders shall provide calculations to justify operation of the PLC over the transmission line(s). This shall include allowance for line length/construction, coupling losses, adverse weather and fail margin - to obtain a suitable mini-mum BER (typically 10-6).

There shall not be any limitations in parallelling the digital PLC with other similar digital PLC terminals on the same transmission line, or with analogue PLC equipment. Bidders shall show clearly the methods of transmission used, and identify the necessary RF frequency spacing between PLC equipment, also any interface equipment needed. The switching off/on of a PLC terminal connected with any other PLC terminals in parallel, shall not cause any interference with other still working PLC.

(e) **Telephone Channels**

To implement speech channels into the data stream the speech shall be sampled. Together with the associated signalling and error coding a bit rate derived from a basic sampling rate of 8 kbit/s shall be typically provided. The interface of each speech channel shall cover the required application and provide for both 4-wire and 2-wire termination. The telephone channel shall be suitable for 4-wire working at transit stations as determined by the requirements of the telephone scheme. Circuits terminating at a station shall be suitable for connection to a two-wire telephone exchange, 2/4 wire switching shall therefore, be available as a standard facility.

Bidders shall state the method of telephone signalling.

Bidders shall state the relative 4-wire levels used for speech transmission and reception.

All speech and VT signal input and output circuits shall be balanced and have a nominal impedance of 600 ohms.

The return loss within the effectively transmitted frequency band shall be not less than 17 dB.

The interface of the speech channel shall include for inter PAX tie lines and "Long line" telephones. The speech channel interface shall manage the following types of interface:

i) E&M
ii) MFC
iii) DTMF
iv) Decadic
v) Data Transmission

Data channels shall be time multiplexed into the output bit stream. The interface for the data channels shall be RS 232 (V.24/V.28). The data channels shall be configured as any combination of synchronous or asynchronous channels.

Bidders shall state the capacity/number of data channels which can be equipped on a link.

Where an audio data channel interface is required to/from and FSK modem, a suitable 600 ohm FSK interface shall be provided. The centre frequency, shift frequencies, and modem levels which shall be managed shall be configurable.

(f) **Receivers**

To provide for level stability on the audio services, the receiver dynamic range shall be approximately 30 dB. Where PLC is required to signal over long transmission lines, proposals for maintaining adequate output capacity and suitable level stability on the audio services shall be included.

An alarm shall be raised in the event of the BER becoming degraded.

(g) **Service Telephone**

A service telephone shall be provided for the PLC terminal. The handset shall be located in the terminal cubicle. A means of telephone calling the equivalent telephone at the remote end of the link shall be included.

(h) **Service Conditions**

The noise generated within the terminals and the cross talk attenuation between speech and VF signalling channels shall comply with IEC recommendation 495.

The level of spurious emission shall be clearly stated in the schedules, together with the frequency response of the speech channel referred to 800Hz and the VFT signalling channels referred to 3.0 kHz.

The equipment shall operate to its stated performance with a variation in power supply voltage of +20% and -15% of the nominal value.

(i) **Voltage Withstand Requirements**

The equipment shall be designed to withstand satisfactorily the insulation tests defined in Section 7 of IEC recommendation 495.

The equipment shall not be subjected to interference by the presence of electrical noise generated by disconnector switching operations. The bandwidth of such noise extends from 10 kHz to 1 MHz and can peak to 1200 volts at the coaxial termination. Limiting diodes of the avalanche type should be provided at the HF cubicle terminals in order to limit this voltage to 400 volts peak to peak.

(j) **Test and Alarm Facilities**

Clearly designated test points shall be provided on modules where adjustments are required or reference points are applicable. However, Bidders may offer alternative methods e.g. a hand held maintenance unit or laptop computer with appropriate software.

Supervisory facilities shall be provided for monitoring the HF output amplifier current, the BER and the cubicle supply voltage etc.

Alarm lamps or LEDs on the terminal shall as a minimum requirement show alarms for ‘receiver fail’, ‘transmitter fail’ and receive low BER. Bidders shall provide details of all alarms available on their equipment. An alarm lamp shall be provided on the cubicle, visible with the cubicle door closed.
In addition to the local annunciation on the PLC terminal, each alarm shall be provided with two sets of potential free contacts, for connection to external alarm monitoring systems.

15.2 Teleprotection Equipment

The protection of the overhead lines shall be arranged as detailed in Section 5. Theteleprotection equipment shall be provided for permissive tripping and direct tripping on the lines.

The permissive tripping signals are required to operate circuit breaker trip relays in conjunction with the distance protection and directional earth fault relays.

The direct tripping signals are required to operate remote circuit breaker tripping relays and hence shall have inherent security against maloperation due to noise present in the bearer channel.

The Bid shall include a technical description of the equipment, which shall include a description of the design, operation, construction, performance and maintenance aspects of the equipment.

15.2.1 Technical Requirements

The teleprotection equipment shall be of modular construction and will preferably be mounted in the power line carrier units and work satisfactorily under the service conditions specified.

Manufacturers shall clearly state the precautions taken in the design of their receiver to safeguard the output against the presence of noise in the channel, and show the difference between their range of equipments used for "direct" and "permissive" signalling.

In the case of the "direct" tripping equipment it shall not be possible to cause a trip output under any of the following conditions:

(a) Removal or reinsertion of any printed circuit module in either transmitter or receiver of a link, including the PLC equipment.
(b) Switching on/off of the power supply to the teleprotection equipment.
(c) Switching on/off of the power line carrier equipment at either end of the 400 kV line.
(d) Shorting of the output of the teleprotection transmitter or shorting of the input to the teleprotection receive.
(e) Operation of disconnectors in the high voltage switchgear.
(f) When the level of the input signal to the receiver is below the receiver fail alarm threshold.

15.2.2 Signalling Conditions

Bidders shall state the precautions taken in the design of the receiver to safeguard the output against the presence of noise in the communications media. Under no circumstances shall a direct trip signal output occur due to:

(a) an equipment fault
(b) removal/restoration of power to the teleprotection or communications equipment
(c) shorting of the teleprotection transmitter/receiver
(d) operation of primary switchgear plant
(e) removal of reinsertion of any PCB in a teleprotection or communications media terminal.

Teleprotection signal outputs shall be inhibited when the level of the input signal to the receiver is below the fail alarm threshold.

Bidders shall provide the following performance graphs:

- Transmission time: SNR versus operate time.
- Security: SNR versus probability of an unwanted command output.
- Dependability: SNR versus probability of failure of an output command.

15.2.3 Signal Transmission Times

The transmission times required from receipt of an input to the provision of a command output at the remote location, shall be less than
(a) 20 milliseconds for permissive tripping
(b) 40 milliseconds for direct tripping

Equipment capable of transmitting more than a single teleprotection signal is only acceptable provided the specified transmission times are met under all circumstances, including when more than one/all signal inputs are initiated simultaneously or part way through a code transmission.

Equipment used for direct tripping shall have the facility to hold on the output signal, so as to be suitable for applications with circuit breaker automatic reclose schemes, to prevent the remote circuit breaker reclosing until the faulted plant is disconnected from the HV system as detailed in a separate section of this Specification.

Direct tripping and permissive signals shall have a trip extension facility. The extension time shall be selectable, typically 200ms.
Bidders shall advise the minimum input pulse length (and the corresponding output), that is required to provide a guaranteed output. Also any limitation on the maximum output pulse length.

15.2.4 Interface

Data and control interfaces shall comply with CCITT RS232 and V24/V28 recommendations.

For digital communications media the interfaces shall comply with X21.

The transmitter signal command shall be initiated by means of the protection equipment switching both poles of the station dc supply to the teleprotection input.

The receiver command output shall be a semiconductor or relay arrangement providing two sets of “contacts”, with the “contacts” normally open (“contacts” shall be closed for a command output). These command output contacts shall be used for switching both poles of the station D.C. supply to the protection equipment.

The receiver shall also provide two sets of potential free command output auxiliary contacts, for connection to external alarm monitoring systems.

The rating of the above “contacts” shall be to the plant requirements.

The insulation requirements of the protection interface shall be 2 kV rms for one minute (IEC recommendation 255).

Individual counters shall be provided to show the number of teleprotection input and ouput commands which have been executed.

15.2.5 Service Conditions

The equipment shall operate to its stated performance with a variation in power supply voltage of +20% and -15% of the nominal value.

The equipment shall incorporate measures to ensure that signals are received and executed in the presence of noise on the communications channel. In the case of coded messages for example, transmission of a single “trip” code is a non-preferred arrangement.

15.2.6 Voltage Withstand Requirements

Voice frequency, signalling and alarm circuits, when free from earth, shall be capable of withstanding without damage a voltage of 500 V D.C. applied for one minute between the terminals of the circuit connected together and earth.
The equipment shall not be subject to interference by the presence of electrical noise generated by disconnector switching operations. The bandwidth of such noise extends from 10 kHz to 1 MHz.

15.2.7 Test and Alarm Facilities

Clearly designated test points shall be provided on modules where adjustments are required or reference points are applicable. Supervisory facilities shall be provided for monitoring the teleprotection input and output at the interface to the communications media.

The alarm output shall be maintained for a minimum period of 100ms, and the operational output shall not be possible until the alarm output condition is removed.

A separate low level (or BER) shall be given, but not prevent operation, when the input signal level drops by typically 6dB from normal. Bidders shall detail the alarm facilities which are available from their equipment and state the level or BER at which the receiver will cease to function.

Alarm lamps or LEDs shall be provided on the equipment, together with two sets of potential free contacts, for connection to external alarm monitoring systems. A cubicle alarm lamp shall also be provided, visible with the cubicle door closed.

15.2.8 Housing

Terminal equipment shall be constructed on a modular basis, accommodated in a 19" or ETSI standard rack configuration, mounted in a cubicle. Equipment required to operate over PLC shall be mounted in the PLC equipment rack.

15.3 Operational Telephone System

A new PAX operational telephone system and equipment (suitable for at least 50 percent spare capacity of the required trunk interfaces and 30 subscriber interfaces) shall be provided and installed at Rampura substation and shall interconnect with the existing network. Bidders shall be deemed to have investigated the existing system.

The trunk numbering plan shall be compatible with the present scheme in service in Bangladesh. The telephone signalling (dialling) system shall be compatible with the present system.

An alarm system shall be provided to indicate traffic failure including blown fuses, loss of power supplies etc. In addition, contacts shall be provided to facilitate extension of the alarms to the telecontrol equipment.

APPENDIX

Appendix Power Line Carrier, Teleprotection and Communication Equipment

A. 400 kV Wave Trap

SL. No.	ITEM	SPECIFICATION
1	Type of Line Trap Installation	To be inserted into high voltage A.C transmission line phase in series
2	Type of mounting	Pedestal
3	Suitable for system Frequency	50Hz
4	Nominal System Voltage	400 kV
5	Highest System Voltage	420 kV
6	Rated Continuous Current	4000 A
7	Rated Short time current for 1 second	63kA
8	Asymmetrical peak value of the First half wave of the rates short Time current	160/125kA
9	Rated inductance	1.0 mH
10	Type of Tuning	Band tuned line trap
11	Blocking Band frequency range	Band-I: 56 to 124 kHz Band-II: 76 to 500 kHz
12	Minimum Guaranteed resistive Component of impedance in Blocking Frequency Rang	500 Ohm
13	Protective device	a) Non-linear resistive type Gapped lightning arresters for A.C system. b) Polymer housed Metal oxide surge arrester without Gaps for A.C system.
14	Nominal discharge current of protective device	10 kA However, Coordination shall be done by taking 20kA, 8/20 micro-sec discharge into consideration.
15	Rated voltage of protective device	>15.72 kV rms
16	Minimum value of power frequency spark over voltage (Dry & wet) of protective device	>23.58 kV rms
17	Visual Corona Extinction Volt	320 kV rms
18	Radio influence Voltage (RIV)	<500 micro Volt@280 kV
19	Attention in tuned frequency band	<7.5 dB

SL. No.	ITEM	SPECIFICATION
20	Maximum tapping loss over blocking Band I & II stated above	2.6 dB
21	Insulation class	Class F Insulation
22	Maximum working stress	Twice the weight of wave trap+500 kgs.

16. Quality Assurance, Inspection, Testing, Commissioning and Warranty

16.1 Scope of Section

The whole of the plant covered by this Contract will be subject to inspection and witnessing the tests by the Employer during manufacture, erection and on completion. The inspection and witnessing the tests at Manufacturer's works may be done by the Employer or an Independent Inspection agency.

The approval of the Employer/Engineer or the passing of any such inspection or test will not, however, prejudice the right of the Employer to reject the plant if it does not comply with the specification when erected or when in service.

The Employer/Engineer or their designated representatives are entitled to attend the **factory acceptance tests**, which shall be performed at the Manufacturer's works/testing laboratories. The con-tractor is advised to go through a schedule of volume 1 for the detail requirement of FAT.

The Contractor shall be responsible for bearing all costs for the mentioned training. All costs are deemed to be included in the contract price.

For notification of testing, four weeks shall be deemed as reasonable advance notice.

Within 45 days of the letter of acceptance for the contract, the contractor shall submit a quality assurance programme and a work quality programme for the Engineer's approval.

The Contractor shall have an approved quality management system.

After the award of Contract, the Engineer shall have the right to carry out a review of the quality assurance procedures operated by the Contractor. The Engineer's review may consider quality assurance in relation to the design and manufacture of plant items, but may equally investigate the Contractor's quality assurance procedures for the overall control of the wide range of design activities necessary for a complex project of this type, and the dissemination of paperwork, design drawings, and data amongst the various design and manufacturing organisations within the Contract. The Contractor shall give all necessary help and assistance to the Engineer in carrying out such a quality assurance review. The Contractor shall consider and discuss the results of the review and make any reasonable improvements in his procedures.

Before any plant is packed or dispatched from the Main or Sub- Contractors' works, all tests called for shall have been successfully carried out in the presence of the Engineer unless otherwise agreed.

30 days' notice shall be given when the plant is ready for inspection or tests and every facility shall be provided by the Contractor and his Subcontractors to enable the Engineer and Employer to carry out the necessary inspection and witnessing of tests.

In the cases where tests or inspection are specified as being carried out on only a sample of the total quantity of items in the Works, and where one or more items of the sample fail the test or inspection, a further batch of the items, at least equal in quantity to the proportion originally specified, shall be tested or inspected. This process shall continue until a sample proves completely acceptable.

16.2 Subcontracts

Within two months of acceptance of the Bid and in order to facilitate the inspection of bought-out materials and plant, the Contractor shall submit to the Engineer for approval three copies of all sub-orders placed by him as soon as they are issued. One copy of any drawing or schedule referred to in the sub-order shall be submitted simultaneously unless agreed otherwise with the Engineer. Any reference to the price may be deleted from the copies so submitted.

The sub-orders and drawings submitted to the Engineer shall cover all components which are subject to electrical and mechanical pressure or stress when the plant is in operation and also auxiliaries and spares which are to be dispatched to Site direct from the Subcontractor's factory.

Sub-orders are to include a statement advising the Subcontractor that the items being ordered will be subject to inspection and test by the Engineer and Employer.

The Contractor shall advise his Subcontractors of all the pertinent clauses in the Specification when ordering bought out plant, equipment or materials.

Every sub-order or subcontract shall contain the following information:

- Main Contractor's name and sub-order or sub-contract number.
- Quantities and description of work.
- Delivery requirements.
- Delivery consignment instructions.
- Details of the Employer and/or main Contractor's applicable drawing or schedule numbers.
- Name of the Engineer.
- A note advising that the plant or equipment which is the subject of the order shall comply in every respect with the Engineer's, Specification and shall be subject to inspection by the Engineer, Employer and the Contractor.
- A reference, particularised in the accompanying Specification, covering the following information:
  - Employer's name

- Project title
- Contract No.
- Engineer's reference number

Subcontractors shall comply with all the applicable requirements of this Specification and the onus is upon the Contractor to ensure that Subcontractors comply with these requirements.

For the purposes of this clause, inter works orders shall be treated as sub-orders.

16.3 Guarantees

The Contractor shall state and guarantee the technical particulars listed in the Technical Schedules and other sections as specified by the Contract for testing procedures. These guarantees and particulars shall be binding and shall not be departed from without the written permission of the Engineer.

The Contractor shall further guarantee that all equipment supplied complies with the Contract Documents.

The tolerances permitted in the IEC and British Standards shall apply unless otherwise stated.

16.4 Quality Audit

The quality programme established by the Contractor shall be followed for all inspection and testing procedures.

The Engineer and Employer may, from time to time, visit the Manufacturer to carry out a quality audit of the Manufacturer's organisation.

16.5 Measuring and Testing Equipment

At prescribed intervals, or prior to each use, all measuring and testing equipment used in inspection shall be calibrated and adjusted against certified equipment having a known valid relationship to inter-nationally recognized standards.

The Manufacturer shall prepare a calibration schedule showing equipment type, identification number, location, frequency of checks, method of checking and action to take when results are unsatisfactory.

16.6 Design Review

16.6.1 Design review for power Transformer

(a) The transformer shall be designed, manufactured and tested in accordance with the best international engineering practices under strict quality control to meet the requirement stipulated in the technical specification. The manufacturer will be required to demonstrate the adequate safety margin w.r.t thermal, mechanical, dielectric and electrical stress, etc. shall be maintained during design, selection of raw material, manufacturing process, etc. in order to achieve long life of transformer with least maintenance and to take into account the uncertainties of his design and manufacturing processes. The scope of such design review shall include but not limited to the requirement of the as mentioned at chapter 3 of this volume.

(b) Design reviews shall be conducted by Purchaser or an appointed consultant during the procurement process for transformers; however, the entire responsibility of design shall be with the manufacturer. Purchaser may also visit the manufacturer's works to inspect design, manufacturing and test facilities at any time.

The design review will commence after placement of award and shall be finalized before the commencement of manufacturing activity. These design reviews shall be carried out in detail to the specific design with reference of the transformer under the scope. It shall be conducted generally following the "Guidelines for conducting design reviews for transformers - Guide-lines for conducting design reviews for power transformers.

(c) The manufacturer shall provide all necessary information and calculations to demonstrate that the transformer meets the requirements for short circuit strength and durability. The latest recommendations of IEC and CIGRE SC 12 shall be applied for short circuit withstand evaluation.

(d) The design review shall be carried out preferably at the employer's country.

16.6.2 Design Review Document for power transformer

SL	Description
1.	Core and Magnetic Design
2.	Over-fluxing characteristics up to 1.7Um
3.	Inrush-current characteristics while charging from HV & IV respectively.
4.	Winding and tapping design

5.	Short-circuit withstand capability including thermal stress for min. 2 Sec.
6.	Thermal design including review of localized potentially hot area.
7.	Cooling design
8.	Overload capability
9.	Eddy current losses
10.	Seismic design, as applicable
11.	Insulation co-ordination
12.	Tank and accessories
13.	Bushings
14.	Tap changers
15.	Protective devices
16.	Fans, pumps, and radiators
17.	Sensors and protective devices– its location, fitment, securing and level of redundancy
23.	Testing capabilities
24.	Inspection and test plan
25.	Transport and storage
26.	The sensitivity of the design to specified parameters
27.	Acoustic Noise
28.	Spares, inter-changeability and standardization
29.	Maintainability
30.	PRD and SPR (number & locations)
31.	Conservator capacity calculation
32.	Winding Clamping arrangement details with provisions for taking it “in or out of tank”
33.	Conductor insulation paper details
34.	Location of Optical temperature sensors
35.	The design of all current connections
36.	Location & size of the Valves

Detailed Data to be provided for Design review shall be provided during execution stage.

16.6.3 Design review for GIS

(a) Design reviews shall be conducted by Employer; however, the entire responsibility of design shall be with the supplier.

(b) Employer may also visit the supplier's works to inspect design, manufacturing and test facilities.

(c) The design review will commence after placement of award with the successful contractor and shall be finalized before the commencement of manufacturing activity. These design reviews shall be carried out in detail to the specific design with reference of the GIS under the scope of this specification. Employers reserve the right to waive off the design review during detailed engineering.

(d) The design review shall be conducted generally following the "User Guide for the application of Gas Insulator Switchgear (GIS) rated voltage of 72.5kV and above" – CIGRE report No. 125 prepared by CIGRE Working Group 23.10.

(e) The manufacturer will be required to demonstrate the use of adequate safety margins for thermal, mechanical, dielectric, insulation coordination and vibration, etc. design to take into account the uncertainties of his design and manufacturing processes.

(f) The scope of such a design review shall at least include the following:

SL	Description
1.	Dielectric Stress of Solid Insulation like Gas Barrier, support insulator etc.
2.	Dielectric stress of SF6 Gas Volume.
3.	Mechanical strength of enclosure, expansion joints, etc.
4.	Criteria for providing expansion joint.
5.	Sealing system
6.	Insulation coordination
7.	Thermal stress and a resulting increase in gas pressure during short circuit condition.
8.	Earthing of enclosure w.r.t circulating current.
9.	Seismic design, as per IEC 62271-207
10.	Circuit Breaker.
11.	Isolator and Earth switch.
12.	Voltage transformer.
13.	Current Transformer.
14.	Surge Arrester.
15.	Bushing.
16.	Ducting.
17.	Corrosion protection.
18.	Electrical and physical Interfaces with the substation.

SL	Description
19.	Testing capabilities.
20.	Inspection and test plan.
21.	Transport and storage.
22.	Maintainability.
23.	Site Test.

(g) Further, the manufacturer shall furnish the following information during detailed engineering:

- The study report of VFTO generated for GIS installation for 400 kV and above.
- The calculation for the adequacy of UHF sensors to be provided in GIS Installation as per clause no 5.41.
- The calculations and documents in support of the average intensity of the electromagnetic field on the surface of the enclosure.
- Calculations to show that there is no Ferro resonance due to the capacitance of GIS for the voltage transformers.
- Calculations in support of touch & step voltages in all enclosures and earthing of complete GIS installation.
- Measures to mitigate transient enclosure voltage by high-frequency currents.
- The acceptance criteria and limits of impact (of impact recorder) in all three directions which can be withstood by the equipment during transportation and handling.

(h) The design review shall be carried out preferably at employer's country.

16.7 Inspection Plan and Procedure

The Inspection Plan, as submitted by the Contractor to the Engineer for approval, shall cover the following:

- Relevant International Standard. For each of the following stages of the work, the acceptance criteria shall be stated.
- The stages of inspection which shall include but not be limited to the following:

  - Tests to review or approve certification of material;
  - Review and approval of manufacturing procedures;
  - Witnessing tests or review and approval of certification of the operator's qualification to carry out the work required;
  - Visual and dimensional examination of components;
  - Pressure tests on casings and vessels;

- Non-destructive examination of materials in progress;
- Functional tests on sub-assemblies, performance tests, type tests on complete units;
- Examination of painting, packing and documentation for shipment.

The Engineer will indicate the inspection requirements on the agreed inspection programme in accordance with the following.

Hold point - Requires a mandatory inspection by the Engineer. This inspection or test shall be witnessed by the Engineer and Employer and further progress in manufacture shall not be made until the plant is approved by the Engineer.

Witness point - Inspection or test of material may be carried out by the Engineer and Employer at their discretion.

Document review - Certification of material and functional test shall be approved by the Engineer before dispatch from the works.

16.8 Test Certificates

Triplicate sets of all test records, test certificates and performance curves, whether or not they have been witnessed by the Engineer and Employer, shall be supplied to the Engineer for all tests carried out in accordance with the provisions of this Contract.

Sets of all test certificates shall be endorsed with sufficient information to identify the material or equipment to which the certificates refer, and shall carry in the top right-hand comer the following reference:

- Employer's name
- Project title
- Contract No.
- Engineer's reference number

All test documentation shall be in the English language.

16.9 Material Tests

The Contractor shall provide test pieces as required by the Engineer to enable him to confirm the quality of the material supplied under the Contract. Such test pieces shall be prepared and supplied free of charge and any cost of the tests shall be borne by the Contractor.
If any test piece fails to comply with the requirements of the appropriate specifications for the material in question, the Engineer may reject the whole of the material represented by that test

piece; the Contractor's or Subcontractor's designers and metallurgists will be consulted before any material is so rejected.

If the Engineer is furnished with certified particulars of tests which have been carried out for the Contractor by the suppliers of material, he may, at his own discretion, dispense with the previously mentioned tests.

16.10 General Requirements for Tests at Manufacturers' Works

16.10.1 Testing of Plant

Tests at Manufacturers' works shall include mechanical, electrical and hydraulic tests to ensure that the plant being supplied complies with the requirements of the Specification.

Works tests shall include all routine electrical, mechanical and hydraulic tests in accordance with the relevant IEC or British Standards, except where departures therefrom and modifications thereto are embodied in this Specification.

Should the plant or any portion thereof fail under test to give the required performance, further tests that are considered necessary by the Engineer shall be carried out by the Contractor and the whole cost of the repeated tests borne by the Contractor. This also applies to tests carried out at the Subcontractors' works.

The Employer or its representative or independent inspection agency may witness the tests. Sufficient notice (minimum of 30 working days) shall be given to enable the necessary arrangements to be made.

If the plant, or any portion thereof, fails under test to give the required performance, such further tests which are considered necessary by the Engineer shall be carried out by the Contractor and the whole cost of the repeated tests shall be borne by the Contractor. This also applies to tests carried out at Subcontractors' works.

Tests shall be conducted in accordance with the specified standards. When no standards are specified, the test procedure shall be agreed between the Employer and the Contractor.

Specific details of tests to be carried out at the Manufacturers' works are defined elsewhere in this Specification.

16.10.2 Rejection of Plant

If any item fails to comply with the requirements of this Specification in any respect whatsoever at any stage of manufacture, test, erection or on completion at Site, the Engineer may reject the item, or defective component thereof, whichever he considers necessary, and after adjustment or modification, as directed by the Engineer, the Contractor shall submit the item for further inspection and/or test.

In the event of a defect on any item being of such a nature that the requirements of this Specification cannot be fulfilled by adjustment or modification, such item is to be replaced by the Contractor, at his own expense, to the entire satisfaction of the Employer.

16.11 Specific Requirements for Tests at Manufacturers' Factories

16.11.1 Pressure Vessels

(a) All pressure vessels shall be designed, fabricated, inspected and tested in accordance with an approved pressure vessel code or standard.
(b) An approved method of radiographic or other non-destructive testing shall be used for proving all welding, at all positions of possible high-stress concentration, such as large branch welds, and their vicinities after all heat treatment are completed. This shall be done whatever the programme of non-destructive testing before heat treatment.
(c) Hydrostatic test shall be conducted in accordance with BS 5500.

16.11.2 Substation Automation System, Control, Relay Protection and Metering

All equipment for substation automation system, control, relay protection and metering shall be fully assembled at the Manufacturer's works and subject to the complete routine and functional tests.

For **factory acceptance test** all equipment for substation automation system, control, relay protection and metering, for each substation, shall be fully assembled at the Manufacturer's works and subjected to visual and functional tests.

All control and relays and associated equipment shall be routinely tested to prove the quality and accuracy. Routine tests shall be in accordance with relevant IEC Recommendations supplemented by additional tests as are considered necessary by the Employer. Routine test reports shall be submitted for each relay and piece of equipment. The reports shall record all measurements taken during the tests.

All relays shall be subjected to the appropriate routine tests as listed below, the individual tests being as detailed in IEC 60255 or as otherwise agreed with the Employer.

- Accuracy of calibrated pick-up and drop-off levels over the effective range of settings
- Insulation tests
- Accuracy of timing elements
- Correct operation of a flag (or other) indicators
- Mechanical requirements, integrity/safety of draw-out units, check of contact pressure and alignment.

16.11.2.1 Wiring

All circuits shall be subjected to the high voltage test specified in the relevant IEC or approved standard. The insulation resistance of all circuits shall be measured before and after any high voltage tests. For AC secondary injection tests a substantially sinusoidal test supply shall be used.

The operating and resetting level (current and/or voltage) and timing of all relays shall be measured over an agreed range of settings for all relays.

For directional relays phase-shifting transformers shall be used to determine the maximum torque angle and the boundaries of operation/restraint.

Other relays shall be fully tested in accordance with the Manufacturer's recommendations.

All DC elements of protection relays shall be tested for operation at 70% rated voltage.

All DC supplies shall be checked for the severity of current inrush when energised by switching on or inserting fuses or links.

16.11.2.2Mechanical Inspection

All panel equipment is to be examined to ensure that it is in proper working condition and correctly adjusted, correctly labeled and that cases, covers, glass and gaskets are in good order and properly fitting.

16.11.2.3General

Sufficient tests shall be performed on the relays and protection schemes to:

- establish that the correct equipment has been supplied and installed.
- confirm that the various items of equipment have been correctly interconnected.
- confirm performance of schemes designed on the bases of calculation e.g. differential protection.
- to provide a set of figures for comparison with future maintenance values allowing the condition of the equipment to be determined.

16.11.2.4 Secondary Injection

Secondary injection shall be carried out on all AC relays, using voltage and current of a sinusoidal waveform and rated power frequency to confirm satisfactory operation and range adjustment.

The polar characteristic of all distance protections shall be recorded at a minimum of 30-degree intervals.

For circulating current protection employing high impedance voltage-operated relays, the points of injection for relay voltage setting tests shall be across the relay and stabilizing resistance.

The fault setting for the type of protection is to be established by secondary injection, where it is impracticable to ascertain this value by primary injection. The injection is to be made across the appropriate relay bus wires with all associated relays, setting resistors, and CT's connected.

16.11.2.5 Primary Injection

All currently operated relays shall be tested by injection of primary current to record the actual relay setting and as final proof of the integrity of all secondary connections.

The stability of all differential schemes shall be checked by the injection of the primary current.

Primary current injection tests are to be carried out by the Contractor and the methods employed for a particular installation are to be agreed with the Engineer.

Tests are to be carried out as follows:

- Local primary injection to establish the ratio and polarity of current transformers as a group care being taken to prove the identity of current transformers of a similar ratio.
- Overall primary injection to prove correct interconnection between current transformer groups and associated relays.
- Fault setting tests, where possible, to establish the value of current necessary to produce the operation of the relays.

16.11.2.6 DC Operations

Tests are to be carried out to prove the correctness of all DC polarities, the operating levels of DC relays and the correct functioning of DC relay schemes, selection and control switching, indications and alarms. The correct functioning of all isolation links and fuses shall also be checked.

16.11.2.7 Tests on Load

Tests on load shall also be done to demonstrate the stability and operation of protection relays as required by the Engineer.

All tripping, control, alarm and interlocking circuits shall be functionally tested to prove satisfactory and fool-proof operation and/or resetting. The functional and safety aspects of all shorting and/or isolation links, fuses and switches devices shall be proved.

The total burdens connected to all voltage transformer circuits shall be measured and recorded.

The total capacitance of all wiring and apparatus connected to the negative pole of each main tripping battery shall be measured and recorded; the value shall not exceed 10 microfarads.

The continuous current drain of all trip circuit supervision relays shall be measured and shall not be greater than half the minimum current required for tripping. The supervision current shall be measured with the circuit breaker (or other devices) both open and closed.

16.11.3 Relays

All relays and associated equipment shall be routinely tested to prove quality and accuracy. Routine tests shall be in accordance with relevant IEC Recommendations supplemented by additional tests as are considered necessary by the Employer. Routine test reports shall be submitted for each relay and piece of equipment. The reports shall record all measurements taken during the tests.

All relays shall be subjected to the appropriate routine tests as listed below, the individual tests being as detailed in IEC 60255 or as otherwise agreed with the Employer.

- Accuracy of calibrated pick-up and drop-off levels over the effective range of settings
- Insulation tests
- Accuracy of timing elements
- Correct operation of a flag (or other) indicators
- Mechanical requirements, integrity/safety of draw-out units, check of contact pressure and alignment.

16.11.4 Electrical Instruments and Meters

One instrument and meter of each type and rating shall be subjected to the tests as specified in IEC 60051.

16.11.5 AC Switchboards

Routine tests shall include general inspection and electrical operation tests.

16.11.6 Contactors

One contactor of each type and rating shall be subjected to type tests as specified in IEC 60292-1.

16.11.7 PVC Cable

Each size and rating of PVC cable shall be subjected to type tests as specified in BS 6346. Routine tests are detailed in Section 5 of this document.

16.11.8 Switchgear (Other than GIS)

All circuit breakers shall be fully assembled at the Manufacturer's works and subjected to routine tests according to the IEC 62271-100.

For **factory acceptance test** one or at least 20% of the circuit breakers of each type, shall be fully assembled at the Manufacturer's works and subjected to routine tests according to the IEC 62271-100.

16.11.9 Disconnectors and Earth Switches

All disconnectors and earthing switches shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 62271-102.

16.11.10 Current and Voltage Transformers

All current transformers and voltage transformers shall be fully assembled at the Manufacturer's works and subjected to routine tests according to the IEC 60044.

16.11.11 Structures of Electrical Equipment

Sample tests on the assembly and galvanizing of the structures shall be carried out. A mechanical type test with the structure loaded with working load multiplied by the appropriate factor of safety shall be carried out.

16.11.12 Surge Arresters

All surge arresters shall be fully assembled at the Manufacturer's works and subjected to routine tests according to the IEC 60099-4.
For **factory acceptance test,** three or at least 20 % of the surge arresters of each type, shall be fully assembled at the Manufacturer's works and subjected to routine tests according to the IEC 60044.

16.11.13 Batteries and Battery Chargers

- Battery: The Contractor shall demonstrate that the battery will perform the duties specified.
- Battery charger: Routine tests according to IEC 60146 (BS 4417), 62040, 61000
- DC Switchboard: Routine tests according to IEC 60439 (BS 5486:Part 1)

Complete charge and discharge tests on each of the combined batteries and chargers shall be conducted and results recorded so as to permit verification of the ampere-hour capacity of the battery.

During these tests, the Engineer shall select at random reference cells and the voltage curves thereof shall be checked when the battery is discharged over three and ten-hour periods. The alarm levels and the automatic voltage control feature of the charger shall be demonstrated over the specified load range. Where load changeover facilities are included, the integrity of the changeover system without a break or volt-age variations during loading of the standby or test charger shall be demonstrated.

For **factory acceptance test,** two or at least 20 % of the battery & charger, shall be fully assembled at the Manufacturer's works and subjected to routine tests according to the IEC 60044.

16.11.14 Control Panels

Routine operation tests and insulation resistance tests shall be carried out.

16.11.15 Busbars

Routine tests including millivolt drop tests shall be carried out in accordance with the specified standard.

16.11.16 Instruments

Calibration tests shall be witnessed on all-important pressure gauges and other instruments as required by the Engineer.

16.11.17 Neutral Earthing Resistor (if needed)

Routine leakage and over-voltage tests.

Bushing insulator wet flashover tests (internal and external).

16.11.18 Power Transformers

Inspection and testing during manufacture shall be in accordance with the General Conditions of Contract and this section of the Specification.

Works tests shall include all routine electrical, mechanical and hydraulic tests in accordance with the relevant IEC Standard, except where departures therefrom and modifications thereto are embodied in this Specification. For Plant not covered by any IEC Standard or specifically mentioned in this Specification, such tests as are relevant shall be agreed with the Engineer.

Should the Plant, or any portion thereof, fail under test to give the required performance, further tests which are considered necessary by the Engineer shall be carried out by the Contractor and the whole costs of the repeated tests borne by the Contractor. This also applies to tests carried out at the Subcontractors' works.

After satisfactory completion of the witnessed tests at the Works, the Plant shall be submitted for the Employer's approval during dismantling preparatory to shipment. No item of Plant is to be dispatched to Site until the Employer has given his approval in writing.

All power transformers shall be fully assembled at the Manufacturer's works and subjected to routine tests and special tests.

For **factory acceptance test,** all power transformers shall be fully assembled at the Manufacturer's works and subjected to repetition of the all routine tests and special tests.

16.11.18.1 Main Transformers

Routine Tests

All transformers shall be subject to the following routine tests in accordance with IEC 60076 and the requirements of this Specification.

Following minimum test shall be performed as Routine test-

- Measurement of winding resistance on all tap positions and phases.
- Ratio, polarity and phase relationship.
- Impedance voltage.
- Load loss at normal, maximum and minimum taps.
- No-load loss and no-load current at normal voltage Un and at +5% Un and at +10% Un.

- Magnetizing current at nominal voltage Un and at -5% Un and +5% Un and at +10% Un.
- Insulation resistance.
- Dielectric withstand tests: It shall be performed as per the latest IEC standard 60076-3.
- All other tests as per the section 04 of this specification
- For detailed test procedure, please refer to section 04 of this specification

Type Tests

- Temperature rise test:
  As per section 04 of this specification

- Noise level tests:
  As per section 04 of this specification

Special Tests

- Measurement of Zero Phase - Sequence Impedance

  The test shall be in accordance with IEC 60076-1 Clause 11.6 and shall be carried out on one transformer of each type.

- All other tests as per section 04 of this specification

16.11.18.2 Voltage Control Equipment

Routine Tests

Each finished tap changer shall be subjected to the routine tests specified in JEC.214 but in addition, the mechanical test shall be carried out at rated voltage and no load.

Type Tests

Shall be carried out entirely in accordance with IEC 60214 except that evidence of the service duty type test shall be in excess of 100,000 operations.

16.11.18.3 Magnetic Circuit

Routine Tests

Each core completely assembled shall be tested for one minute at 500V DC between core bolts, side plates, structural steelwork and core at the core and coil stage. After the transformer is tanked and completely assembled, a further test shall be applied between the core and the earthed structural steel-work to prove that the core is earthed through the removable link, at one point only.

16.11.19 Outdoor Bushing Assemblies with Porcelain Insulators

Hollow insulators tested in accordance with IEC 60233 Complete bushings tested in accordance with IEC 60137

Routine Tests

Routine tests shall include:

- Oil leakage test
- 50Hz dry withstand the test
- Power factor/voltage test
- Partial discharge test on all bushings of which the major insulation is either oil impregnated paper or resin impregnated paper.

16.11.20 Tanks

Routine Tests

Oil Leakage: All tanks, conservators and oil-filled compartments, which are subjected in service or during maintenance to oil pressure, shall withstand without leakage a hydraulic pressure test equal to69 kN/m² or the normal pressure plus 34kN/m² whichever is the greater, for 24 hours during which time no leakage or oil ingress into normally oil-free spaces shall occur.

16.11.21 Cooling Plant

Routine Tests

- Coolers: Pressure test to be as specified above.
- Motors and Control Gear: To the requirements as specified.

16.11.22 Gas and Oil-Actuated Relays

Routine Tests

- Oil leakage: When subject to an internal oil pressure of 207kN/m² for fifteen minutes.
- Gas collection
- Oil surge
- Performance test under service conditions. Voltage: 2kV for one minute between electrical circuits and casing.

16.11.23 Galvanizing

Routine Tests

To the requirements of BS 443 or BS 729 whichever is applicable

16.11.24 Earthing Transformers (if needed)

Routine Tests

- Measurement of winding resistance
- Ratio, polarity and phase relationships
- Measurement of impedance voltage
- Measurement of loss
- Short duration power frequency voltage-withstand test
- Induced overvoltage withstand the test
- Insulation resistance of each winding

Special Tests

- Measurement of zero-phase sequence impedance

16.11.25 GIS Equipment, when applicable

Clause reference of type tests and routine tests are listed below. Any other tests specified by the referred standard (current and future issues) but not listed shall be applicable as well.

Type tests shall have been carried out on the switchgear components in accordance with the relevant IEC Standards. Limiting values obtained during Type Test shall form the basis for Factory Acceptance Tests. The limiting values shall be highlighted in the Routine Test Reports/Witness Tests.

Routine Tests

(a) **One Complete Bay**

IEC 62271-203 clause	
7.1.1	Power-frequency voltage tests on the main circuit
7.1.2	Partial discharge measurement
7.2	Tests on auxiliary and control circuits
7.3	Measurement of the resistance of the main circuit
7.4	Tightness test
7.101	Pressure tests of enclosures
7.102	Mechanical operation tests
7.103	of auxiliary circuits, equipment and interlocks in the control mechanism
7.104	Pressure test on partitions

16.11.26 Fibre Optic Multiplexer Equipment

Works tests shall be in accordance with the IEC standard.

16.11.27 Telephone Equipment

Comprehensive system testing including subscriber to subscriber tests with transit working shall be carried out with the exchanges fed from normal, high and low volts. Hunting, alternative routing and priority facilities, etc., shall be checked.

16.11.28 Teleprotection Equipment

Back to back tests shall be carried out to determine the satisfactory operation of the teleprotection equipment.

These tests shall be via fiber optic multiplexer equipment links, simulated lines or communication channels dependent on the actual application.

Random tests shall be performed which demonstrate to the Engineer the ability of the equipment to operate satisfactory (reliability) and within the specified time limits (speed) in the presence of interfering signals or noise and also the ability not to malfunction (security) in the presence of interfering signals or noise at levels likely to occur when the equipment is installed in the power system substations.

16.11.30 Transducers

Transducers shall be tested in accordance with IEC 60688-1.

16.12 Dismantling Prior to Shipment

After the satisfactory completion of all tests at the factory, the plant shall be submitted for the Engineer's approval during dismantling preparatory to shipping. No item of a plant shall be dispatched to the site until the Engineer has given approval in writing.

16.13 Inspection and Testing during Site Erection

16.13.1 General

The Contractor shall be responsible for the submission to the Engineer of all plant supplied under the Contract for inspection and testing during site erection, to ensure correct erection and compliance with the Specification.

During the course of erection, the Contractor shall provide access as required by the Engineer for inspecting the progress of the works and checking its accuracy to any extent that may be required.

The Contractor shall provide, at his own cost, all labor, materials, stores, and apparatus as may be required and as may be reasonably demanded to carry out all tests during erection, whether or not the tests are specifically referred to in this specification.

Tests on completion of erection shall be carried out by the Contractor in accordance with the General Conditions of Contract. The Contractor shall provide all necessary test equipment to carry out the site tests, but were required in the Schedule of Prices, shall include the cost of the equipment so that the Employer may have the option to buy the equipment on completion of the Contract.
The Contractor shall submit a written programme of tests and checks according to this Clause for the approval of the Engineer.

A brief description of all tests and testing procedures shall be provided before tests commence and the method of testing, unless otherwise specified, shall be agreed with the Engineer.
The Contractor shall provide experienced test personnel and testing shall be carried out during normal working hours as far as is practicable. Tests that involve existing apparatus and outages may be carried out outside normal working hours. The Contractor shall give sufficient notice to allow for the necessary outage arrangements to be made in conformity with the testing programme.

The Contractor shall advise the Engineer in writing, at the time of commencement of site erection, of the site supplies which will be required for the operation of the test equipment, to

enable the Engineer to arrange accordingly or to agree with alternative arrangements should this be necessary.

The Contractor shall record the results of the tests clearly, on an approved form and with a clear reference to the equipment and items to which they refer, so that the record can be used as the basis for maintenance tests during the working life of the equipment. The required number of site test result records shall be provided by the Contractor to the Engineer as soon as possible after the completion of the tests.

No tests as agreed under the programme of tests shall be waived except upon the instruction or agreement of the Engineer in writing.

The Contractor's test equipment shall be of satisfactory quality and condition and, where necessary, shall be appropriately calibrated by an approved authority at the Contractor's expense. Details of the test equipment and instruments used shall be noted in the test sheets in cases where the instrument or equipment characteristics can have a beating on the test results.

The testing requirements detailed under this Specification may be subject to some variation upon the instruction or agreement of the Engineer where necessitated by changed conditions at Site or by differing design, manufacture, or construction techniques.

The Bidder is required to submit proposals for site dielectric tests and to include in his price the costs of such tests and of such equipment as deemed necessary.

16.13.2 Mechanical Equipment

The extent of testing during erection shall include, but not be limited to, the following:

- Checking the accuracy and alignment of the plant erected. The accuracy shall comply with the relevant standards, the specification or the plant Manufacturer's requirements as may be applicable or, where no requirements exist, to a standard to be agreed between the Engineer and the Con-tractor.
- Checking the alignment of rotating equipment to the Manufacturer's requirements.
- Non-destructive testing of site welds as required by the relevant standard and as detailed in this specification.
- Hydrostatic testing of pipework systems at a pressure of 1.5 times the design pressure but not less than 4.5 bar for a period of 2 hours, or at such other conditions as may be required by the pipework design code.
- Air piping shall be subjected to an air pressure test rather than a hydrostatic test.
- Site fabricated tanks and vessels shall be subjected to hydrostatic tests in accordance with the relevant standards.
- Hydrostatic tests shall be carried out on steam generating units in accordance with the boiler design code.

- After the hydrostatic test is carried out, the complete assembly shall be drained and any non-drainable sections shall be injected with an oxygen-absorbent chemical and elements plugged.
- Pressure vessels and other parts, including pipework, that is made up on-site and are subject to pressure or vacuum under normal or abnormal working conditions, shall be subjected to a site hydraulic test at approved pressures and for approved periods in accordance with the relevant standard. Where no appropriate standard exists the hydraulic test pressure shall not be less than 1.5 times design pressure or at such pressure to be agreed by the Engineer.
- Should, in the opinion of the Contractor and with the agreement of the Engineer, a hydraulic test be impracticable due to excessive loading on foundations other than steel, an air pressure test may be employed in accordance with requirements set out in BS 5500.
- Vacuum tests shall be carried out at the maximum test vacuum obtainable and the condition maintained for a period of two hours with the system isolated. The Contractor shall state in the Schedule of Guarantees the fall in vacuum anticipated during this period but the rate of fall shall not exceed that which would occur due to the designed air leakage rate being attained.
- Calibration checks on all instrumentation.
- Tests to demonstrate the correct functioning of the control loops, protective devices, interlocks and alarms.
- Flushing out of all pipework systems which have not been fully cleaned and sealed before shipping to site.
- Other tests as specified which have not been previously conducted.

16.13.3 Electrical Equipment (if needed)

16.13.3.1 General

A general check of all the main switchgear and ancillary equipment shall be made and shall include a check of the completeness, correctness and condition of earth connections, labeling, arcing ring and horn gaps, clearances, painted surfaces, cables, wiring, pipework, valves, blanking plates and all other auxiliary and ancillary items. Checks shall be made for oil and gas leaks and that insulators are clean and free from external damage. A check shall be made that loose items that are to be handed over to the Employer e.g. blanking plates, tools, spares, are in order and are correctly stored or handed over.

The following general tests are to be carried out on electrical equipment after erection at site:

- Routine high voltage tests to the appropriate IEC Standard. Where no relevant standard exists, tests shall be agreed with the Engineer.
- Insulation resistance tests on all electrical equipment.

- Continuity and conductivity resistance tests.
- Test operation of alarm and tripping, devices to local and remote.
- Rotational tests on all motors.
- Polarity tests on CTs and VTs.
- Oil tests.
- Grounding system and electrode tests.
- Ratio, Vector Grouping and magnetizing current tests on each transformer.
- Calibration of winding and oil temperature devices.
- Vector group and phasing tests on VT circuits.
- Magnetization current/voltage tests and winding resistance tests on all current transformers.
- Primary and secondary injection tests on relays, protection devices and equipment.

16.13.3.2 Circuit breakers

Circuit breakers shall be visually inspected.In the case of gas type circuit breakers testing will be required on the gas system to prove the gas pressure, quantity, dryness and dielectric strength.

Contact resistance tests shall be carried out. In the case of multi-interrupter circuit breakers resistance tests will be required at each interrupter or pair of interrupters as well as through the series of interrupters on each pole.

Operational tests shall include local and remote trip/close. Timing tests shall be carried out on all circuit breakers, except those which are below 66kV and which are neither assembled at Site nor have mechanically ganged pole operation.

Local air components associated with the pneumatic operation, including air compressors, shall be tested and air loss measurements and pressure and alarm settings checked. Tests shall be made also on mechanical and hydraulic operating systems.

16.13.3.3 Disconnectors and Earth Switches

Manual operation of disconnectors and earth switches shall be subject to operational tests to confirm contact pressures, contact resistances, simultaneous operation of all phases and the ease of operation.
Motorised operation of disconnectors, and earth switches shall be tested to prove the motor operation, including local and remote operation, and timing tests shall also be carried out. Motor protection shall be tested.

Checks shall be made on interlocks, local and remote indications and operation of auxiliary contacts.

Earth switches shall be tested to confirm the opening and closing sequences and checks shall be made on interlocks, indications and manual locking devices.

16.13.3.4 Busbars and Connections

Flexible busbars and connections shall be tested to ensure that the correct tensions, sags and clearances will be maintained over the range of environmental conditions and loads without stress to other equipment. If dynamometers are used to check the sags and tensions, they shall be checked both before and after use.

Rigid busbars and connections shall be tested to ensure that the busbars will not cause overloading of the supporting insulators under load conditions and under the range of climatic variations applicable to the site and that expansion and contraction of the equipment are fully accommodated by flexible connections.

Conductivity tests shall be carried out on all connections and joints which are made on site, without exception.

16.13.3.5 Earthing System

Tests shall be made on the effectiveness of the bonding and earthing which will include conductivity tests on selected joints, on the main earthing system, and at the connections to equipment and structures. Checks shall also be made on precautions taken to avoid corrosion. attack on the earthing system.

Test probes at approximately 300 and 600 meters separation will normally be required to effectively test the earthing system. The use of transmission line conductors may be arranged to simplify these testing procedures.

The earth resistance shall be measured during the installation and on completion as follows:

- of each earth rod after driving
- of the earth grid after completion and backfilling of the trenches
- of each group of earth rods or earth point after completion of the connection from the test link terminal
- of the completed installation without any connections outside the substation

The tests shall be carried out by a method and with equipment approved by the Engineer. All tests are to be witnessed and the equipment and method used recorded with the test results.

The Contractor may also be called upon to provide assistance in the measurement of earth resistance after earth connections to the system have been completed.

16.13.3.6 Control Relays and Metering Panels, Instruments and Protective Devices

(a) **Wiring**

- After complete erection and cabling, all circuits shall be subjected to the high voltage test specified in the relevant IEC or approved standard.
- The insulation resistance of all circuits shall be measured before and after any high voltage tests.
- For AC secondary injection tests a substantially sinusoidal test supply shall be used.
- The operating and resetting level (current and/or voltage) and timing of all relays shall be measured over an agreed range of settings for all relays.
- For directional relays, phase-shifting transformers shall be used to determine the maximum torque angle and the boundaries of operation/restraint.
- Other relays shall be fully tested in accordance with the Manufacturer's recommendations.
- All DC elements of protection relays shall be tested for operation at 70% rated voltage.
- All DC supplies shall be checked for the severity of current inrush when energized by switching on or inserting fuses or links.

(b) **Mechanical Inspection**

All panel equipment is to be examined to ensure that it is in proper working condition and correctly adjusted, correctly labeled and that cases, covers, glass and gaskets are in good order and properly fitting.

(c) **General**

Sufficient tests shall be performed on the relays and protection schemes to:

- establish that the equipment has not suffered damage during transit.
- establish that the correct equipment has been supplied and installed.
- confirm that the various items of equipment have been correctly interconnected.
- confirm performance of schemes designed on the bases of calculation e.g. differential protection.
- to provide a set of figures for comparison with future maintenance values allowing the condition of the equipment to be determined.

(d) **Secondary Injection**

- Secondary injection shall be carried out on all AC relays, using voltage and current of sinusoidal wave form and rated power frequency to confirm satisfactory operation and range adjustment.
- The polar characteristic of all distance protections shall be recorded at a minimum of 30 degree intervals.
- For circulating current protection employing high impedance voltage operated relays, the points of injection for relay voltage setting tests shall be across the relay and stabilizing resistance.
- The fault setting for the type of protection is to be established by secondary injection, where it is impracticable to ascertain this value by primary injection. Injection is to be made across the appropriate relay bus wires with all associated relays, setting resistors, and CT's connected.
-

(e) **Primary Injection**

- All current operated relays shall be tested by injection of primary current to record the actual relay setting and as a final proof of the integrity of all secondary connections.
- The stability of all differential schemes shall be checked by injection of primary current.
- Primary current injection tests are to be carried out by the Contractor and the methods employed for a particular installation are to be agreed with the Engineer.
- Tests are to be carried out as follows:
-
- Local primary injection to establish the ratio and polarity of current transformers as a group, care being taken to prove the identity of current transformers of similar ratio.
- Overall primary injection to prove correct interconnection between current transformer groups and associated relays.
- Fault setting tests, where possible, to establish the value of current necessary to produce operation of the relays.

(f) **DC Operations**

Tests are to be carried out to prove the correctness of all DC polarities, the operating levels of DC relays and the correct functioning of DC relay schemes, selection and control switching, indications and alarms. The correct functioning of all isolation links and fuses shall also be checked.

(g) **Tests on Load**

- Tests on load shall also be done to demonstrate stability and operation of protection relays as re-quired by the Engineer.

- All tripping, control, alarm and interlocking circuits shall be functionally tested to prove satisfactory and fool-proof operation and/or resetting. The functional and safety aspects of all shorting and/or isolation links, fuses and switches devices shall be proved.
- The total burdens connected to all voltage transformer circuits shall be measured and recorded.
- The total capacitance of all wiring and apparatus connected to the negative pole of each main tripping battery shall be measured and recorded; the value shall not exceed 10 microfarads.
- The continuous current drain of all trip circuit supervision relays shall be measured and shall not be greater than half the minimum current required for tripping. The supervision current shall be measured with the circuit breaker (or other devices) both open and closed.

16.13.3.7 Batteries and Chargers

Tests shall be carried out on the batteries and chargers to confirm the charger ratings and adjustment, the battery and charger alarm systems and battery capacity.

The open-circuit cell voltages of the batteries when fully charged shall be recorded.

The insulation to earth of the complete DC installation shall be tested.

16.13.3.8 Power Cables

Each completed circuit shall be tested for continuity and insulation resistance.

16.13.3.9 Current Transformers

A magnetization curve shall be obtained for each current transformer in order to:

- Detect damaged in transit or installation
- Prove that the correct cores have been wired out to the relevant terminals
- For high impedance relay schemes, to confirm that correct relay settings have been calculated.

The DC resistance of each current transformer secondary winding shall be measured and also the trans-formers and connecting leads, each item being recorded separately.

The insulation resistance of all secondary circuits shall be measured at 1000 volt and recorded.

Primary current injection tests shall be conducted on all current transformers using adequate primary current to prove correct ratio, polarity and, for differential protection schemes, to prove the correct relative polarities of all current transformers of each scheme.

16.13.3.10 Voltage Transformers

The transformer ratio and polarity shall be checked using a primary voltage high enough to give a clearly measurable secondary voltage or by using rated primary voltage and comparison with an already proven voltage transformer. The phasing and phase rotation shall be checked. For three phase voltage trans-formers a test shall be conducted to show that energising each primary winding produces an output from only the correct phase secondary winding. The residual voltage of any open delta or broken delta winding shall be measured with rated primary voltage applied.

16.13.3.11 Control and Instrumentation Equipment

The following general tests shall be performed on control and instrumentation equipment at site:

- High voltage testing of all circuits, as specified in the relevant IEC or approved standard.
- Insulation resistance testing of all circuits.
- Functional tests of all tripping, control, alarm and interlocking circuits.
- The testing of all equipment in accordance with the Manufacturer's instructions or as advised by the Engineer.

16.13.3.12 Transformers and Ancillary Equipment

The following tests shall be performed:

- Insulation resistance tests on bushings.
- Insulation resistance test at 2000V between core and core clamping structure.
- Voltage withstands tests on insulating oil to BS 148.
- Ratio.
- Phase relationship.
- Magnetization characteristics of current transformers of winding temperature devices.
- Calibration of winding temperature devices.
- Tap Selector and Diverter Switch alignment.
- Calibration of automatic voltage control equipment.
- Proving tests as necessary on control schemes.
- Measurement of winding resistance on all taps and phases.

Where applicable the above tests shall also be carried out on earthing transformers.

16.13.3.13 FOX, Teleprotection and Communication

Tests shall be exhaustive and shall demonstrate that the overall performance satisfies every requirement specified. The following tests shall be carried out:

- Physical inspection unit testing and demonstration of diagnostic aids as appropriate of al equipment in stand-alone mode.
- System testing of 48V power supply equipment.
- System testing of FOX equipment for speech and teleprotection.
- System testing of telephone equipment.
- System testing of teleprotection equipment to plant.

16.14 Staffing

During pre-commissioning, the Contractor shall provide all necessary supervisory and operating staff.

The only involvement of the Employer's staff will be in accordance with the training and instruction as in this specification.

During the commissioning phase, the Employer's operating staff will operate plant and equipment under the supervision of the Contractor's supervisors.

The Contractor shall have satisfied himself as to the capability of the Employer's operators to carry out such operations as he may direct and shall remain responsible for the successful performance of such operations. Throughout the whole of the Commissioning Period the Contractor shall provide suitably qualified and experienced operating staff, who shall instruct the Employer's staff in the correct operating procedures.

The Contractor shall provide a team of suitably qualified and experienced engineers and technicians to pre-commission and commission the overall plant. The Contractor shall also ensure that a suitably qualified commissioning engineer from the respective Manufacturer's own service organisation shall visit the site to check the erection or installation of each significant plant item, and to supervise the commissioning of the plant item until the basic functioning of the item has been demonstrated to the Engineer's satisfaction.
At all times the Contractor shall ensure that his staff and any Subcontractor's or seconded staff, observe all prescribed safety rules and permit systems.

16.15 Taking Over

After satisfactory completion of the tests on completion, the Engineer will issue a Taking Over Certificate for the plant. The issue of any such certificate shall not however relieve the Contractor of any of his responsibilities in respect of proving that the performance of the plant meets the guaranteed values.

The Taking Over Certificate shall make reference to a schedule of outstanding minor defects and omissions which have been accepted by the Engineer as not affecting the full and safe operation of the plant. The Contractor shall rectify such defects and omissions not later than 3 months after Taking Over.

The date certified in the Taking Over Certificate shall be the date on which the tests on completion were completed.

16.16 Defects after Taking Over

In accordance with the General Conditions of Contract, the Contractor shall be responsible for making good defects or damage which may appear or occur during a 12 month guarantee period from the date certified in the Taking Over Certificate.

Following any remedial work or replacement of any component part during the 12 months, the guarantee period for such a part shall be extended, commencing from the date at which the remedial work was completed.

Immediately prior to the completion of this period the Employer reserves the right to request the Con-tractor to open up for inspection the whole or any part of the Plant. The Employer will provide the labour to work under the direct supervision of the Contractor's representative for the purpose of such inspection.

The Contractor shall submit for approval the arrangements he intends making under this Contract for the making good of defects and for providing the supervisory service detailed above.

16.17 Final Acceptance Certificate

Application for the Final Certificate may be made to the Engineer after the Contractor has ceased to be under any obligation under the Contract. This shall include the submission of final contract record drawings and fully bound version of the Installation, Operation and Maintenance Manuals. If a Taking-Over Certificate has been issued in respect of any Section or Portion of the Works, only one Final Certificate will be issued after all the said obligation

has ceased. Final Certificate will be issued after all the said obligation has ceased. Where the Contractor has carried out replacements or renewals to the Works, the Contractor's obligations shall continue, but the right of the Contractor to apply for a Final Certificate other than for the replacements or renewals shall not be affected by that fact.

17A. 33kV Power Cables and Cable Terminating Accessories

17A.1 GENERAL:

This specification covers the general requirements of the design, manufacture, testing and inspection requirement of 33 KV XLPE Insulated Copper Cable (300 mm2) as specified.

17A.2 STANDARDS:

The cable as specified in this Section shall be conforming to the latest edition of the following standards for operation under local ambient conditions. Design, Manufacture, Testing and Performance of the cable shall be in accordance with the IEC 60502-2, IEC 60228 or equivalent International standards.

17A.3 CONDITIONS UPON WHICH CURRENT CARRYING CAPACITIES ARE BASED:

Soil thermal resistivity	°C.m/W	1.5
Ground temperature	°C	30
Air temperature	°C	40
Conductor temperature	°C	90
Burial depth	m	1.0
Axial Spacing between phase cables	mm	Trefoil touching
Axial spacing between Circuits	mm	850
Type of earth bonding		Solid
Protection in ground		Trench

17A.4 Specifications:

17A.4.1 General

The manufacturing process shall be designed to eliminate irregularities like protrusions, voids and contamination etc. to ensure the long-term reliability of the 33kV XLPE Cu cable.

Raw materials used to manufacture the cable shall be of highest quality and it should meet material standards mentioned in IEC 60 502-2. The materials shall be clean and packed in moisture and dust proof packing. Material received by manufacturer should be checked/ tested to ensure that it meets material specification.

The cross linking, curing and cooling may be carried out in one operation and shall be a gas curing process under high pressure to eliminate the formation of voids in the insulation and contaminants in the dielectric. Process conditions such as curing and cooling temperatures, production speed etc. shall be closely monitored during manufacture to ensure a good degree of cross-linking through the whole insulation.

17A.4.2 Cable Construction

The 33kV XLPE Cable shall have stranded compacted round copper conductor, taped with semi conducting tapes, conductor screening with extruded semi conducting thermosetting compound, with completely gas cured XLPE insulation, adequate insulation screening consisting of extruded semi conducting thermosetting compound layer, taped with semi conducting water swellable tape, metallic screen and overall extruded termite repellent black PE sheathed with outer conducting layer.

17A.4.3 Conductor

The conductor shall be stranded compacted round copper conductor complying the requirement of flexibility Class-2 of IEC 60228. The wires shall be made of high conductivity copper and shall be stranded mid compacted. The copper used for the conductor shall be of highest purity. The nominal area of conductor shall be 800 sq. mm.

The minimum number of wires in conductor shall be 61 and the maximum DC resistance of conductor shall be 0.0221 Ω/KM at 20°C.

17A.4.4 Conductor Screen

The conductor screen shall consist of an extruded layer of thermosetting semi conducting compound and shall be continuous and cover the whole surface of the conductor. The screen shall be firmly bonded to XLPE insulation. The minimum thickness of conductor screen shall be 0.8 mm. (approx.)

A non-hygroscopic semi conducting tape may be applied over the conductor surface under extruded layer. The outer surface of the conductor screen shall be circular and free from irregularities.

17A.4.5 Insulation

The insulation shall be cross-linked polyethylene (XLPE). The insulation material shall comply with the requirement as per IEC 60 502-2. The insulation shall be applied by extrusion and vulcanisation to form a compact homogenous body free from micro voids and contaminants. The nominal thickness of insulation shall be 8.0 mm.

17A.4.6 Insulation Screen

The insulation screen shall consist of an extruded layer of thermosetting semi conducting compound and shall be continuous and cover the whole surface area of insulation. It shall be firmly bonded to the insulation.

The minimum thickness of insulation screen shall be 0.5 mm.

17A.4.7 Metallic Screen

The metallic Screen shall consist of a concentric layer of copper wires or a combination of copper wires and helically applied coppertape(s) as per IEC Standard.

The metallic Screen shall be so designed to carry the specified earth fault current of 31.5kA for 1 second.

17A.4.8 Separation Sheath

The Separation Sheath should covering the whole surface area of the metallic screen as per IEC Standard.

17A.4.9 Outer sheath

The outer sheath shall consist of an extruded layer of black medium density polyethylene. The outer sheath shall be of sufficient hardness to discourage termite attacks. The properties of outer sheath material shall be as per IEC 60 840. The nominal thickness of outer sheath shall be 2.6 mm.

17A.5 Marking on Outer Sheath

The following particulars shall be either marked on Cable outer sheath or printed over a tape at suitable regular intervals.

a) Manufacturer's name and/or trade name.
b) Voltage grade viz. 33 kV.
c) Cable size (no. of core x conductor cross section).
d) Year of manufacture.
e) Purchaser's name i.e. *(INSERT THE NAME OF THE ORGANIZATION).*

The spacing between one set of marking and lie beginning of the next on the legend shall not exceed 300 mm.In case of printed over a tape, the same shall be provided inside the cable.

17A.6 Sealing and Drumming

Immediately after the works and tests, both ends of every length of cable shall be sealed by means of heat shrinkable end caps.

Cables shall be wound on metallic drums. All the drums shall be arranged to take a round spindle and is lagged with strong closely fitting wooden battens so as to prevent damage to the Cable.

Each drum shall bear an identification number permanently stencilled or branded on the outside of the flange. Particulars of the Cable i.e. Voltage grade, Size & length of cable, gross weight, net weight, direction of rolling, Purchaser's name & contract number, name of manufacturer and year of manufacture etc. shall be clearly marked on one flange on the drum.

Standard drum length shall be 500 meter in one length. A tolerance of ±3% will be permissible on standard drum length. However, exact drum length shall be advised to successful bidder after award of contract.

17A.7 Tests for Cables

All type, routine and acceptance (special) tests shall be carried out as per IEC 60 502-2. The manufacturer of cable must have at least ISO 9001 certified quality Assurance system in their manufacturing system.

14A.7.1 Routine Tests

The following routine tests shall be carried out on each manufactured length

a) Partial discharge test
b) Voltage test
c) DC voltage test on outer sheath
d) Conductor resistance test

17A.7.2 Special (Acceptance) Tests

The following tests shall be made on samples which, for the tests in items (b) and (g), may be on complete drum length of cable taken to represent batches

a) Conductor examination
b) Measurement of electrical resistance of conductor
c) Measurement of thickness of insulation and non-metallic sheath
d) Measurement of thickness of metallic sheath
e) Measurement of overall cable diameter
f) Hot set test for XLPE insulation
g) Measurement of capacitance

17A.7.3 Frequency of Tests for Special (Acceptance) Tests

The above special (acceptance) tests shall be made on one length from each manufacturing series of the same type size of cable, but shall be limited to not more than 10% of the number of lengths in any contract, rounded to upper unity.

APPENDIX

Appendix 33 kV XLPE Power Cables

A. 33 kV XLPE Power Cables

SL. Nos.	Description
Rated system voltage	33 kV
Max. permissible system voltage	
Rated frequency	50Hz
Nos. of cable	1/phase
Cross sectional area	300mm^2 Cu
Impulse withstand voltage	
Power frequency withstand voltage	
Shape of conductor	Stranded/Compact
Insulation thickness	round 8-9 mm
Min. bending radius DC resistance at 20 ℃	D (D is external diameter of cable) To be proposed
Short circuit rating for 1 sec	31.5 kA
Three phase symmetrical fault current for 1 sec.	31.5 kA

SECTION 17B

POWER CABLES AND CABLE TERMINATING ACCESSORIES (HV)

17B.1 SCOPE

These clauses describe the General Technical Requirements for the 132 kV and above power cables & cable terminating accessories and installation of cables and shall be read in conjunction with the Project Requirements, Schedules and Drawings in the specification.

The power cables and accessories shall be suitable for connecting the overhead transmission lines, power transformers with GIS.

The HV cables used for different connection in this Contract are provided in **Annex-17B.1.**

The Contractor shall demonstrate that the cables have been designed, built and installed in accordance with the relevant international standards and the specification. It shall also operate and perform on a site in accordance with the requirements of the specification and in the environment defined therein.

The design shall be proven by the submission of test certificates covering all specified tests deemed to be pertinent to the plant and to the conditions in which it will operate at the time of Biding.

The scope of work also includes supply and installation of cable sealing ends at both ends including terminating insulators.

17B .2 STANDARDS

The cable and accessories shall comply with this specification and the latest version of relevant IEC, BS or approved equivalent.

17B .3 CONDITIONS OF OPERATION

All cables shall be suitable for operation, at the guaranteed continuous ratings specified, throughout all seasons of the year. The nominal system voltage to which the cables will be connected and the highest operating voltage Um are provided in **Annex-17B .2**.

The maximum foreseeable three phase symmetrical fault current to which the cables may be subjected be as per shall be **Annex-17B .2**.

Cable shall be designed to operate continuously at temperature of 90°C. Each conductor and the metal sheath/screen shall be capable of carrying the specified fault current for the specified time and its final temperature shall not exceed 250°C. Adequate measure should be taken to protect against ingress of moisture and water.

Short circuit earth fault rating of cable conductor and metal sheath or metallic screen shall be as perAnnex-**17B** .2.

The maximum continuous current carrying capacity and maximum permissible conductor temperature, and the factors for determining such rating and temperature, shall be based on IEC 60287 and subsequent amendments, and all conditions obtaining on Site. The following conditions for the design of the cables shall be assumed:-

- Soil Thermal receptivity (ground level) 1.5 °C.m/W
- Installation arrangement
  Trefoil touching
- Type of earth bonding
  Solid

Other conditions for cables laid in concrete ducts/tunnels/buried pipes shall be assumed:-

- Max. ambient air temperature: 40°C
- Continuous conductor temperature: 90°C
- Max. conductor temperature under fault: 250°C

The contractor shall confirm that the cable sizes are adequate for the required circuit ratings based on the specified foregoing parameters, and he shall also confirm that the cables are adequate for the short-circuit requirements specified. The contractor will be required to produce cable design calculations to verify that the selected cable sizes are suitable for the selected cable laying conditions in concrete cable ducts, tunnels or buried pipes.

If the contractor considers that the conditions and the proximity to other power cables, spacing and method of installation are likely to reduce the maximum current carrying capacity he shall increase the cable conductor cross section accordingly.

The conductor section of the cable circuits shall be adequate for carrying the specified short-circuit current when operating under the specified load conditions without deterioration of the dielectric or other component materials of the cable.

17B .4 TYPE APPROVAL

Cables and accessories shall have satisfactorily passed type approval tests in accordance with the Specification and details of the cable designs offered shall be given in the Schedule of Particulars and Guarantees. Type test reports shall include cable design details and design drawings of each jointing accessory

included in the type test.

The Contractor shall certify that the cables and/or accessories offered will be identical in all essential particulars in respect of design, materials and workmanship with the cables and/or accessories for which type approval certificates are offered in support of this bid.

The Contractor shall also ensure that all materials used will be subjected to and shall have satisfactorily withstood such tests as are customary in the manufacture of the types of cable specified.

Records of such tests shall be available for inspection, if required by the Engineer.

17B .5 CABLE LENGTHS

Cables shall be supplied in maximum drum lengths bearing in mind the transport limitations in gaining access to the site. No drum shall contain more than one length. Cables shall be installed in maximum possible lengths and straight through jointing between shorter lengths will not be permitted.

The cable routes on the drawings (if any) attached to the Bidding Documents are provided for information only, and it is Contractor's responsibility to establish the exact quantities of cables and accessories required to complete the whole of the works as described in the Specification.

17B.6 CABLE DRUMS

Cable drums shall be non-returnable and shall be made of steel suitably protected against corrosion. They shall be lagged with closely fitting battens in accordance with the relevant BS or equivalent IEC standard.

Each cable drum shall bear a distinguishing number on the outside of one flange. Particulars of the cable, i.e. voltage, conductor size and material, number of cores, type, length, gross and net weights shall also be clearly shown on one flange. The direction of rolling shall be indicated by an arrow on both flanges. The method of drum marking shall be to the Engineer's approval.

Cable maintenance lengths and spare lengths shall be wound on to steel drums before they are handed over to the Purchaser's stores. Particulars of the cable (as stated above) shall be clearly marked on one flange.

17B.7 SPARE CABLE

In addition to the cable maintenance lengths supplied against the Schedule of Spares the Purchaser shall have the option to purchase from the Contractor at the rates stated in the Schedule any spare cut lengths of cable for future maintenance purposes.

Brass or other approved sealing caps of the correct size shall be supplied for each end of spare cut cable lengths to enable them to be properly stored for future maintenance purposes. The Contractor shall be responsible for the immediate sealing of such cut lengths and the cost thereof shall be deemed to be included in the contract price.

17B.8 SPECIAL TOOLS

Special tools used for the purpose of the cable installation, they shall be handed over to the purchaser's stores after the taking over of the installation.

Price for such special tools is to be considered as included in the price schedule.

117B.9 CABLE JOINTING INSTRUCTIONS AND DRAWINGS

Copies of the instructions for the jointing of each type of cable terminating and jointing accessories supplied shall be submitted to the Engineer for approval before any work is commenced at site. One copy of each instruction shall be bound into each copy of the Operating and Maintenance Instructions to be supplied to the Engineer at the completion of the Contract for the use of the Purchaser.

The following drawings shall be submitted by the Contractor for approval by the Engineer. "As installed" drawings of cable routes shall be drawn to a scale of 1/200. The route shall be dimensioned in such manner that it may be used for pinpointing accurately the cables in the future. All drawings shall be submitted for approval before the issue of the Taking-Over certificate.

17B.10 CABLE SPECIFICATION

14.10.1 General

This Specification applies to single core cables with triple extrusion type solid dielectric. They shall be generally manufactured in accordance with the relevant International Electro technicalCommission Publication (IEC) 60840, 62067 and British Standard (BS) where applicable.

The cable shall be manufactured in Triple Extrusion in one Operation and shall be cured in Dry Curing Process in order to have maximum reliability.

The specified manufacturing process is the vertical continuous vulcanisation (VCV)/Catenary continuous vulcanizing (CCV)line to ensure the highest standards of concentricity.

17B.10.2 Conductors

Conductors shall be of stranded plain annealed copper wires to IEC 60228 or BS filled to make the cables longitudinally watertight by extrusion during stranding. This shall be to prevent ingress of water into the cable should the outer sheath become damaged. The allowable operating temperature of conductor and waterproofing shall be 90°C. The form of conductor is either stranded compacted circular or milliken (segmental compacted circular). Miilliken type is applicable for conductor size more than 1000mm^2

17B.10.3 Conductor Screen

Semi-conductive tape for preventing ingress of semi-conductive XLPE and gluing onto the stranded conductors temperature resistance up to 250°C. Semi-conductive extruded cross-linked material to provide a smooth cylindrical equi-potential surface to which the insulation can be intimately bonded. The material shall be compatible in all respects with its conductor and insulation materials.

117B.10.4 Insulation

Cross-liked polyethylene (XLPE) melted together with the conductor screen capable to operate at continuous conductor temperature of 90°C and short circuit temperature of 250°C. Cross-linking process using curing is not permitted, dry process shall be given. The insulation of the completed cable shall be substantially free from voids and contaminants.

17B.10.5 Insulation Screen

Semi-conductive compound of extruded layer firmly bonded to the XLPE insulation. The conductor screen, the insulation and the insulation screen are to be extruded in a single process to keep the interface smooth.

17B.10.6 Metallic Screen

Where the cable core screens are inadequate to meet the earth fault current specified, a metallic layer of adequate cross-sectional area shall be included in the design applied over the screen. The metallic layer shall be Copper screen with counter helix filled with swelling powder sheathed in accordance with latest BS or IEC Publication.

117B.10.7 Intermediate Layer

An intermediate layer of suitable compound shall be provided in between metallic screen and aluminium sheath if necessary.

117B .10.8 Corrugated Seamless Aluminium Sheath

Metallic sheath shall consist of the extruded corrugated seamless aluminum sheath. Aluminum used for the sheath shall have the minimum purity of 99.5% and shall be of best quality metal free from pinhole flaws and other imperfections. The minimum thickness at any point shall not fall below 85% of the specified nominal thickness by more than 0.1 mm.

117B.10.9 MDPE Outer Sheath

After applying the bitumen compound over the aluminum sheath, the extruded MDPE outer sheath shall be applied.

The nominal thickness of outer sheath shall be not less the specified value. The minimum thickness at any point shall not fall below 85% of the specified nominal thickness by more than 0.1mm.

An outer graphite coating shall be applied to outer sheath as an electrode for the voltage test on the extruded outer sheath.

17B.10.10 Identification of Cable

The outer PVC sheath of all cables shall carry the following identification marks in three meter intervals approximately.

"ELECTRIC CABLES –in Volts and cross section in sq. mm.cu. PGCB, the name of the manufacture and the year of fabrication."

The letters and numerals shall comply with IEC or BS Publication.

117B.11 SEALING AND DRUMMING

Immediately after the works tests, both ends of the cable shall be sealed against the ingress of moisture, dirt and insects and the end projecting from the drum shall be adequately protected against mechanical damage during handling. The cable drums shall be arranged to take a round spindle and be lagged with strong, closely fitting so as to take a round spindle and be lagged with strong, closely fitting battens so to prevent damage to the cable. Only steel cable drum shall be used.

The complete cable shall be rolled on steel cable drums capable of withstanding the rough handling during transport without damage of the cable and enabling easy and safe unrolling of the cable during erection.

Each drum shall have marked in indelible point on both flanges, the following indications besides the shipping instructions.

- Destination
- Type of cable
- Exact length
- Net and gross weight
- Trade mark
    - An arrow pointing in the direction of unrolling.

17B .12 TERMINATING ACCESSORIES

Detailed drawings showing the types of cable sealing ends, terminal boxes and glands proposed for the installation shall be submitted at the time of Bidding. All cable sealing ends and terminal boxes shall be designed with jointing faces below compound level which will ensure the retention of the filling medium and/or cable compound under operating conditions and exclude the entry of air, dust or moisture. Cable sealing ends and terminal boxes designed for use with fluid or semi-fluid filling media shall have fanged joints, the faces of which shall be machined.

An earthing strip shall be provided on all boxes terminating lead sheathed cables.

The external dimensions, fixing cables and terminal arrangements for all sealing ends and terminal boxes shall be agreed with the Engineer.

Sealing ends and terminal boxes shall be provided with all necessary fittings, including external flexible connections as required. The design of flexible connections shall be to approval.

Drain plugs shall be of ample size to permit the filling medium to be removed. The contact faces of the cable sockets shall be thoroughly cleaned, the lugs shall be placed in the most suitable positions and arranged as required to avoid unnecessary bending of cable cores inside the box. Provision shall be made for earthing the body of the box, and for expansion of the conductors in the box. Provision shall also be made for the expansion of the filling medium and arrangements made to prevent the formation of air spaces when filling.

17B.13 INSTALLATION OF CABLE

17B.13.1 Cable Tunnels and Trenches with Pits, Ducts and Drains

The contractor shall design and construct cable trenches required for connecting/Laying 230 kV & 33kV power cables inside substation area. Width and height of cable tunnels shall conform to required cable spacing and working spaces. The structure of cable tunnels is reinforced concrete and must be designed enough bearing capacity cause by some parts of cable tunnel are under heavy equipment.

The contractor shall design and construct all trenches required for the work. The depth of the cable trenches shall be minimum 1.5 meter from the Substation switchyard, finished level and the width shall conform to required cable spacing and working spaces.

The thickness of cable tunnel or trench wall and floor shall be minimum 150mm and should be designed to withstand the subsoil water pressure.

Cables in cable tunnels or trenches shall be laid on cable supports at every ½ (half) meter interval.

Cable trenches shall be covered with concrete trench covers. Trenches will be built with the top edge of the walls 50mm above the finished switchyard level.

The Cable tunnels and trenches shall have a suitable bed slope with sufficient number of drainage pits so that water could be drained off naturally as well as by artificial means.

The removable trench covers shall be of recast reinforced concrete adequately designed to safely withstand a load of 2,500 N at the center of each cover. The trench covers shall be of such size as to facilitate their handling by manual labor.

17B.13.2 Supports and Racks

Cable laid supports and racks together with fixing clamps, bolts, nuts and screws for outdoor installations and in outdoor concrete lined trenches shall be of hot dip galvanised steel.

Cable support and rack designs shall be submitted for the written approval of the Engineer before manufacturer or erection.

The single core cables shall be clamped to the racks with smooth finish split packing pieces or cleats with bores of the correct size for the cable diameters. The cleats shall be of Silicon aluminium, glass filled nylon or other tough non-hygroscopic or non magnetic material. Wooden cleats are prohibited.

17B.13.3 Bonding

The cables shall be installed as an insulated sheath system. Single core cable sheaths may either be solidly bonded (single bonding).

Bonding leads shall be of sufficient cross sectional area to carry the maximum imposed short circuit current level. A schematic diagram detailing the proposed bonding systems and stating bonding leads cross section shall be submitted with the Bid.

17B.14 TESTS

17B.14.1 Type Tests

The cable shall be tested and shall satisfy the most recent relevant IEC Publications.

The tests need not be carried out again if they can be provided by already existing type tests reports of recognized laboratories.

If the cable is not yet type tested, the relevant tests shall be carried out.

17B.14.2 Routine/Sample Tests

The cable shall be tested and shall satisfy the most recent relevant IEC Publication.

17B.14.3 Tests at site

After completion of the erection and before commissioning, each cable shall be submitted to the following test:

a) Verification of the proper and complete erection of the cable and the terminals.
b) Verification of the proper conductor's of the external surface.
c) Verification of the proper earthing of the sheath.
d) Direct current voltage test no cables and cable terminals.
e) Power frequency test.

17B.15 EARTHING SYSTEM

The cable sheath for single bonding of cable and cable end termination structures shall be earthed at earthing mat by extending the earthing system.

Annex-17B.1: HV Cable connections

Sl.	*Site*	*Voltage level, U kV*	*Cable Size, mm^2*	*Connection*
1.	Kaliganj	230	2000	230kV GIS outdoor bushing to Outdoor CSE in front of gnatry

Annex-17B.2: HV Cable types used

Sl.	*Cable type*	*Max. Voltage, Um kV*	*Max. Three phase symmetrical fault current, kA/3 sec*	*Min. Short circuit rating of cable conductor, kA/1 sec*	*Min. Short circuit rating of metallic sheath, kA/3 sec*
1.	230kV, 2000 mm^2	245	63	286	63

18. Study under Design Service

18.1 Over-voltage study

18.1.1 TOV Studies to verify Surge Arresters

This task will perform TOV (Transient Over-Voltage) studies to verify surge arrester designs. A PSCAD TOV model (developed for Task 1 above) will be used.
The following TOV studies shall be performed: -

- Line energization studies
- Transformer energization studies
- TOVs due to fault recovery

These studies are statistical in nature– the full model is first run to steady state and a "snapshot" is taken. Hundreds (or thousands) of runs are then started from the snapshot, and the point-on-wave timing of the breaker energization (or fault point-on-wave) instant is varied statistically. The results from the statistical/multiple runs are then recorded, and objective functions are created to identify the worst case (ie like the case that produces the highest voltage, or the highest energy in a surge arrester). These are key simulation findings for the insulation coordination report.

Note that, line insulation coordination studies are not proposed for the purposes of line design (ie computing the CFO (critical flashover) and PFO (probability of flashover) etc…) – these studies are normally performed as part of the AC line design. The study will utilize the chosen surge arresters (at transformer bushing at all line entrances) and through studies will determine the TOV level (which can be compared to the designed SSIL levels) and the energy in surge arrester (which is verified against the energy capability in the manufacturer specifications).

For line energization studies, this study shall be based on the following minimum case list:

- Energizing the longest AC line into the station
- Closing of phase A breaker every 20 degrees over a full cycle
- For every closing instant, phases B and C are statistically closed 25 times (with a pole-spread closing time of +/- 5 msec).
- A total of 19*25=475 runs for each scenario
- Repeated for 2 base cases (strong and weak system)
- Repeated for the initial energization (of a discharged line), but also after x

seconds for a TPAR reclose (with trapped charge)

- Total # of cases are 475 * 2 * 2 (base cases) = 1900 cases

For transformer energization studies, this study shall be based on the following minimum case list:

- Energizing the largest transformer at the station
- Transformers setup with remanence (i.e. trapped flux) to give the worst case inrush - Closing of phase A breaker every 20 degrees over a full cycle
- For every closing instant, phases B and C are statistically closed 25 times (with a pole-spread closing time of +/- 5 msec).
- A total of 19*25=475 runs for each scenario
- Repeated for 2 base cases (strong and weak system)
    - Repeated for the initial energization (of the first transformer), but also repeated for the second trans-former (with the first already in-service (to see sympathetic inrush effects)

    - Total # of cases are 475 * 2 (1 transformer or 2) * 2 (base cases) = 1900 cases

For fault studies, this study task shall be based on the following minimum case list:

- Study of two fault types (SLG and LLLG)
- Application of the fault on phase A every 20 degrees over a full cycle for LLLG faults or every 10 degrees for SLG Faults.
- For LLLG faults, phases B and C faults are statistically applied 25 times (with a pole-spread closing time of +/- 5 msec) for each fault instant on phase A.
- A total of 19*25=475 runs for each scenario (for LLLG Faults) and 37 runs (for SLG faults)
- Application of faults at 2 locations
- Repeated for 2 base cases (strong and weak system)
- Total # of cases are 475 (LLLG Faults) * 2 (locations) * 2 (base cases) + 37 (SLG Faults) * 2 (locations) * 2 (base cases) = 1900 + 148 = 2048 cases

The sensitivity of the results will also be shown for various breaker pre-insertion resistance values – these sensitivity studies are generally not repeated for all of the statistical/thousands of runs, but are repeated for the worst case.

The highest TOV recorded and the highest energy in any surge arrester (expressed in p.u. of its energy capability) will be reported. If the energy exceeds 0.3 p.u. for any case (which allows for an initial disturbance, one automatic reclose, and one manual reclose + margin) then this will be reported and subject to changed arrester design (i.e. adding another arrester parallel column).

Note that, this case list is not exhaustive, but is representative of typical/normal events. If an expanded case list is required, it shall be conveyed during detail Engineering.

18.1.2TRV studies on 400 kV Substation

Transient recovery voltage (TRV) is the voltage which appears across the terminals of a pole of a circuit breaker following the interruption of fault current. This is directly related to the RRRV (rate of recovery of voltage) during the rising edge of the voltage build-up. IEEE/IEC standard C37.06-2009 defines criteria for how high and fast this voltage can rise for a given fault type, fault location and fault current. Note that breaker manufacturers may be able to provide the exact TRV specification to which a breaker was tested (which should be higher than the standard requirements). It is expected that the circuit breakers will be able to withstand recovery voltages that are within the appropriate criteria.

For the purpose of defining the scope/budget, the breaker TRV is to be assessed for one line breaker and one transformer breaker. The level of TRV is largely affected by the total capacitance in the station (so detailed data on the station layout, GIS and Transformer etc.) are common between the models.

Plots of the voltage across the breaker will be super-imposed on the IEC/IEEE standard withstand curves – any violations (where the voltage exceeds the voltage-time standard) will be reported. No mitigation studies are proposed (although in the event of a violation the first step is to contact the breaker manufacturer to see if their breaker can withstand the predicted TRV levels).

Note that, this TRV study shall also compute the ITRV (initial TRV) – ITRV is a very specialized ultra-fast high frequency transient effect due to reflections within the bus work within the station.

18.1.3 Lightning Over voltages

The lightning induced overvoltage can be a result of a direct strike onto a phase conductor (shielding failure) or due to 'back flashover' resulting from a lightning strike on a shielding (ground wire). Induced lighting event shall also be considered. All events would cause transient voltage escalations at the terminals of station equipment. The study will identify the severity of such transients. It will also identify the required rating and location of surge arresters (in this case, verify the proposed sizes and design) to ensure that such over voltages do not exceed the insulation strength of the main equipment.

Lightning strikes to towers (and ground wires) on the 400 kV side as well as direct strikes to conductors will be studied.

18.1.4 Switching Surge Over-voltages

Switching over-voltages are simulated to determine the air clearance. The switching over-voltages are classified as four kinds of disturbances, such as, fault initiation overvoltage, fault clearing overvoltage, closing overvoltage and reclosing overvoltage. The purpose of the study is to determine

- Re-closing time determination
- Closing/Re-closing overvoltage
- Pre-insertion resister value

18.1.5 BIL design & Insulation coordination for Transmission Line & Substation equipment

The BIL design shall be performed. In case of TL, the study shall include:

(a) Contamination design
- Determination of number of insulators

(b) Air clearance design
- Air clearance, swing angle of conductor
- Drawing of air clearance diagram

(c) Lightning protection

- Prediction of lightning outage rate
- Shielding angle of ground wire
- Design of tower/gantry footing resistance

It is necessary to estimate the lightning flashover rate of the transmission line.

In case of Substation, the following shall be included as a part of the study:
- The equipment insulation strength is the BIL and BSL of all equipment
- The phase to ground and phase-phase clearance
- The need for the location, the rating and the number of surge arrester
- The need for the location, the configuration, and spacing of protective gaps
- The need for, the location, and type (mast and shield wire), of substation shielding
- The need for, the amount, and method of achieving an improvement in lightning performance of the line immediately adjacent to the station

18.1.6 VFTO Analysis for GIS

Detailed analysis shall be performed as per agreed method with PGCB during detailed engineering.

18.1.7 Reporting

The study deliverables will be:

- Preliminary task reports (one for each of the above tasks)
- Interim report
- A final report which summarizes all the tasks.

The reports will be first issued in draft form, with provision to address questions/concerns from the client. A finalized report will follow.

19. Drawings Forming Part of the Specification

19.1 General

The drawings provided in this section are solely for the purpose of bid information and bid preparation. Therefore, the bid drawings shall not be considered for& as final design & costing accordingly. Final design shall be as per Employer's approval during execution stage. Bidders are to consider such issues in their bids.

They present the typical details of the project facilities and plant requirements for the following.

- NEW 400/230/132kV Indoor GIS Substation at Kaliganj

19.2 List of Bid Drawings

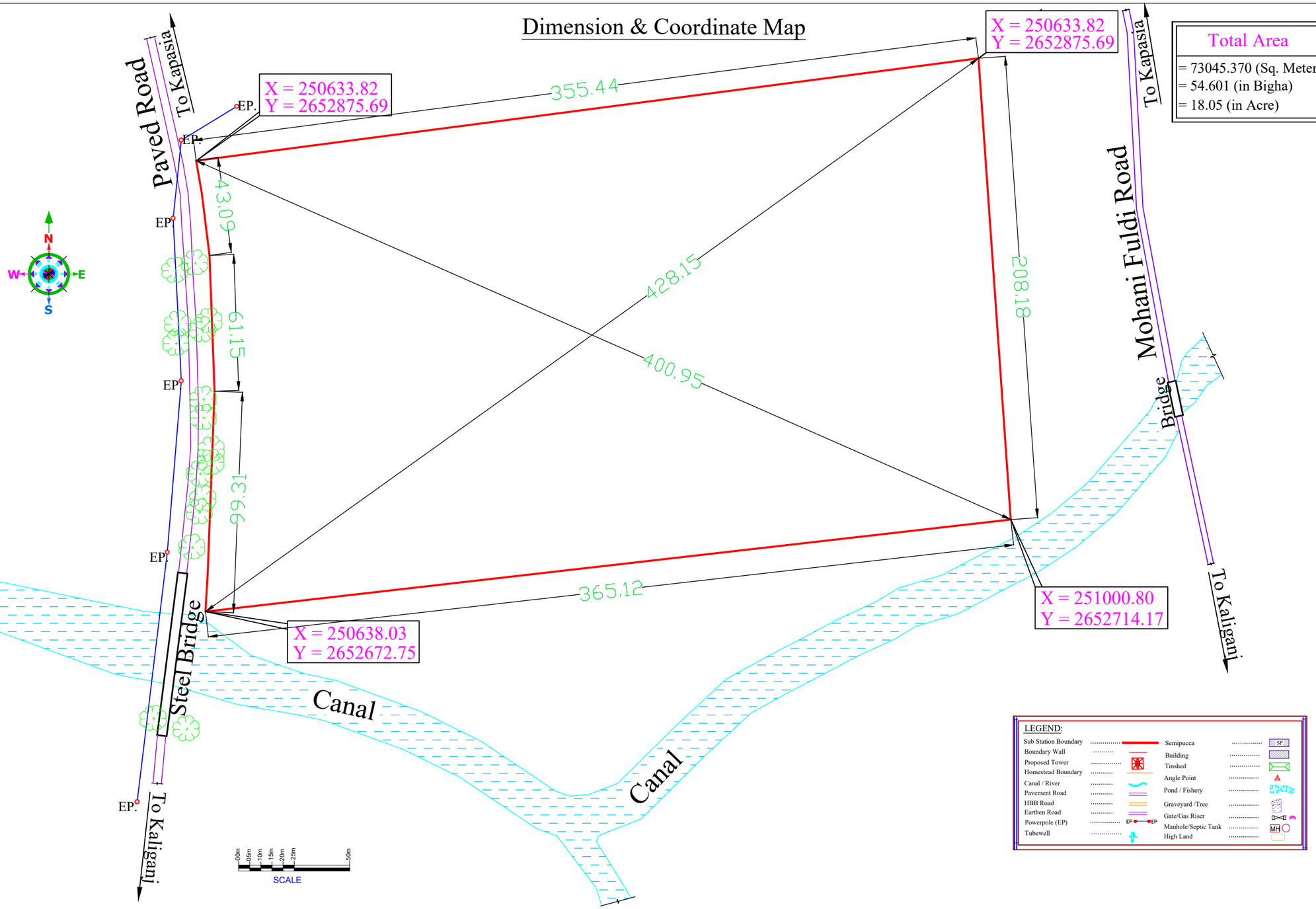
19.2.1 Kaliganj Substation Drawing List

Sl. No.	Drawing No.	Title
1.	PGCB/DESIGN/2021/KALIGANJ/MAP	Coordinate and dimensional map of new Kaliganj grid substation
2.	PGCB/DESIGN/2021/KALIGANJ/E01	Kaliganj grid substation layout
3.	PGCB/DESIGN/2021/KALIGANJ/E02	Kaliganj grid substation SLD (400kV side)
4.	PGCB/DESIGN/2021/KALIGANJ/E03	Kaliganj grid substation SLD (230kV side)
5.	PGCB/DESIGN/2021/KALIGANJ/E04	Kaliganj grid typical bay SLD (400kV side)
6.	PGCB/DESIGN/2021/KALIGANJ/E05	Kaliganj grid typical bay SLD (230kV side)
7.	PGCB/DESIGN/2021/KALIGANJ/E06	PSLD and trip logic of typical 230kV GIS line bay
8.	PGCB/DESIGN/2021/KALIGANJ/E07	PSLD and trip logic of typical 230kV GIS bus coupler bay

9.	PGCB/DESIGN/2021/KALIGANJ/E08	PSLD and trip logic of typical 230kV GIS bus section bay
10.	PGCB/DESIGN/2021/KALIGANJ/E09	PSLD and trip logic of typical 400kV GIS line bay
11.	PGCB/DESIGN/2021/KALIGANJ/E10	PSLD and trip logic of typical 400kV and 230kV transformer bay
12.	PGCB/DESIGN/2021/KALIGANJ/E11	PSLD and trip logic of typical 400kV GIS bus coupler bay
13.	PGCB/DESIGN/2021/KALIGANJ/E12	PSLD and trip logic of typical 400kV GIS bus section bay
14.	PGCB/DESIGN/2021/KALIGANJ/E13	Typical SLD of 110V DCDB
15.	PGCB/DESIGN/2021/KALIGANJ/E14	Typical SLD of 48 DCDB
16.	PGCB/DESIGN/2021/KALIGANJ/E15	Typical SLD of ACDB
17.	PGCB/DESIGN/2021/KALIGANJ/E16	Typical SAS Architecture Drawing
18.	PGCB/DESIGN/2021/KALIGANJ/E17	LV 230V AC Inverter Drawing for SAS
19.	PGCB/DESIGN/2021/KALIGANJ/E18	Telecommunication Schematic Diagram
20.	PGCB/DESIGN/2021/KALIGANJ/C01	400kV GIS Building
21.	PGCB/DESIGN/2021/KALIGANJ/C02	230kV GIS Building
22.	PGCB/DESIGN/2021/KALIGANJ/C03	Carport
23.	PGCB/DESIGN/2021/KALIGANJ/C04	Sentry Post
24.	PGCB/DESIGN/2021/KALIGANJ/C05	Guard House
25.	PGCB/DESIGN/2021/KALIGANJ/C06	Switchyard Gravelling and Relative Levels of Different Structures
26.	PGCB/DESIGN/2021/KALIGANJ/C07	Typical Road sections
27.	PGCB/DESIGN/2021/KALIGANJ/C08	Ansar Barack
28.	PGCB/DESIGN/2021/KALIGANJ/C09	Typical Section of Chain linked fencing
29.	PGCB/DESIGN/2021/KALIGANJ/C10	Main Entrance Gate

30.	PGCB/DESIGN/2021/KALIGANJ/C11	Boundary wall without retaining wall
31.	PGCB/DESIGN/2021/KALIGANJ/C12	Boundary wall with RCC retaining wall
32.	PGCB/DESIGN/2021/KALIGANJ/C13	Slope (1V:2H) protection with turfing
33.	PGCB/DESIGN/2021/KALIGANJ/C14	AUX Power Supply & CAF Room
34.	PGCB/DESIGN/2021/KALIGANJ/C15	Typical Walkway Sections
35.	PGCB/DESIGN/2021/KALIGANJ/C16	Slpoe (1V:2H) protection with CC blocks
36.	PGCB/DESIGN/2021/KALIGANJ/C17	Property Line demarkation
37.	PGCB/DESIGN/2021/KALIGANJ/C18	Septik Tank
38.	PGCB/DESIGN/2021/KALIGANJ/C19	Soak Well for Septik Tank

Dimension & Coordinate Map

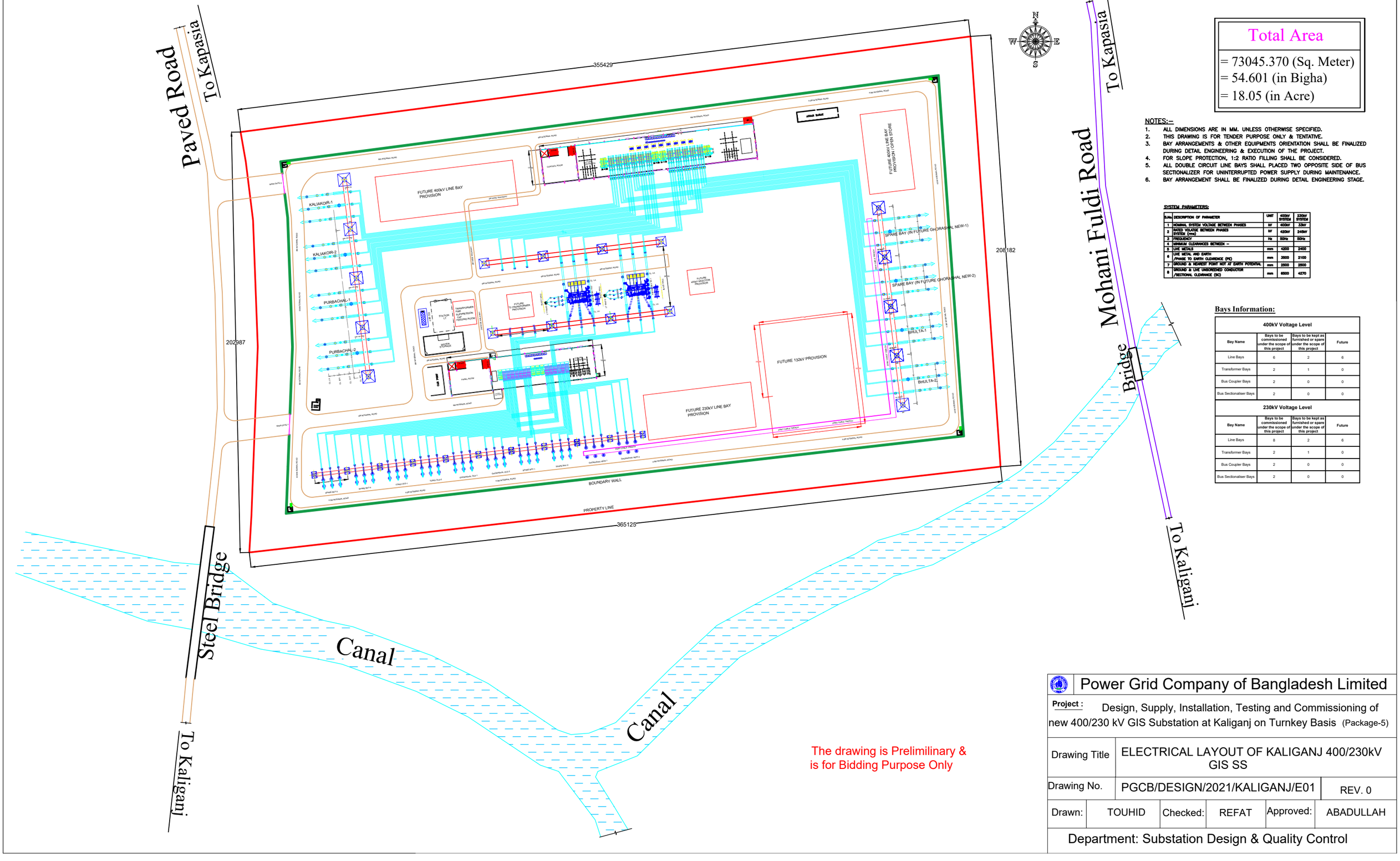


Total Area
= 73045.370 (Sq. Meter)
= 54.601 (in Bigha)
= 18.05 (in Acre)

LEGEND:

Sub Station Boundary		Semipucca	SP
Boundary Wall		Building	
Proposed Tower		Tinshed	
Homestead Boundary		Angle Point	
Canal / River		Pond / Fishery	
Pavement Road		Graveyard /Tree	
HBB Road		Gate/Gas Riser	
Earthen Road		Manhole/Septic Tank	MH
Powerpole (EP)	EP EP	High Land	
Tubewell			

DRAWING NO.	PROJECT	LOCATION	SURVEYED BY :	
PGCB/DESIGN/2021/KALIGANJ/MAP	Design, Supply, Installation, Testing and Commissioning of new 400/230 kV GIS Substation at Kaliganj on Turnkey Basis (Package-5)	**AREA SURVEY BY DIGITAL SURVEY EQUIPMENT** EXISTING PHYSICAL FEATURES SURVEY **Proposed Kaliganj Sub - Station** **400/230 kV Indoor GIS Substation** **Phuldi, Kaliganj, Dhaka.**	SURVEYED BY : / Drawn BY : / Analysis & Programmer / CHECKED BY :	DATE : 10-10-2021 SCALE = 1 : 1700 (A3) Sheet no : N/A



Total Area
= 73045.370 (Sq. Meter)
= 54.601 (in Bigha)
= 18.05 (in Acre)

NOTES:–

1. ALL DIMENSIONS ARE IN MM. UNLESS OTHERWISE SPECIFIED.
2. THIS DRAWING IS FOR TENDER PURPOSE ONLY & TENTATIVE.
3. BAY ARRANGEMENTS & OTHER EQUIPMENTS ORIENTATION SHALL BE FINALIZED DURING DETAIL ENGINEERING & EXECUTION OF THE PROJECT.
4. FOR SLOPE PROTECTION, 1:2 RATIO FILLING SHALL BE CONSIDERED.
5. ALL DOUBLE CIRCUIT LINE BAYS SHALL PLACED TWO OPPOSITE SIDE OF BUS SECTIONALIZER FOR UNINTERRUPTED POWER SUPPLY DURING MAINTENANCE.
6. BAY ARRANGEMENT SHALL BE FINALIZED DURING DETAIL ENGINEERING STAGE.

SYSTEM PARAMETERS:

S.No.	DESCRIPTION OF PARAMETER	UNIT	400kV SYSTEM	230kV SYSTEM
1	NOMINAL SYSTEM VOLTAGE BETWEEN PHASES	kV	400kV	33kV
2	RATED VOLATGE BETWEEN PHASES SYSTEM (rms)	kV	420kV	245kV
3	FREQUENCY	Hz	50Hz	50Hz
4	MINIMUM CLEARANCES BETWEEN –			
5	LIVE METALS	mm	4200	2400
6	LIVE METAL AND EARTH /PHASE TO EARTH CLEARANCE (PE)	mm	3500	2100
7	GROUND & NEAREST POINT NOT AT EARTH POTENTIAL	mm	2500	2500
8	GROUND & LIVE UNSCREENED CONDUCTOR /SECTIONAL CLEARANCE (SC)	mm	6600	4270

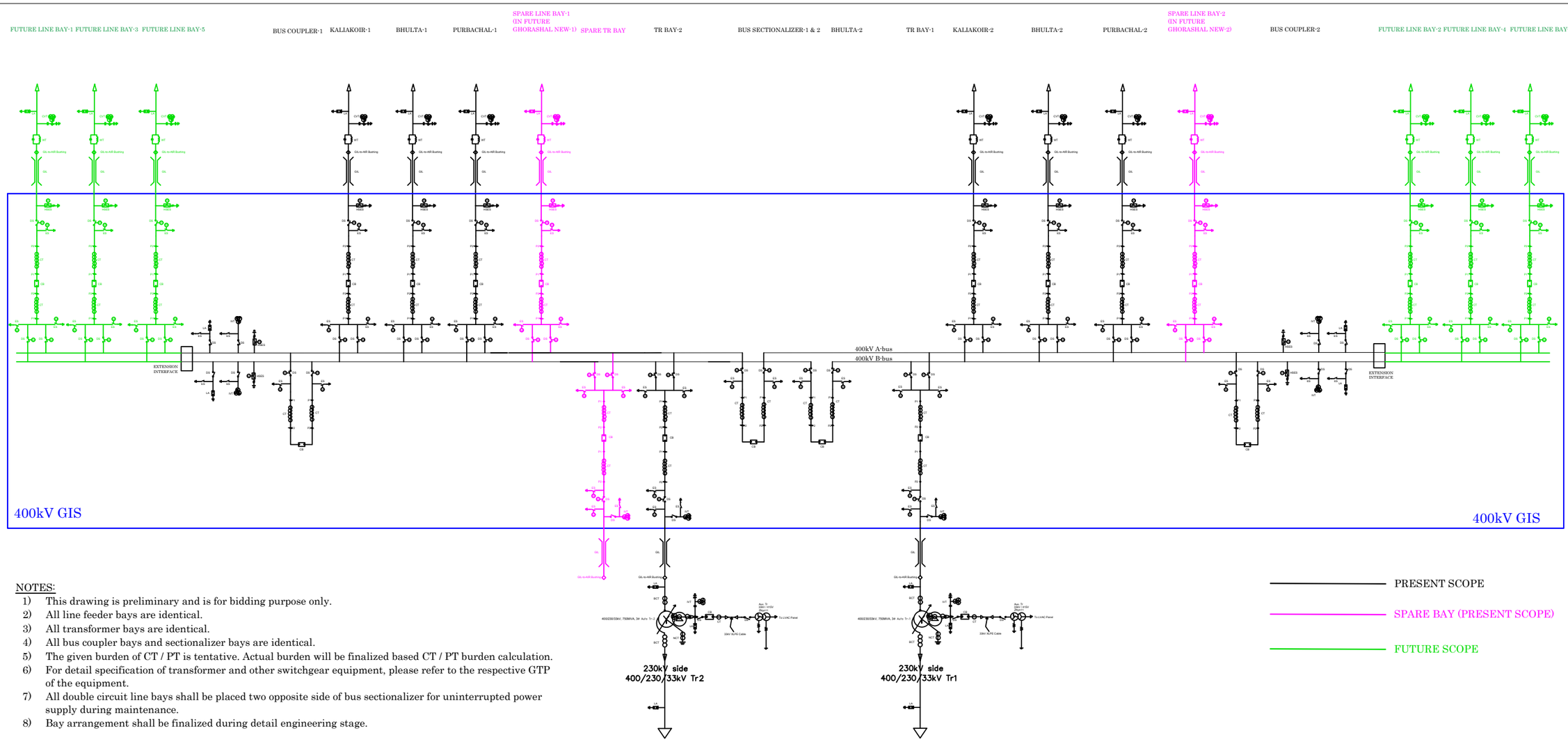
Bays Information:

400kV Voltage Level			
Bay Name	Bays to be commissioned under the scope of this project	Bays to be kept as furnished or spare under the scope of this project	Future
Line Bays	6	2	6
Transformer Bays	2	1	0
Bus Coupler Bays	2	0	0
Bus Sectionaliser Bays	2	0	0

230kV Voltage Level			
Bay Name	Bays to be commissioned under the scope of this project	Bays to be kept as furnished or spare under the scope of this project	Future
Line Bays	8	2	6
Transformer Bays	2	1	0
Bus Coupler Bays	2	0	0
Bus Sectionaliser Bays	2	0	0

The drawing is Prelimilinary & is for Bidding Purpose Only

Power Grid Company of Bangladesh Limited					
Project : Design, Supply, Installation, Testing and Commissioning of new 400/230 kV GIS Substation at Kaliganj on Turnkey Basis (Package-5)					
Drawing Title	ELECTRICAL LAYOUT OF KALIGANJ 400/230kV GIS SS				
Drawing No.	PGCB/DESIGN/2021/KALIGANJ/E01				REV. 0
Drawn:	TOUHID	Checked:	REFAT	Approved:	ABADULLAH
Department: Substation Design & Quality Control					



NOTES:

1) This drawing is preliminary and is for bidding purpose only.
2) All line feeder bays are identical.
3) All transformer bays are identical.
4) All bus coupler bays and sectionalizer bays are identical.
5) The given burden of CT / PT is tentative. Actual burden will be finalized based CT / PT burden calculation.
6) For detail specification of transformer and other switchgear equipment, please refer to the respective GTP of the equipment.
7) All double circuit line bays shall be placed two opposite side of bus sectionalizer for uninterrupted power supply during maintenance.
8) Bay arrangement shall be finalized during detail engineering stage.

PRESENT SCOPE

SPARE BAY (PRESENT SCOPE)

FUTURE SCOPE

Line Feeder Bay Specification		
Equipment	Symbol	Rating
AIS LA		U_r-396kV, U_c-317kV, 10kA
AIS CVT		Core i: Core ii: Core iii:
AIS WT		420kV, 4000A, 1mH, 63kA/3sec
HSES		63kA/3sec
DS (Line side)		4000A, 63kA/3sec
CT (Line side)		4000-2000/1A, 63kA/3sec Core i: Core ii:
CB		Single Pole, 4000A, 63kA/3sec
CT (Bus side)		4000-2000/1A, 63kA/3sec Core i: Core ii: Core iii: Core iv:
DS (Bus side)		4000A, 63kA/3sec

Transformer Bay Specification		
Equipment	Symbol	Rating
Transformer		750MVA, 3ϕ, Auto Tr
AIS LA		U_r-396kV, U_c-317kV, 10kA
IVT with externally operated isolation link (without degassing)		Core i: Core ii: Core iii:
DS (Tr side)		4000A, 63kA/3sec
CT (Tr side)		4000-2000/1A, 63kA/3sec Core i: Core ii:
CB		Single Pole, 4000A, 63kA/3sec
CT (Bus side)		4000-2000/1A, 63kA/3sec Core i: Core ii: Core iii: Core iv:
DS (Bus side)		4000A, 63kA/3sec

Bus, Bus Coupler Bay, & Bus Sectionalizer Bay Specification		
Equipment	Symbol	Rating
Bus Scheme & Capacity		Double Bus, 5000A, 63kA/3sec
BUS IVT with externally operated isolation link (without degassing)		Core i: Core ii: Core iii:
BUS LA		U_r-390kV, U_c-312kV, 10kA
BUS HSES		63kA/3sec
DS (Bus Side)		5000A, 63kA/3sec
CT1		5000-2500/1A, 63kA/3sec Core i: Core ii: Core iii: Core iv:
CB		Single Pole, 5000A, 63kA/3sec
CT2		5000-2500/1A, 63kA/3sec Core i: Core ii: Core iii: Core iv:

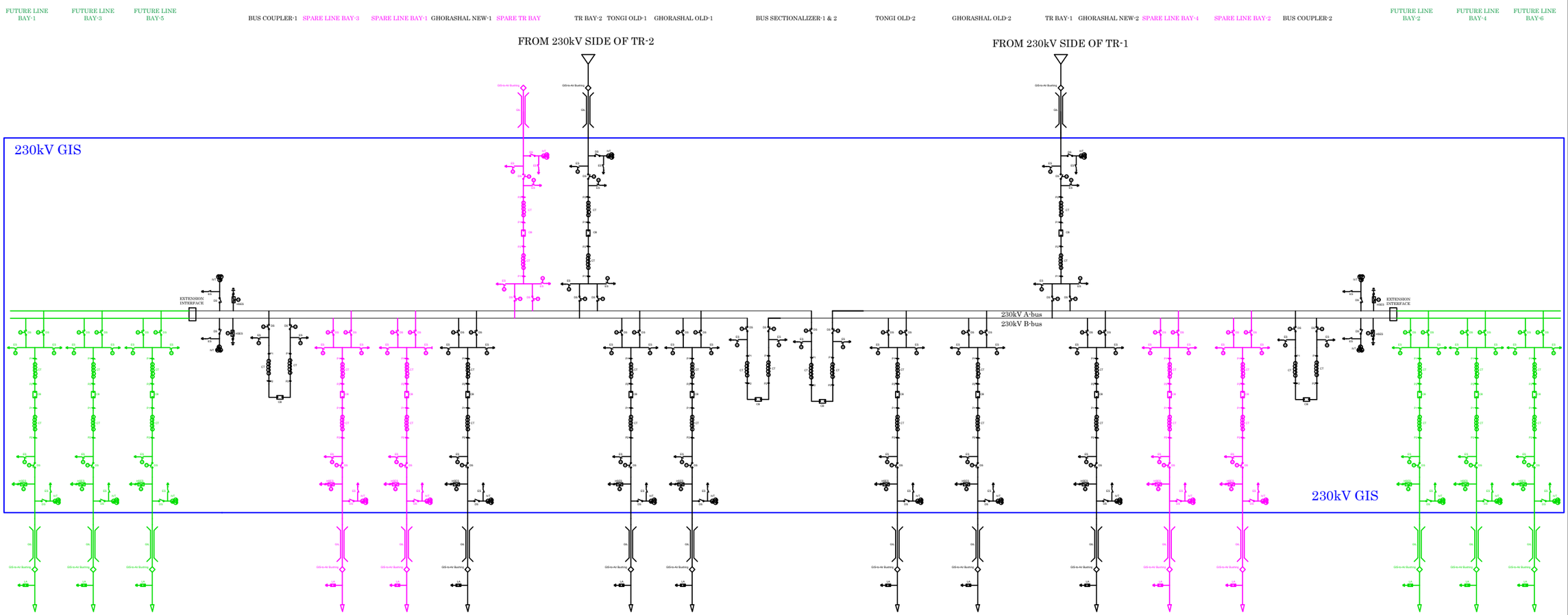
The drawing is Prelimilinary & is for Bidding Purpose Only

Power Grid Company of Bangladesh Limited

Project : Design, Supply, Installation, Testing and Commissioning of new 400/230 kV GIS Substation at Kaliganj on Turnkey Basis (Package-5)

Drawing Title	Single Line Diagram: KALIGANJ 400/230kV GIS SS (400kV Side)				
Drawing No.	PGCB/DESIGN/2021/KALIGANJ/E02			REV. 0	
Drawn:	TOUHID	Checked:	REFAT	Approved:	ABADULLAH

Department: Substation Design & Quality Control



Line Feeder Bay Specification		
Equipment	Symbol	Rating
AIS LA		U_r-198kV, U_c-158kV, 10kA
IVT with externally operated isolation link (without degassing)		Core i: Core ii: Core iii:
HSES		63kA/3sec
DS (Line side)		3150A, 63kA/3sec
CT (Line side)		3200-1600/1A, 63kA/3sec Core i: Core ii:
CB		Single Pole, 3150A, 63kA/3sec
CT (Bus side)		3200-1600/1A, 63kA/3sec Core i: Core ii: Core iii:
DS (Bus side)		3150A, 63kA/3sec

Transformer Bay Specification		
Equipment	Symbol	Rating
AIS LA		U_r-198kV, U_c-158kV, 10kA
IVT with externally operated isolation link (without degassing)		Core i: Core ii: Core iii:
DS (Tr side)		3150A, 63kA/3sec
CT (Tr side)		3200-1600/1A, 63kA/3sec Core i: Core ii:
CB		Triple Pole, 3150A, 63kA/3sec
CT (Bus side)		3200-1600/1A, 63kA/3sec Core i: Core ii: Core iii:
DS (Bus side)		3150A, 63kA/3sec

Bus, Bus Coupler Bay, & Bus Sectionalizer Bay Specification		
Equipment	Symbol	Rating
Bus Scheme & Capacity		Double Bus, 4000A, 63kA/3sec
BUS IVT with externally operated isolation link (without degassing)		Core i: Core ii: Core iii:
BUS HSES		63kA/3sec
DS (Bus Side)		4000A, 63kA/3sec
CT1 (BUS COUPLER)		4000-2000/1A, 63kA/3sec Core i: Core ii: Core iii:
CB		Triple Pole, 4000A, 63kA/3sec
CT2 (BUS COUPLER)		4000-2000/1A, 63kA/3sec Core i: Core ii: Core iii:
CT1 (BUS SECTIONALIZER)		4000-2000/1A, 63kA/3sec Core i: Core ii: Core iii:
CT2 (BUS SECTIONALIZER)		4000-2000/1A, 63kA/3sec Core i: Core ii: Core iii:

NOTES:

1) This drawing is preliminary and is for bidding purpose only.
2) All line feeder bays are identical.
3) All transformer bays are identical.
4) All bus coupler bays and sectionalizer bays are identical.
5) The given burden of CT / PT is tentative. Actual burden will be finalized based CT / PT burden calculation.
6) For detail specification of transformer and other switchgear equipment, please refer to the respective GTP of the equipment.
7) All double circuit line bays shall be placed two opposite side of bus sectionalizer for uninterrupted power supply during maintenance.
8) Bay arrangement shall be finalized during detail engineering stage.

The drawing is Prelimilinary & is for Bidding Purpose Only

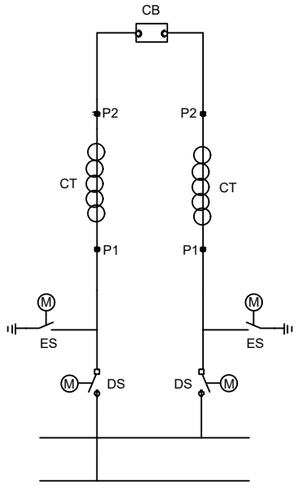
Power Grid Company of Bangladesh Limited

Project : Design, Supply, Installation, Testing and Commissioning of new 400/230 kV GIS Substation at Kaliganj on Turnkey Basis (Package-5)

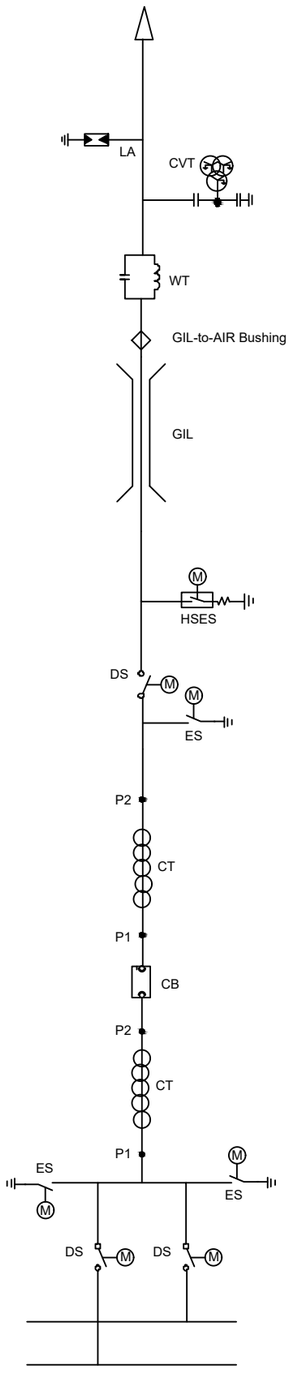
Drawing Title	Single Line Diagram: KALIGANJ 400/230kV GIS SS (230kV Side)				
Drawing No.	PGCB/DESIGN/2021/KALIGANJ/E03			REV.	0
Drawn:	TOUHID	Checked:	REFAT	Approved:	ABADULLAH

Department: Substation Design & Quality Control

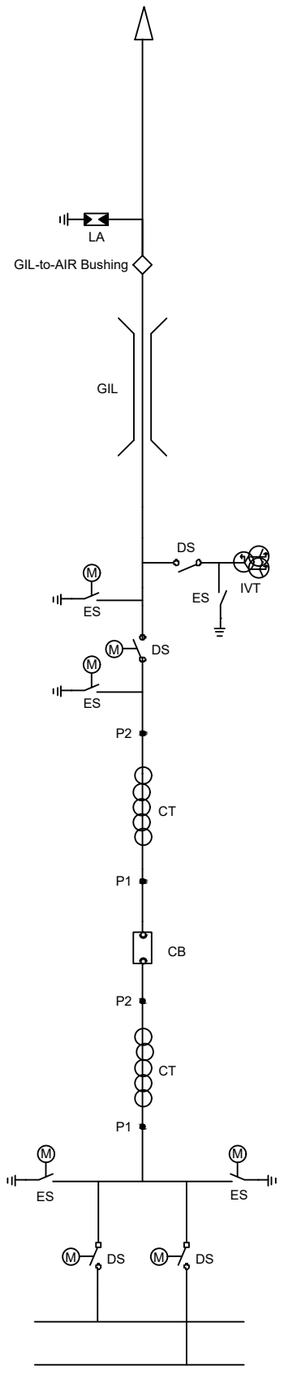
TYPICAL BUS COUPLER BAY



TYPICAL LINE BAY



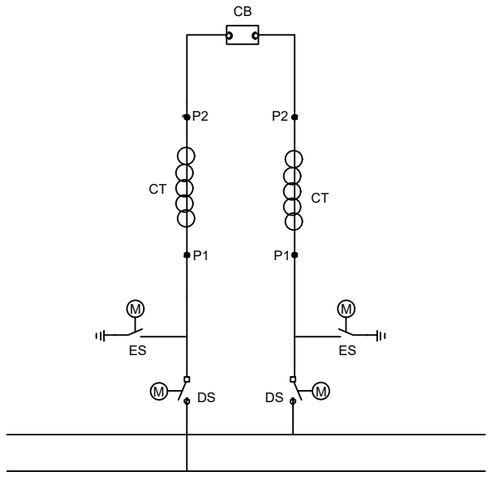
TYPICAL TRANSFORMER BAY



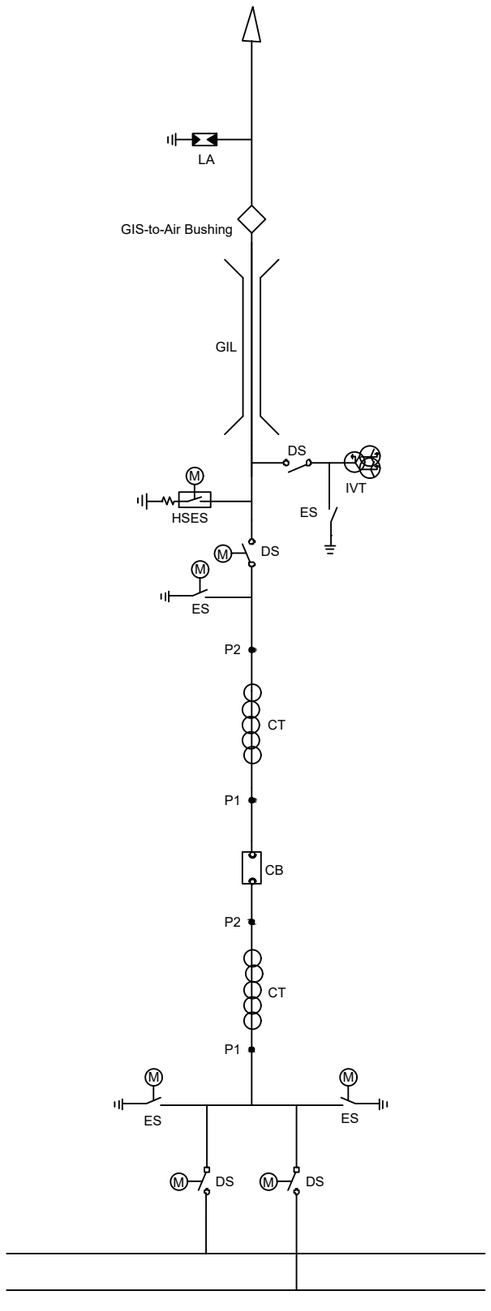
The drawing is Prelimilinary & is for Bidding Purpose Only

Power Grid Company of Bangladesh Limited					
Project : Design, Supply, Installation, Testing and Commissioning of new 400/230 kV GIS Substation at Kaliganj on Turnkey Basis (Package-5)					
Drawing Title	TYPICAL BAY CONFIGURATION OF KALIGANJ 400/230/132kV GIS SS (400kV Side)				
Drawing No.	PGCB/DESIGN/2021/KALIGANJ/E04				REV. 0
Drawn:	TOUHID	Checked:	REFAT	Approved:	ABADULLAH
Department: Substation Design & Quality Control					

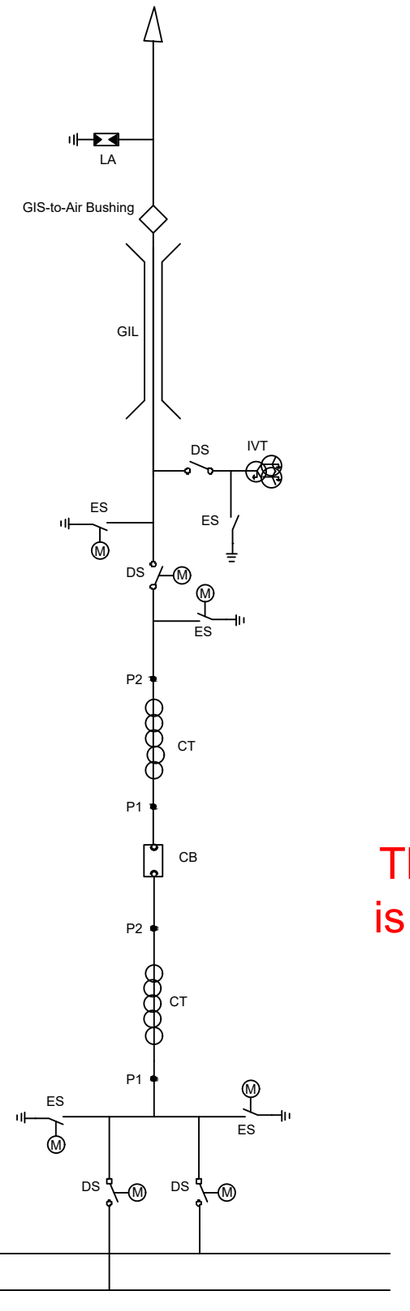
TYPICAL BUS COUPLER BAY



TYPICAL LINE BAY

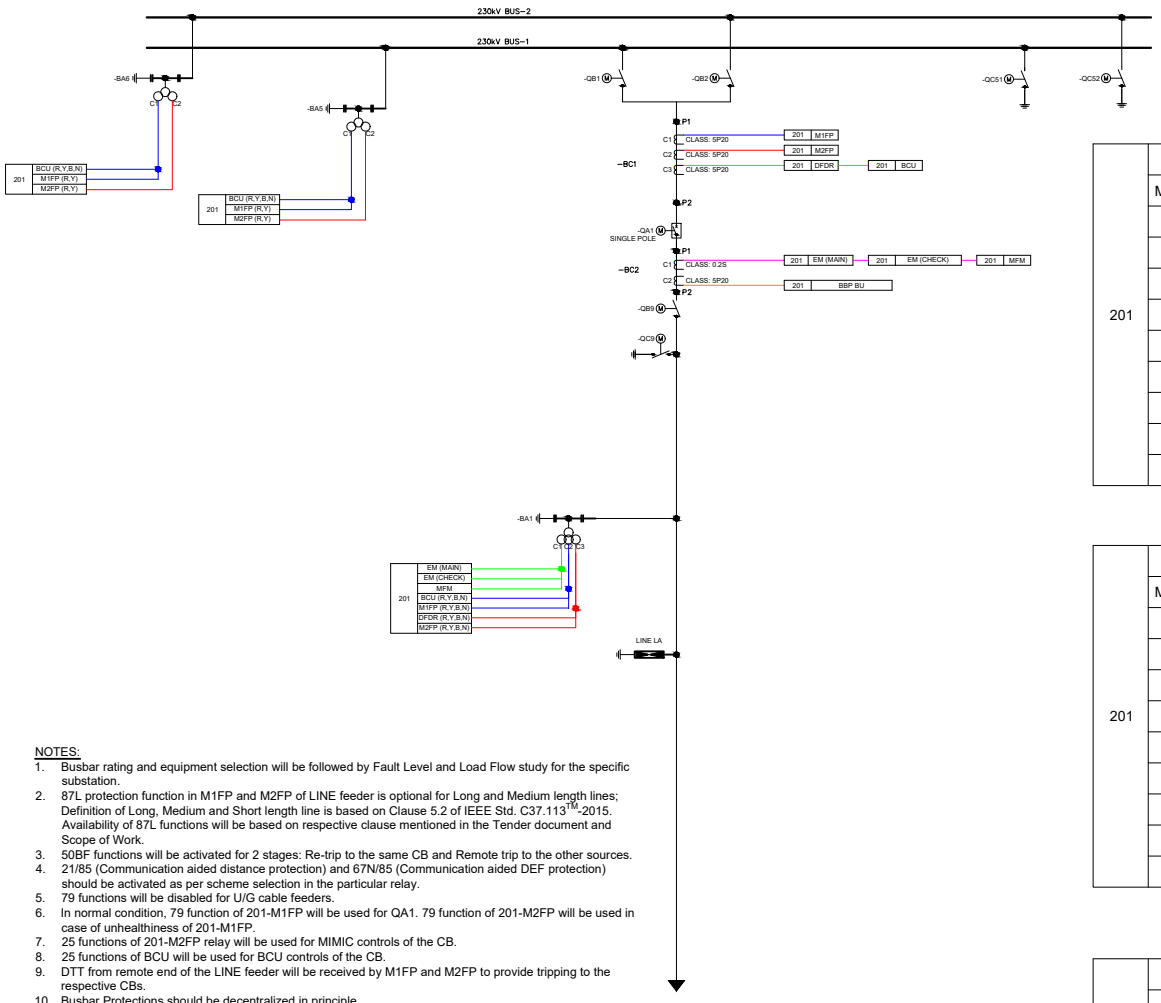


TYPICAL TRANSFORMER BAY



The drawing is Prelimilinary & is for Bidding Purpose Only

Power Grid Company of Bangladesh Limited					
Project : Design, Supply, Installation, Testing and Commissioning of new 400/230 kV GIS Substation at Kaliganj on Turnkey Basis (Package-5)					
Drawing Title	TYPICAL BAY CONFIGURATION OF KALIGANJ 400/230/132kV GIS SS (230kV Side)				
Drawing No.	PGCB/DESIGN/2021/KALIGANJ/E05				REV. 0
Drawn:	TOUHID	Checked:	REFAT	Approved:	ABADULLAH
Department: Substation Design & Quality Control					



NOTES:

1. Busbar rating and equipment selection will be followed by Fault Level and Load Flow study for the specific substation.
2. 87L protection function in M1FP and M2FP of LINE feeder is optional for Long and Medium length lines; Definition of Long, Medium and Short length line is based on Clause 5.2 of IEEE Std. C37.113™-2015. Availability of 87L functions will be based on respective clause mentioned in the Tender document and Scope of Work.
3. 50BF functions will be activated for 2 stages: Re-trip to the same CB and Remote trip to the other sources.
4. 21/85 (Communication aided distance protection) and 67N/85 (Communication aided DEF protection) should be activated as per scheme selection in the particular relay.
5. 79 functions will be disabled for U/G cable feeders.
6. In normal condition, 79 function of 201-M1FP will be used for QA1. 79 function of 201-M2FP will be used in case of unhealthiness of 201-M1FP.
7. 25 functions of 201-M2FP relay will be used for MIMIC controls of the CB.
8. 25 functions of BCU will be used for BCU controls of the CB.
9. DTT from remote end of the LINE feeder will be received by M1FP and M2FP to provide tripping to the respective CBs.
10. Busbar Protections should be decentralized in principle.
11. For 50BF Remote Trip of Bus CBs, tripping will be issued to all CBs connected to the respective Busbar; the trip logic will be implemented internally with BBP Central Unit.
12. Optical Multiplexer based communication should be established between both end substations of the LINE feeder.
13. Main-1 and Main-2 LINE protection relays, BBP relays and BFP relays should preferably of different manufacturer. Alternatively, different model of the same manufacturer.
14. Voltage Transformers in GIS will be either CVT or IVT depending on manufacturer's practice.
15. The PSLD is for conceptualization of protection philosophy; it does not represent actual configurations for switching objects of GIS.
16. Any aspect mentioned in the Standard Document may be superseded by the Tender document and Scope of Work depending on specific application.

	M1FP	
	MAIN-1 FEEDER PROTECTION	
201	87L	51/51N
	21	50/50N
	21/85	46BC
	67N/85	27
	SOTF	59
	68	79 (QA1)
	VTFF	25 (QA1)
	21FL	DDR
	67/67N	

	M2FP	
	MAIN-2 FEEDER PROTECTION	
201	87L	51/51N
	21	50/50N
	21/85	46BC
	67N/85	27
	SOTF	59
	68	79 (QA1)
	VTFF	25 (QA1)
	21FL	DDR
	67/67N	

	BCU	
	BAY CONTROL UNIT	
201	kV	25 (QA1)
	A	CONTROL
	MW	INTERLOCK
	MVAR	

	EM (MAIN)	
	ENERGY METER	
201	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

	EM (CHECK)	
	ENERGY METER	
201	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

	MFM	
	MULTIFUNCTION METER	
201	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

	BBP BU	
	BUSBAR PROTECTION BAY UNIT	
201	87B	50BF
	EFP	

TENDER PURPOSE ONLY

REVISION	DATE	REMARKS
1	10.06.2020	AS PER SSD'S COMMENTS
0	08.04.2020	FIRST PREPARATION

STANDARD DOCUMENT NUMBER: 08

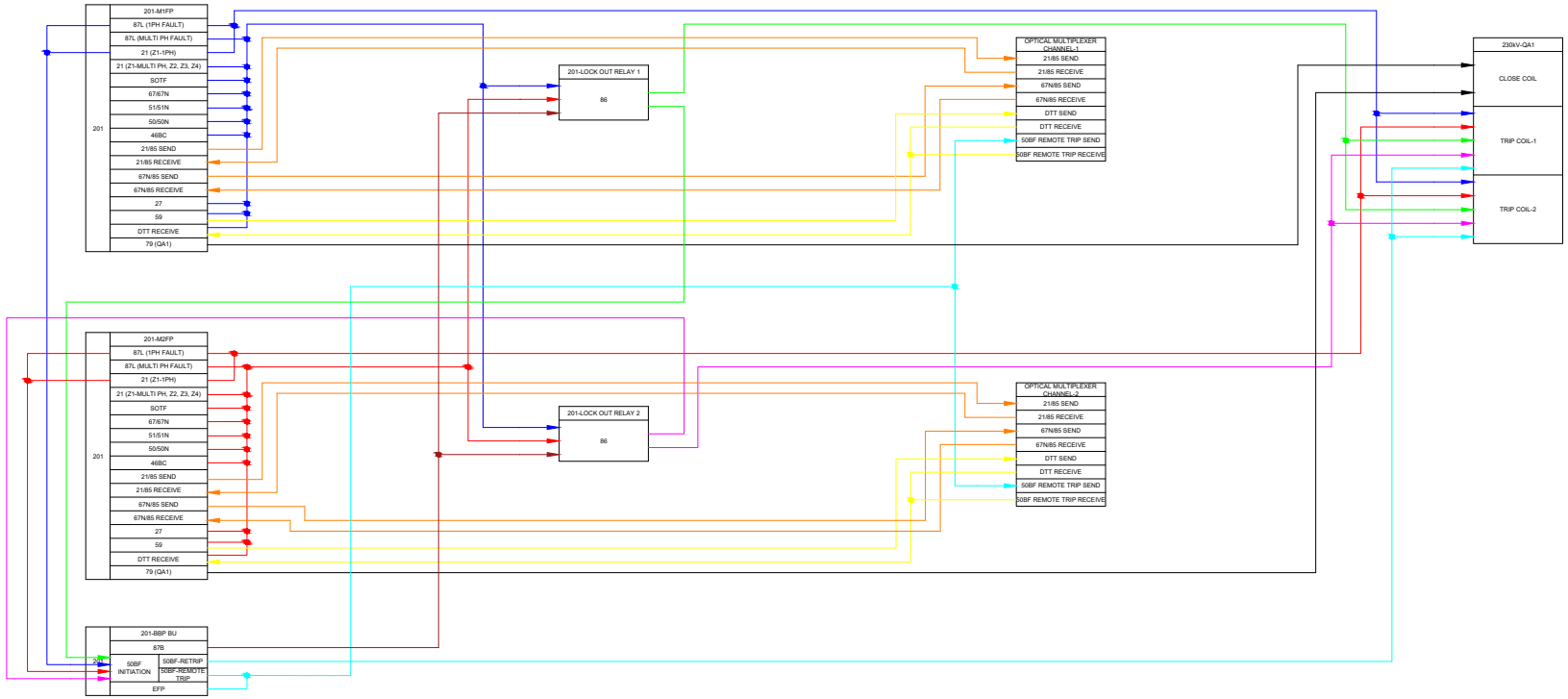
POWER GRID COMPANY OF BANGLADESH LTD.

TITLE: PROTECTION SLD & TRIP LOGIC OF 230kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR LINE FEEDER

DOCUMENT ID: PGCB_DESIGN_2021_KALIGANJ_E06

SHEET 1 of 2

NEXT SHT 2



TENDER PURPOSE ONLY

REVISION	DATE	REMARKS
1	10.06.2020	AS PER SSD'S COMMENTS
0	08.04.2020	FIRST PREPARATION

STANDARD DOCUMENT NUMBER: 08

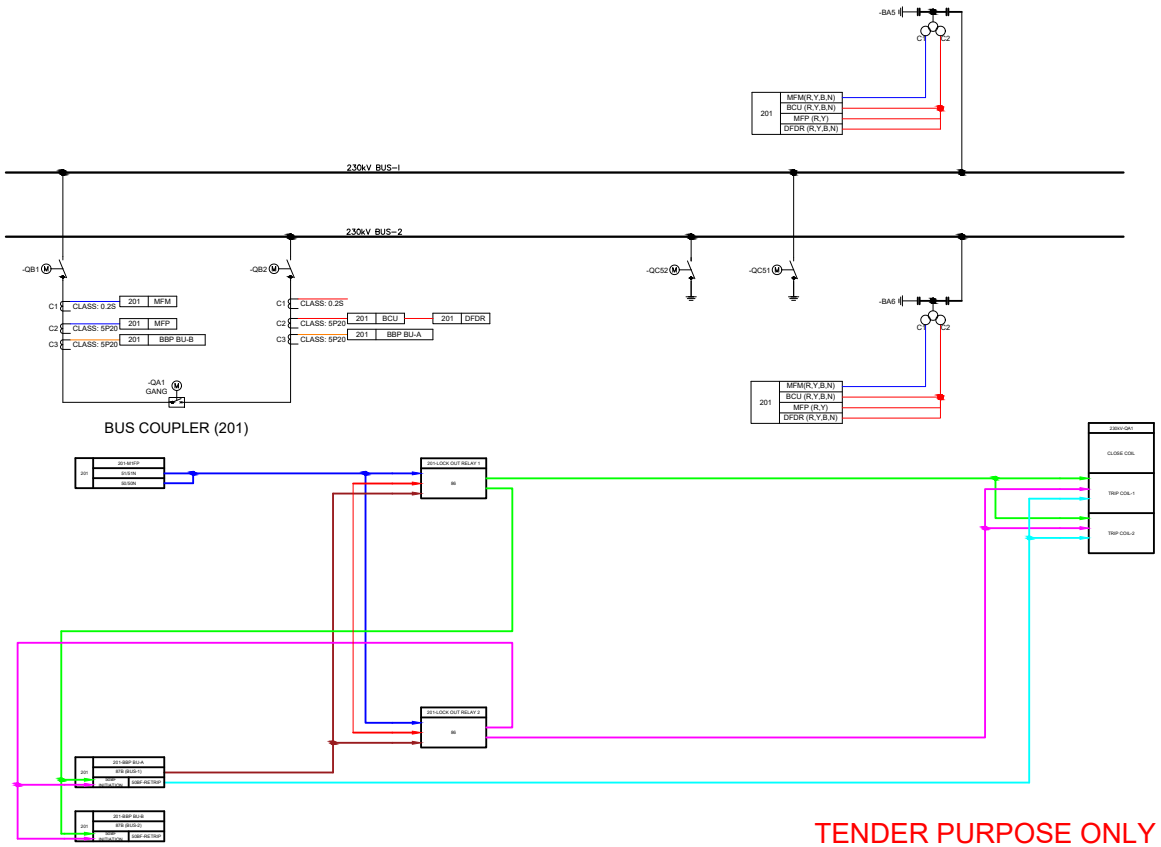
POWER GRID COMPANY OF BANGLADESH LTD.

TITLE: PROTECTION SLD & TRIP LOGIC OF 230kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR LINE FEEDER

DOCUMENT ID: PGCB_DESIGN_2021_KALIGANJ_E06

SHEET 2 of 2

NEXT SHT N/A



TENDER PURPOSE ONLY

201	MFP
	MAIN-1 FEEDER PROTECTION
	51/51N / DDR
	50/50N / 25 (QA1)

201	BCU
	BAY CONTROL UNIT
	kV / 25 (QA1)
	A / CONTROL
	MW / INTERLOCK
	MVAR /

201	MFM
	MULTIFUNCTION METER
	kV / FREQ
	A / PF
	MW / kWh
	MVAR / kVARh

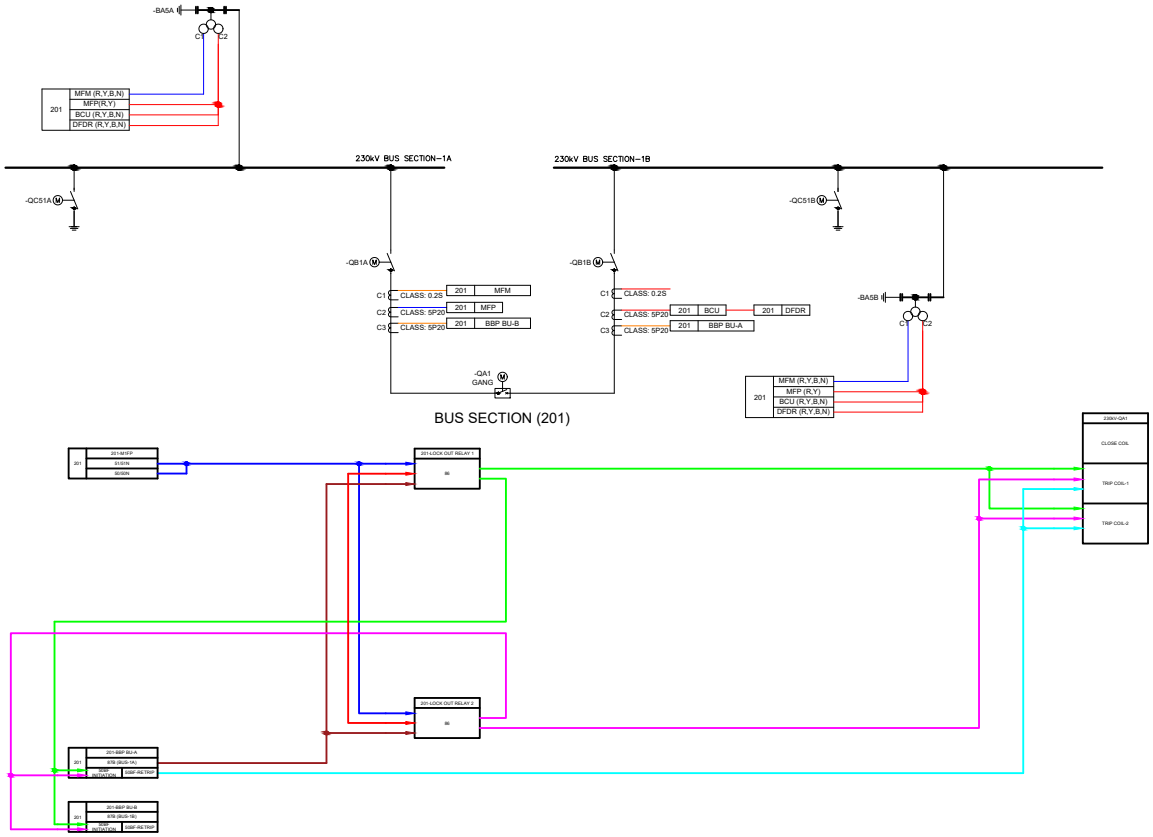
201	BBP BU-A
	BUSBAR PROTECTION BAY UNIT-A
	87B (BUS-1) / 50BF

201	BBP BU-B
	BUSBAR PROTECTION BAY UNIT-B
	87B (BUS-2) / 50BF

NOTES:

1. Busbar rating and equipment selection will be followed by Fault Level and Load Flow study for the specific substation.
2. 50BF functions will be activated for 1 stage: Re-trip to the same CB.
3. 25 functions of 201-MFP relay will be used for MIMIC controls of the CB.
4. 25 functions of BCU will be used for BCU controls of the CB.
5. Busbar Protections should be decentralized in principle.
6. For 50BF Remote Trip of Bus Coupler CB, tripping will be issued to all CBs connected to both Busbars; the trip logic will be implemented internally with BBP Central Unit.
7. BBP BU-B will be used for CT measurement for the respective Busbar. Tripping will be issued from BBP BU-A for both Bus Zone Trip.
8. Main-1 and Main-2 FEEDER protection relays should preferably of different manufacturer. Alternatively, different model of the same manufacturer.
9. Voltage Transformers in GIS will be either CVT or IVT depending on manufacturer's practice.
10. The PSLD is for conceptualization of protection philosophy; it does not represent actual configurations for switching objects of GIS.
11. Any aspect mentioned in the Standard Document may be superseded by the Tender document and Scope of Work depending on specific application.

REVISION	DATE	REMARKS	STANDARD DOCUMENT NUMBER: 13A	POWER GRID COMPANY OF BANGLADESH LTD.	TITLE: PROTECTION SLD & TRIP LOGIC OF 230kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR BUS COUPLER FEEDER	SHEET 1
0	13.07.2020	FIRST PREPARATION			DOCUMENT ID: PGCB_DESIGN_2021_KALIGANJ_E07	NEXT SHT N/A



NOTES:

1. Busbar rating and equipment selection will be followed by Fault Level and Load Flow study for the specific substation.
2. 50BF functions will be activated for 1 stage: Re-trip to the same CB.
3. 25 functions of 201-MFP relay will be used for MIMIC controls of the CB.
4. 25 functions of BCU will be used for BCU controls of the CB.
5. Busbar Protections should be decentralized in principle.
6. For 50BF Remote Trip of Bus Coupler CB, tripping will be issued to all CBs connected to both Busbars; the trip logic will be implemented internally with BBP Central Unit.
7. BBP BU-B will be used for CT measurement for the respective Busbar. Tripping will be issued from BBP BU-A for both Bus Zone Trip.
8. Main-1 and Main-2 FEEDER protection relays should preferably of different manufacturer. Alternatively, different model of the same manufacturer.
9. Voltage Transformers in GIS will be either CVT or IVT depending on manufacturer's practice.
10. The PSLD is for conceptualization of protection philosophy; it does not represent actual configurations for switching objects of GIS.
11. Any aspect mentioned in the Standard Document may be superseded by the Tender document and Scope of Work depending on specific application.

201	MFP	
	MAIN-1 FEEDER PROTECTION	
	51/51N	DDR
	50/50N	25(QA1)

201	BCU	
	BAY CONTROL UNIT	
	kV	25 (QA1)
	A	CONTROL
	MW	INTERLOCK
	MVAR	

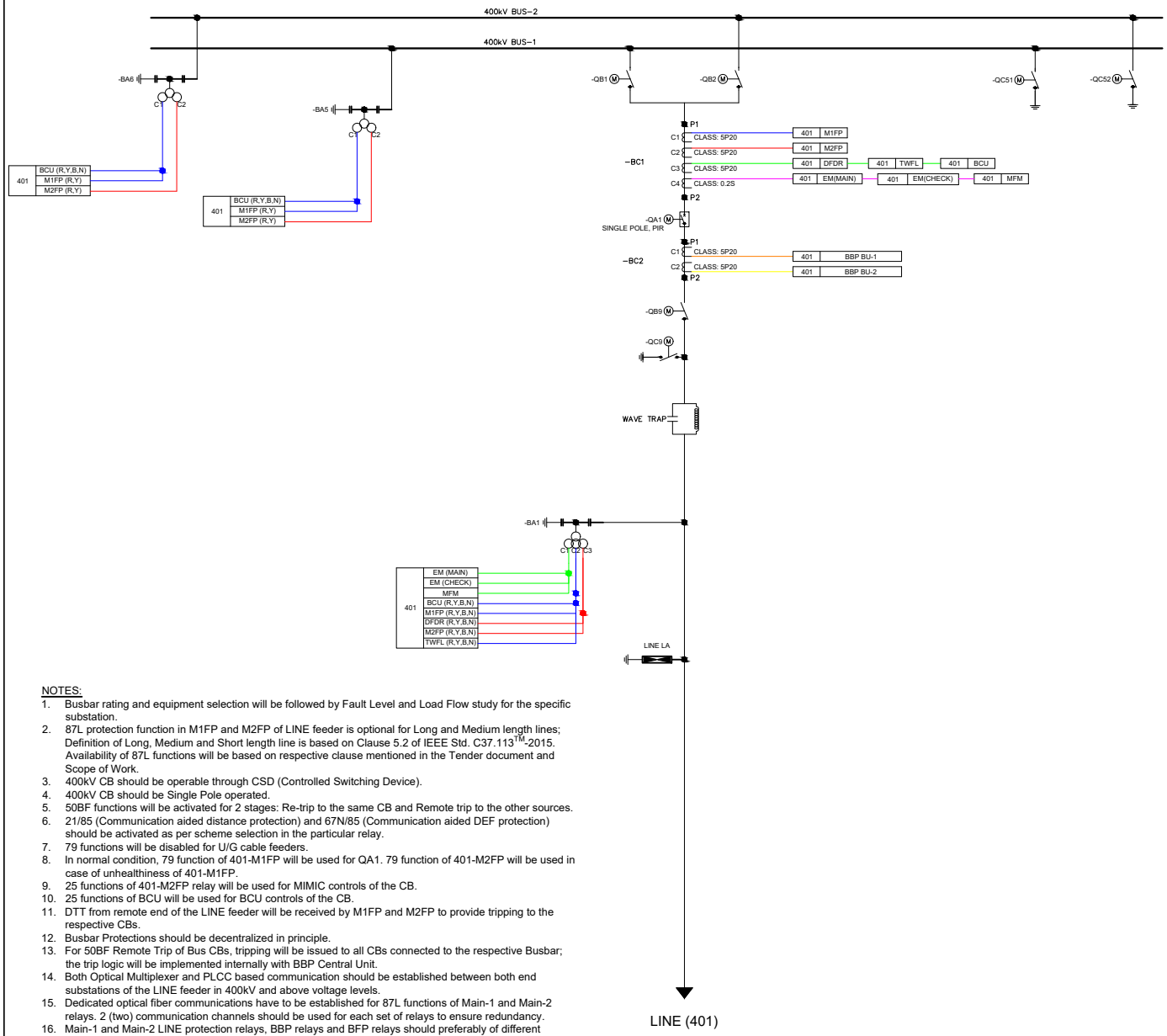
201	MFM	
	MULTIFUNCTION METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

201	BBP BU-A	
	BUSBAR PROTECTION BAY UNIT-A	
	87B (BUS-1A)	50BF

201	BBP BU-B	
	BUSBAR PROTECTION BAY UNIT-B	
	87B (BUS-1B)	50BF

TENDER PURPOSE ONLY

			STANDARD DOCUMENT NUMBER: 14A	POWER GRID COMPANY OF BANGLADESH LTD.	TITLE: PROTECTION SLD & TRIP LOGIC OF 230kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR BUS SECTION FEEDER	SHEET 1
0	16.07.2020	FIRST PREPARATION			DOCUMENT ID: PGCB_DESIGN_2021_KALIGANJ_E08	NEXT SHT N/A
REVISION	DATE	REMARKS				



NOTES:

1. Busbar rating and equipment selection will be followed by Fault Level and Load Flow study for the specific substation.
2. 87L protection function in M1FP and M2FP of LINE feeder is optional for Long and Medium length lines; Definition of Long, Medium and Short length line is based on Clause 5.2 of IEEE Std. C37.113™-2015. Availability of 87L functions will be based on respective clause mentioned in the Tender document and Scope of Work.
3. 400kV CB should be operable through CSD (Controlled Switching Device).
4. 400kV CB should be Single Pole operated.
5. 50BF functions will be activated for 2 stages: Re-trip to the same CB and Remote trip to the other sources.
6. 21/85 (Communication aided distance protection) and 67N/85 (Communication aided DEF protection) should be activated as per scheme selection in the particular relay.
7. 79 functions will be disabled for U/G cable feeders.
8. In normal condition, 79 function of 401-M1FP will be used for QA1. 79 function of 401-M2FP will be used in case of unhealthiness of 401-M1FP.
9. 25 functions of 401-M2FP relay will be used for MIMIC controls of the CB.
10. 25 functions of BCU will be used for BCU controls of the CB.
11. DTT from remote end of the LINE feeder will be received by M1FP and M2FP to provide tripping to the respective CBs.
12. Busbar Protections should be decentralized in principle.
13. For 50BF Remote Trip of Bus CBs, tripping will be issued to all CBs connected to the respective Busbar; the trip logic will be implemented internally with BBP Central Unit.
14. Both Optical Multiplexer and PLCC based communication should be established between both end substations of the LINE feeder in 400kV and above voltage levels.
15. Dedicated optical fiber communications have to be established for 87L functions of Main-1 and Main-2 relays. 2 (two) communication channels should be used for each set of relays to ensure redundancy.
16. Main-1 and Main-2 LINE protection relays, BBP relays and BFP relays should preferably of different manufacturer. Alternatively, different model of the same manufacturer.
17. TWFL (Traveling Wave Fault Locator) may be either single ended or double ended in terms of operating mechanism; if double ended, devices in both ends should be provided, installed and tested by the the contractor.
18. Voltage Transformers in GIS will be either CVT or IVT depending on manufacturer's practice.
19. The PSLD is for conceptualization of protection philosophy; it does not represent actual configurations for switching objects of GIS.
20. Any aspect mentioned in the Standard Document may be superseded by the Tender document and Scope of Work depending on specific application.

401	M1FP	
	MAIN-1 FEEDER PROTECTION	
	87L	51/51N
	21	50/50N
	21/85	46BC
	67N/85	27
	SOTF	59
	68	79 (QA1)
	VTFF	25 (QA1)
	21FL	DDR
	67/67N	

401	BBP BU-1	
	BUSBAR PROTECTION BAY UNIT-1	
	87B	50BF

401	BBP BU-2	
	BUSBAR PROTECTION BAY UNIT-2	
	87B	50BF

401	EM (MAIN)	
	ENERGY METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

401	M2FP	
	MAIN-2 FEEDER PROTECTION	
	87L	51/51N
	21	50/50N
	21/85	46BC
	67N/85	27
	SOTF	59
	68	79 (QA1)
	VTFF	25 (QA1)
	21FL	DDR
	67/67N	

401	EM (CHECK)	
	ENERGY METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

401	BCU	
	BAY CONTROL UNIT	
	kV	25 (QA1)
	A	CONTROL
	MW	INTERLOCK
	MVAR	

401	MFM	
	MULTIFUNCTION METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

TENDER PURPOSE ONLY

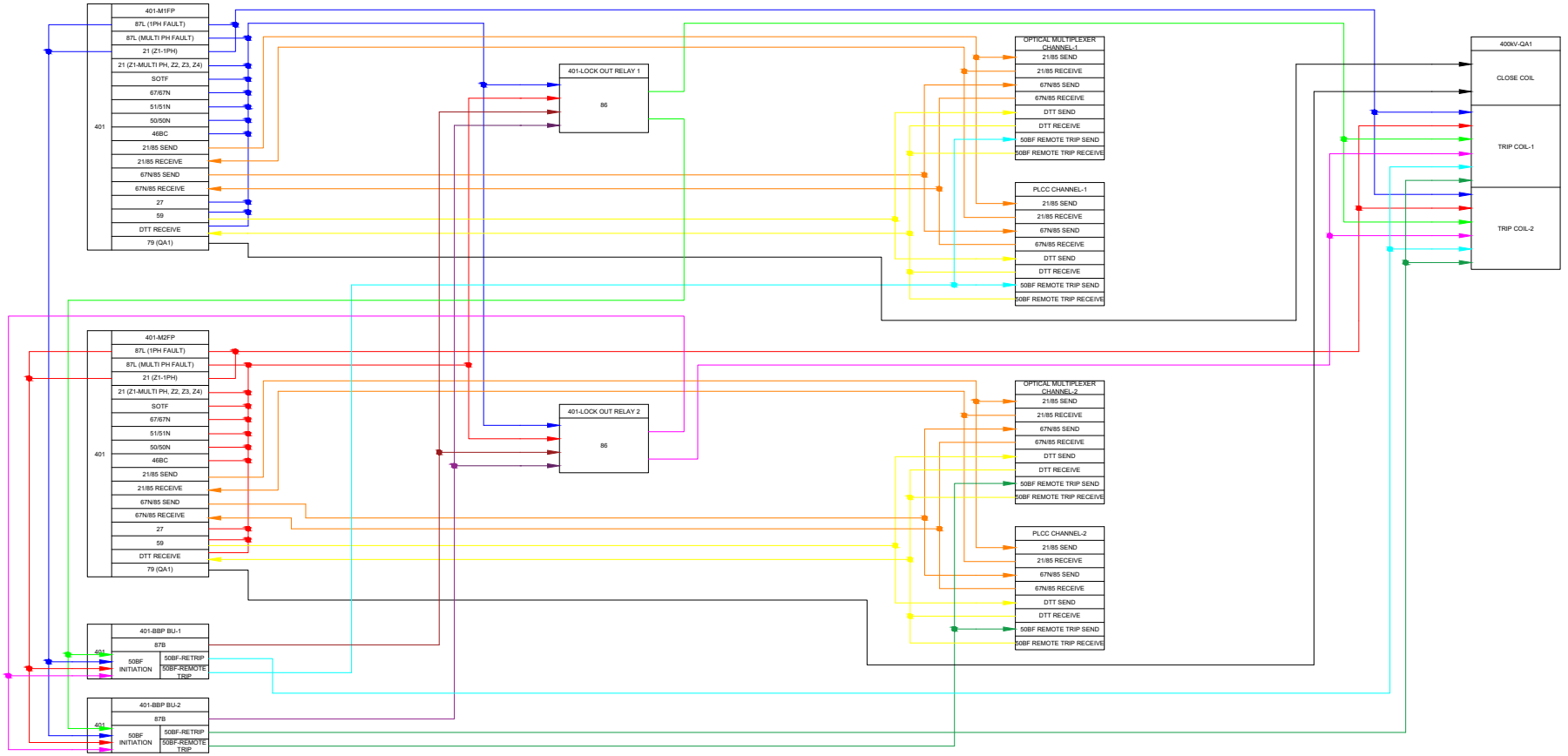
REVISION	DATE	REMARKS
1	10.06.2020	AS PER SSD'S COMMENTS
0	07.04.2020	FIRST PREPARATION

STANDARD DOCUMENT NUMBER: 16

POWER GRID COMPANY OF BANGLADESH LTD.

TITLE: PROTECTION SLD & TRIP LOGIC OF 400kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR LINE FEEDER WITHOUT REACTOR

DOCUMENT ID: PGCB_DESIGN_2021_KALIGANJ_E09



TENDER PURPOSE ONLY

REVISION	DATE	REMARKS
1	10.06.2020	AS PER SSD'S COMMENTS
0	07.04.2020	FIRST PREPARATION

STANDARD DOCUMENT NUMBER: 16

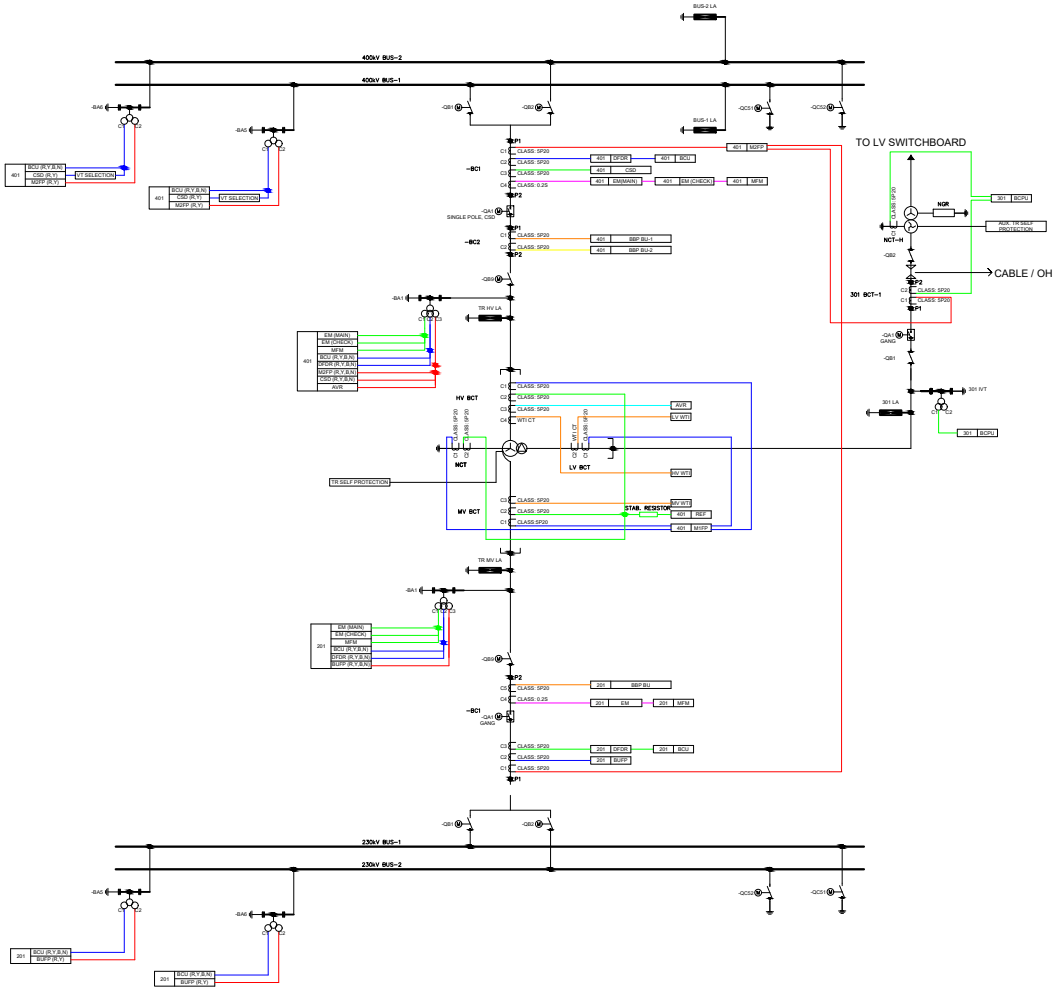
POWER GRID COMPANY OF BANGLADESH LTD.

TITLE: PROTECTION SLD & TRIP LOGIC OF 400kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR LINE FEEDER WITHOUT REACTOR

DOCUMENT ID: PGCB_DESIGN_2021_KALIGANJ_E09

SHEET 2 of 2

NEXT SHT N\A



NOTES:

1. Busbar rating and equipment selection will be followed by Fault Level and Load Flow study for the specific substation.
2. 400kV CB should be operable through CSD (Controlled Switching Device).
3. 400kV CBs should be Single Pole operated.
4. 50BF functions will be activated for 2 stages: Re-trip to the same CB and Remote trip to the other sources.
5. 25 function of 401-M2FP and 201-BUFP relays will be used for MIMIC controls of the respective CBs.
6. 25 functions of BCU will be used for BCU controls of the respective CBs.
7. Busbar Protections should be decentralized in principle.
8. For 50BF Remote Trip of Bus CBs, tripping will be issued to all CBs connected to the respective Busbar; the trip logic will be implemented internally with BBP Central Unit.
9. Main-1 and Main-2 Transformer protection relays, BBP relays and BFP relays should preferably of different manufacturer. Alternatively, different model of the same manufacturer.
10. Voltage Transformers in GIS will be either CVT or IVT depending on manufacturer's practice.
11. The PSLD is for conceptualization of protection philosophy; it does not represent actual configurations for switching objects of GIS.
12. Any aspect mentioned in the Standard Document may be superseded by the Tender document and Scope of Work depending on specific application.

401	M1FP	
	MAIN-1 FEEDER PROTECTION	
	87T1	50/50N (LV)
	87N (LOW IMP)	24
	67/67N (HV)	27
	51/51N (HV)	59
	50/50N (HV)	DDR
	51/51N (LV)	

401	M2FP	
	MAIN-2 FEEDER PROTECTION	
	87T2	24
	67/67N (HV)	27
	51/51N (HV)	59
	50/50N (HV)	DDR
	25 (QA1)	

401	BCU	
	BAY CONTROL UNIT	
	kV	25 (QA1)
	A	CONTROL
	MW	INTERLOCK
	MVAR	

401	CSD	
	CONTROLLED SWITCHING DEVICE	
	POW	

401	EM	
	ENERGY METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

401	MFM	
	MULTIFUNCTION METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

401	BBP BU-1	
	BUSBAR PROTECTION BAY UNIT-1	
	87B	50BF

401	BBP BU-2	
	BUSBAR PROTECTION BAY UNIT-2	
	87B	50BF

401	REF	
	RESTRICTED EARTH FAULT	
	87N (HIGH IMP)	

401	TR SELF PROTECTION	
	ALARM	TRIP
	HV-WTI	HV-WTI
	MV-WTI	MV-WTI
	LV-WTI	LV-WTI
	OTI-1	OTI-1
	OTI-2	OTI-2
	BUCHHOLZ (MAIN)	BUCHHOLZ (MAIN)
	BUCHHOLZ (OLTC)	BUCHHOLZ (OLTC)
	OIL LEVEL	PRD-1
		PRD-2
		OSR

201	BUFP	
	BACK-UP FEEDER PROTECTION	
	67/67N (MV)	27
	51/51N (MV)	59
	50/50N (MV)	DDR
	25 (MV-QA1)	

201	BCU	
	BAY CONTROL UNIT	
	kV	25 (MV-QA1)
	A	CONTROL
	MW	INTERLOCK
	MVAR	

201	EM (MAIN)	
	ENERGY METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

201	EM (CHECK)	
	ENERGY METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

201	MFM	
	MULTIFUNCTION METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

201	BBP BU	
	BUSBAR PROTECTION BAY UNIT	
	87B	50BF
	EFP	

301	BCPU	
	BAY CONTROL & PROTECTION UNIT	
	87N (REF)	kW
	51/51N (LV)	kVAR
	50/50N (LV)	CONTROL
	kV	INTERLOCK
	A	DDR

301	AUX. TR SELF PROTECTION	
	ALARM	TRIP
	WTI	WTI
	OTI	OTI
	BUCHHOLZ	BUCHHOLZ
	OIL LEVEL	PRD

TENDER PURPOSE ONLY

REVISION	DATE	REMARKS
1	10.06.2020	AS PER SSD'S COMMENTS
0	07.04.2020	FIRST PREPARATION

STANDARD DOCUMENT NUMBER: 20

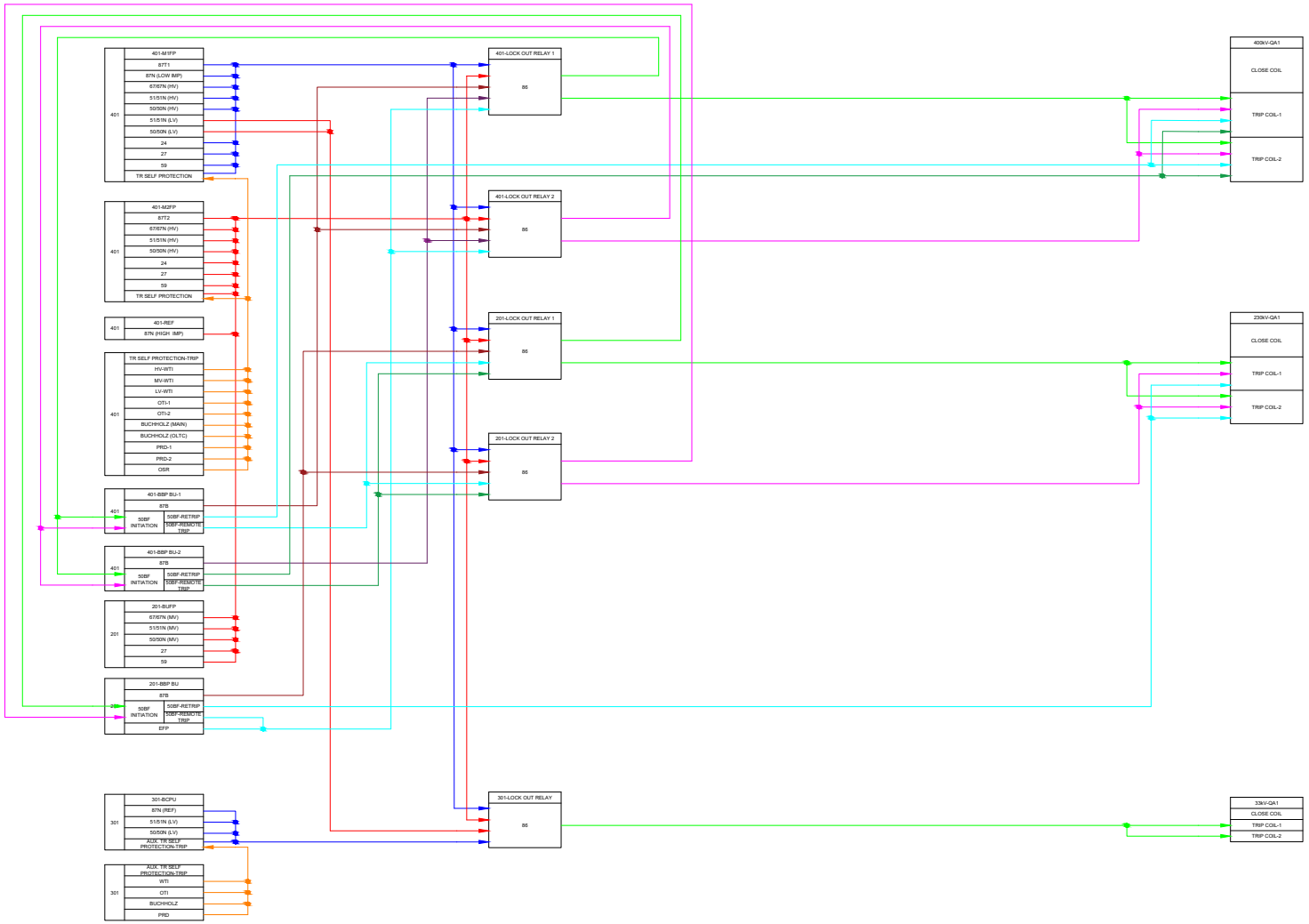
POWER GRID COMPANY OF BANGLADESH LTD.

TITLE: PROTECTION SLD & TRIP LOGIC OF 400kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR TRANSFORMER FEEDER

DOCUMENT ID: PGCB_DESIGN_2021_KALIGANJ_E10

SHEET 1 of 2

NEXT SHT 2



TENDER PURPOSE ONLY

REVISION	DATE	REMARKS
1	10.06.2020	AS PER SSD'S COMMENTS
0	07.04.2020	FIRST PREPARATION

STANDARD DOCUMENT NUMBER: 20

POWER GRID COMPANY OF BANGLADESH LTD.

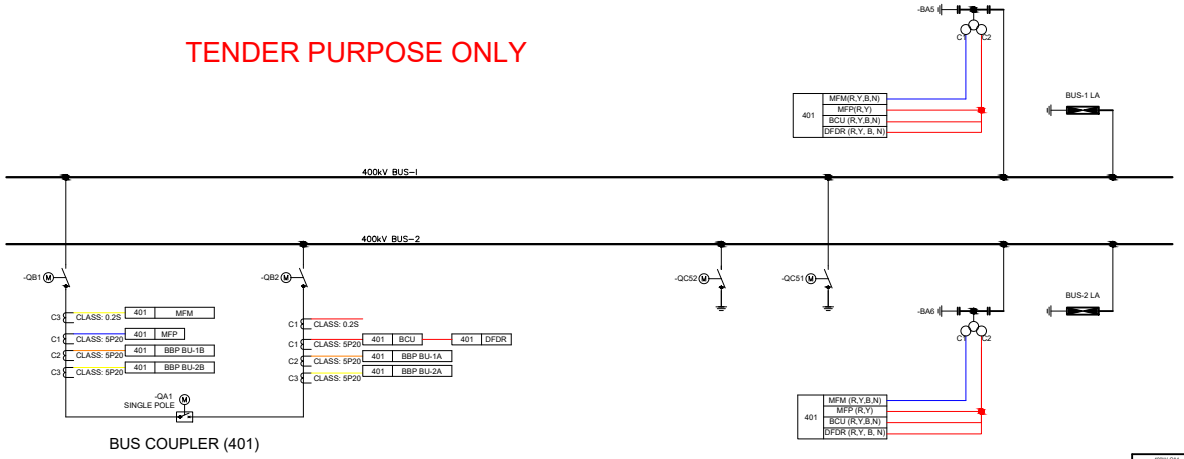
TITLE: PROTECTION SLD & TRIP LOGIC OF 400kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR TRANSFORMER FEEDER

DOCUMENT ID: PGCB_DESIGN_2021_KALIGANJ_E10

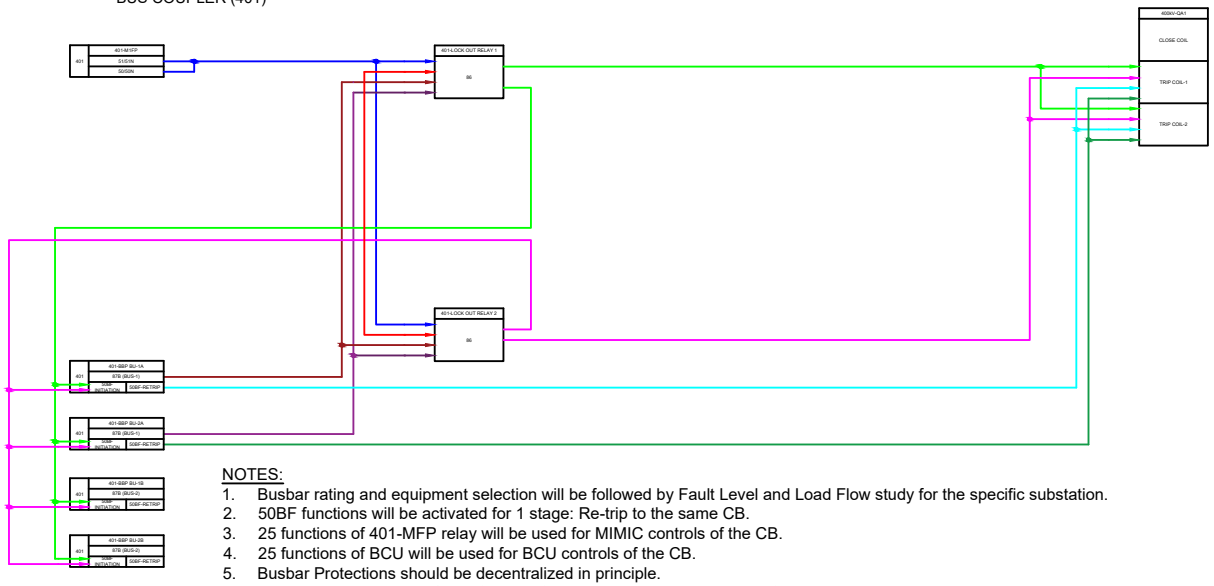
SHEET 2 of 2

NEXT SHT N/A

TENDER PURPOSE ONLY



BUS COUPLER (401)



NOTES:

1. Busbar rating and equipment selection will be followed by Fault Level and Load Flow study for the specific substation.
2. 50BF functions will be activated for 1 stage: Re-trip to the same CB.
3. 25 functions of 401-MFP relay will be used for MIMIC controls of the CB.
4. 25 functions of BCU will be used for BCU controls of the CB.
5. Busbar Protections should be decentralized in principle.
6. For 50BF Remote Trip of Bus Coupler CB, tripping will be issued to all CBs connected to both Busbars; the trip logic will be implemented internally with BBP Central Unit.
7. BBP BU-1B and BBP BU-2B will be used for CT measurement for the respective Busbar. Tripping will be issued from BBP BU-1A and BBP BU-2A for both Bus Zone Trip.
8. Main-1 and Main-2 FEEDER protection relays, BBP relays and BFP relays should preferably of different manufacturer. Alternatively, different model of the same manufacturer.
9. Voltage Transformers in GIS will be either CVT or IVT depending on manufacturer's practice.
10. The PSLD is for conceptualization of protection philosophy; it does not represent actual configurations for switching objects of GIS.
11. Any aspect mentioned in the Standard Document may be superseded by the Tender document and Scope of Work depending on specific application.

401	MFP	
	MAIN-1 FEEDER PROTECTION	
	51/51N	DDR
	50/50N	25(QA1)

401	BCU	
	BAY CONTROL UNIT	
	kV	25 (QA1)
	A	CONTROL
	MW	INTERLOCK
	MVAR	

401	MFM	
	MULTIFUNCTION METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

401	BBP BU-1A	
	BUSBAR PROTECTION BAY UNIT-1A	
	87B (BUS-1)	50BF

401	BBP BU-2A	
	BUSBAR PROTECTION BAY UNIT-2A	
	87B (BUS-1)	50BF

401	BBP BU-1B	
	BUSBAR PROTECTION BAY UNIT-1B	
	87B (BUS-2)	50BF

401	BBP BU-2B	
	BUSBAR PROTECTION BAY UNIT-2B	
	87B (BUS-2)	50BF

REVISION	DATE	REMARKS
1	13.07.2020	AS PER SSD'S COMMETNS
0	27.04.2020	FIRST PREPARATION

STANDARD DOCUMENT NUMBER: 25

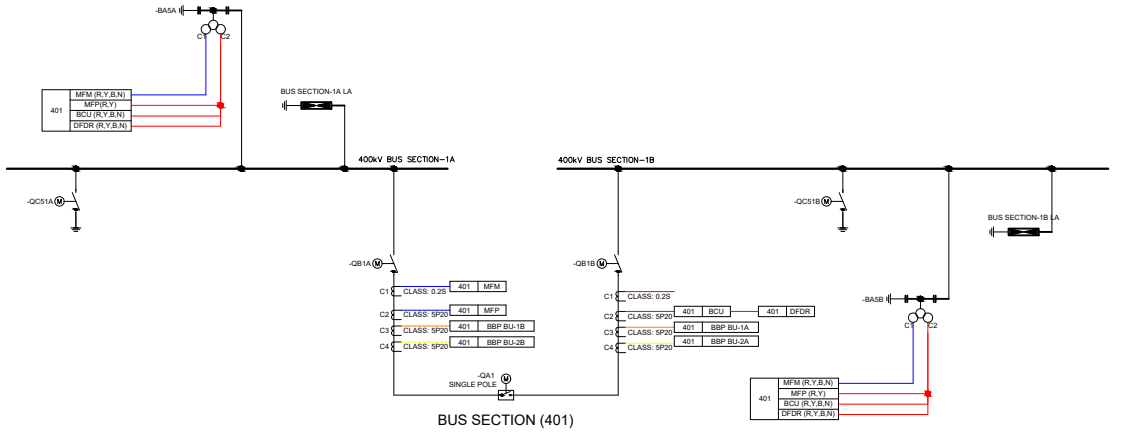
POWER GRID COMPANY OF BANGLADESH LTD.

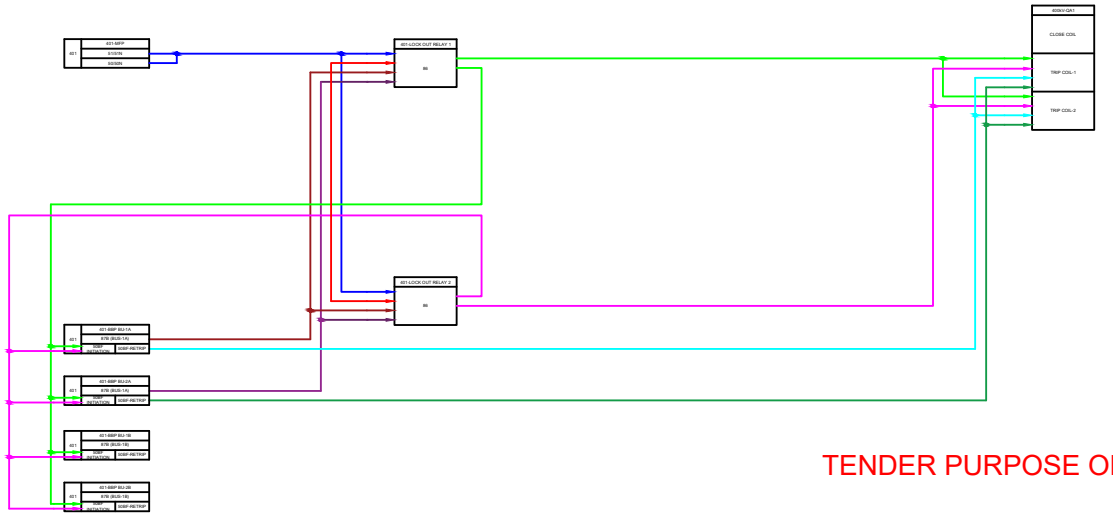
TITLE: PROTECTION SLD & TRIP LOGIC OF 400kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR BUS COUPLER FEEDER

DOCUMENT ID: PGCB_DESIGN_2021_KALIGANJ_E11

SHEET 1

NEXT SHT N/A





TENDER PURPOSE ONLY

NOTES:

1. Busbar rating and equipment selection will be followed by Fault Level and Load Flow study for the specific substation.
2. 50BF functions will be activated for 1 stage: Re-trip to the same CB.
3. 25 functions of 401-MFP relay will be used for MIMIC controls of the CB.
4. 25 functions of BCU will be used for BCU controls of the CB.
5. Busbar Protections should be decentralized in principle.
6. For 50BF Remote Trip of Bus Coupler CB, tripping will be issued to all CBs connected to both Busbars; the trip logic will be implemented internally with BBP Central Unit.
7. BBP BU-1B and BBP BU-2B will be used for CT measurement for the respective Busbar. Tripping will be issued from BBP BU-1A and BBP BU-2A for both Bus Zone Trip.
8. Main-1 and Main-2 FEEDER protection relays, BBP relays and BFP relays should preferably of different manufacturer. Alternatively, different model of the same manufacturer.
9. Voltage Transformers in GIS will be either CVT or IVT depending on manufacturer's practice.
10. The PSLD is for conceptualization of protection philosophy; it does not represent actual configurations for switching objects of GIS.
11. Any aspect mentioned in the Standard Document may be superseded by the Tender document and Scope of Work depending on specific application.

401	MFP
	MAIN-1 FEEDER PROTECTION
	51/51N / DDR
	50/50N / 25(QA1)

401	BCU
	BAY CONTROL UNIT
	kV / 25 (QA1)
	A / CONTROL
	MW / INTERLOCK
	MVAR /

401	MFM
	MULTIFUNCTION METER
	kV / FREQ
	A / PF
	MW / kWh
	MVAR / kVARh

401	BBP BU-1A
	BUSBAR PROTECTION BAY UNIT-1A
	87B (BUS-1A) / 50BF

401	BBP BU-2A
	BUSBAR PROTECTION BAY UNIT-2A
	87B (BUS-1A) / 50BF

401	BBP BU-1B
	BUSBAR PROTECTION BAY UNIT-1B
	87B (BUS-1B) / 50BF

401	BBP BU-2B
	BUSBAR PROTECTION BAY UNIT-2B
	87B (BUS-1B) / 50BF

REVISION	DATE	REMARKS
1	13.07.2020	AS PER SSD'S COMMENTS
0	27.04.2020	FIRST PREPARATION

STANDARD DOCUMENT NUMBER: 26

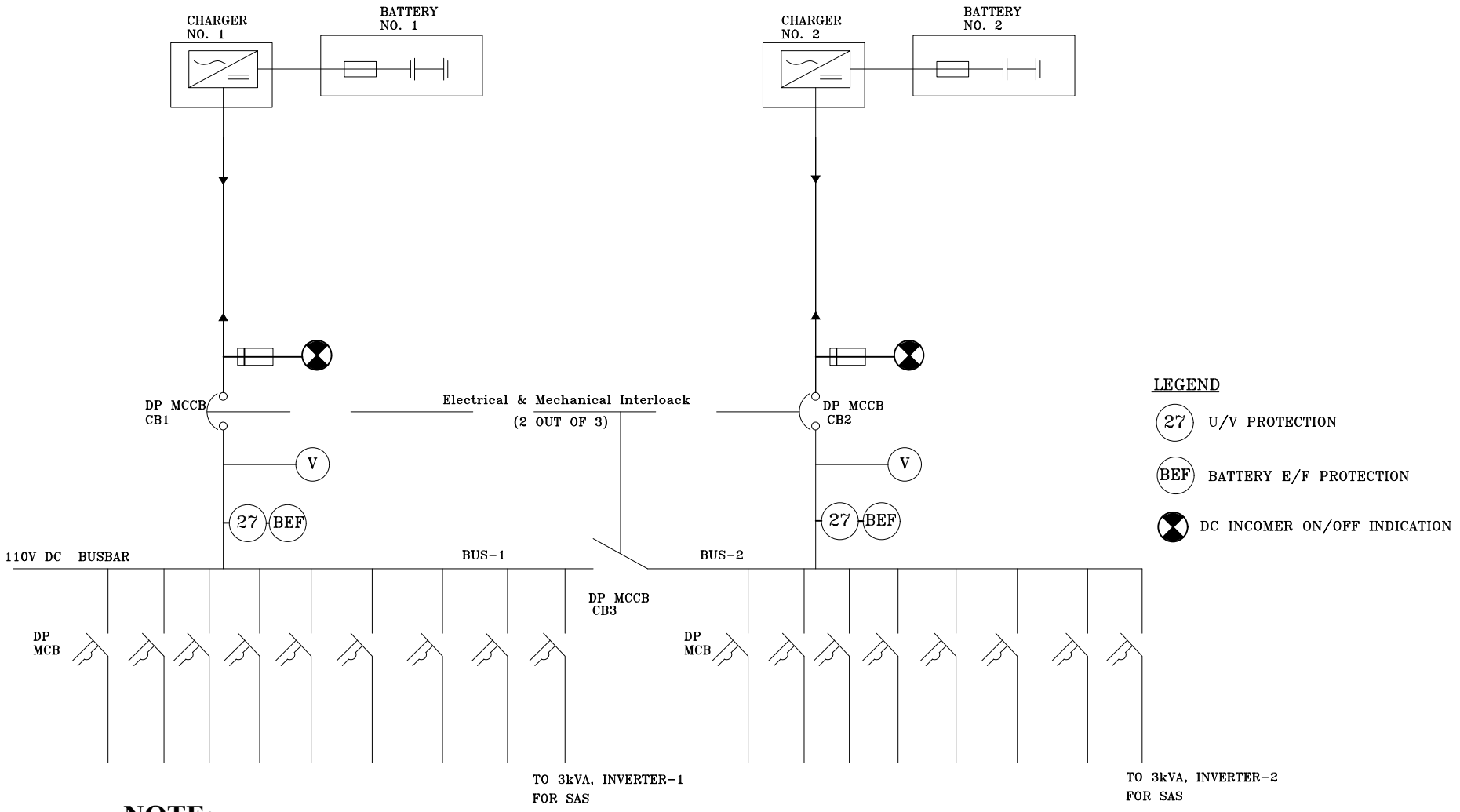
POWER GRID COMPANY OF BANGLADESH LTD.

TITLE: PROTECTION SLD & TRIP LOGIC OF 400kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR BUS SECTION FEEDER

DOCUMENT ID: PGCB_DESIGN_2021_KALIGANJ_E12

SHEET 1

NEXT SHT N/A



NOTE:

1. All the MCB/MCCB ratings shall be determined during detailed Engineering
2. 25% overall spare MCB shall be provided for future extension in addition to present requirement
3. Necessary status shall be integrated to SAS.

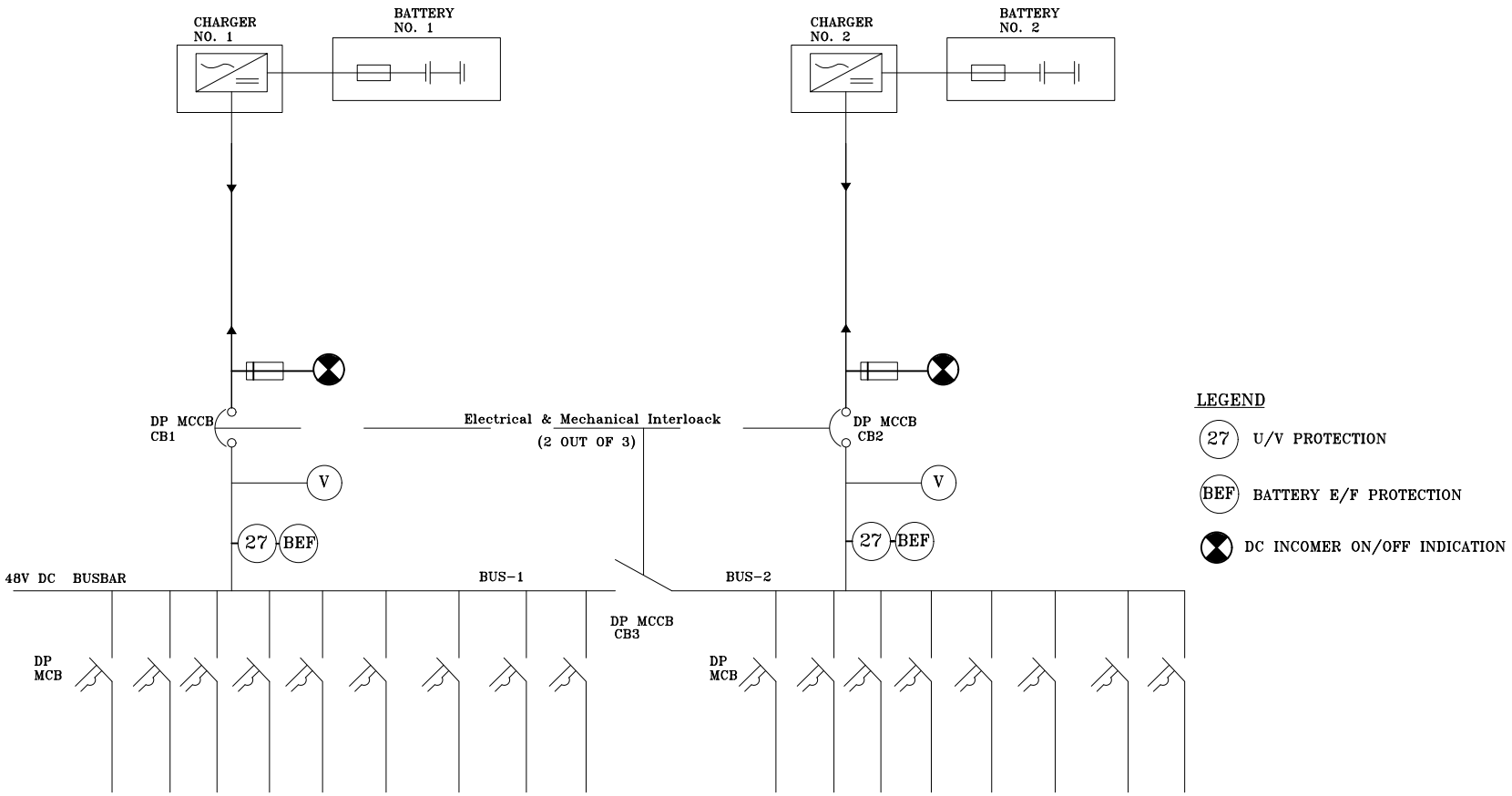
DRAWING FOR TENDER PURPOSE ONLY

POWER GRID COMPANY OF BANGLADESH LIMITED

TITLE

110 V DC DISTRIBUTION SYSTEM FOR 400/230kV KALIGANJ GRID SS

Drawing No:- PGCB/DESIGN/2021/KALIGANJ/E13 , Rev. 0



NOTE:

1. All the MCB/MCCB ratings shall be determined during detailed Engineering
2. 25% addtional feeders shall be provided for future extension in addtion to present requirement.
3. Necessary status shall be integrated to SAS.

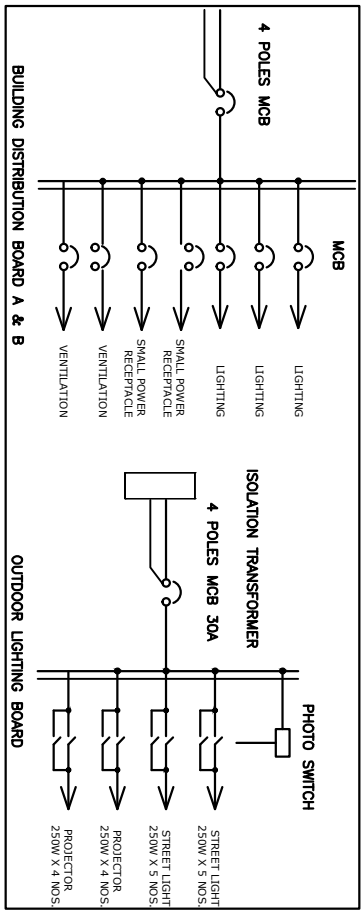
DRAWING FOR TENDER PURPOSE ONLY

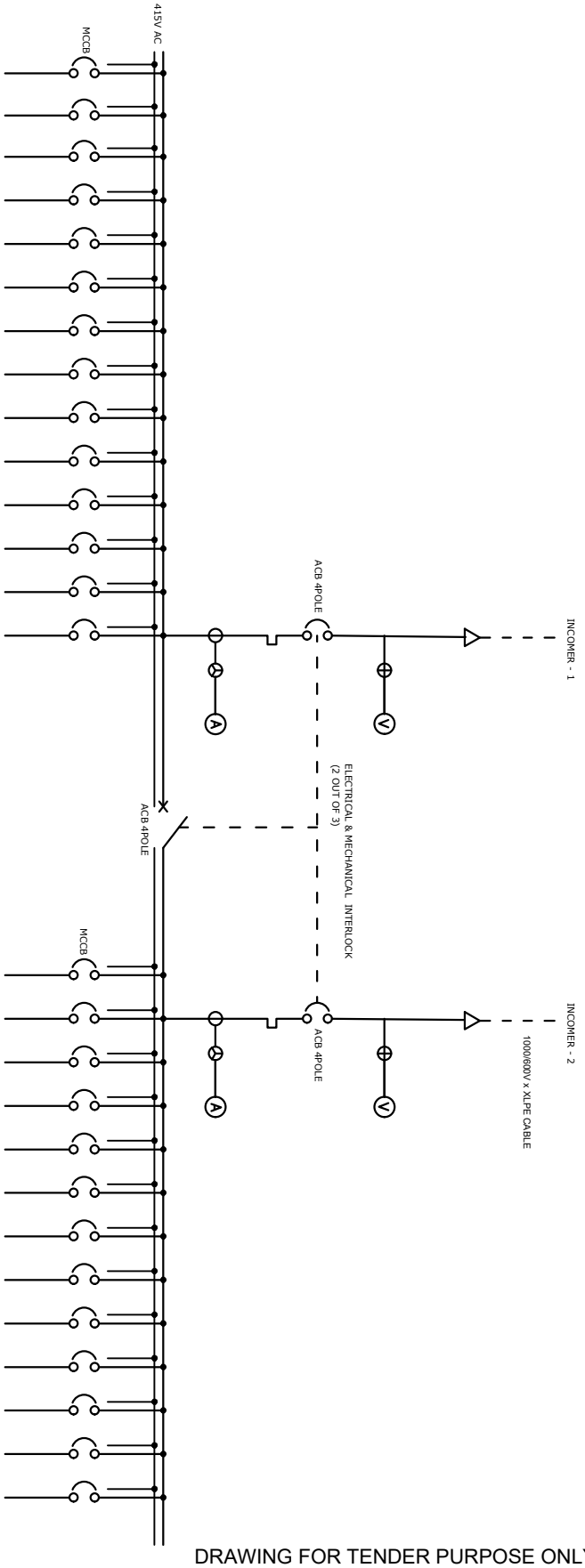
POWER GRID COMPANY OF BANGLADESH LIMITED

TITLE

48 V DC DISTRIBUTION SYSTEM FOR 400/230kV KALIGANJ GRID SS

Drawing No:- PGCB/DESIGN/2021/ KALIGANJ/E14, Rev. 0





NOTE:

1.All the MCB ratings shall be determined during detailed Engineering.
2. 25% overall spare MCB shall be provided for future extension in addtion to present requirement.
3. Necessary status shall be integrated to SAS.

DRAWING FOR TENDER PURPOSE ONLY

POWER GRID COMPANY OF BANGLADESH LIMITED (PGCB)
DESIGN OFFICE

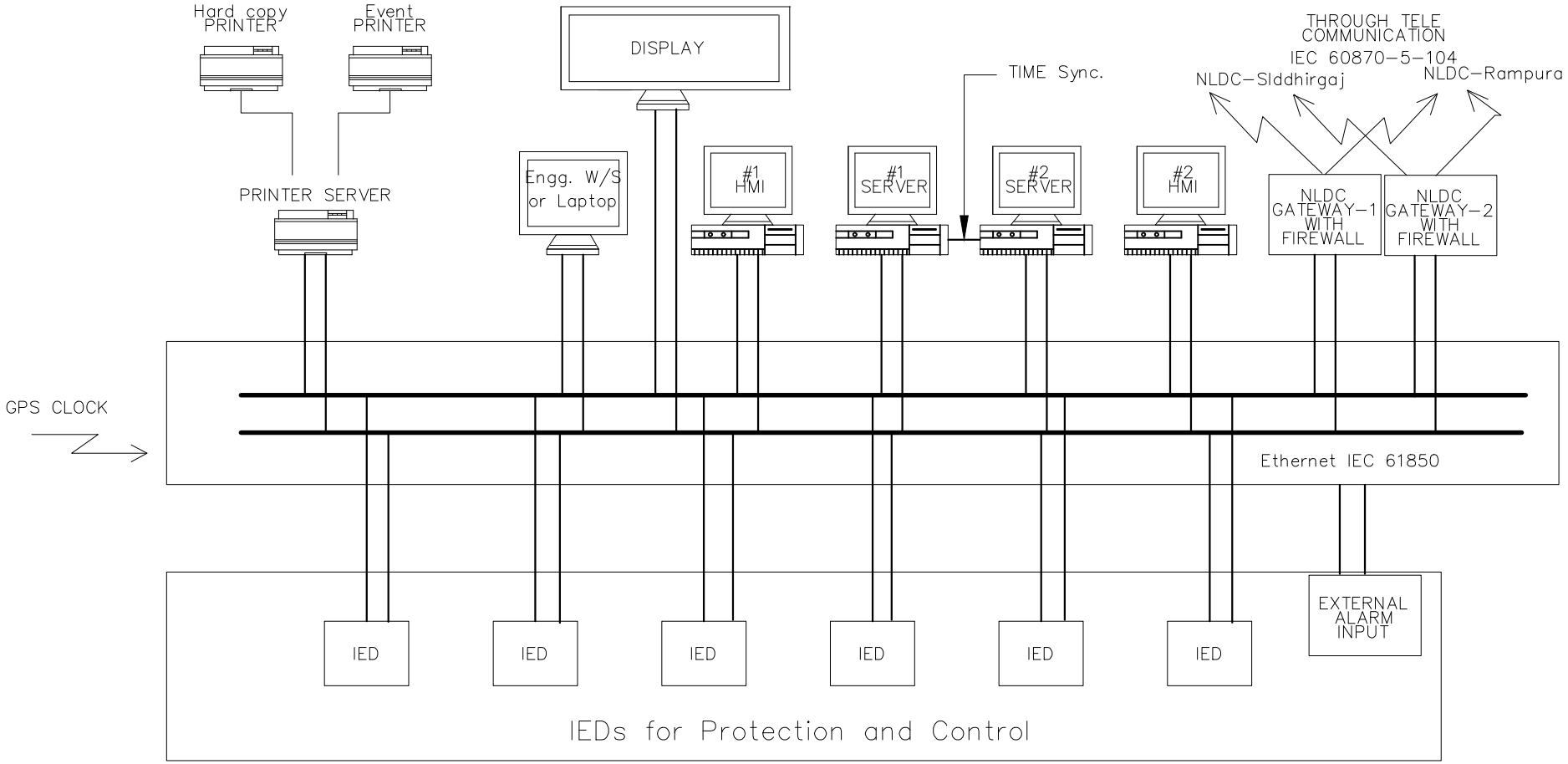
DRAWING FOR

400/230kV SUBSTATION

DRAWING TITLE :

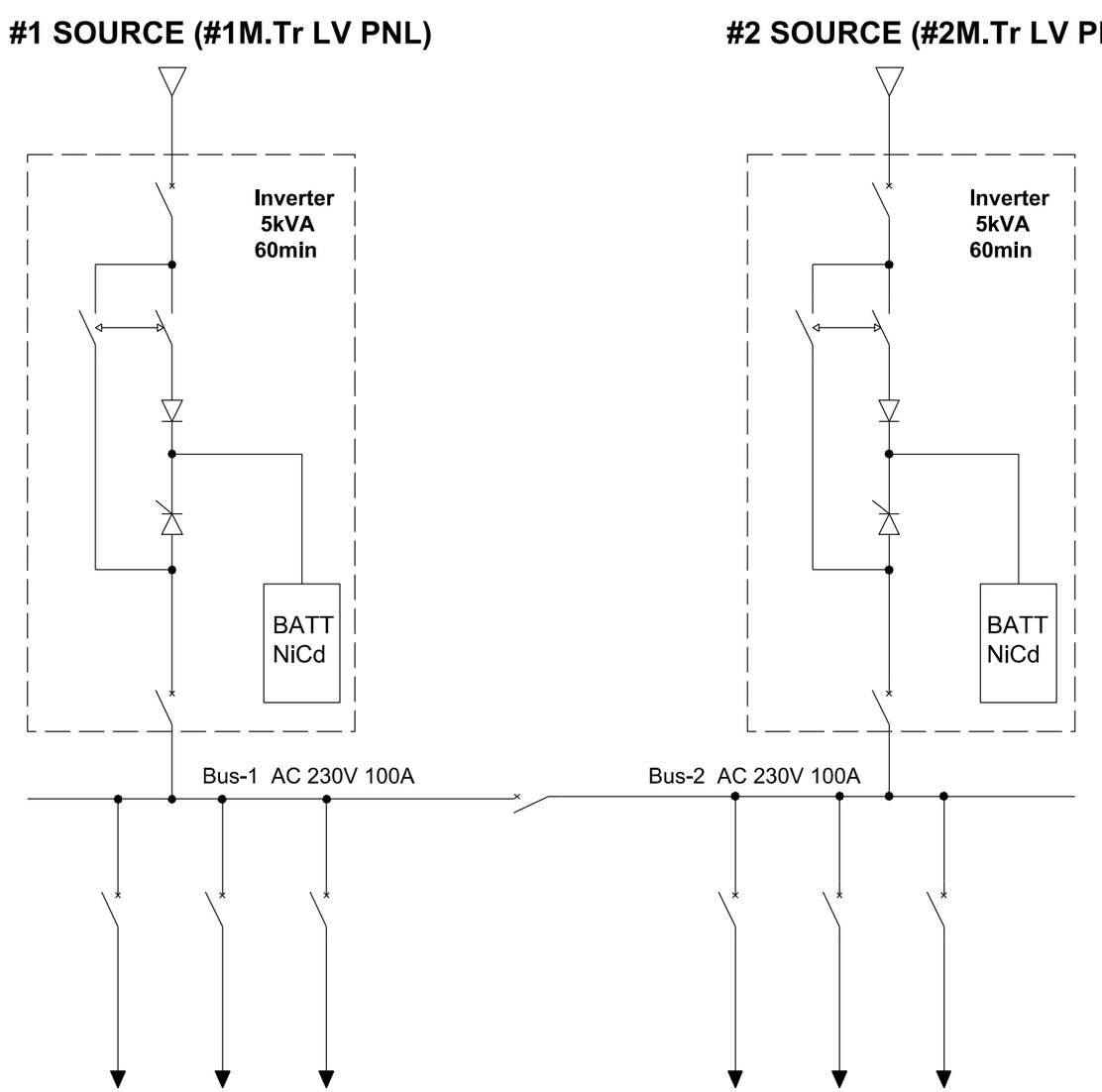
LVAC Distribution

DWG NO :
PGCB/DESIGN/2021/ KALIGANJ/E15, Rev. 0



DRAWING FOR TENDER PURPOSE ONLY

POWER GRID COMPANY OF BANGLADESH LIMITED (PGCB) DESIGN OFFICE	DRAWING FOR 400/230KV GIS SUBSTATION	DRAWING TITLE : SUBSTATION AUTOMATION SYSTEM ARCHITECTURE DWG NO :PGCB/DESIGN/2021/ KALIGANJ/E16, Rev. 0

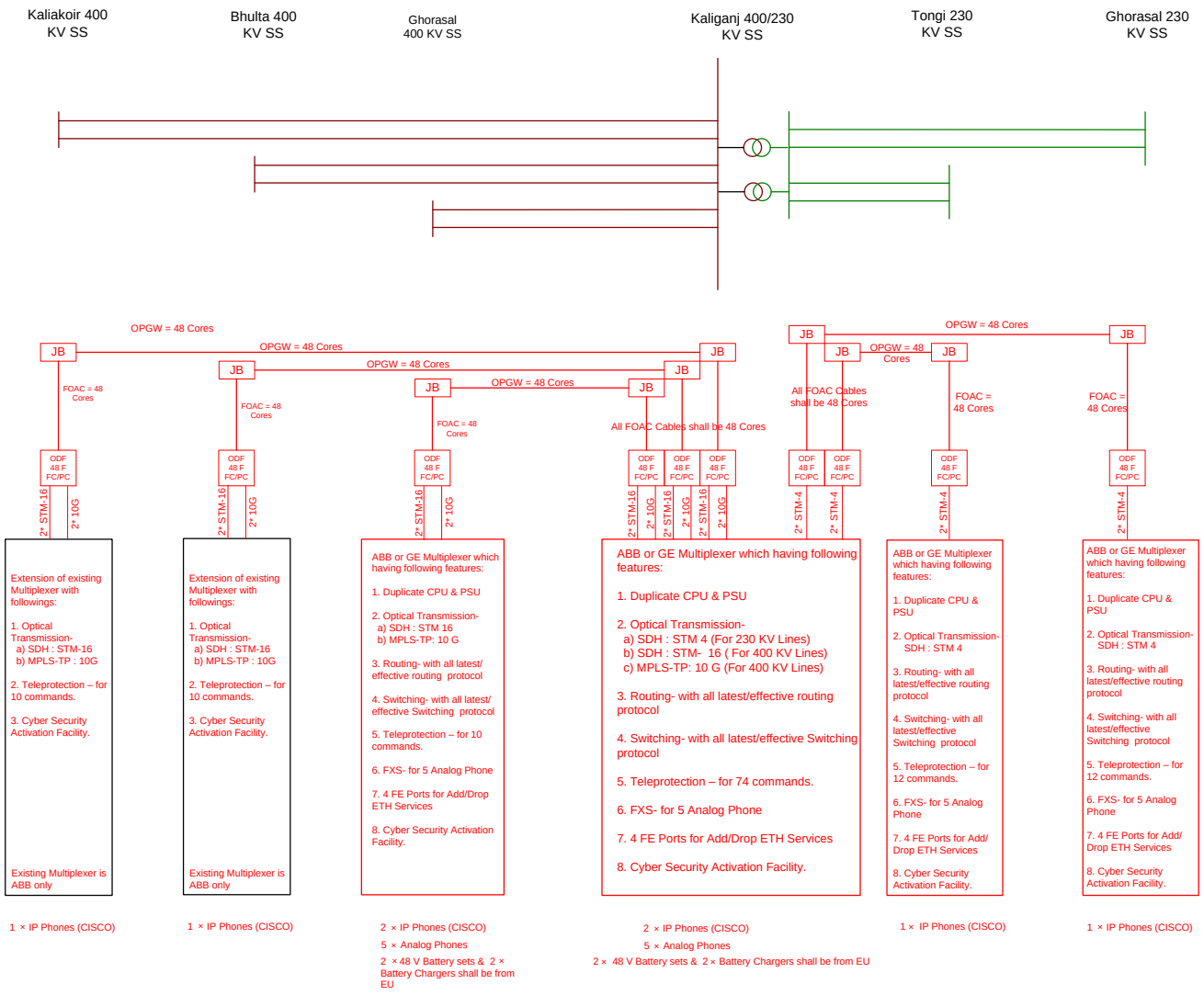


FOR TENDER PURPOSE ONLY

Power Grid Company of Bangladesh Limited	
Project	Design, Supply, Installation, Testing and Commissioning of new 400/230 kV GIS Substation at Kaliganj on Turnkey Basis (Package-5)
Drawing Title	**LV AC 230V Inverter**
Drawing No.	PGCB/DESIGN/2021/KALIGANJ/E17
Drawn / Checked / Approved	
Consultant	

A1 (841mmX594mm)

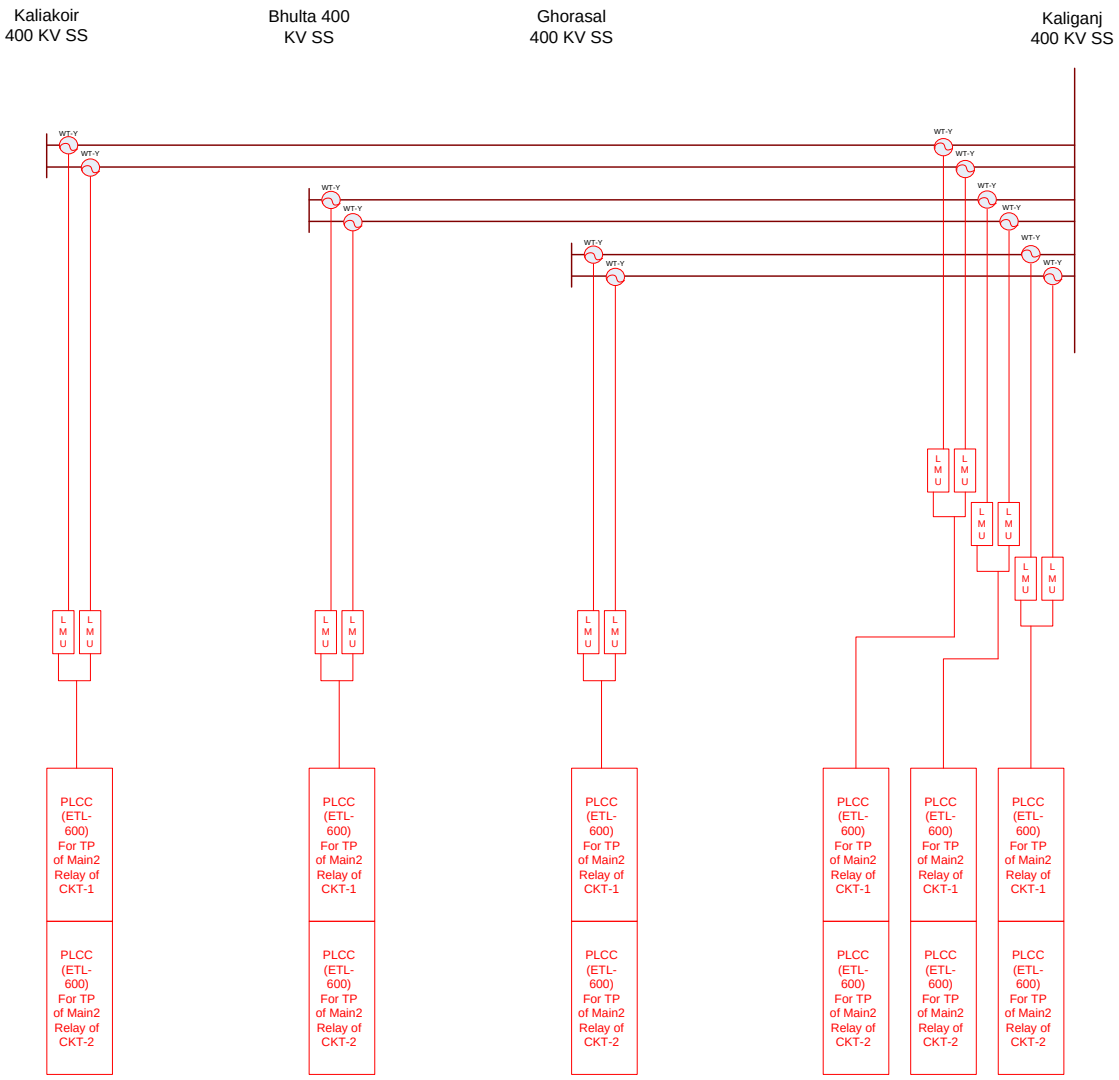
Proposed Optical Communication Scheme for Kaliganj 400 KV SS



N. B. : 1. All RED are scope of this project.
2. MPLS-TP link is Optional

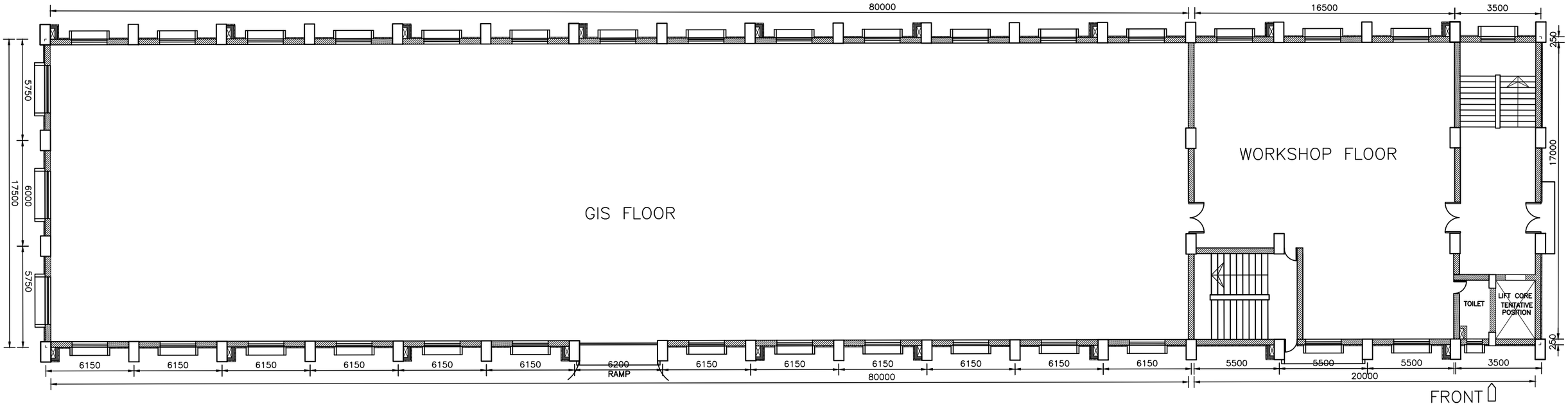
Project Name	Design, Supply, Installation, Testing and Commissioning of new 400/230 kV GIS Substation at Kaliganj on Turnkey Basis (Package-5)	
Drawing Title	Telecommunication Diagram	Page 1 of 2
Drawing no.	PGCB_DESIGN_2021_KALIGANJ_E18	

Proposed Power Line Carrier Communication Scheme for Kaliganj 400 KV SS



N. B. : All RED are scope of this project.

Project Name	Design, Supply, Installation, Testing and Commissioning of new 400/230 kV GIS Substation at Kaliganj on Turnkey Basis (Package-5)	
Drawing Title	Telecommunication Diagram	Page 2 of 2
Drawing no.	PGCB_DESIGN_2021_KALIGANJ_E18	



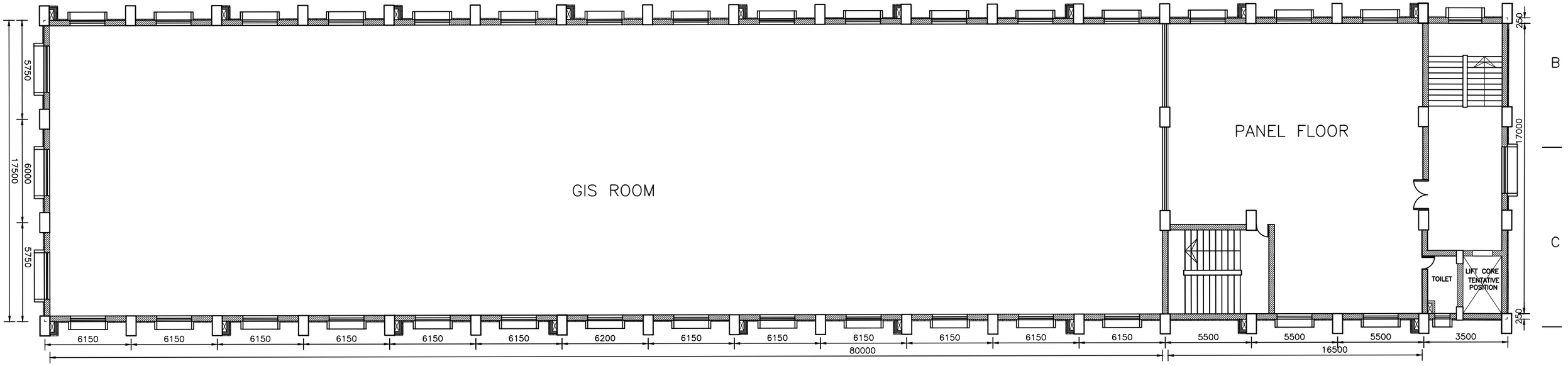
GROUND FLOOR PLAN

Note:

1) Floor area and height of the building provided here are minimum required size. If larger size is required due to bidder's GIS specifications, number of bays (including future); the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.
2) If transformers are positioned near the GIS building, due to fire safety reasons no window shall be provided on the transformer side of the building. But, if transformers are positioned sufficiently far from the GIS building, then windows shall be provided on the transformer side of the building.
3) Position and size of GIS equipments, cable ducts, cable shaft, loading & unloading platform, columns, doors, wind*ows,* emergency exit stair, lift core *etc.* will be finalized during detail design.

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: 400 KV GIS BUILDING – GROUND FLOOR PLAN	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C01	Page 01



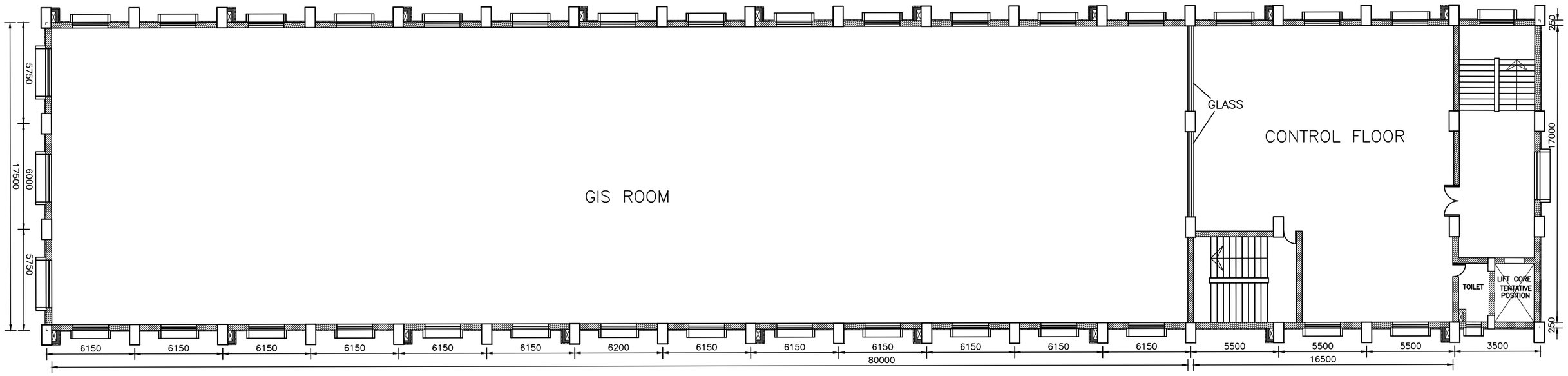
1ST FLOOR PLAN

Note:

1) Floor area and height of the building provided here are minimum required size. If larger size is required due to bidder's GIS specifications, number of bays (including future); the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.
2) If transformers are positioned near the GIS building, due to fire safety reasons no window shall be provided on the transformer side of the building. But, if transformers are positioned sufficiently far from the GIS building, then windows shall be provided on the transformer side of the building.
3) Position and size of GIS equipments, cable ducts, cable shaft, loading & unloading platform, columns, doors, windows, emergency exit stair, lift core *etc.* will be finalized during detail design.

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: 400 KV GIS BUILDING – 1ST FLOOR PLAN (TENTATIVE POSITION OF GIS EQUIPMENTS)	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C01	Page 02



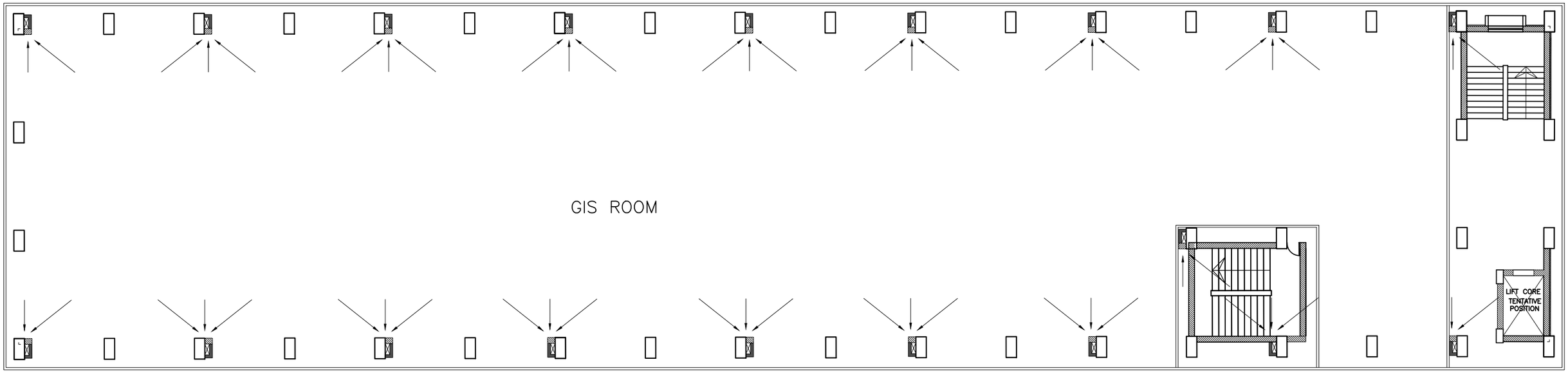
2ND FLOOR PLAN

Note:

1) Floor area and height of the building provided here are minimum required size. If larger size is required due to bidder's GIS specifications, number of bays (including future); the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.
2) If transformers are positioned near the GIS building, due to fire safety reasons no window shall be provided on the transformer side of the building. But, if transformers are positioned sufficiently far from the GIS building, then windows shall be provided on the transformer side of the building.
3) Position and size of GIS equipments, cable ducts, cable shaft, loading & unloading platform, columns, doors, windows, emergency exit stair, lift core *etc.* will be finalized during detail design.

Tender Drawing

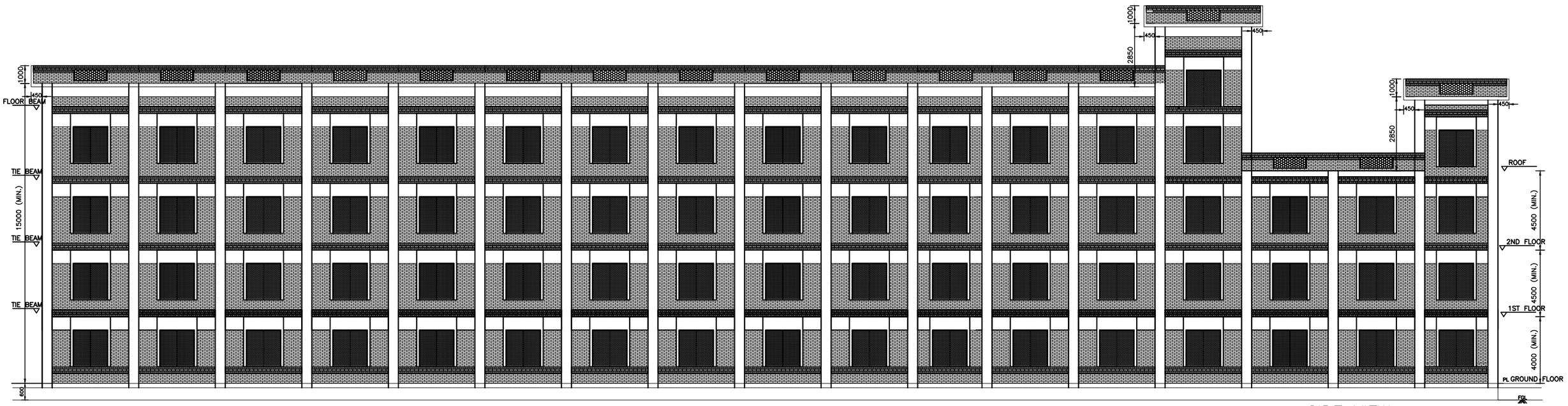
EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: 400 KV GIS BUILDING – 2ND FLOOR PLAN (TENTATIVE POSITION OF PANELS)	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C01	Page 03



ROOF PLAN

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: 400 KV GIS BUILDING – ROOF FLOOR PLAN	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C01	Page 04



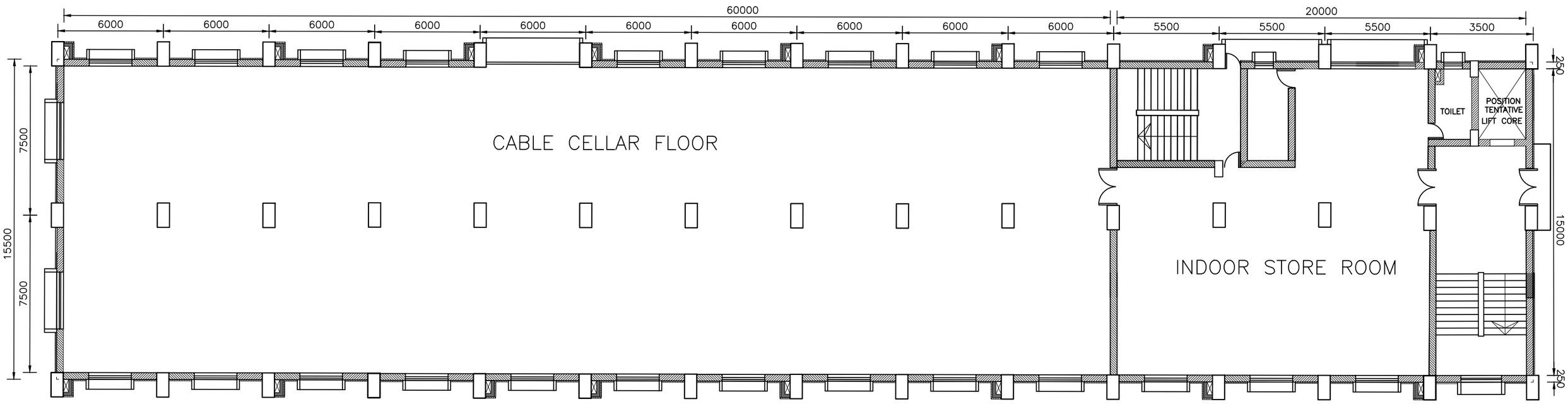
SIDE VIEW

Tender Drawing

Note:

1) Floor area and height of the building provided here are minimum required size. If larger size is required due to bidder's GIS specifications, number of bays (including future); the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.
2) If transformers are positioned near the GIS building, due to fire safety reasons no window shall be provided on the transformer side of the building. But, if transformers are positioned sufficiently far from the GIS building, then windows shall be provided on the transformer side of the building.
3) Position and size of GIS equipments, cable ducts, cable shaft, loading & unloading platform, columns, doors, windows, emergency exit stair, lift core *etc.* will be finalized during detail design.

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: 400 KV GIS BUILDING – FRONT ELEVATION	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C01	Page 05



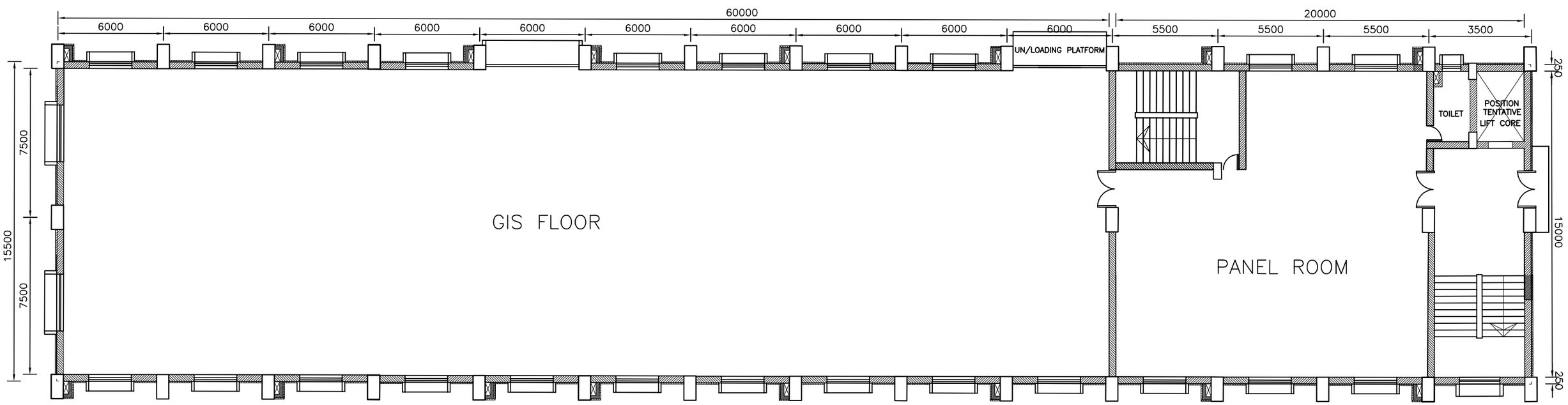
GROUND FLOOR PLAN

Tender Drawing

Note:

1) Floor area and height of the building provided here are minimum required size. If larger size is required due to bidder's GIS specifications, number of bays (including future); the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.
2) If transformers are positioned near the GIS building, due to fire safety reasons no window shall be provided on the transformer side of the building. But, if transformers are positioned sufficiently far from the GIS building, then windows shall be provided on the transformer side of the building.
3) Position and size of GIS equipments, cable ducts, cable shaft, loading & unloading platform, columns, doors, windows, emergency exit stair, lift core *etc.* will be finalized during detail design.

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: 230 KV GIS BUILDING – GROUND FLOOR PLAN	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C02	Page 01



1ST FLOOR PLAN

Note:

1) Floor area and height of the building provided here are minimum required size. If larger size is required due to bidder's GIS specifications, number of bays (including future); the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.
2) If transformers are positioned near the GIS building, due to fire safety reasons no window shall be provided on the transformer side of the building. But, if transformers are positioned sufficiently far from the GIS building, then windows shall be provided on the transformer side of the building.
3) Position and size of GIS equipments, cable ducts, cable shaft, loading & unloading platform, columns, doors, windo*ws,* emergency exit stair, lift core *etc.* will be finalized during detail design.

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: 230 KV GIS BUILDING – 1ST FLOOR PLAN	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C02	Page 02



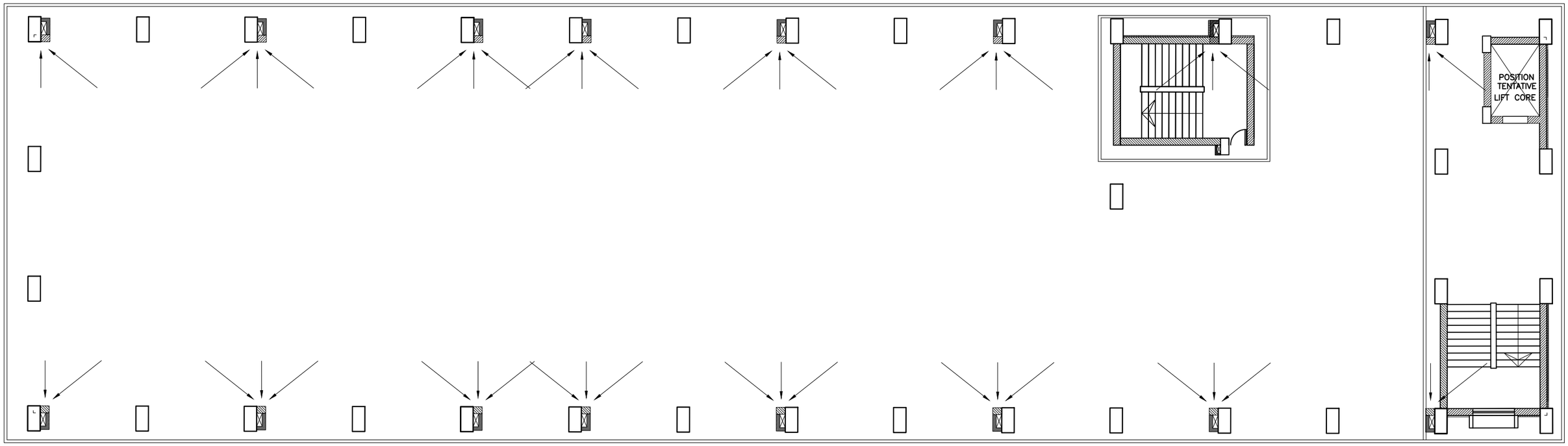
2ND FLOOR PLAN

Note:

1) Floor area and height of the building provided here are minimum required size. If larger size is required due to bidder's GIS specifications, number of bays (including future); the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.
2) If transformers are positioned near the GIS building, due to fire safety reasons no window shall be provided on the transformer side of the building. But, if transformers are positioned sufficiently far from the GIS building, then windows shall be provided on the transformer side of the building.
3) Position and size of GIS equipments, cable ducts, cable shaft, loading & unloading platform, columns, doors, wind*ows,* emergency exit stair, lift core *etc.* will be finalized during detail design.

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: 230 KV GIS BUILDING –2ND FLOOR PLAN	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C02	Page 03



ROOF PLAN

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: 230 KV GIS BUILDING – ROOF FLOOR PLAN	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C02	Page 04



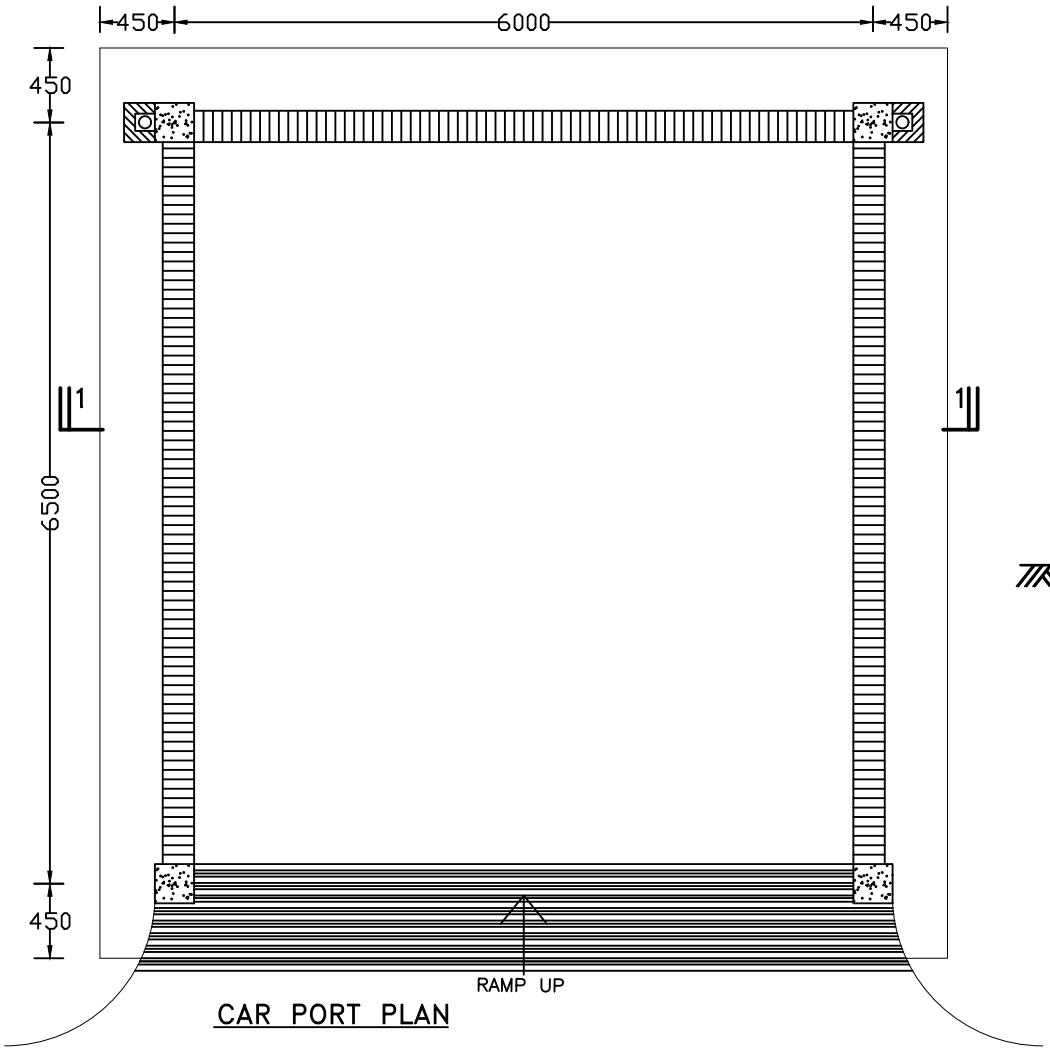
SIDE VIEW

Note:

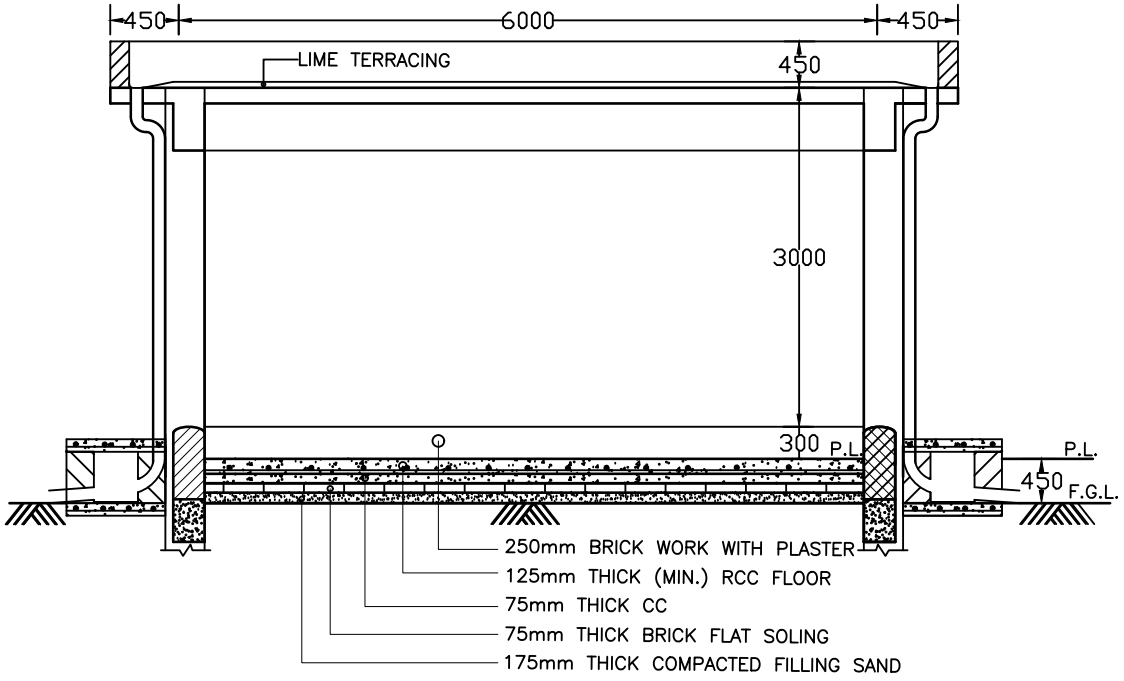
1) Floor area and height of the building provided here are minimum required size. If larger size is required due to bidder's GIS specifications, number of bays (including future); the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.
2) If transformers are positioned near the GIS building, due to fire safety reasons no window shall be provided on the transformer side of the building. But, if transformers are positioned sufficiently far from the GIS building, then windows shall be provided on the transformer side of the building.
3) Position and size of GIS equipments, cable ducts, cable shaft, loading & unloading platform, columns, doors, windows, emergency exit stair, lift core *etc.* will be finalized during detail design.

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: 230 KV GIS BUILDING – SIDE VIEW	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C02	Page 05



CAR PORT PLAN

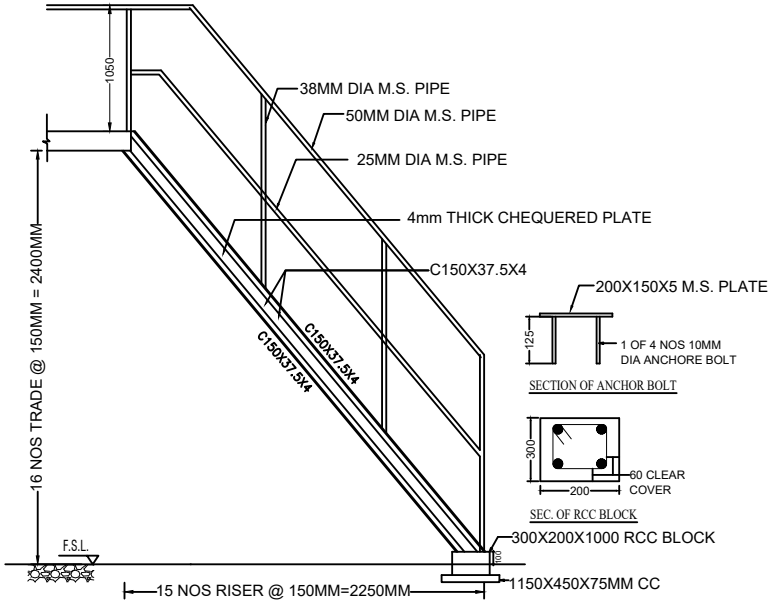


SECTION:1–1

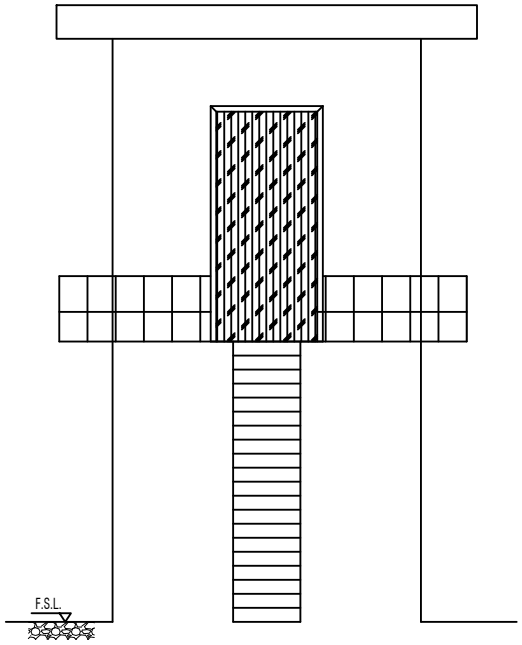
NOTES:
1. DETAILS OF ARCHITECTURAL, STRUCTURAL & FOUNDATION DRAWING SHALL BE SUBMITTED FOR APPROVAL.
2. ROOF SHALL BE WATER PROOFED WITH LIME TERRACING 2:2:7–LIME, SHURKI (POWDERED BRICK) & 0.75'' DOWN BRICK CHIPS.
3. RAIN WATER DOWN PIPE SHALL BE TAKE INTO CONSIDER PRIOR TO SLAB CASTING.

Tender Drawing

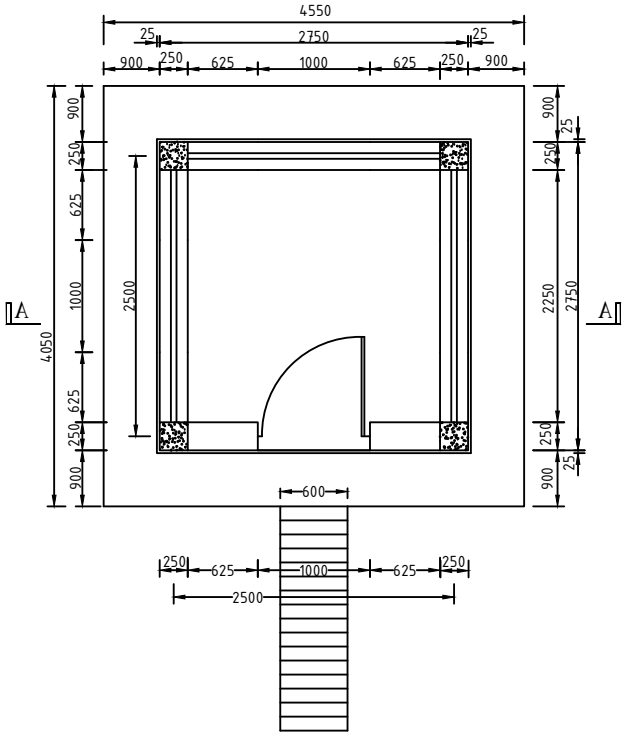
Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Car Port (For Two Cars)
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C03
Drawn:	Checked: Approved:



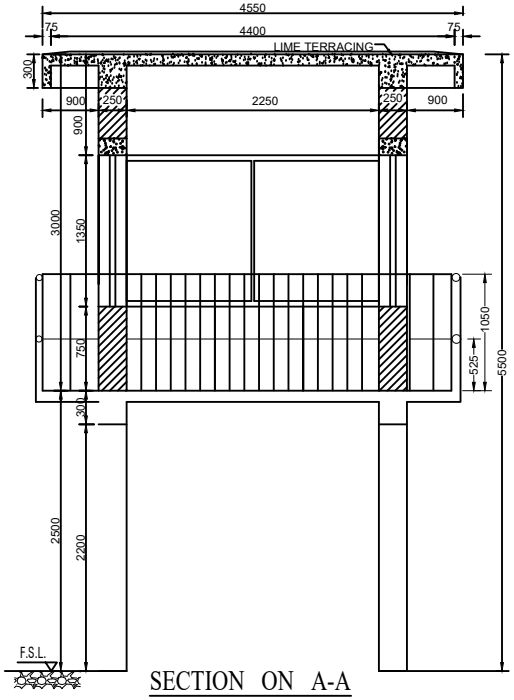
DETAILS OF STAIR



FRONT ELEVATION



PLAN OF SENTRY POST

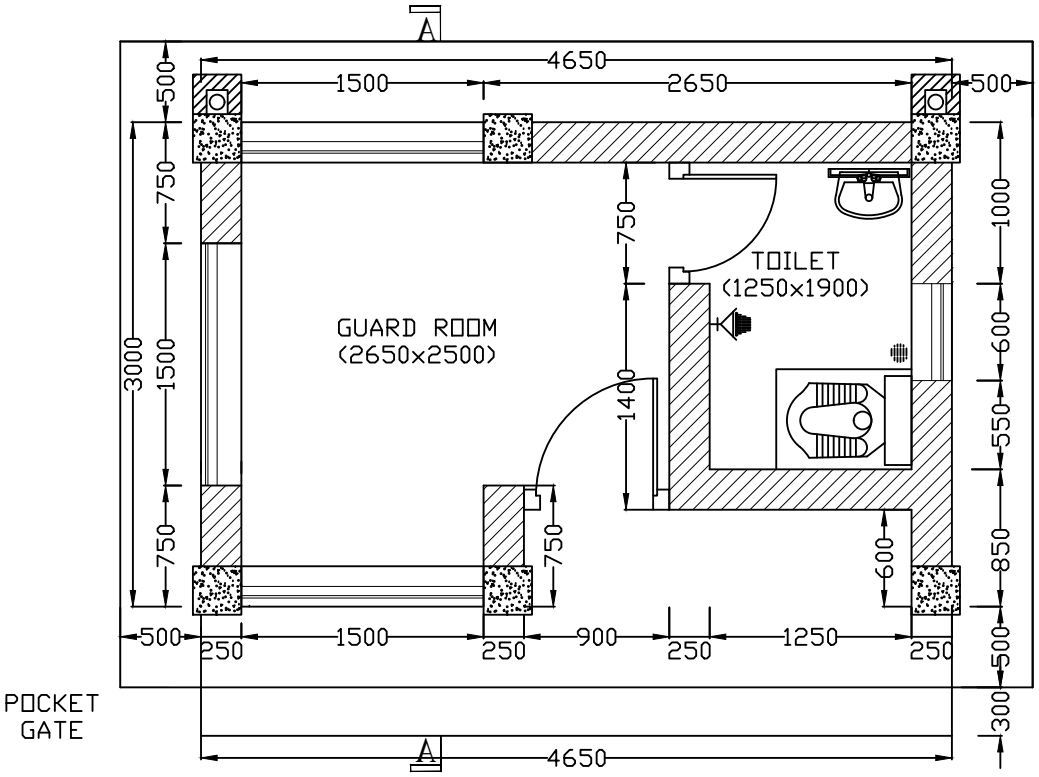


SECTION ON A-A

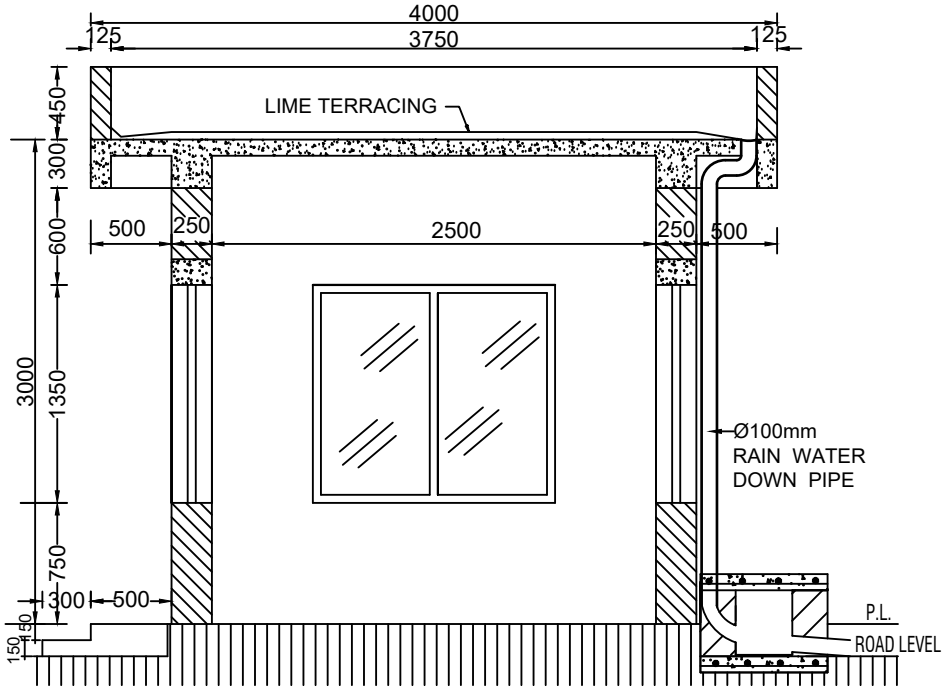
NOTES:
1. DETAILS OF ARCHITECTURAL, STRUCTURAL & FOUNDATION DRAWING & LADDER DETAILS SHALL BE SUBMITTED FOR APPROVAL.
2. ROOF SHALL BE WATER PROOFED WITH LIME TERRACING 2:2:7–LIME, SHURKI (POWDERED BRICK) & 0.75" DOWN BRICK CHIPS.
3. RAIN WATER DOWN PIPE & BUILDING DRAINAGE SYSTEM SHALL BE TAKE INTO CONSIDER PRIOR TO SLAB CASTING.
4. POWER CONNECTION LAYOUT SHALL BE APPROVED BEFOR WORK.
5. ALL EXPOSED STEEL SHALL BE GALVANIZED PAINT.

Tender Drawing

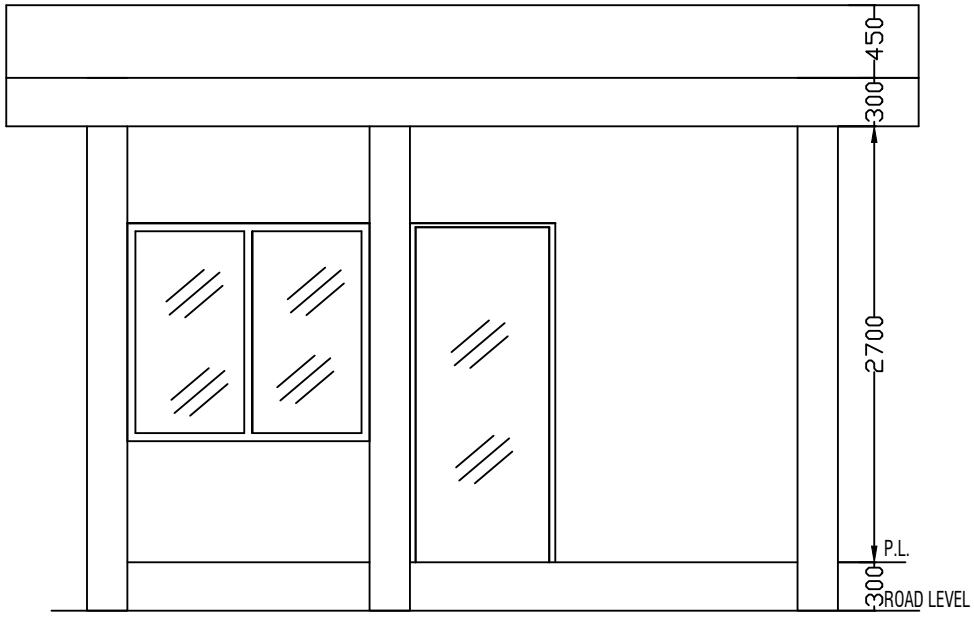
Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Sentry Post
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C04
Drawn:	Checked: Approved:



PLAN OF GUARD HOUSE



SECTION : A-A



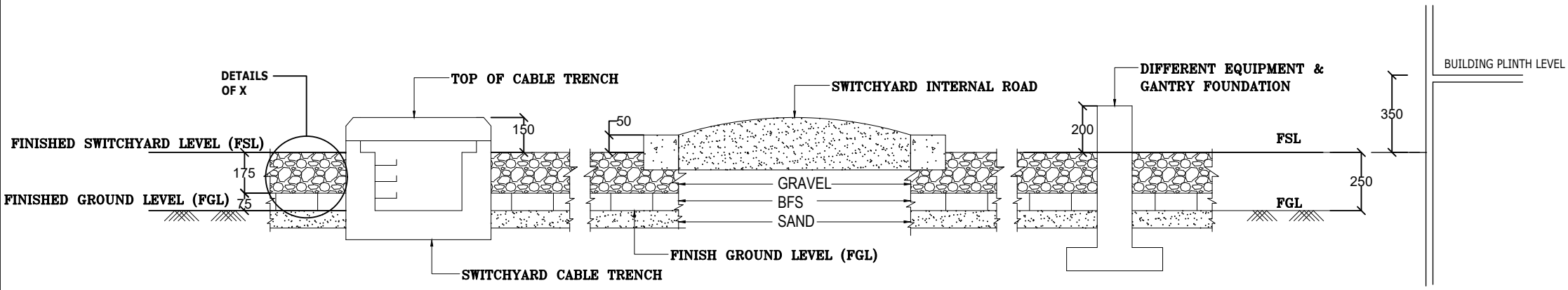
ROAD SIDE ELEVATION

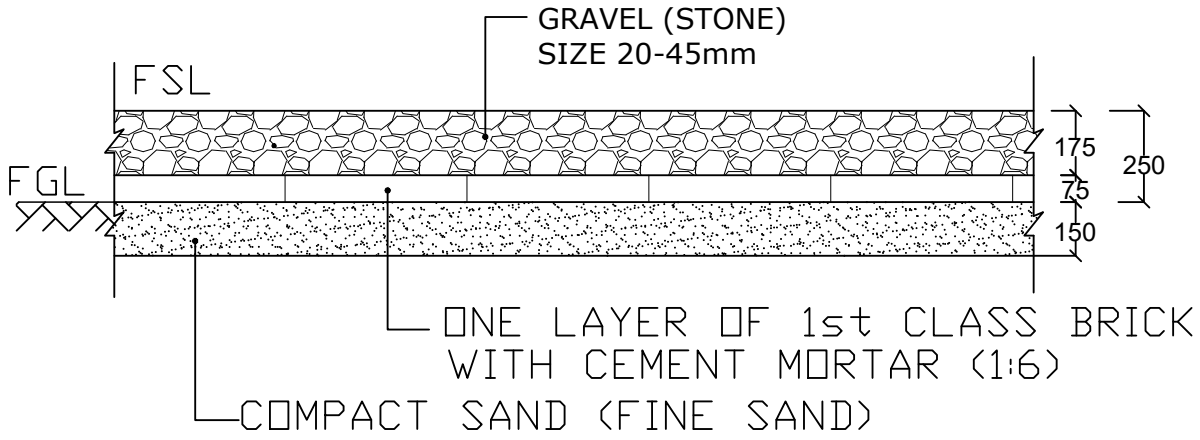
NOTES:

1. DETAILS OF ARCHITECTURAL, STRUCTURAL & FOUNDATION DRAWING SHALL BE SUBMITTED FOR APPROVAL.
2. WATER SUPPLY SYSTEM, TOILET & OTHER SANITARY FITTINGS SHALL BE PROVIDED.
3. ROOF SHALL BE WATER PROOFED WITH LIME TERRACING 2:2:7– LIME, SHURKI (POWDERED BRICK) & 0.75'' DOWN BRICK CHIPS.
4. RAIN WATER DOWN PIPE & BUILDING DRAINAGE SYSTEM SHALL BE TAKE INTO CONSIDER PRIOR TO SLAB CASTING.
5. POWER CONNECTION LAYOUT SHALL BE APPROVED BEFORE WORK.

Tender Drawing

Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Gaurd House
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C05
Drawn:	Checked: Approved:





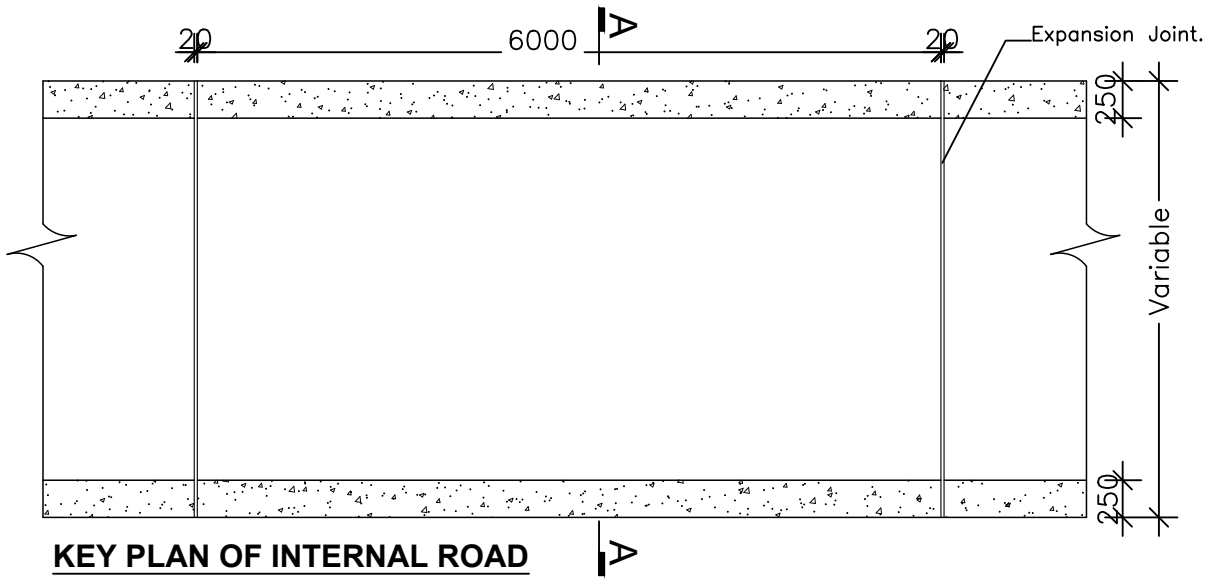
DETAIL OF X

NOTE:

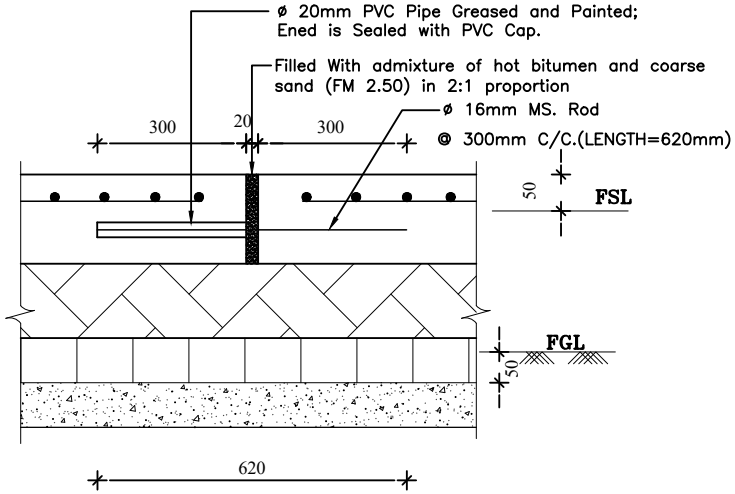
After determination of Finished Ground Level (FGL) with respect to MSL/PWD, the contractor should prepare and submit the relative RLs of all the structures for approval for each site.

Tender Drawing

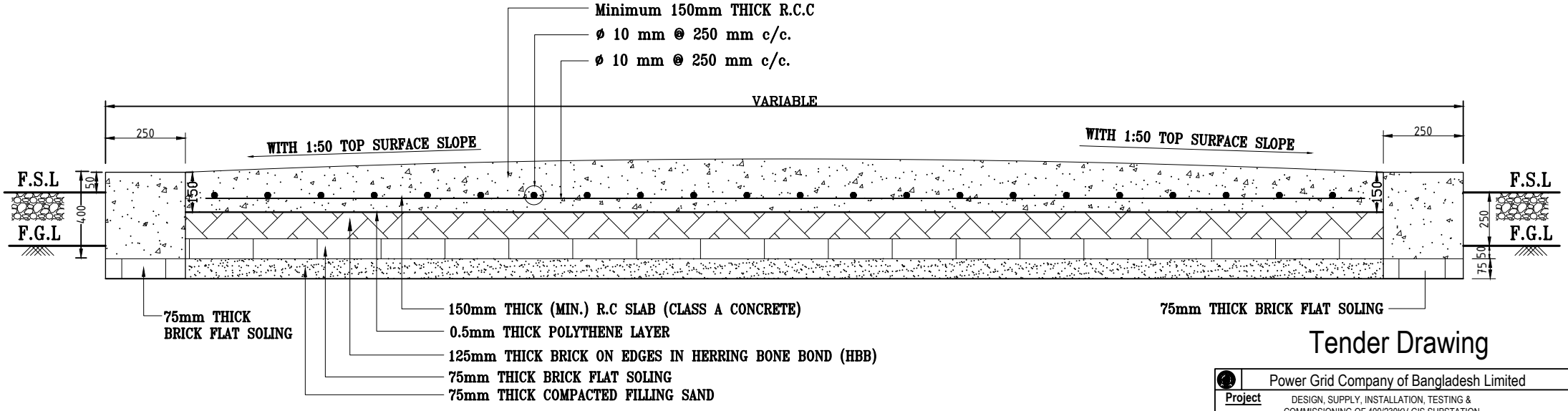
Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Switchyard Gravelling and Relative Levels of Different Structures
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C06
Drawn:	Checked: Approved:



KEY PLAN OF INTERNAL ROAD
(SCALE - NTS)



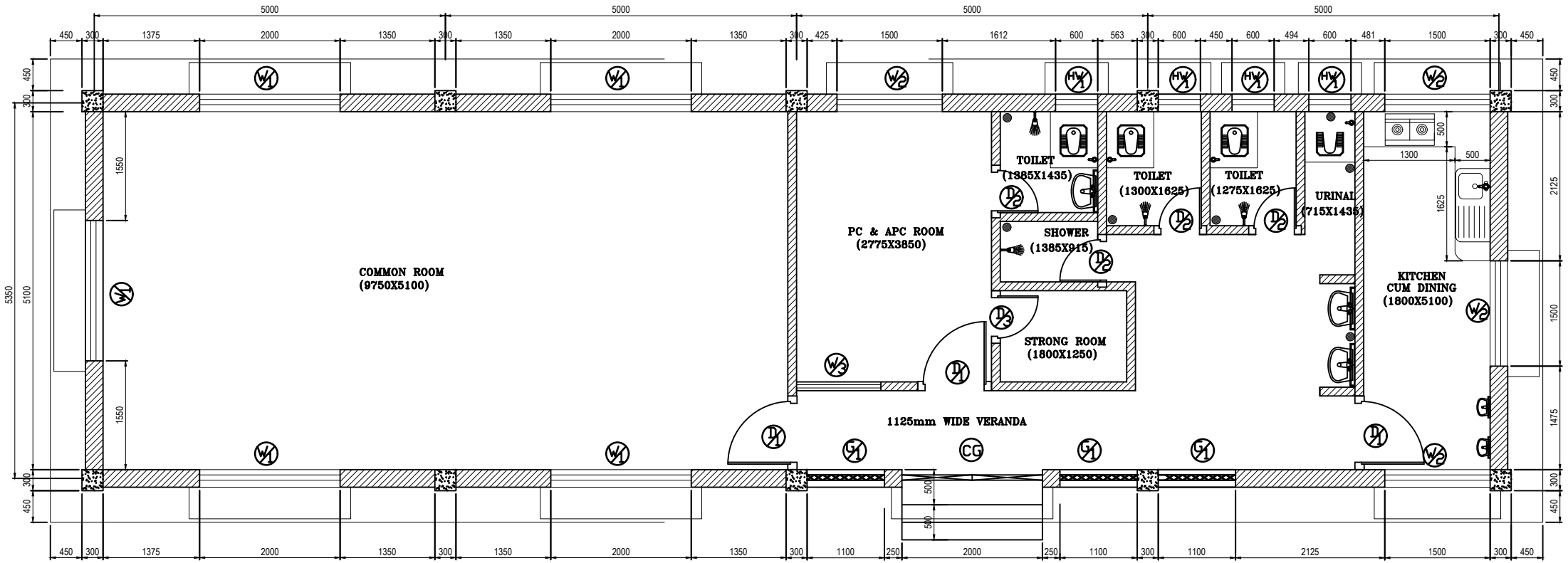
DETAIL OF EXPANSION JOINT
(SCALE - NTS)



ROAD CROSS SECTION : A-A
(SCALE - NTS)

Tender Drawing

Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Typical Road sections
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C07
Drawn:	Checked: Approved:



PLAN OF ANSAR BARRACK

FRONT

LEGEND

D = DOOR
W = WINDOW
HW = HIGH WINDOW
CG = COLLAPSIBLE GATE
G = VERANDA GRIL

DOOR SCHEDULE

S.L.	NO.	SIZE		MATERIAL
		WIDTH	HEIGHT	
CG	1	2000	2100	M. STEEL
D /1	3	1050	2100	TIMBER
D /2	4	750	2100	PLASTIC
D /3	1	750	2100	M. STEEL

WINDOW / VERANDA GRIL SCHEDULE

S.L.	NO.	SIZE		MATERIAL
		WIDTH	HEIGHT	
W /1	5	2000	1350	ALUMINIUM
W /2	4	1500	1350	ALUMINIUM
W /3	1	1200	1350	ALUMINIUM
HW /1	4	600	600	ALUMINIUM
G/1	3	1100	1350	MS PLAIN/ FLAT BAR

NOTES:
1. ANSAR BARRACK BUILDING SHALL BE RCC FRAME STRUCTURE AND FLOOR HEIGHT SHALL BE 3.0 METER.
2. DETAILS OF ARCHITECTURAL, STRUCTURAL & FOUNDATION DRAWING SHALL BE SUBMITTED FOR APPROVAL.
2. WATER SUPPLY SYSTEM, TOILET & OTHER SANITARY FITTINGS SHALL BE PROVIDED.
3. ROOF SHALL BE WATER PROOFED WITH LIME TERRACING 2:2:7–LIME, SHURKI (POWDERED BRICK) & 0.75" DOWN BRICK CHIPS.
4. RAIN WATER DOWN PIPE & BUILDING DRAINAGE SYSTEM SHALL BE TAKE INTO CONSIDER PRIOR TO SLAB CASTING.
5. POWER CONNECTION LAYOUT SHALL BE APPROVED BEFORE WORK.

Tender Drawing

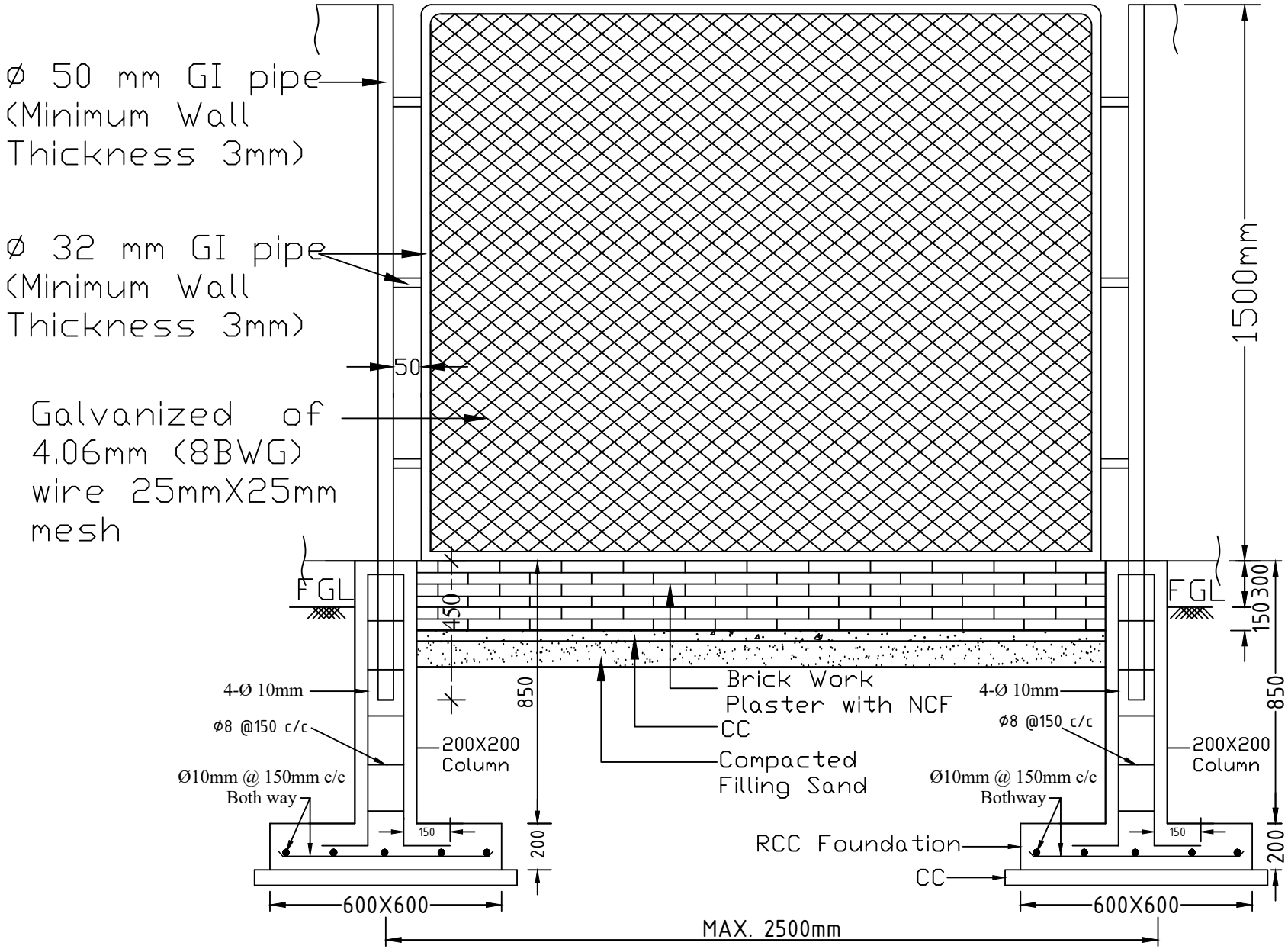
Power Grid Company of Bangladesh Limited

Project: DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.

Drawing Title: Ansar Barak

Drawing No.: DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C08

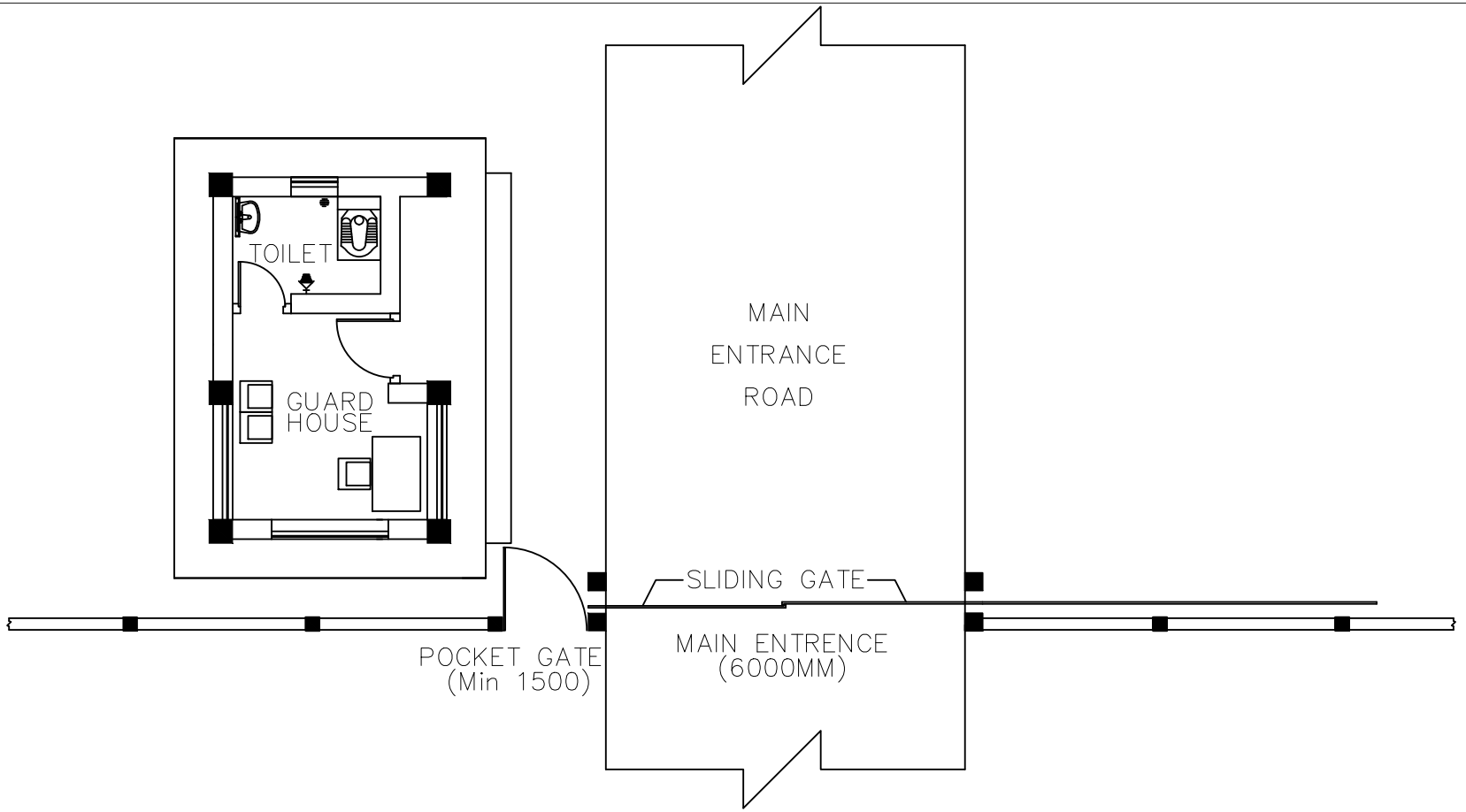
Drawn: | Checked: | Approved:



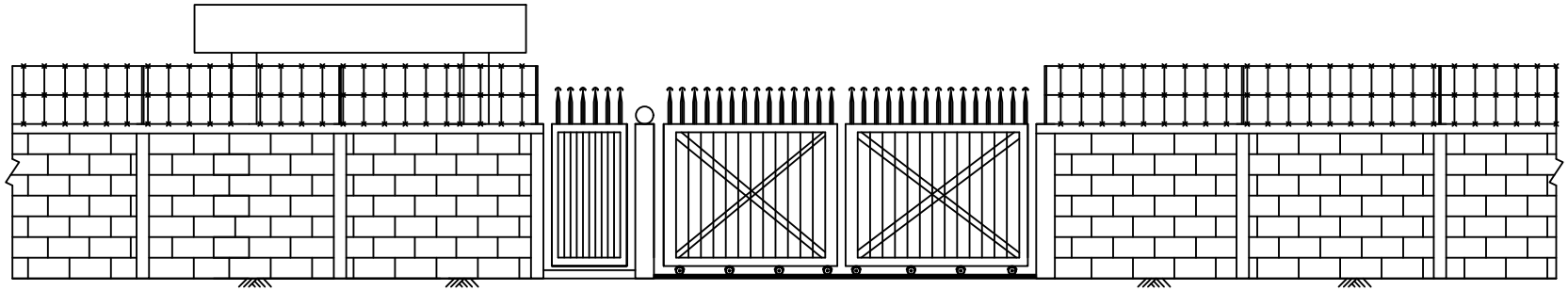
Typical Section of Chain Linked Fencing

Tender Drawing

Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Typical Section of Chain linked fencing
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C09
Drawn:	Checked: Approved:



PLAN VIEW



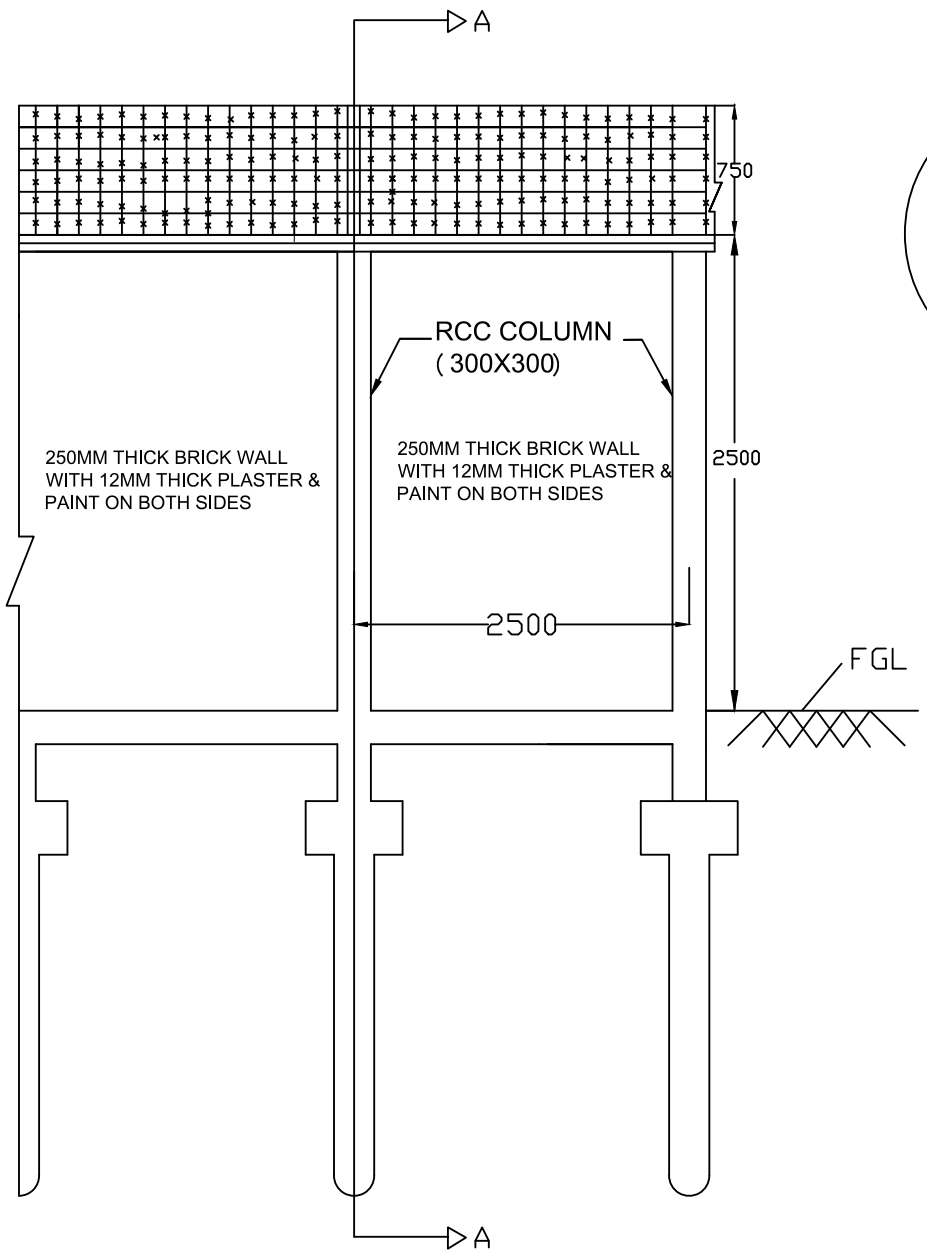
FRONT VIEW

ENTRANCE GATE

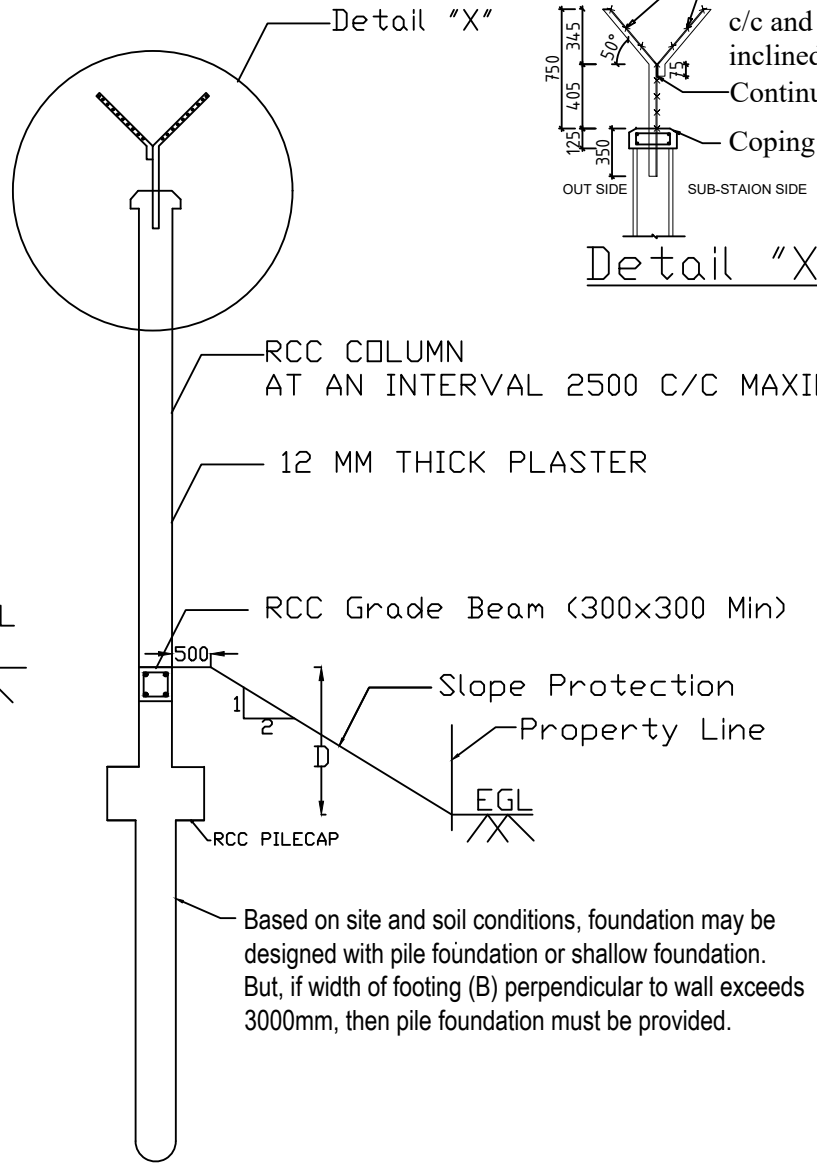
NOTE: Gate design shall be finalized during design stage.

Tender Drawing

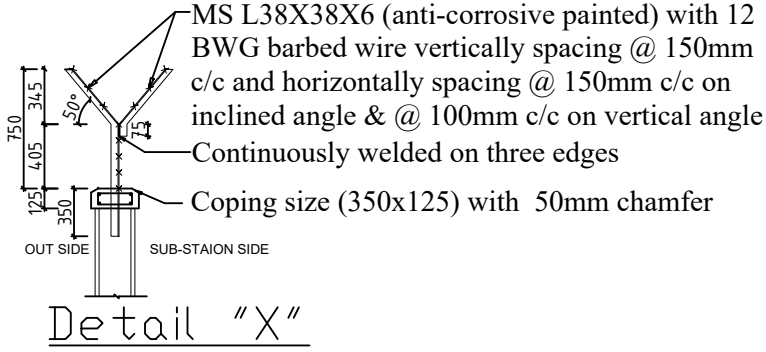
Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Main Entrance Gate
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C10
Drawn:	Checked: Approved:



FRONT ELEVATION



SECTION:A-A



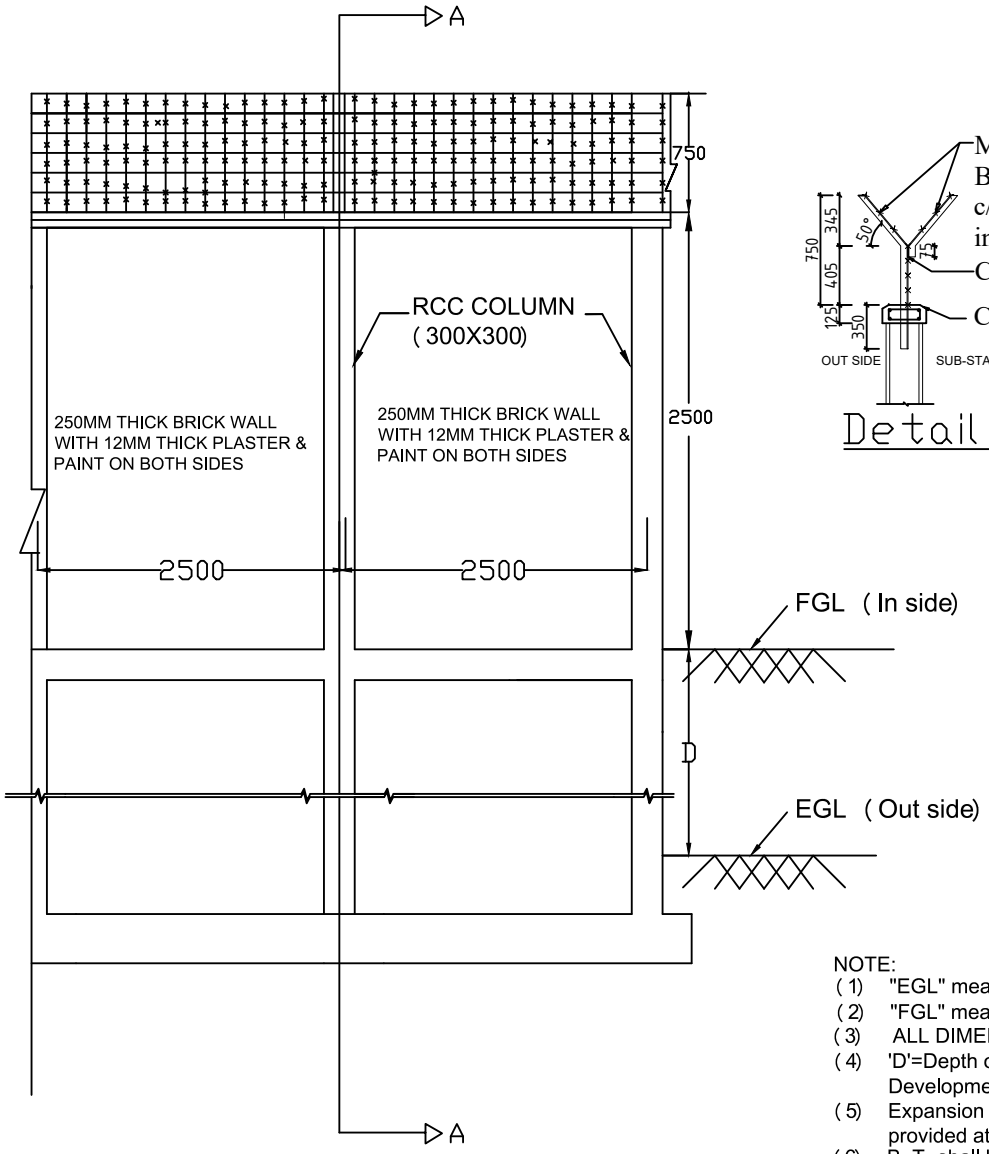
Detail "X"

NOTE:

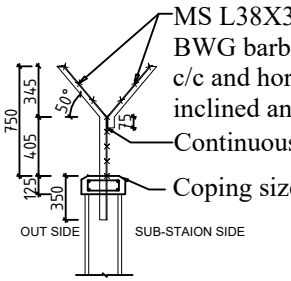
1) "EGL" means Existing Ground level
2) "FGL" means Finished Ground level
3) ALL DIMENSIONS ARE IN MM
4) 'D'=Depth of Earth Filling for Land Development
5) Expansion Joints shall have to be provided at maximum 25m Interval.

Tender Drawing

Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Boundary wall without retaining wall
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C11
Drawn:	Checked: Approved:



FRONT ELEVATION

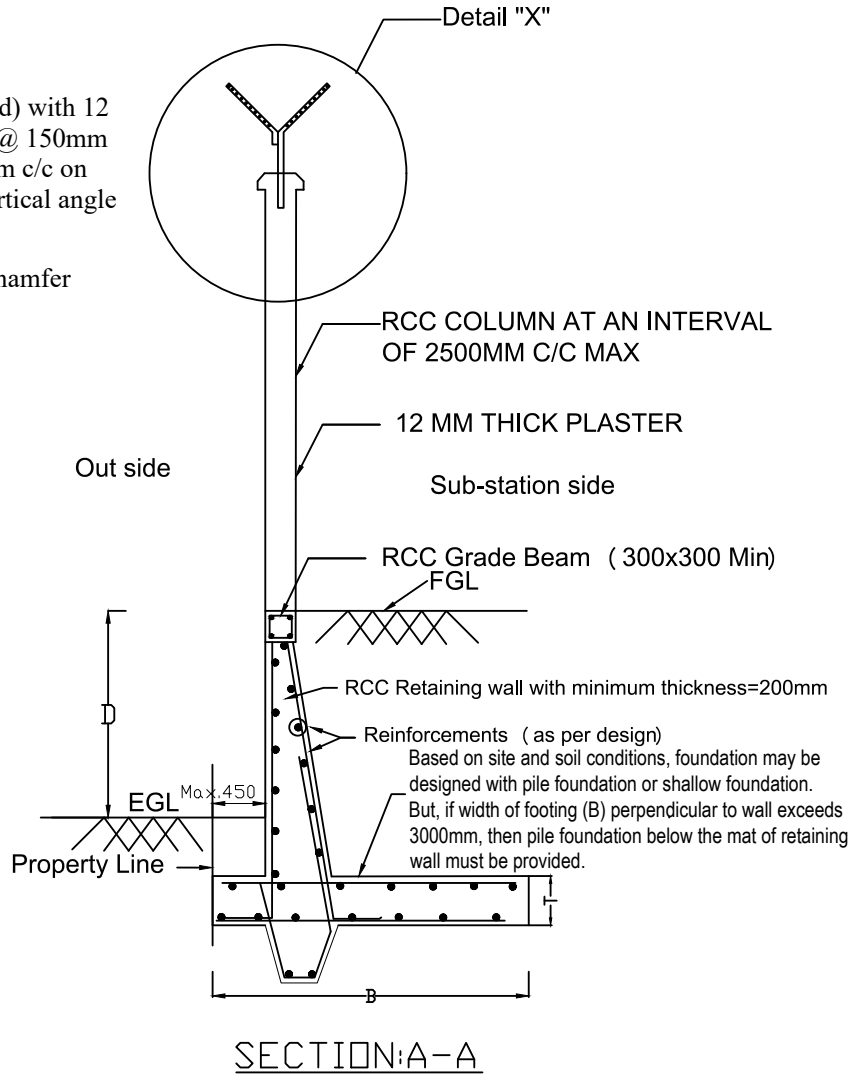


MS L38X38X6 (anti-corrosive painted) with 12 BWG barbed wire vertically spacing @ 150mm c/c and horizontally spacing @ 150mm c/c on inclined angle & @ 100mm c/c on vertical angle

Continuously welded on three edges

Coping size (350x125) with 50mm chamfer

Detail "X"



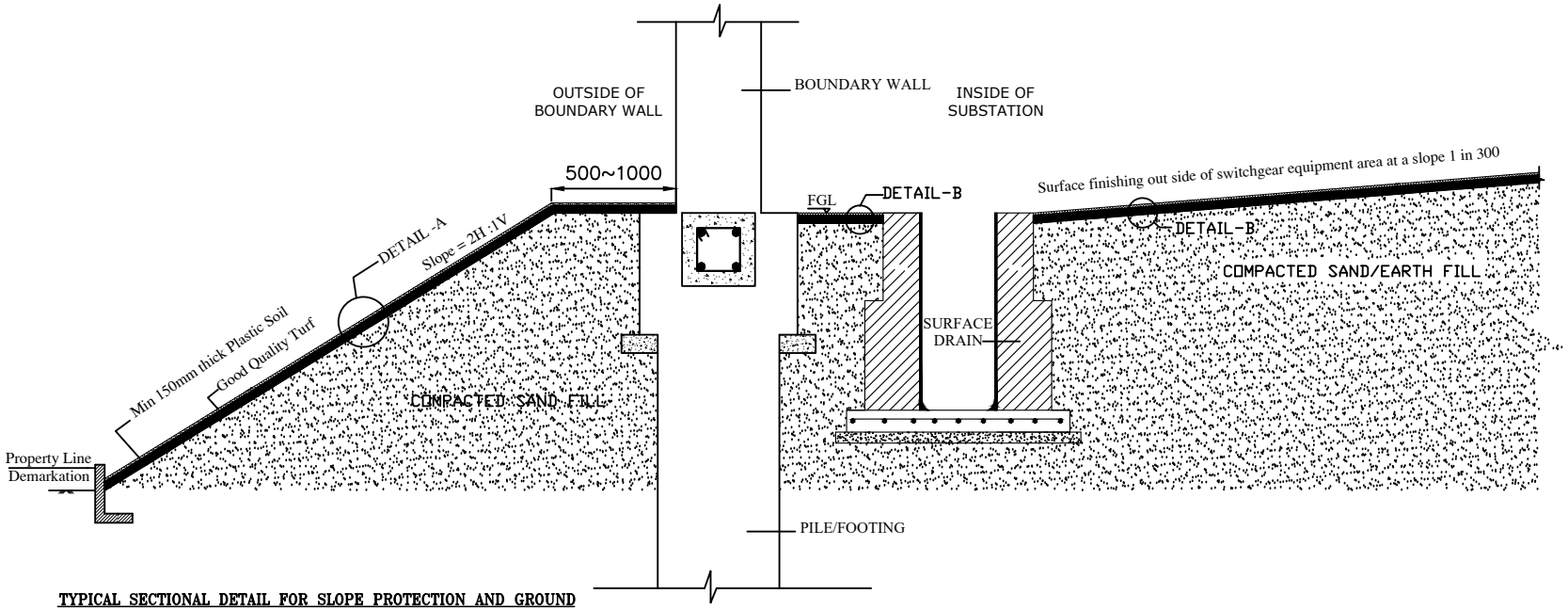
SECTION:A-A

NOTE:

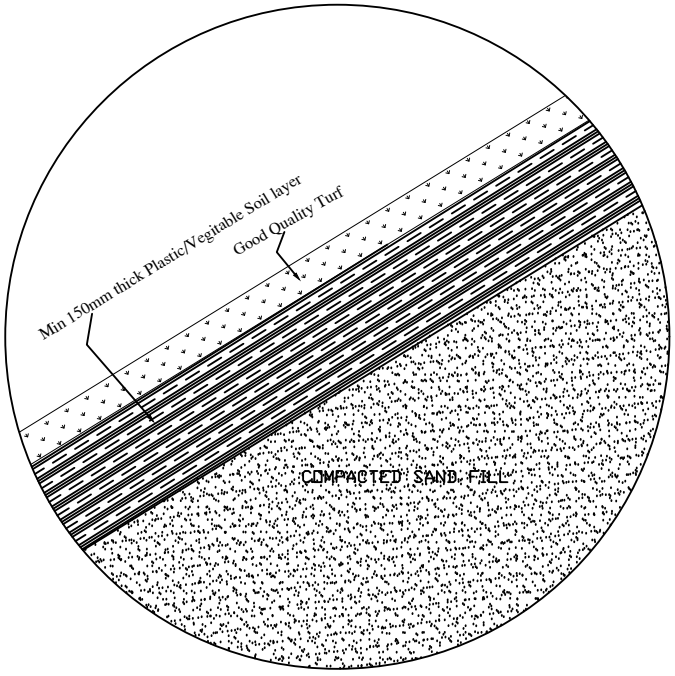
(1) "EGL" means Existing Ground level
(2) "FGL" means Finished Ground level
(3) ALL DIMENSIONS ARE IN MM
(4) 'D'=Depth of Earth Filling for Land Development (as per site condition)
(5) Expansion Joints shall have to be provided at 25m Interval.
(6) B, T- shall be designed considering wind force, lateral earth pressure, depth of filling (D) and soil bearing capacity.

Tender Drawing

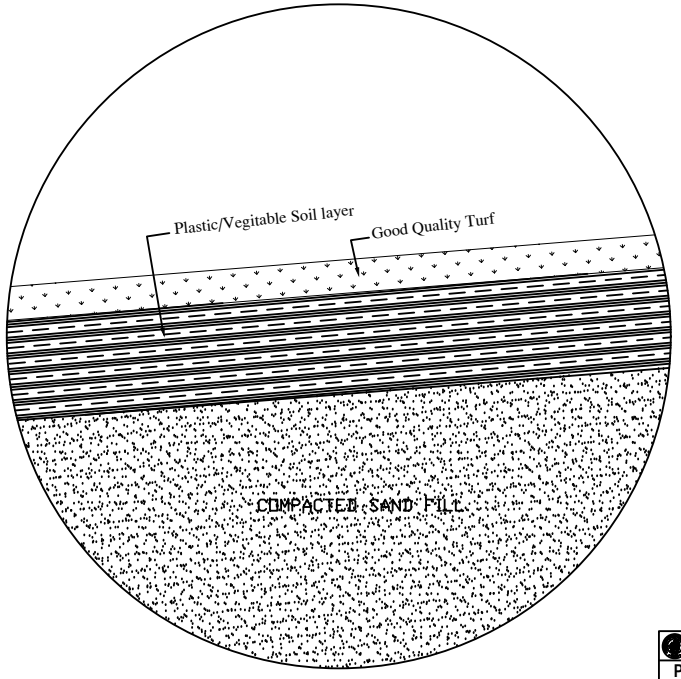
Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Boundary wall with RCC retaining wall
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C12
Drawn:	Checked: Approved:
Department: civil Design	



TYPICAL SECTIONAL DETAIL FOR SLOPE PROTECTION AND GROUND SURFACE FINISHING AROUND THE SURFACE DRAIN



DETAIL-A



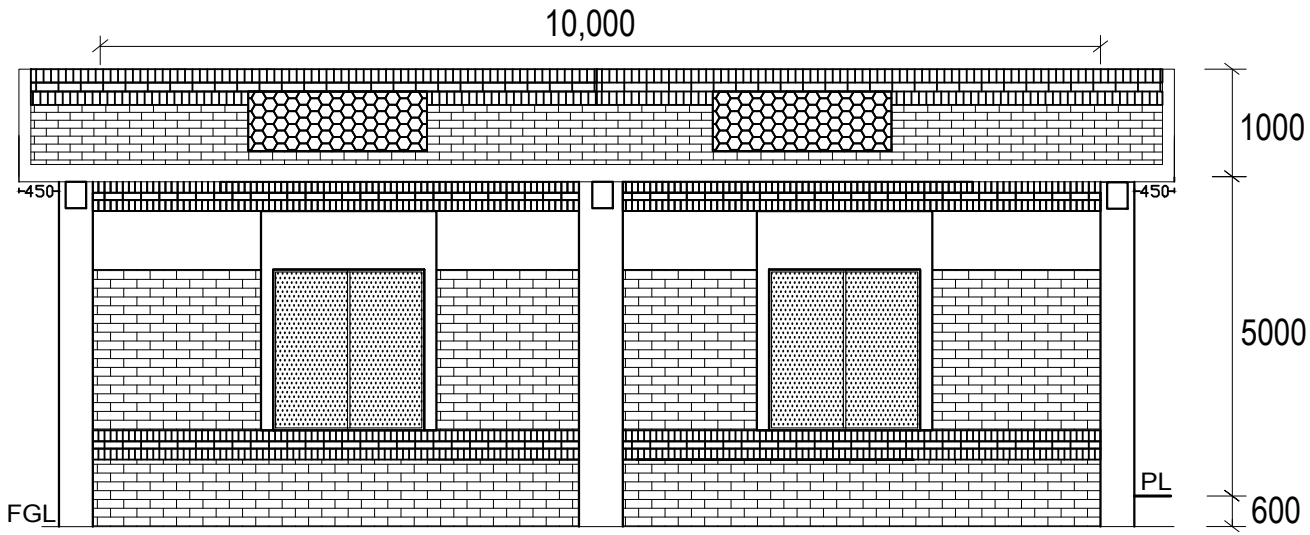
DETAIL-B

NOTE :

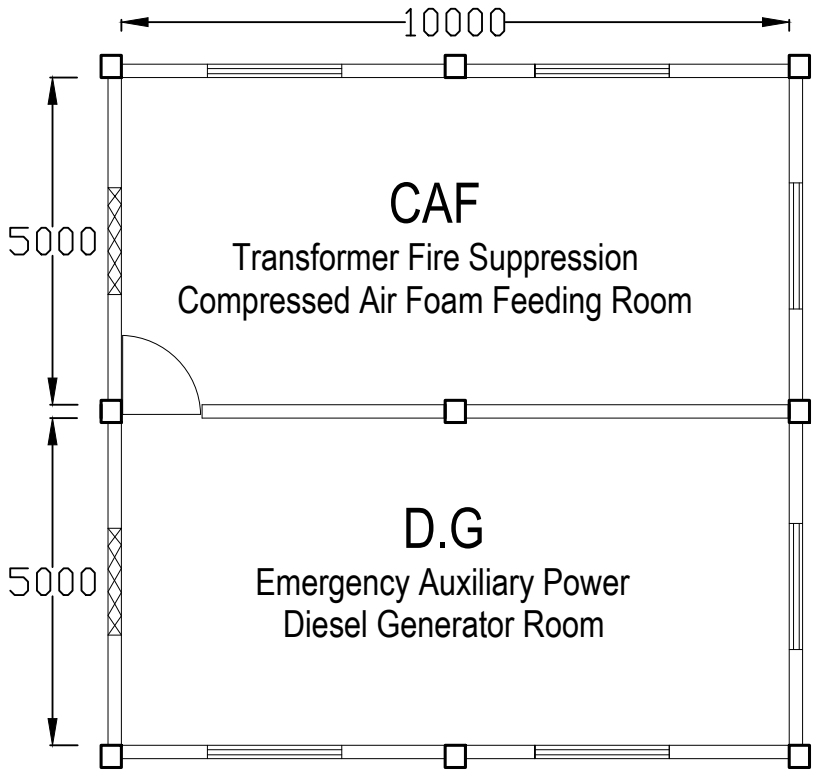
The substation plot, outside of the designated switchgear equipment areas, shall be turfed. Turf shall be of good quality, free from weeds and impurities. Samples of the turf which is proposed to use shall have to be approved by the Engineer. The turfs shall be laid to even surfaces on a bed of vegetable soil, which shall be raked and consolidated to provide a suitable bed.

Tender Drawing

Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Slpoe (1V:2H) protection with turfing
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C13
Drawn:	Checked: Approved:



Side View



Plan

All dimensions are in mm.

Note:

1) Floor area and height of the building provided here are minimum required size. If larger size is required due to bidder's CAF & DG specifications (including future); the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.

2) Position and size of equipments, ducts, columns, doors, windows, emergency exit *etc.* will be finalized during detail design.

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: AUX Power Supply & CAF Room – PLAN & SIDE VIEW	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C14	Page 01

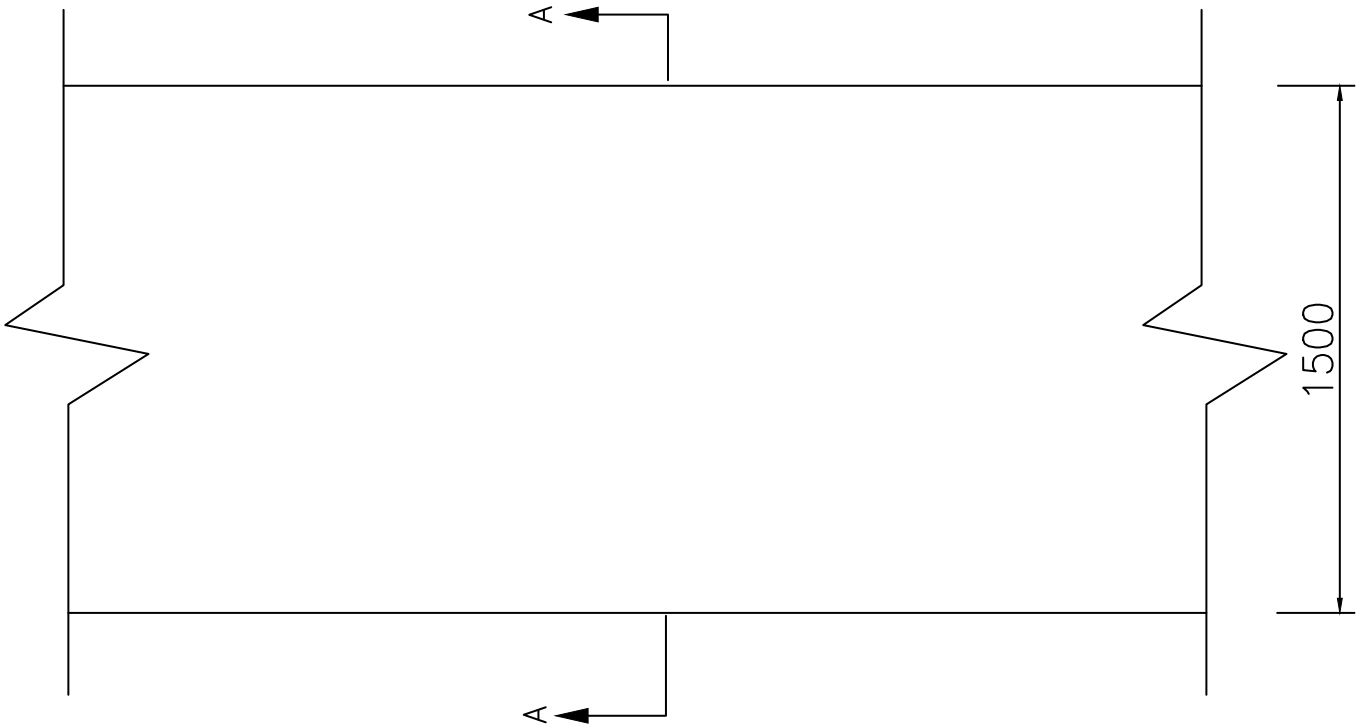
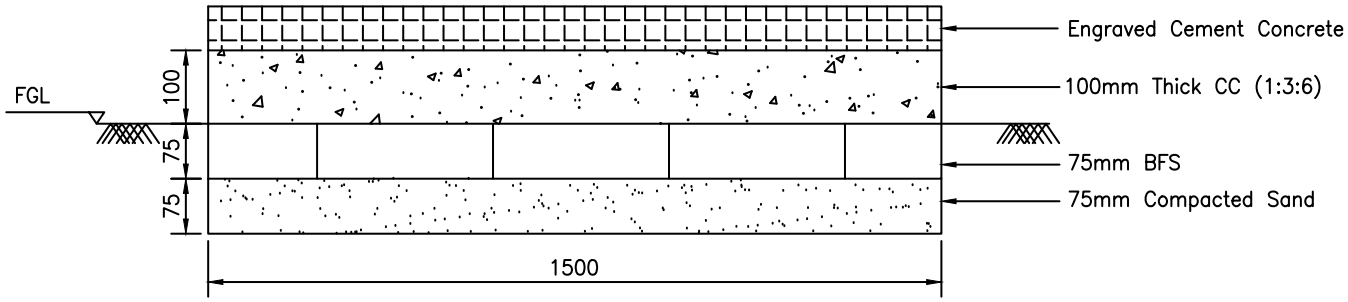


FIG: WALKWAY ROAD PLAN



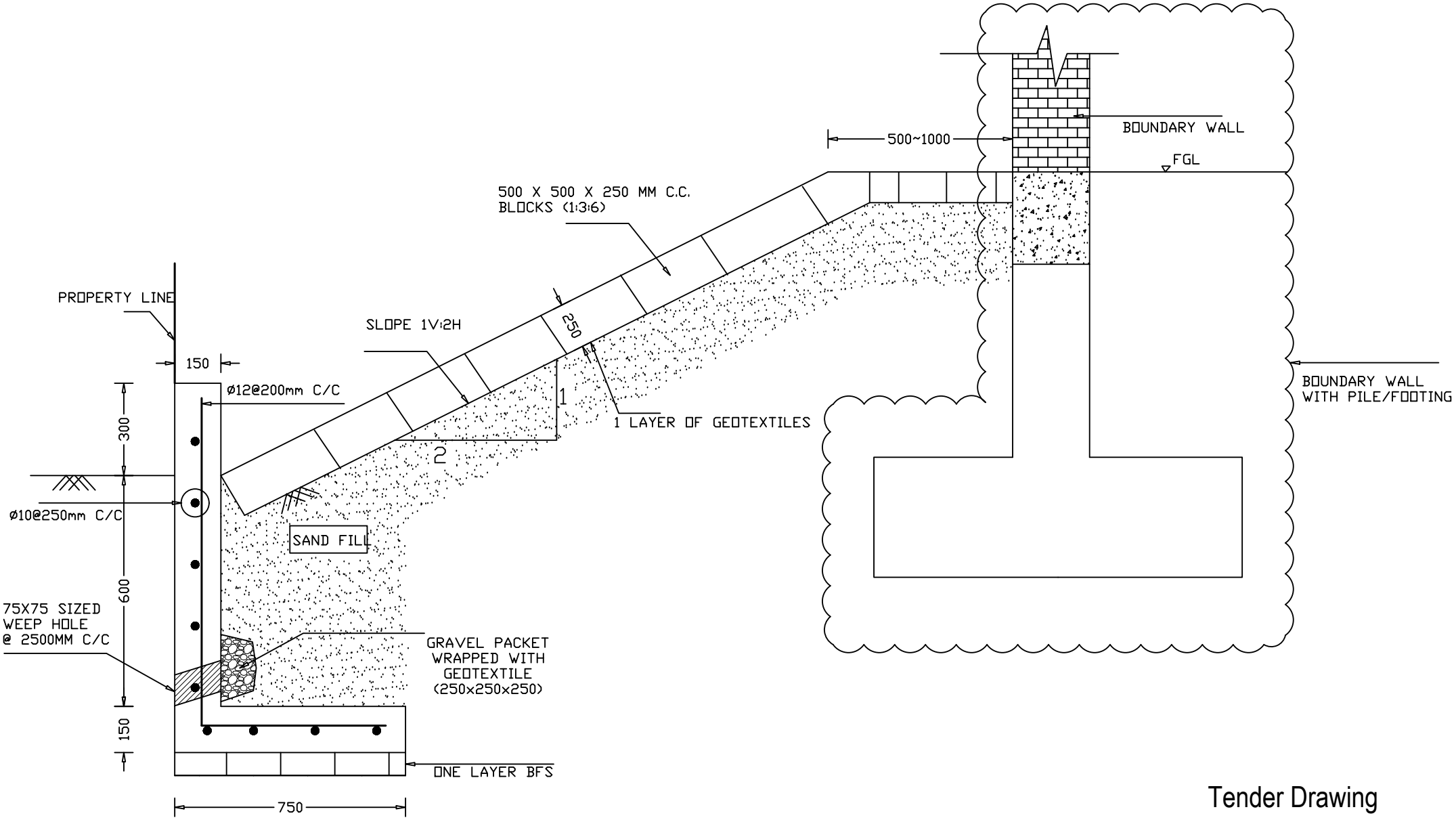
SECTION: A–A

GENERAL NOTES:

1. ALL DIMENSIONS ARE IN MILIMETERS WHERE NOT MENTIONED.

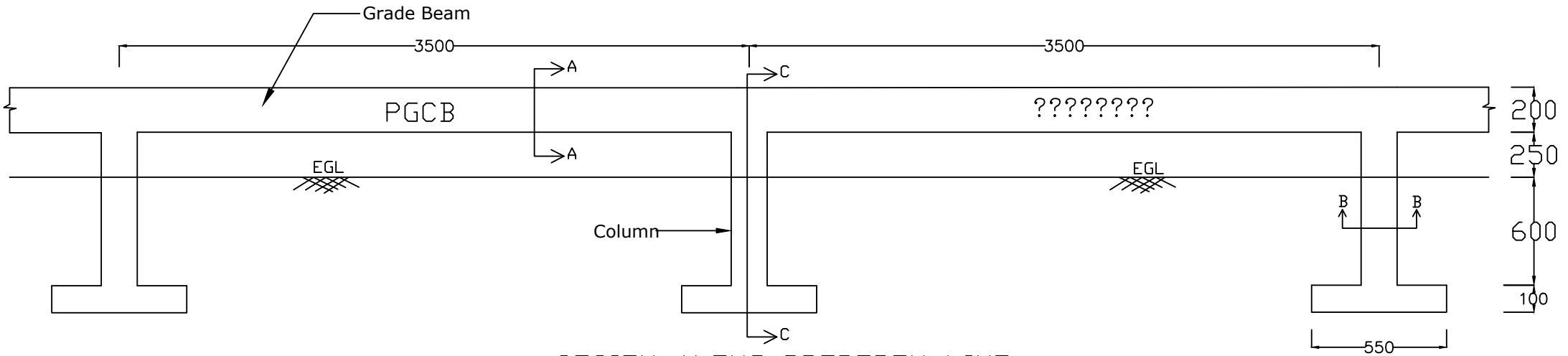
Tender Drawing

Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Typical Walkway Sections
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C15
Drawn:	Checked: Approved:

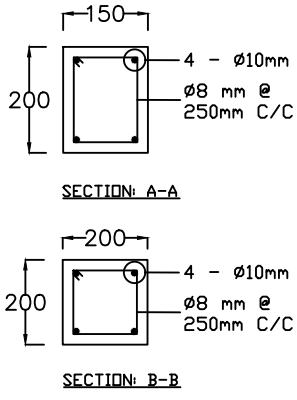


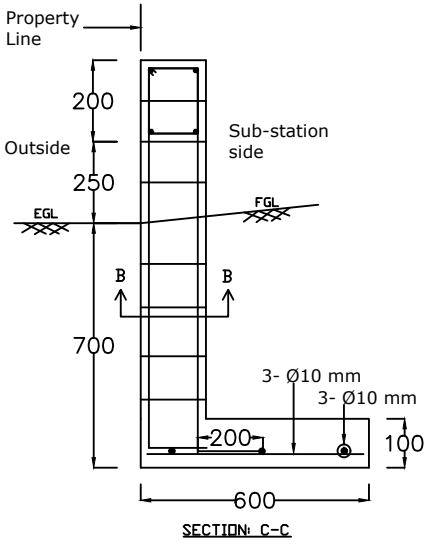
Tender Drawing

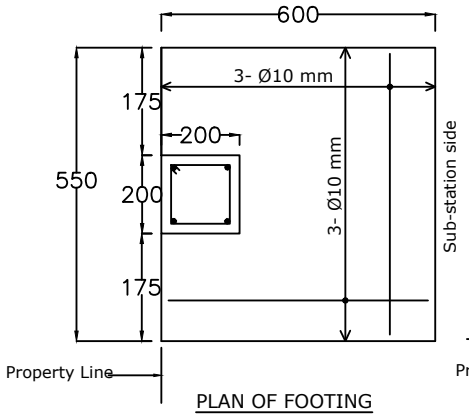
Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Slpoe (1V:2H) protection with CC blocks
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C16
Drawn:	Checked: Approved:

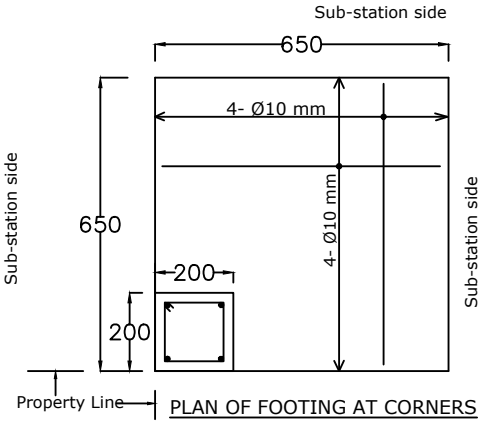


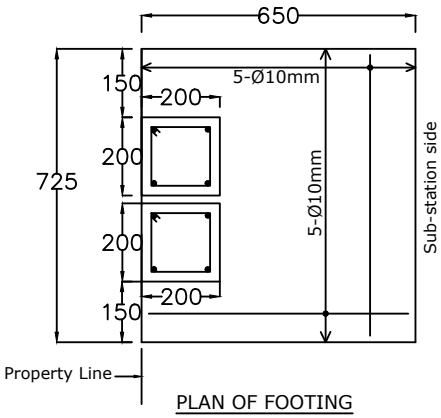
SECION ALONG PROPERTY LINE









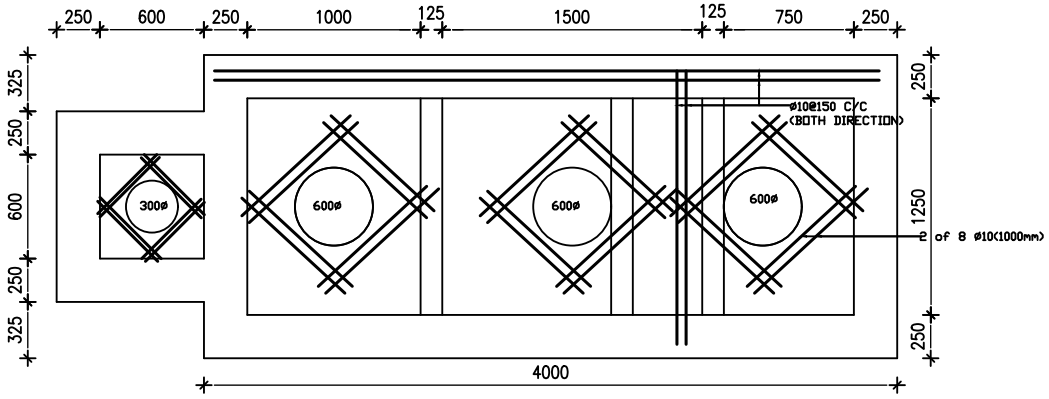


Tender Drawing

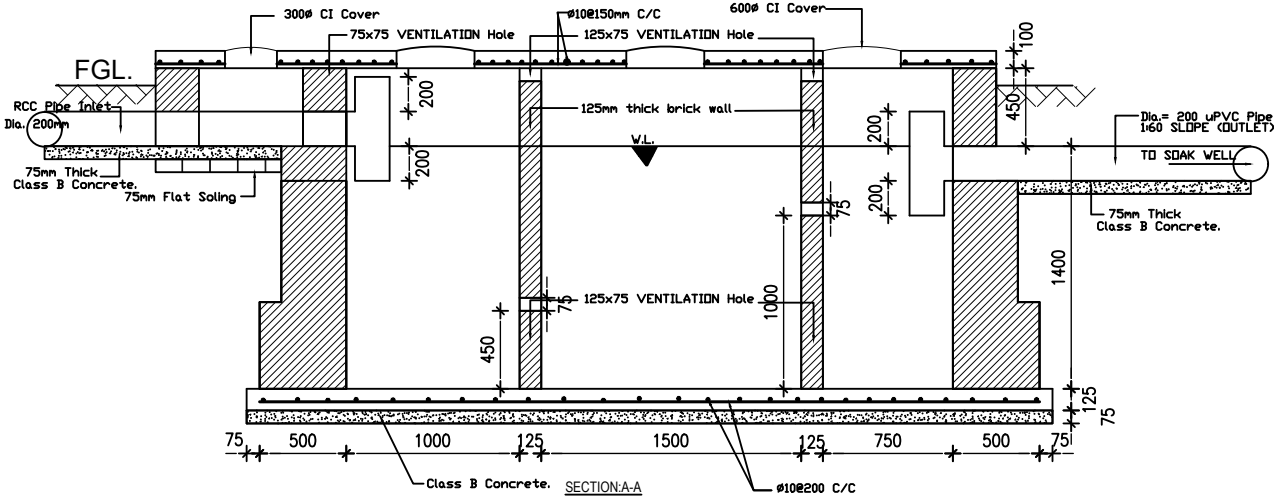
General Notes:

1. Grade beams, columns and footings are Class A Reinforced Cement Concrete(RCC) structures.
2. Grade of rebar shall be deformed bar of Fy 415 MPa minimum.
3. Clear cover both side and bottom: For Grade beam & column= 25mm and for Footing= 40mm.
4. Maximum centre to centre distance of columns = 3500mm.
5. 25mm expansion gap shall be provided at 35000mm interval by double column.
6. All dimension are in mm where not stated.

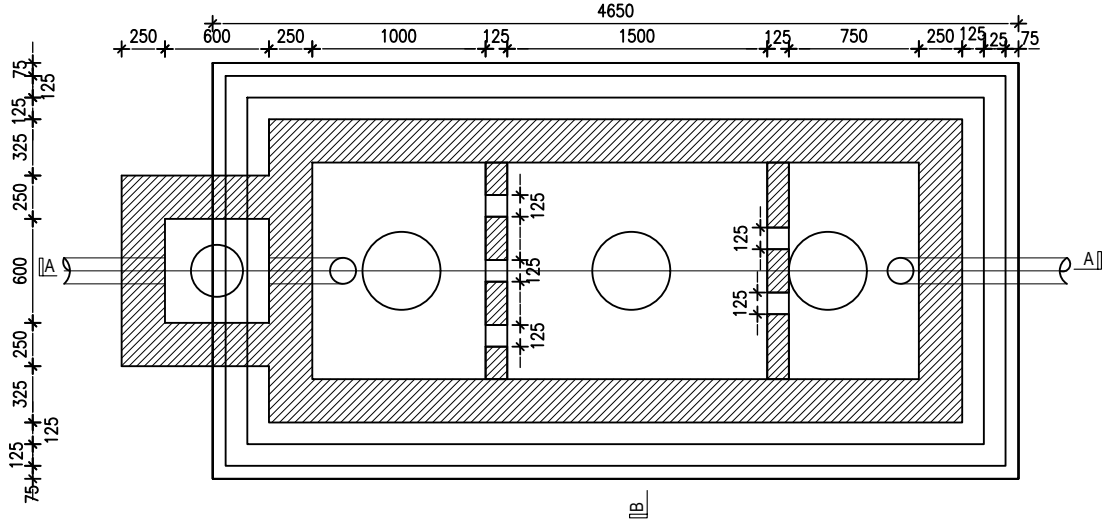
EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.		
CONTRACT NO:			
Prepared		TITLE: Property Line Demarcation	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C17	Page 01



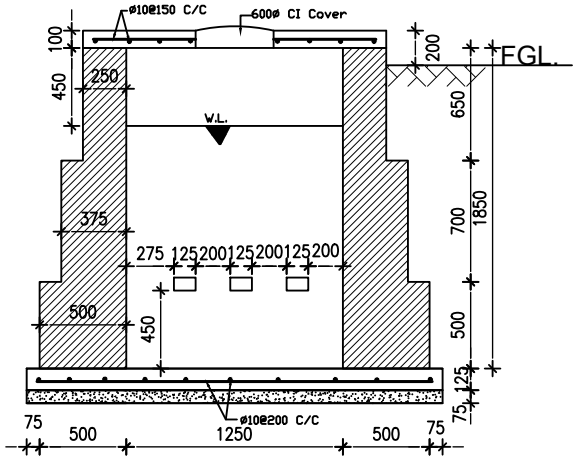
TOP SLAB REINFORCEMENT OF SEPTIC TANK



B



PLAN OF SEPTIC TANK



SECTION:B-B

NOTES:

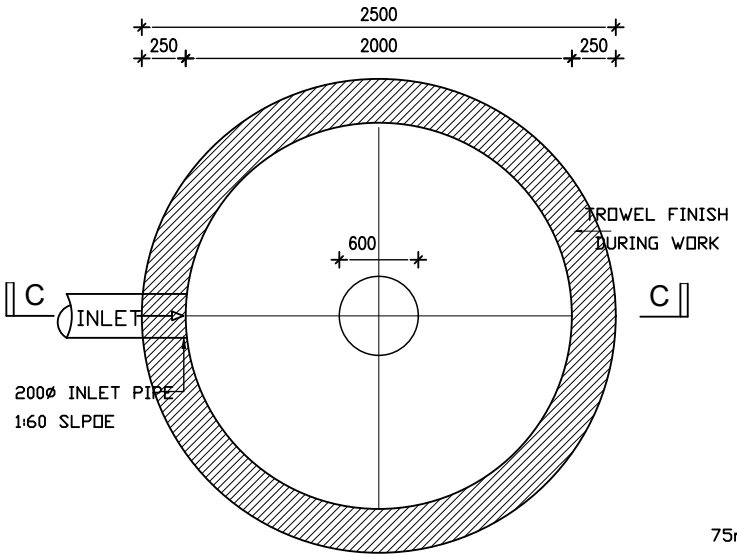
1. TYPE OF COVER FOR ALL INSPECTION HOLES IS C.I.
2. SIZE OF THE HOLE INSIDE BRICK HOLE INSIDE BRICK WALL FOR SEPTIC TANK IS 125X75 mm2.
3. R.C.C. WORK AS PER APPROVED MIX. DESIGN.
4. MINIMUM YIELD STRENGTH OF REBAR IS 415 N/ mm2.
5. MORTAR MIXING PROPORTION IS 1:4
6. PLASTER MIXING PROPORTION IS 1:3.
7. THE INTERIOR OF ALL SEPTIC TANKS AND MANHOLES CARRYING FOUL SEWAGE SHALL RECEIVE TWO COATS OF BITUMASTIC PAINT.
8. ALL SPECIFICATION WILL BE FOLLOWED AS SPECIFIED IN THE CONTRACT.
9. ALL EXTERIOR BRICK WORK OF SP & SW SHALL BE FURNISHED WITH NCF.
10. MINIMUM CLEAR COVER OF THE REBAR (BELOW GROUND LEVEL) IS 60mm.
11. SEPTIC TANK SHOULD BE LOCATED ADEQUATE DISTANCE FROM CONTROL BUILDING.
12. ALL DIMENSIONS ARE IN mm WHERE NOT STATED.

Tender Drawing

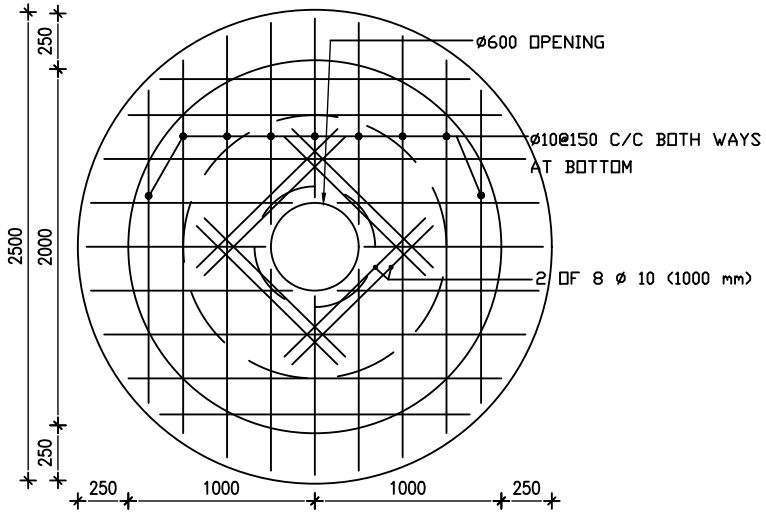
Power Grid Company of Bangladesh Limited

Project: DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.

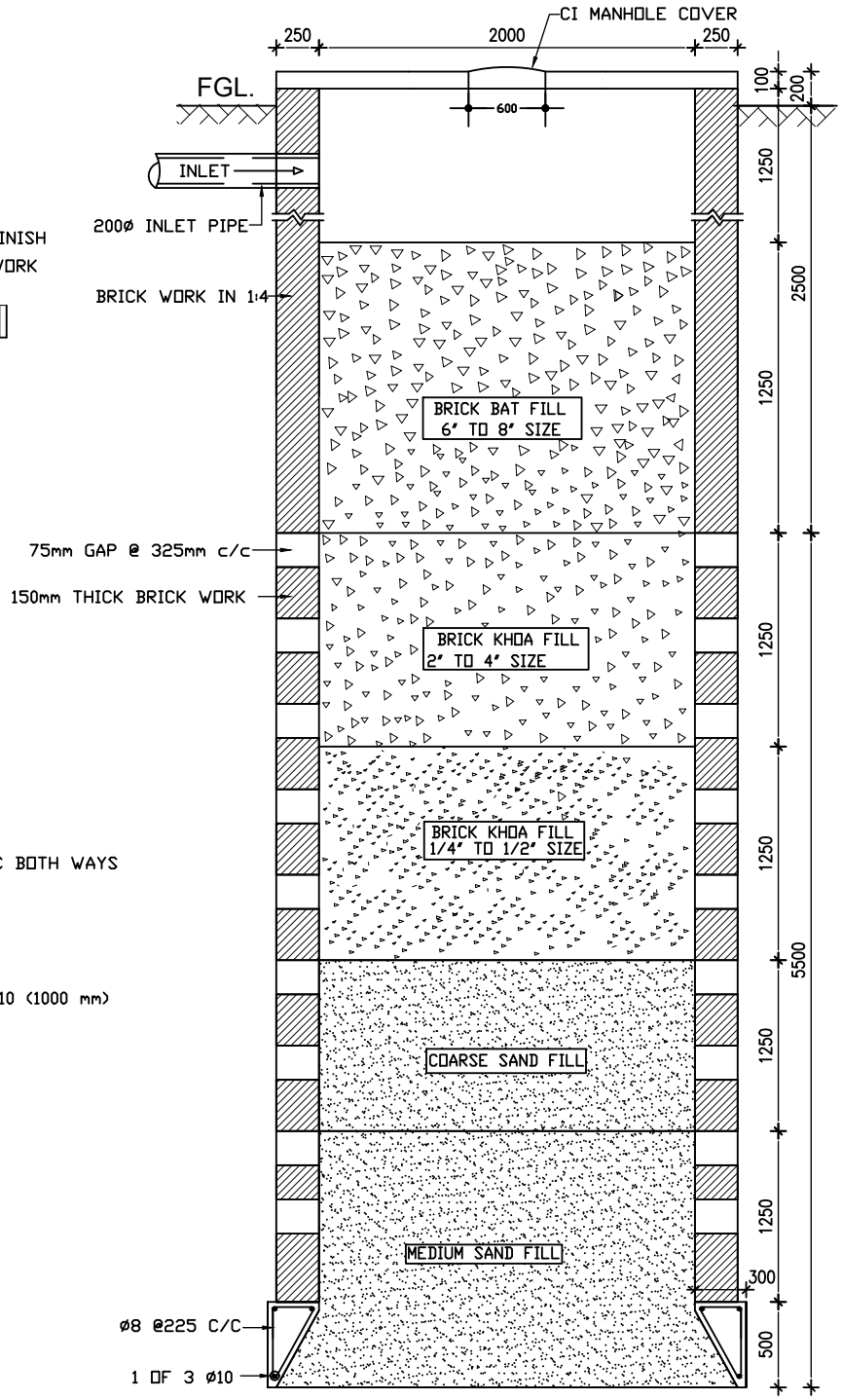
Drawing Title	Septik Tank
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C18
Drawn:	Checked: Approved:



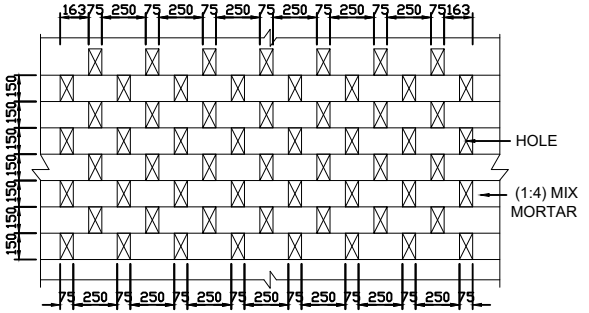
PLAN OF SOAK WELL (SW)



SLAB OF SW
REINFORCEMENT PLAN OF TOP



SECTION ON C - C



PART VIEW OF WALL WITH HOLE

Tender Drawing

Power Grid Company of Bangladesh Limited	
Project	DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF 400/230KV GIS SUBSTATION AT KALIGANJ ON TURNKEY BASIS.
Drawing Title	Soak Well for Septik Tank
Drawing No.	DOCUMENT ID: PGCB/DESIGN/2021/KALIGANJ/C19
Drawn:	Checked: Approved: