POWER GRID BANGLADESH PLC

Tender Documents
For
Procurement of

Design, Supply, Installation, Testing and Commissioning of 400 kV Transformer Bay and 230 kV Transmission Line Diameter Extension at Kaliakoir Substation

(One Stage Two Envelope Tendering Method)

Volume 2 of 3

Invitation for Tenders No. : 27.21.0000.101.07.432.26.2629; Date- 10.06.2026

OCB No. : POWERGRID/BayExtensions/KaliakoirSS

Country : Peoples Republic of Bangladesh

Employer:

Power Grid Bangladesh PLC
Grid Bhaban, Avenue-03, Jahurul Islam City
Aftabnagar, Badda, Dhaka-1212, Bangladesh

Contents of the Tender Documents

Volume 1

Section 1. Instructions to Tenderers (ITT)
Section 2. Tender Data Sheet (TDS)
Section 3. General Conditions of Contract (GCC)
Section 4. Particular Conditions of Contract (PCC)
Section 5. Tender and Contract Forms
Section 6. Procuring Entity's Requirements
Section 7. Drawings

Volume 2

Technical Specifications
Drawings forming Part of the Specification

Volume 3

Scope of Works
Schedule A: Introduction & Preamble to the Price & Technical Schedules
Schedule B: Bid Prices & Schedules
Schedule C: Bar Chart Program of Key Activities-Delivery & Completion Time Schedule
Schedule D: Manufacturers, Places of Manufacture and Testing
Schedule E: Technical Particulars and Guarantees

Index of Volume-2

SECTION-1: System Parameters & Design

SECTION-2: Technical Specifications

SECTION-3: HV Switchgear and Neutral Earthing Equipment

SECTION-4: Power Transformer

SECTION-5: Protection, Metering & Control and Substation Automation System

SECTION-6: Auxiliary Power and Control Cables

SECTION-7: Earthing System & Lightning Protection

SECTION-8: Batteries, Chargers, and DC Switchgear

SECTION-9: LV AC Distribution Switchgear

SECTION-10: National Load Dispatch Centre (NLDC) Control Facilities

SECTION-11: Buildings and Civil Engineering Works (For Outdoor GIS And AIS)

SECTION-12: Supporting Structures for Outdoor Equipment

SECTION-13: Lighting, Small Power, Heating, and Ventilation

SECTION-14: Fiber Optic Multiplexer and Power Line Carrier Equipment for Communication and Protection

SECTION-15: Quality Assurance, Inspection, Testing, Commissioning and Warranty

SECTION-16: Conductors, Clamps, Connectors

SECTION-17: Drawings forming Part of the Specifications

SECTION-1:

System Parameters & Design

Index of Contents

SL No.	Name of Items	Page No.
1.1	System Electrical Parameters	03
1.2	Climatic Conditions	05
1.3	System & Plant Design	06

1. System Parameters & Design

1.1 System Electrical Parameters

1.1.1 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 Equipment /1550 for Bus PI	1050	650	170
Rated Switching Impulse withstand voltage			1050 for Equipment/1175 for Bus PI	NA	NA	NA
Rated power frequency withstand voltage		kV, 1 min	650	460	275	70
Rated symmetrical short-circuit current						
For	GIS Switchyard	kA, 3 sec	63	50	40	31.5
	AIS Switchyard	kA, 1 sec	63	50	40	31.5

1.1.2 System Earthing

1.1.2.1 All Main Transformer Neutrals shall be solidly earthed (The 400/230/33kVAuto-Transformers, 230/132/33kV Auto-Transformers, 400/132/33kV Auto-Transformers and 132/33kV Power Transformers are solidly earthed.

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

1.1.2.3 The 33 kV system is solidly earthed at some of the 132/33 kV grid substations and resistance earthed at some of the grid substations.

1.1.3 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			
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	31.5			

1.1.4 Low Voltage AC System

Description	Unit	Required for equipment design	At Load Terminal	
			Lighting	Other uses
Rated service voltage (3 phase, 4 wire 50 Hz)	V	415	415	
Tolerance on rated voltage	%	+15%, -15%	6%	8%
Switchgear symmetrical breaking capacity	kA	15 kA, 3 sec		
System earthing	-	solid		

1.1.5 Low Voltage DC System

For d.c. motor driven auxiliaries, relays, tripping, indicating lamps and controls.

Description	Unit	Required for equipment design	At Load Terminal	
			Lighting	Other uses
Nominal DC voltage	V	110	110	
Tolerance on rated voltage	%	+15%, -15%	6%	8%

For telecommunication & SCADA

Description	Unit	Required for equipment design	At Load Terminal
Nominal DC voltage	V	48	48
Tolerance on rated voltage	%	+15%, -15%	8%

1.2 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 45 °C with periods of high humidity.

Between May and November, low-lying areas are subjected 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 for GIS and AIS is mentioned below. 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	45
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 for Indoor GIS
		0.1 for AIS & Outdoor GIS
Soil type	-	Alluvial
Soil temperature (at 1.1m)	°C	30 °C at 1.1 meter depth
Soil thermal resistivity	°Cm/W	1.5
Isokeraunic level (thunderstorm days/year)	days/year	80
Peak Amplitude of Lightning Impulse (for Lightning Insulation Co-ordination)	kA	200

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.

1.3 System & Plant Design

1.3.1 Under the system & plant design, this section defines all necessary design works required for the present scope of work for this turnkey project, including the creation of design drawings, providing site support during the construction phase and the provision of final as built drawings.

1.3.2 The Contractor shall provide supporting documentation, calculations, system studies, drawings, descriptions, manuals, manufacturer quality plan, as specified in this Specification.

1.3.3 The Contractor shall provide progress reports and meetings with the PGCB's Representative whenever the Principal demands and as specified in the bid document.

1.3.4 The design of the substation shall be in accordance with the relevant standard as mentioned in the bid document, and the PGCB approved Substation Standards. However, the Contractor must be responsible for the content of all drawings created or modified as part of the project.

1.3.5 The Requirements set out herein represent the minimum Requirements acceptable to the Principal (PGCB).

1.3.6 Once approved, the Contractor shall not modify the drawings, designs, calculations or any part thereof during the construction period, unless the request derives from a serious omission or error in the design. Such modification shall be only acceptable prior to employer's approval.

1.3.7 The Contractor shall provide all design drawing calculation files (such as .cad file) used in production of the studies to the PGCB.

1.3.8 The Contractor shall incorporate the PGCB's standard identification nomenclature and labelling into all design.

1.3.9 Any design, drawings & calculation shall be notified in writing to the Principal (PGCB) for approval and shall be based on the methods given in the standards listed

The design scope of works shall include the following:

1.3.10 Station Design:

1.3.10.1 The contactor shall provide design, drawings & calculations listed below:

- GA drawing of station under scope of work
- Clearance Diagram
- Single Line Diagram
- Erection Key Diagram
- Conductor Sizing
- Power Cable Sizing Calculation (when required)
- Communication & SCADA Diagram
- General Agreement Drawing of Layout plan
- Erection key diagram
- Control Room Equipment / Internal Layout Drawing
- Switchyard SPR Equipment/ Internal Layout Drawing
- HV Power Cable Route Plan
- Cable Trench Drawing
- Cantilever Force Calculation

- Sag Tension Calculation

1.3.10.2 The Contractor must design the works to suit the environmental and system conditions defined in 1.1 & 1.2 System Electrical parameters & Climatic Conditions.

1.3.11 Protection & Control System Design:

1.3.11.1 The contactor shall provide design, drawings & calculations listed below:

- Protection and Metering Single Line Diagram
- Interlocking Diagram (hardware & software) & Trip Matrix Diagram.
- CT-PT Sizing Calculation
- Relay Setting Calculation
- Digital Fault & Disturbance Recorder (DFDR) Scheme Drawing
- GTP, BoQ and component manuals and other documents as required by this specification.

1.3.11.2 Detail information & criteria for design, drawing, calculation of protection & control system shall be in accordance with Section 5: Volume 2, Schedule A: Volume 3 & Tender drawings.

1.3.12 Substation Automation System Design

1.3.12.1 The contactor shall provide design, drawings & calculations listed below:

- Substation Automation System (SAS) Architecture Drawing
- GTP, BoQ and component manuals and other documents as required by this specification.

1.3.12.2 Detail information & criteria for design, drawing, calculation of substation automation system shall be in accordance with Section 5: Volume 2, Schedule A: Volume 3 & Tender drawings.

1.3.13 Equipment Design:

1.3.13.1 All Equipment design shall be designed in line with relevant sections of this specification.

1.3.13.2 The contactor shall provide the following least basic design, drawings & calculations of equipment listed below (detail submission requirement shall be finalized during execution):

1	Power/Main Transformer:	
	1	Outline/ GA Drawing
	2	Section Drawing
	3	Shipping Drawing
	4	Nameplate / Rating Plate
	5	Connection Diagram (Sometimes it's merged with Nameplate Drawing)
	6	Value Schedule
	7	Transformer Oil
	8	Over Fluxing Wave
	9	Oil-Temperature Curve
	10	Sub-Vender List

	11	Cooling Calculation
	12	Short Circuit Force Withstand Calculation / Short Circuit Design
	13	Bushing [High Voltage(HV), Low Voltage(LV), Tertiary Voltage(TV), Neutral Voltage(NV)] Outline, Nameplate & GTP of BCT Drawing
	14	Transformer Base Detail Drawing
	15	Painting Specification
	16	GTP of Transformer
	17	GTP & GA of Motor
	18	GTP & GA of Core
	19	GTP & GA of Winding
	20	GTP & GA of On Load Tap Changing (OLTC)
	21	Catalogue / GA of Rubber Bag / Silica gel / Valve
	22	Catalogue / GA of Relays[Pressure Relief Device (PRD) / Oil Surge Relay, Buchholz Relay]
	23	Local Control Panel (LCP) drawing/ Local Control Cubicle (LCC) Drawing
	24	Fan Control Scheme Drawing
	25	Signalling Scheme Drawing
	26	Remote Tap-changer Control Cubicle (RTCC) Drawing
2	Circuit Breaker (CB) :	
	1	GA / Outline with Section
	2	GTP
	3	Base Detail
	4	Control Circuit Diagram
	5	Local Control Panel (LCP) Drawing
	6	Mechanism Box (MB) Drawing
	7	Nameplate Drawing
3	Disconnector Switch (DS) :	
	1	GA / Outline with Section
	2	GTP
	3	Control Circuit Diagram
	4	Mechanism Box (MB) Drawing
	5	Nameplate Drawing
5	Potential Transformer (PT) / Capacitance Voltage Transformer (CVT) :	
	1	GA / Outline
	2	GTP
	3	Sectional Drawing
	4	Secondary Box Drawing
	5	Nameplate Drawing

6	Lightning Arrester (LA)	
	1	GA / Outline
	2	GTP
	3	Sectional Drawing
	4	Nameplate Drawing
	5	Surge Counter GA & GTP
7	Wave Trap (WT):	
	1	GA / Outline
	2	GTP
	3	Sectional Drawing
	4	Nameplate Drawing
8	GIS :	
	1	GA & GTP with Section
	2	SLD
	3	Gas Zone SLD
	4	Maintenance, Repair & Extension (MRE) Philosophy
	5	GIS Room Drawing with GIS (for Indoor GIS)
9	Post Insulator (PI) & Disc Insulator (DI) GA & GTP	
10	Conductor GA & GTP	
11	Fittings /Clamp-Connector GA & GTP	
12	Substation Automation System (SAS) GA & GTP	
13	Digital Fault & Disturbance Recorder (DFDR) GA & GTP	
14	Power Cable GA & GTP	
15	Control Cable GA & GTP	
16	Fire Fighting System GA & GTP	
17	Oil Treatment Plant GA & GTP	
18	Auxiliary Transformer GA & GTP	
19	Junction Box	
20	Fibre Optic Cable GA & GTP	
21	Test Equipment	
21	Fiber Optics Telecommunication System GA & GTP	
23	Gravel Layout Drawing	
24	Cable Trench Drawing :	
	1	Cable Sealing End
	2	Cable Termination Kits
	3	Cable Gland
	4	Cable Tray & Rack
25	Load Break Switch / DS with Fuse GA & GTP	
26	Metering Panel :	
	1	Scheme

	2	Manufacturer Drawing

1.3.13.3 Detail information & criteria for design, drawing, calculation of substation automation system shall be in accordance with Section 2: Volume 2, Section 3: Volume 2, Schedule A: Volume 3, Schedule E: Volume 3 & Tender drawings.

1.3.14 Telecommunication System Design:

1.3.14.1 The contactor shall provide design, drawings & calculations listed below:

- Communication Scheme Diagram
- SCADA system diagram.
- GTP, BoQ and component manuals and other documents as required by this specification.

1.3.14.2 Detail information & criteria for design, drawing, calculation of telecommunication system, shall be in accordance with Section 14: Volume 2, Section 15: Volume 2, Schedule A: Volume 3 & Tender drawings.

1.3.15 Civil Design:

- Detail information & criteria for design, drawing, calculation of
  - Building design shall be accordance with Section 10: Volume 2, Schedule A: Volume 3 & Tender drawings.
  - Outdoor equipment supporting structure shall be accordance with Section 11: Volume 2, Schedule A: Volume 3 & Tender drawings.

1.3.16 Earthing & Lightning Protection:

1.3.16.1 The contactor shall provide design, drawings & calculations listed below:

- Direct Stroke Lightning Protection Layout & Calculation
- Earthing System Design & Layout
- Earthing System Installation Philosophy
- Earth Resistivity Calculation Methodology
- Earthing Materials GA & GTP.
- GTP, BoQ and component manuals and other documents as required by this specification.

1.3.16.2 Detail information & criteria for design, drawing, calculation of earthing system and lightning protection shall be in accordance with Section 7: Volume 2, Schedule A: Volume 3 & Tender drawings

1.3.17 DC System Design

1.3.17.1 The contactor shall provide design, drawings & calculations listed below:

- DC System (110 V & 48 V) Scheme & SLD.
- GA & GTP of DCDB.
- GA & GTP of Battery & Charger.
- Battery & Charger Sizing Calculation.
- GA, GTP & Scheme of UPS.
- GTP, BoQ and component manuals and other documents as required by this specification.

1.3.17.2 Detail information & criteria for design, drawing, calculation of DC system shall be in

accordance with Section 8: Volume 2, Section 1.1.5: Volume 2, Schedule A: Volume 3 & Tender drawings.

1.3.18 LVAC System Design

1.3.18.1 The contactor shall provide design, drawings & calculations listed below:

- LVAC system Scheme & SLD.
- LV Cable Sizing Calculation
- LV Power Cable Schedule for AC & DC System for Substation
- Lighting Layout with Power Distribution Scheme for Buildings & Switchyard.
- Auxiliary Transformer Sizing Calculation
- GTP, BoQ and component manuals and other documents as required by this specification.

1.3.18.2 Detail information & criteria for design, drawing, calculation of LVAC system shall be in accordance with Section 9: Volume 2, Section 13: Volume 2, Section 6: Volume 2, section 1.1.6: Volume 2, Schedule A: Volume 3 & Tender drawings.

1.3.19 HVAC System Design

1.3.19.1 The contactor shall provide design, drawings & calculations listed below:

- Air-conditioning system for Switchyard Panel Room and Control Room.
- GTP, BoQ and component manuals and other documents as required by this specification.

1.3.19.2 Detail information & criteria for design, drawing, calculation of HVAC system shall be in accordance with Section 13: Volume 2, Schedule A: Volume 3 & Tender drawings.

1.3.20 Non-Major Items design:

All other no-major items shall be designed in line with relevant sections of this specification.

SECTION-2:

TECHNICAL SPECIFICATIONS

Index of Contents

SL No.	Name of Items	Page No.
2.1	Ancillary Mechanical and Electrical Apparatus	04
2.2	References	04
2.3	Erection Marks	08
2.4	Cleaning and Painting	08
2.5	Rating Plates, Nameplates and Labels	15
2.6	Environmental Protection & Topicalization	16
2.7	Platforms, Stairways, Ladders and Hand-Railing	18
2.8	Nuts, Bolts, Studs and Washers	19
2.9	Forgings	20
2.10	Castings	20
2.11	Galvanised Work	25
2.12	Pumps	25
2.13	Pipework	26
2.14	Valves	27
2.15	Pressure Vessels	27
2.16	Lubrication	28
2.17	Oil Level Indicators	28
2.18	Pressure Gauges	29
2.19	Thermometer Pockets	29
2.20	Gauge Cubicles and Panels	29
2.21	Locking Facilities	29
2.22	Electrical Equipment	30
2.23	Electrical Insulation	33
2.24	Insulating Oil	33
2.25	Control and Selector Switches	34
2.26	Panels, Desks and Cubicles	34
2.27	Instruments & Meters	36
2.28	Control and Instrument Panel Wiring, Cable Terminations and Terminal Boards	39
2.29	Cable Boxes and Glands	41
2.30	Box-Filling Compounds	43
2.31	Oil or Compound-Filled Chambers	44
2.32	Joints and Gaskets	44
2.33	Valves on Electrical Equipment Fluid Lines and Vessels	44

2.34	Junction and Marshalling Boxes	44
2.35	Conduit and Accessories	45
2.36	Trunking	46
2.37	Electric Motors	46
2.38	Miniature Circuit Breakers, Fuses and Links	51
2.39	Earthing and Bonding	51

2.1 Ancillary Mechanical and Electrical Apparatus

2.1.1 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 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
61869-1	Instrument transformers-Part 1: General Requirements
61869-2	Instrument transformers-Part 2: Additional Requirements for Current transformers
61869-3	Instrument transformers-Part 3: Additional Requirements for Voltage transformers
61869-5	Instrument transformers-Part 5: Additional Requirements for Capacitive Voltage transformers
60051	Direct acting indicating analogue 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
62271-108	High-voltage switchgear and controlgear - Part 108: High-voltage alternating current disconnecting circuit-breakers for rated voltages of 72.5 kV and above.
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 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

2.2.5 Definition of Terms

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

2.2.6 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.

2.2.7 Design Standards and Codes: 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.

2.2.8 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.

2.2.9 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:

1. Statutory regulations of Bangladesh
2. Standards named in the specification
3. Other international standards
4. 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.

2.2.10 Substitution of Standards and Design Codes

The Contractor may offer works that comply with international standards, or internationally recognised 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 acceptable if the manufacturing organisation 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 Contractor 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.

2.3 Erection Marks

2.3.1 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 galvanising, shall be clearly readable afterwards.

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

2.4 Cleaning and Painting

2.4.1 General

2.4.1.1 Following award of the Contract, the Contractor shall submit the name of the proposed paint supplier and applicator, together with a quality assurance programme, for approval. All paints for the outdoor equipment on the Contract shall be provided by one Manufacturer and preferably shall be manufactured in one country to ensure compatibility. All painting of outdoor 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 authorised representative of the paint Manufacturer.

2.4.1.2 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.

2.4.1.3 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 paintwork that occurs during transport shall be made good at site.

2.4.1.4 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 need for only minor remedial work in that period.

2.4.1.5 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.

2.4.1.6 Where paint coatings are proposed for the protection of surfaces of equipment exposed to corrosive conditions, such as plant items exposed to brine or sea water, 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.

2.4.1.7 If the defects revealed by the above test procedure do not exceed one per 5 m^2 of coating surface, the coating need not be re-tested after the defects have been repaired. If the defects exceed one per 5 m^2 of 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 m^2 of coating surface. After repair of these defects, the equipment can be placed in service without further testing.

2.4.1.8 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.

2.4.1.9 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.

2.4.1.10 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.

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

2.4.1.12 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.

2.4.1.13 Where lapped or butted joints from part of an assembly that is assembled or part assembled prior to 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.

2.4.1.14 Paint shall not be applied to surfaces which 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 dew point, except to the approval of the Engineer or his duly appointed representative.

2.4.1.15 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.

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

2.4.1.17 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.

2.4.1.18 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".

2.4.1.19 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.

2.4.1.20 All outdoor painting shall be checked prior to 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.

2.4.1.21 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, colours being in accordance with BS 1710 and BS 4800, or equivalent material standards.

2.4.2 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)	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

Treatment at Factory	Treatment at Site after Completion of Erection
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).	one coat alkyd gloss (25 microns)
(b) Steel floors, chequer plates, galleries, stairways, treads, kick stops.	
Galvanise 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 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 stairwaystop 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	Thoroughly clean to remove oil, grease and dirt.

Treatment at Factory	Treatment at Site after Completion of Erection
amplitude 40-75 microns	Priming coat to be touched up where necessary. Then apply: 1st coat chlorinated rubber primer to Manufacturer's instructions 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

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. After the protection period, thoroughly clean to remove oil, grease and dirt and apply one coat (50	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
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	
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).
(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)
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, prime, undercoat and paint in accordance with the painting schedule for structural and supporting steelwork, with finish coat of paint	Clean and touch up as necessary

Treatment at Factory	Treatment at Site after Completion of Erection
applied at Manufacturer's works	
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: 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).	Sectional Construction: Touch up damaged areas as necessary.
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	

Treatment at Factory	Treatment at Site after Completion of Erection
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.	

2.5 Rating Plates, Nameplates and Labels

2.5.1 General

2.5.1.1 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.

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

2.5.1.3 Items of 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.

2.5.1.4 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.

2.5.1.5 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.

2.5.1.6 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.

2.5.1.7 All equipment within panels and desks shall be individually identified.

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

2.5.2 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.

2.5.3 Circuit Labels

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

2.5.3.2 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.

2.5.4 Pipe Service Identification

2.5.4.1 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.

2.5.4.2 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.

2.5.4.3 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.

2.5.4.4 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.

2.6 Environmental Protection & Topicalization

2.6.1 General

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

2.6.1.2 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.

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

2.6.1.4 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.

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

2.6.1.6 Where the performance, reliability or life of the plant would be adversely affected by solar radiation, including the effects of prolonged exposure to ultra violet 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.

2.6.1.7 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.

2.6.1.8 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.

2.6.1.9 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.

2.6.2 Tropicalisation

In choosing materials and their finishes, due regard shall be given to the humid tropical conditions under which equipment shall work, and good 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 galvanised 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.

2.7 Platforms, Stairways, Ladders and Hand-Railing

2.7.1 General

2.7.1.1 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.

2.7.1.2 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.

2.7.1.3 Galleries and platforms around plant 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.

2.7.1.4 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 be supplied for one side only but an edging strip shall be provided on the side without handrail. The minimum headroom on platforms and galleries shall be 2100 mm.

2.7.1.5 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.

2.7.2 Flooring

2.7.2.1 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.

2.7.2.2 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.

2.7.2.3 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.

2.7.2.4 Open grid floor panels shall be not less than 25 mm in depth and shall be fitted neatly between kerbs 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.

2.7.2.5 Where chequer plate is supplied it shall be galvanised 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 galvanised countersunk screws of not less than 10 mm nominal size.

2.7.3 Hand-Railing and Protective Barriers

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

2.7.3.2 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.

2.7.3.3 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.

2.7.3.4 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.

2.7.3.5 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.

2.7.3.6 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.

2.7.4 Stairways

2.7.4.1 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.

2.7.4.2 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.

2.7.5 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.

2.8 Nuts, Bolts, Studs and Washers

2.8.1.1 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.

2.8.1.2 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.

2.8.1.3 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.

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

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

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

2.8.1.7 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 required by the Engineer.

2.8.1.8 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.

2.9 Forgings

2.9.1.1 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.

2.9.1.2 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.

2.9.1.3 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.

2.9.1.4 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.

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

2.9.1.6 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.

2.10 Castings

2.10.1 General

2.10.1.1 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.

2.10.1.2 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.

2.10.2 Steel Castings

2.10.2.1 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.

2.10.2.2 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

2.10.2.3 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.

2.10.2.4 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.

2.10.3 Iron Castings

2.10.3.1 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.

2.10.3.2 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.

2.10.3.3 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.

2.10.3.4 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.

2.10.4 Aluminium Bronze Castings

2.10.4.1 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.

2.10.4.2 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.

2.10.4.3 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.

2.10.5 General Welding Requirements

2.10.5.1 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.

2.10.5.2 General Fabrication

The Engineer shall be notified at least two days prior to commencement of any assembly or fabrication work on site. The CO_2 and flux-cored welding process will not be acceptable for site welding.

2.10.5.3 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.

2.10.5.4 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 results of weld procedure qualification tests previously carried out under the supervision of an internationally recognised 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.

2.10.5.5 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.

2.10.5.6 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.

2.10.5.7 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.

2.10.5.8 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.

2.10.5.9 Internal Examination

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

2.10.5.10 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.

2.10.5.11 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.

2.10.5.12 Magnetic Crack Detection

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

2.10.5.13 Dye Penetrant Tests

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

2.10.5.14 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.

2.10.5.15 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.

2.10.5.16 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.

2.10.5.17 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.

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

2.11 Galvanised Work

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

2.11.2 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.

2.11.3 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.

2.11.4 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.

2.11.5 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.

2.11.6 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.

2.11.7 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.

2.12 Pumps

2.12.1 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.

2.12.2 Preventive and routine maintenance time should be minimised 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.

2.12.3 Pumps shall be capable of continuous operation with minimum maintenance.

2.13 Pipework

2.13.1 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 pipework 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.

2.13.2 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 dismantling of piping.

2.13.3 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.

2.13.4 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.

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

2.13.6 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 pipework 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 a support is to be subject to the approval of the Engineer.

2.14 Valves

2.14.1 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.

2.14.2 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.

2.14.3 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.

2.14.4 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.

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

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

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

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

2.15 Pressure Vessels

2.15.1 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:

2.15.1.1 Vessels with a water containment capacity of less than 454 litres for the containment of water under pressure, including those containing air, the compression of which serves only as a cushion.

2.15.1.2 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.

2.15.1.3 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.

2.15.1.4 vessels having an internal diameter not exceeding 150 mm.

2.15.1.5 vessels and equipment covered more appropriately by boiler or pipework design codes.

2.15.2 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.

2.15.3 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.

2.15.4 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.

2.16 Lubrication

2.16.1 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.

2.16.2 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.

2.16.3 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.

2.17 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.

2.18 Pressure Gauges

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

2.18.2 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.

2.18.3 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.

2.19 Thermometer Pockets

2.19.1 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.

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

2.20 Gauge Cubicles and Panels

2.20.1 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.

2.20.2 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.

2.21 Locking Facilities

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

2.21.1.1 Control position selector switches in all positions provided, except where other electrical or mechanical interlocking is approved.

2.21.1.2 Marshalling, operating and terminal kiosks or cubicle access doors and panels.

2.21.1.3 Isolating valves in open or closed positions.

2.21.2 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.

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

2.21.4 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.

2.21.5 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.

2.21.6 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.

2.21.7 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.

2.22 Electrical Equipment

2.22.1 General

2.22.1.1 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.

2.22.1.2 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.

2.22.1.3 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 equipment.

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

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

2.22.1.6 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.

2.22.1.7 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.

2.22.1.8 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.

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

2.22.2 Electrical Equipment Enclosures

2.22.2.1 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 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

2.22.2.2 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.

2.22.3 Current Ratings

2.22.3.1 Normal Current Ratings

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

2.22.3.3 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.

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

2.22.4 Temperature Rise

2.22.4.1 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.

2.22.4.2 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.

2.22.4.3 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.

2.22.4.4 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.

2.22.4.5 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.

2.22.5 Short-Time Current Ratings

2.22.5.1 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 elsewhere in this Specification.

2.22.5.2 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 inception of the short circuit.

2.22.5.3 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.

2.22.6 Voltage Ratings

2.22.6.1 Normal Voltage Ratings

2.22.6.1.1 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.

2.22.6.1.2 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.

2.22.6.1.3 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

2.22.6.2 Short-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.

2.23 Electrical Insulation

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

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

2.23.3 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.

2.23.4 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.

2.23.5 Linseed oil and untreated materials of fibre, leatheroid, presspahn, 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.

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

2.23.7 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.

2.23.8 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.

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

2.24 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.

2.25 Control and Selector Switches

2.25.1 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.

2.25.2 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.

2.25.3 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.

2.25.4 Pushbutton test switches shall be provided along 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.

2.25.5 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.

2.25.6 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.

2.25.7 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.

2.25.8 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.

2.25.9 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.

2.26 Panels, Desks and Cubicles

2.26.1 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.

2.26.2 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.

2.26.3 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.

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

2.26.5 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.

2.26.6 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.

2.26.7 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.

2.26.8 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.

2.26.9 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.

2.26.10 The bottom and/or top of all panels shall be sealed by means of removable gasketted steel gland plates. Gland plates for bottom entry shall be at least 250mm above the floor of the cubicle.

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

2.26.12 Each panel shall include rear access doors internal power sockets and door-operated internal lighting, and be clearly labelled 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 labelled. 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.

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

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

2.26.15 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.

2.26.16 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.

2.26.17 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.

2.26.18 Earth connection between adjacent panels shall be achieved by extending the bar through the panel sides and not by interconnecting external cabling.

2.26.19 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 outgoing cable to a "clean earth" system.

2.26.20 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 the systems: voltage high, voltage low, no volts and earth fault. The alarms shall be signalled to the Control Room.

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

2.26.22 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.

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

2.27 Instruments & Meters

2.27.1 Indicating Instruments

2.27.1.1 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.

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

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

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

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

2.27.2 Electrical Meters

2.27.2.1 All electrical meters shall comply with IEC 62053 and other relevant IEC standards and, unless otherwise 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.

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

2.27.2.3 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.

2.27.2.4 Where commercial grade metering is specified the meters shall be calibrated to commercial grade accuracy to IEC standards.

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

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

2.27.2.7 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 kilowatts the value of the impulses received from each kilowatt-hour meter. Printometers shall be of an approved type having the specified demand interval.

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

2.27.2.9 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.

2.27.3 Indicating Lamps and Fittings

2.27.3.1 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.

2.27.3.2 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.

2.27.3.3 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.

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

2.27.3.5 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 emitting diodes, are used in place of lamps then these shall have the same life expectancy and performance capability as the lamps they replace.

2.27.3.6 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.

2.27.3.7 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.

2.27.3.8 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

2.27.3.9 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.

2.27.4 Anti-Condensation Heaters

2.27.4.1 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.

2.27.4.2 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".

2.27.4.3 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.

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

2.28.1 General

2.28.1.1 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.

2.28.1.2 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.

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

2.28.1.4 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.

2.28.1.5 The following minimum conductor sizes shall be used:

1.5 mm²	except where specified otherwise,
4.0 mm²	for current transformer secondary circuits ~~with a rated secondary current of not exceeding 1A.~~

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

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

2.28.1.8 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.

2.28.1.9 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.

2.28.1.10 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.

2.28.1.11 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.

2.28.2 Identification of Wires

2.28.2.1 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.

2.28.2.2 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, complying with BS 3858. Heat shrink marking sleeves may be used, but adhesive markers are not acceptable.

2.28.2.3 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.

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

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

2.28.2.6 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.

2.28.3 Terminals and Terminal Blocks

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

2.28.3.2 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.

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

2.28.3.4 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.

2.28.3.5 Pinch screw type terminals shall not be permitted.

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

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

2.28.3.8 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.

2.28.3.9 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.

2.28.3.10 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.

2.28.3.11 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.

2.28.3.12 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.

2.28.3.13 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.

2.28.3.14 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.

2.28.3.15 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.

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

2.29 Cable Boxes and Glands

2.29.1 General

2.29.1.1 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.

2.29.1.2 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.

2.29.1.3 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.

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

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

2.29.1.6 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.

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

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

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

2.29.1.10 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.

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

2.29.1.12 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.

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

2.29.1.14 Removable gasketed 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.

2.29.1.15 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.

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

2.29.2 Additional Requirements for Compound-filled Cable Boxes

2.29.2.1 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.

2.29.2.2 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.

2.29.2.3 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.

2.29.3 Cable Glands

2.29.3.1 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.

2.29.3.2 All glands shall be provided with an earthing tag or equal facility. For cables having conductors not larger than 4 mm^2 serrated washers may be used in place of earthing tags to provide earth continuity.

2.29.3.3 Glands for armoured or screened cables greater than or equal to 240 mm^2 and all insulated glands for power cables shall be provided with an integral earthing lug. On cable glands up to and including 40 mm 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.

2.29.3.4 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.

2.29.3.5 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.

2.29.3.6 Polymeric cable glands complying with BS 6121 Part 2 may be used, but only when terminating unarmoured cables.

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

2.30 Box-Filling Compounds

2.30.1 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.

2.30.2 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.

2.30.3 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.

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

2.31 Oil or Compound-Filled Chambers

2.31.1 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.

2.31.2 Insulating compound shall comply with BS 1858.

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

2.32 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.

2.33 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.

2.34 Junction and Marshalling Boxes

2.34.1 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.

2.34.2 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.

2.34.3 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.

2.34.4 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.

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

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

2.35 Conduit and Accessories

2.35.1 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.

2.35.2 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.

2.35.3 No conduit smaller than 20mm diameter shall be used.

2.35.4 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.

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

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

2.35.7 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.

2.35.8 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.

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

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

2.35.11 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.

2.36 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.

2.37 Electric Motors

2.37.1 General

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

2.37.2 Type and Rating

2.37.2.1 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 voltage. They shall be suitable for control by either circuit breaker or fused contactor.

2.37.2.2 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.

2.37.2.3 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.

2.37.3 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.

2.37.4 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 whichever 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.

2.37.5 Starting Performance

2.37.5.1 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.

2.37.5.2 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.

2.37.5.3 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.

2.37.5.4 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 between successive starts. After a cooling period of 30 minutes at rest another starting sequence of two successive starts shall be permissible.

2.37.6 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.

2.37.7 Enclosures and Methods of Cooling

2.37.7.1 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 housing.
Where motors are exposed to solar radiation, sunshades shall be fitted, if required by the Manufacturer to

meet his guarantees.

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

IC4AIA1 or IC5AIA1 for LV motors, or IC4AIAO for small power LV motors.
IC4AIAI, IC5AIAI, IC6A1A1 or IC7AIW7 for HV motors.
Ferrous metals should be used for the frames and end shields of all ratings of motors.

2.37.7.3 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.

2.37.8 Anti-condensation Heaters

2.37.8.1 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.

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

2.37.9 Terminals and Terminal Boxes

2.37.9.1 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.

2.37.9.2 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.

2.37.9.3 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.

2.37.9.4 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.

2.37.9.5 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.

2.37.9.6 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".

2.37.10 Earth Terminal

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

2.37.11 D.C. Motors

2.37.11.1 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.

2.37.11.2 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.

2.37.11.3 All d.c. motors shall be provided with brush-gear that does not require to be moved to suit load conditions.

2.37.11.4 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.

2.37.12 Motor Starters and Contactors for Separate Mounting

2.37.12.1 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.

2.37.12.2 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.

2.37.12.3 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 current. Separate contacts for a remote trip alarm shall be provided, and

connected up if required.

2.37.12.4 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.

2.37.13 Pushbuttons and Separately Mounted Pushbutton Stations

2.37.13.1 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.

2.37.13.2 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

2.37.13.3 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.

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

2.37.13.5 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.

2.37.13.6 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.

2.37.13.7 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 pushbuttons 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.

2.37.13.8 Stop pushbuttons mounted local to motors shall trip the associated circuit breaker or contactor regardless of the control position selected.

2.37.13.9 The contacts of all pushbuttons 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.

2.38 Miniature Circuit Breakers, Fuses and Links

2.38.1 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.

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

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

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

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

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

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

2.39 Earthing and Bonding

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

2.39.2 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.

2.39.3 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.

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

2.39.5 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.

2.39.6 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.

2.39.7 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.

2.39.8 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 mm^2 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.

2.39.9 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 mm^2 cross-sectional area, or by other means to the approval of the Engineer.

2.39.10 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 earths may be supplied and the actual means of interconnecting with the station earth system shall be agreed with the Engineer.

SECTION-3:

HV Switchgear and Neutral Earthing Equipment

Index of Contents

SL No.	Name of Items	Page No.
3.1	Scope	03
3.2	References	03
3.3	Design Principles	04
3.3.1	General Requirement	04
3.3.2	Availability for Maintenance, Repair, Extensions, Testing	05
3.4	HV Switchgear	06
3.4.1	Switchgear - Design and Performance	06
3.4.2	Current Ratings	07
3.4.3	Corona	07
3.4.4	Local, Remote and Supervisory Control	07
3.4.5	HV GIS Equipment	07
3.4.6	HVAC Circuit Breakers	44
3.4.7	HV Disconnectors	51
3.4.8	HV Instrument Transformers	56
3.4.9	Surge Arresters	62
3.4.10	Post Insulators	65
3.4.11	Neutral Grounding Resistors	68
3.4.12	Insulators, Bushings, Buses and Hardware	68
3.4.13	Interlocking Facilities	73
3.4.14	Auxiliary Switches and Contactors	74
3.4.15	Interference with Existing Equipment	75
3.5	Appendixes	76

3.1 Scope

3.1.1 These clauses describe the general technical requirements for the new 230 kV, 132 kV and 33 kV Gas Insulated Switchgear (GIS) and Air Insulated Switchgear (AIS), and 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 61869	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 normal operations will be effected from the National Load Dispatching Centre (NLDC) at Rampura. The Bidder shall take into consideration the unmanned operation of the substation in his

design (No operators are necessary in the new substation control rooms).

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

3.3.1.3 The following provisions shall be made for control and indications:

3.3.1.3.1 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.

3.3.1.3.2 Remote control panel in the control 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.

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

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

3.3.1.3.5 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.

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

3.3.1.3.7 In the event of leakage of SF_6 gas from any compartment, equipment shall withstand rated voltage with SF_6 at atmospheric pressure.

3.3.1.3.8 The insulation levels shall be able to withstand test voltages in accordance with the relevant standards for Synchronising Operation for Breakers.

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

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

3.3.2.3 MRE testing on/of buscoupler 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.

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.

3.4 HV Switchgear

3.4.1 Switchgear - Design and Performance

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

3.4.1.2 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 in Schedule F of Departures in Volume 3.

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

3.4.1.4 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.

3.4.1.5 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.

3.4.1.6 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.

3.4.1.7 Electrical clearances provided between isolated equipment and nearest live metal work shall not be less than the distance data as mentioned in sub-clause 1.2.3 of Section 1 of this specification.

3.4.1.8 Insulation creepage distances shall not be less than 30 mm per kV of rated voltage between phases.

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

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

3.4.2 Current Ratings

3.4.2.1 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.

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

3.4.3 Corona

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

3.4.4 Local, Remote and Supervisory Control

3.4.4.1 Circuit breakers and motorised disconnectors shall be electrically controlled locally, remotely and by supervisory telecontrol.

3.4.4.2 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.

3.4.4.3 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 10.

3.4.5 HV GIS Equipment

3.4.5.1 These clauses describe the General Technical Requirements for the new 400kV, 230kV and 132 kV GIS switchgear equipment, and shall be read in conjunction with the Project Requirements, Schedules and Drawings in the specification.

3.4.5.2 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.

3.4.5.3 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. 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.

Installation, testing and commissioning of all GIS shall be done by the Authorized Switchgear Engineer(s) of the GIS manufacturer(s).

3.4.5.4 APPLICABLE STANDARDS

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

LIST OF STANDARDS

IEC 62271-1	Common clauses for high voltage switchgear and control gear standards
IEC 62271-100	High voltage alternating circuit breakers
IEC 62271-102	Alternating current disconnectors (isolators) and earthing switches
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 62271-200	AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
IEC 62271-203	Gas insulated metal-enclosed switchgear for rated voltages 52 kV and above
IEC 62271-209	Cable connections for gas insulated metal - enclosed switchgear for rated voltages of 52 kV and above
BS 7354	Design of high voltage open terminal stations
IEC 60376	Specification and acceptance of new sulphur hexafluoride
IEC 60358	Coupling capacitors and capacitor dividers
IEC 60364	Electrical installation of buildings (Part-1: Scope, object and fundamental principles)
IEC 60364	Electrical installation of buildings (Part-2: Definitions- Chapter 21: Guide to general items)
IEC 60364	Electrical installation of buildings (Part-4: Protection for safety-Chapter 41: Protection against electric shock)
IEC 60071	Insulation co-ordination (Part-1: Definition, principles and rules, Part-2: Application guide)
IEC 60815	Guide for the selection of insulators in respect of polluted conditions
IEC 60137	Bushings for alternating voltages
IEC 60099-4	Metal - Oxide surge arresters without gaps for a.c. systems
IEC 61869-1	Instrument transformers, Part-1: General requirements
IEC 61869-2&3	Instrument transformers, Part-2&Part-3: Current & Voltage Transformers
IEC 61869-5	Instrument transformers, Part-5: Capacitive Voltage Transformers
IEC 60282	High voltage fuses.
IEC 60269	Low voltage fuses.
IEC 60865-1	Short-circuit currents — Calculation of effects (Part-1: Definitions and calculation methods)

IEC 61639 Direct connection between power transformers and gas insulated metal enclosed switchgear for rated voltages of 72.5 kV and above

3.4.5.5 DESIGN CRITERIA

The GIS shall be designed to ensure satisfactory operation under the site and system operating conditions as per design criteria described in Section-1 Volume 2 of 3 of this Bidding Document.

Switchgear and substation equipment shall be suitable for continuous operation on a 3-phase, 50 Hz system of 400kV, 230 kV and 132 kV nominal voltage as per "Design Criteria" and under the climatic conditions specified. The 400kV, 230 kV and 132 kV systems are effectively earthed.

The detailed ratings of 400kV, 230 kV and 132 kV GIS shall be as stated in the Schedules in Volume 3.

3.4.5.6 TYPE OF SWITCHGEAR

3.4.5.6.1 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 400kV, 230kV & 132kV GIS shall be as per Technical requirements of Volume 3.

3.4.5.6.2 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.

3.4.5.6.3 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.

3.4.5.6.4 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. Provision shall be kept for adding future bays and for connecting GIS of different makes

3.4.5.6.5 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.

3.4.5.7 DESIGN PRINCIPLES

3.4.5.7.1 The design and performance of the switchgear shall comply with this Specification and the latest revision of the relevant International Electrotechnical Commission (IEC), if no other standards are specified. Deviations from these specifications and standards shall be stated in the appropriate Schedule.

3.4.5.7.2 The drawings issued with this Specification are only indicative for possible switch-room layout.

3.4.5.7.3 The switchgear shall be supplied complete with all auxiliary equipment necessary for safe operation, routine and periodic maintenance and repairs with sufficient space between modules.

3.4.5.7.4 The normal operations will be effected from the National Load Control Centre. The bidder shall take into consideration the unmanned operation of the substation in his design.

3.4.5.7.5 GIS design shall consider Sufficient Buffer zone 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.

3.4.5.8 Local, Remote and Supervisory Control

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

3.4.5.8.2 The following provisions shall be made for control and indications:-

3.4.5.8.3 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.

3.4.5.8.4 Special adaptations shall be provided for GIS local control cubicles (LCC) having degree of IP protection (IP 55) for outdoor conditions with adequate ventilation, temperature and humidity control.

3.4.5.8.5 Outdoor–proof cable material shall be provided for Control cables of GIS LCC along with water proof cable glands together with special location of cable entry to give protection against rodents and termites.

3.4.5.8.6 Supervisory control from a system control room centre - provision of control of circuit breakers and disconnectors switches where power operated, with position indication in each instance.

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

3.4.5.8.8 Circuit identifying labels shall be fitted at the front and rear of each individual circuit assembly and on the local control cubicle.

3.4.5.8.9 In case of labels not visible when standing on the floor, additional name plate shall be fixed at a suitable location.

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

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

3.4.5.8.12 The insulation levels shall be able to withstand basic test voltages in accordance with the relevant standards for Synchronising Operation for Breakers.

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

3.4.5.8.14 For Busbars 245 kV and above, passive busbars is preferable.

3.4.5.8.15 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.

3.4.5.9 Availability for Maintenance, Repair, Extensions, Testing

3.4.5.9.1 Maintenance, Repair, HV Testing and Extension on one busbar with directly connected apparatuses shall be possible with the other busbar in normal operation.

3.4.5.9.2 Sufficient Buffer zone shall be provided so as to minimize the interruption zone & time during MRE. The proposal shall be approved by the employer during execution. Any modification required in the GIS design, shall be done without any commercial implication.

3.4.5.9.3 HV Testing on one switchgear bay shall be possible with all other switchgear bays in normal operation on one busbar.

3.4.5.9.4 HV Testing of bus coupler bay shall be possible with one busbar at the time in normal operation and all switchgear bays in normal operation.

3.4.5.9.5 Maintenance access to each bay shall be possible without necessitating the outage of adjacent bay.

3.4.5.10 Gas Compartments

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

3.4.5.10.2 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.

3.4.5.10.3 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.

3.4.5.10.4 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.

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

3.4.5.10.6 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.

3.4.5.10.7 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.

3.4.5.10.8 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.

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

3.4.5.10.10 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

3.4.5.10.11 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.

3.4.5.10.12 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.

3.4.5.11 Gas Barrier and Supporting Insulators

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 having full pressure.

3.4.5.12 Enclosures

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

3.4.5.12.2 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.

3.4.5.12.3 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.

3.4.5.12.4 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.

3.4.5.12.5 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.

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

3.4.5.12.7 Special consideration shall be considered for selection of material for support structure & enclosures suitable for withstanding environmental effects.

3.4.5.12.8 Surface treatment of enclosures followed by extra layer of coating of paint shall be provided to give protection against atmospheric effects.

3.4.5.12.9 Sealing the flange connection with appropriate grease together with special casing for insulators (Gas barrier) to give protection against atmospheric effects and water drainage resulting in extra material for bay construction shall be provided.

3.4.5.12.10 Special covers shall be provided for viewing windows & position indicator installed on Disconnector & Earthing switch for better visibility of internal parts, readability of display & protection against atmospheric effects resulting in additional material for bay construction.

3.4.5.12.11 Leveled platform/slab shall be provided with min. tolerance of not more than (+/-10 mm) required for GIS installation results in increased civil cost for outdoor installation in order to adapt to landscape available at site.

3.4.5.13 SF6 Gas

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.

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.

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

3.4.5.14 Gas Monitors

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.

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.

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.

3.4.5.15 Position Indicators

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.

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.

3.4.5.16 Temperature Rise

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.

The design of sliding type current carrying connectors and joints shall be such that they meet the aforementioned 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.

3.4.5.17 Arrangement

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.

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

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.

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

mobile platform suitable to reach any equipment,
Handles of manual operation of CB, D/S, E/S and
any special tool required for the operation of the switchgear.
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.

3.4.5.18 Mechanical Construction

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.

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

3.4.5.19 Testing Facilities

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.

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

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.

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.

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.

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.

3.4.5.20 Sealing of Enclosures

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:-

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

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.

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.

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.

3.4.5.21 Gas Losses

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.

3.4.5.22 Gas Handling Equipment

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

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.

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.

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.

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.

Vacuum Pump	
Nominal suction capacity	10 m^3/h
Achievable final vacuum	< 1 mbar
Compressor	
Theoretical intake volume	3 m^3/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 SF_6
Filling performance	120 kb SF_6/h

SF6 gas analyzer:

The SF6 gas analyser should be of portable type and instruments shall have following features:

a. In-built calibration facility.
b. Sensitivity of the equipment shall not be affected by any atmospheric conditions like dust,

humidity, heat, wind etc.
c. Equipment shall work on zero gas loss principle i.e. gas should be pumped back to the com partment after measurement without any exposure to the atmosphere.
d. Equipment shall be supplied with suitable regulator which can be used to connect SF6 cylinder if required.
e. Following acidic/impurities products should be detected as per IEC 60480 and IEC 60376

i) SF6 purity – Range: 0-100 % & Accuracy: +/- 2 deg
ii) Dew point - Range : -60 to +20 deg C & Accuracy: +/- 4 deg C
iii) SO2 - Range : 0-150 ppm & Accuracy : +/- 2 %
iv) HF - Range : 0-10ppm & Accuracy : +/- 10 %

f. Instrument should work on AC source as well as on rechargeable battery
g. Input pressure: upto 10 bar
h. It should be housed in a robust IP67 case with wheels

The make of the equipment shall be EU, UK, USA or Japan.

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.

3.4.5.23 Earthing System

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.

The earthing system shall fulfil the following requirements:

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

Provide ground connections to all electrical apparatus enclosures and structural steelworks adequate to carry prospective ground faults without excessive heating or fire risk

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

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.

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.

All major equipment shall be connected at least twice to the earthing system at their ex-treme 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.

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.

3.4.5.24 Earthing Mesh of the Building

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.

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.

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.
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.

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.

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.

From the ring conductor inside the respective room connections to the panels, cable trays, conduits, doors, steelworks, buried floor screens, etc., shall be made.

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.

3.4.5.25 GIS Bonding and Earthing

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.

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.

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.

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.

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.

Supporting structures are to be earthed separately using these copper conductors as earth potential.
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.

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.

3.4.5.26 Cable Trays

Metallic cable trays and vertical runs are to be connected to the earthing system at least within 20 meter 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.

3.4.5.27 Earthing Details

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.

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.

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).

3.4.5.28 Circuit Breakers

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.

Circuit breakers shall be complete with spring operated mechanisms.

3.4.5.28.1 TRV

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

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.

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.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.

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.

3.4.5.28.2 Interrupting Duty

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 currents 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.

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.\

3.4.5.28.3 Fault Clearance Time

The overall fault clearance time including relay operating time shall be in accordance with the requirements specified in this specification.

3.4.5.28.4 General Arrangement

Facilities for measurement of circuit breaker contact resistance and timing tests without removal of covers or SF6 gas filling shall be provide. Full details of the testing procedures shall be submitted with the Bid.

Means shall be provided to allow access for the inspection and maintenance of fixed and moving contacts and other enclosed components.

Circuit breakers use the SF6 gas conforming to IEC or other approved standard as the insulating medium as well as for arc quenching.

Circuit breakers shall operate on the principle of self-generating gas pressure within the interrupter for arc extinction. e.q 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 equivalent origin.

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.

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.

3.4.5.28.5 Operating Mechanisms

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.

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.

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.

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.

The circuit breaker shall be driven by a single mechanism coupled to the three phases or by three mechanisms coupled to each phase separately.

All circuit breaker operating mechanisms shall be fitted with independent duplicate shunt trip coils suitable for independent operation.

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.

Operating mechanisms shall be capable of storing energy for at least two complete closing and tripping operations or one O-C-0 operation, local to the equipment and without recharging. Mechanisms shall preferably utilize DC supplies for recharging duties.

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.

3.4.5.28.6 Spring Charged Mechanisms

Circuit-breakers fitted with power charged spring operated closing mechanism shall also meet the following requirements.

When fully charged the spring mechanism shall have sufficient stored energy to permit the operating sequence 0-C-0/2 C-0 to be performed following the loss of supply to the charging motor.

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.
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.

Manual Spring charging facility shall be provided.

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".

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.

3.4.5.29 Disconnectors and Earthing Switches

3.4.5.29.1 Three position Disconnectors including the Earthing Switches shall be supplied as shown on the contract 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.

3.4.5.29.2 High speed make-proof earthing switch shall be provided as per the single line diagram.

3.4.5.29.3 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.

3.4.5.29.4 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.

3.4.5.29.5 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 padlock the mechanism in the open and closed positions with the motor automatically disengaged (isolator and earth switch).

3.4.5.29.6 Transparent window shall have to be provided as required to see the Disconnector and Earth switch contact status (Close or Open).

3.4.5.29.7 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.

3.4.5.29.8 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.

3.4.5.29.9 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.

3.4.5.29.10 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.

3.4.5.29.11 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.

3.4.5.30 Maintenance Earthing Switches

3.4.5.30.1 Earthing switches shall generally comply with the requirements of IEC 62271-100 and 62271-203.

3.4.5.30.2 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.

3.4.5.30.3 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.

3.4.5.30.4 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 for safety reasons.

3.4.5.30.5 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.

3.4.5.30.6 Direct visual indication of the earthing switch position should be provided, with clear markings to show that the device is fully open or closed.

3.4.5.31 High Speed Earthing Switches

3.4.5.31.1 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.

3.4.5.31.2 They shall be located at all feeder terminal points and busbars or other locationwhere there is no certainty that the point to be earthed is not energised.

3.4.5.31.3 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.

3.4.5.31.4 The operating mechanism of High Speed Earthing Switches shall be motor wound spring operated type with one of the following features :-

3.4.5.31.5 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.

3.4.5.31.6 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.

3.4.5.31.7 In both the designs, facility for padlocking the mechanism in the open position of the switch shall be provided.

3.4.5.31.8 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.

3.4.5.31.9 These earthing switches shall otherwise be in accordance with the requirements for maintenance earthing switches.

3.4.5.32 Current Transformers

3.4.5.32.1 Current transformers shall be supplied suitable for the duty specified and comply with the requirements of IEC 61869-1&2 and BS 3938 as appropriate.

3.4.5.32.2 Current 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 current transformer or in the associated switchgear chamber.

3.4.5.32.3 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.

3.4.5.32.4 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.

3.4.5.32.5 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.

3.4.5.32.6 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.

3.4.5.32.7 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.

3.4.5.32.8 CT sizing calculations shall be submitted to the PGCB for approval.

3.4.5.32.9 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.

3.4.5.32.10 The characteristics of current transformers used for protection circuits shall include the following requirements.

3.4.5.32.11 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.

3.4.5.32.12 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.

3.4.5.32.13 (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.

3.4.5.32.14 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.

3.4.5.32.15 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.

3.4.5.32.16 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.

3.4.5.32.17 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.

3.4.5.33 Voltage Transformers

3.4.5.33.1 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.

3.4.5.33.2 Voltage transformers shall comply with the common sections of this Specification, comply with the requirements of IEC 61869-1&3 and shall be provided with requirement mentioned in Technical requirements of Volume 3 of 3.

3.4.5.33.3 The rated secondary voltage per phase shall be 110/√3volts in the case of star connected windings and the rated voltage factor shall be 1.2 continuous; 1.5 for 30 seconds.

3.4.5.33.4 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.

3.4.5.33.5 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.

3.4.5.33.6 Voltage transformers shall be capable of carrying continuously, without thermal damage 150% of their rated output.

3.4.5.33.7 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.

3.4.5.33.8 Primary connections shall have the same short time current rating as the associated switchgear.

3.4.5.33.9 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.

3.4.5.33.10 Separate sets of MCBs shall be provided at the VT for:-

Each protection scheme
Instruments, disturbance recorder, fault locator etc.
Synchronizing

3.4.5.33.11 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.

3.4.5.33.12 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.

3.4.5.33.13 Fixed ladders and/or cat walk structures with handrails are to be provided for the VTs for inspection/testing/replacement of fuse, etc.

3.4.5.33.14 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.

3.4.5.33.15 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.

3.4.5.33.16 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.

3.4.5.34 Feeder and Transformer Connections

SF6 immersed cable sealing end chambers or SF6 gas insulated bus ducts with SF6/AIR bushings shall be provided as specified for outgoing circuits.

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 switchgear phase terminals and conductors.

The Contractor is required to coordinate design of SF6 filled enclosures such that the integrity of gas and/or oil pressure compartments is maintained.

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.

Sealing ends shall be provided with all fittings including flexible connections where necessary. Stress cones or other approved means for grading the voltage stress shall be provided for insulating the cable within the sealing end. (The insulated flange and external casing shall be provided by the cable manufacturer). Glands shall be insulated from the chamber.

3.4.5.34.1 General

SF6 immersed Gas Insulated Line (GIL) sealing end chambers and SF6 Gas Insulated Lines (GILs) or other type bus ducts and/or open type terminal bushings and/or overhead lines, etc. shall be provided as specified for Line outgoing circuits. When the circuits are connected via X LPE power cables directly to the SF6 switchgear terminals the cable and sealing ends shall be to the specification given in below in item (2) & (3).

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 switchgear phase terminals and conductors. The manufacturer of the switchgear is required to coordinate design of SF6 filled enclosures with that of GIL or power cable sealing ends and overhead line bushings and transformers supplied by other manufacturers such that the integrity of gas and/or oil pressure compartments is maintained. Facilities shall be provided for high voltage DC testing and conducting cable fault location measurements of cabled circuits, by the other Contractor. But, during the DC high voltage test at Site, the Contractor shall cooperate with the other Contractor for the underground cable Contract. To reduce the effect of solar gain all SF6 or other types of insulated bus ducts exposed to direct sunlight can be covered with metallic sun shielding.

The manufacturer of GIS & GIL shall be same. In case the GIS manufacturer can not supply GIL, the GIL shall be provided from same Origin i.e. Europe/North America/Japan/Korea.

3.4.5.34.2 Cable Sealing Ends

Cable sealing ends shall be suitable for terminating the cables specified directly into the GIS switchgear. The dimensions and terminal arrangements, together with details of filling medium of the sealing end shall be submitted for approval by the Engineer before manufacture is commenced. All type of high voltage cables complying with IEC 62271-209 can be connected. The inspection hole also shall be provided with the connection flange for high voltage cable testing set. During high voltage cable testing, the primary conductor between the cable sealing end and the switchgear can be removed. All sealing ends shall be suitable for filling and shall be designed with joint faces which will ensure leak-free operation and exclude the entry of oil or gas.Where required to reduce local heating when single-core cables are adopted non-magnetic gland plates shall be provided or alternatively, non-magneticinserts. Design of cable termination equipment must ensure that the following conditions are maintained throughout the life of the equipment:
(a) The insulating material, either gas or oil, from inside the cable does not scape and penetrate the switchgear enclosure.
(b) The SF6 gas does not enter the cable from the enclosure.
(c) The cable sealing end does not introduce moisture into the gas in the sealing end enclosure.
(d) The sealing end is capable of withstanding the cable test voltages and differential pressures without damage including overpressure of +30% of normal operating pressure

3.4.5.34.3 Insulating and Earthing

Sealing ends shall be provided with all fittings including flexible connections where necessary. Stress cones or other approved means for grading the voltage stress shall be provided for insulating the cable within the sealing end. (The insulated flange and external casing shall be provided by the cable manufacturer). Glands shall be insulated from the chamber. Removable links shall be provided close to the GIS to enable sheath tests to be carried out and to prevent arcing to adjacent. metal framework during
isolator operation.

3.4.5.34.4 Material

Porcelain or moulded insulators used in the manufacture of cable sealing ends shall be sound, free from defects and thoroughly vitrified so that the glaze or surface treatment is not depended upon for insulation.

The insulators and fittings shall be unaffected by the filling media or rapid temperature changes likely to arise when operating in the Site conditions and shall be designed so as to facilitate cleaning. Porcelain shall not engage directly with hard metal and, where necessary, an approved resilient material shall be interposed between the 'porcelain and the end fittings. All porcelain clamping surfaces in contact with gaskets shall be accurately ground and free from glaze.

All fixing material used shall not enter into chemical action with the metal parts or cause fracture by expansion during service. Where cement is used as a fixing medium, the thickness of cement shall be as small and even as possible and proper care shall be taken to centre and locate the individual parts correctly during cementing. Each porcelain or moulded insulator shall have marked upon it the manufacturer's identification mark and such other mark' as may be approved to assist in the representative selection of insulators for the type tests. The mark shall be clearly legible and also visible after assembly of end fittings and shall be imprinted before firing.

3.4.5.34.5 Transformer/Cable Sealing End Enclosures

Where applicable the metal enclosed cable sealing end chamber necessary for enclosing the cable sealing 'end insulator suitable for termination of transformers and HV power cables shall be supplied as part of this Contract. Design shall be in accordance with IEC 62271-305. The dimensions of the enclosure which is necessary to accommodate thetransformer bushing and cable sealing end shall be determined by the switchgear supplier who will be responsible for the dielectric performance of the combined arrangements. Both the earthed and high voltage ends of the cable sealing end shall adequately seal off the SF6 gas insulation by bolted flanges provided with multiple rings-and gaskets which shall be coordinated with the cable sealing end design/manufacturer.

End covers shall be provided to enable completion of erection and testing of the switchgear in the absence of cable terminations. The design and sealing end pressure shall be coordinated by the switchgear supplier so as to minimize the risk of SF6 gas penetration into the transformers 'or HV power cables and to accommodate any movement due to expansion.

In the gas filled section of the cable chamber a bolted link shall be provided for isolating the HV cable from the switchgear busbars and connections. The design of the link when removed shall be sufficient to withstand HV DC testing of cable and the full insulation requirements specified for the switchgear. A three phase set of test bushings together with sufficient plug-in connections shall be provided for

HV withstand testing. The terminations of the test bushing shall be suitable for connection to the test equipment. Following completion of the Works the test bushings shall be handed over to the Employer. Cable termination chamber designed to allow HV DC cable testing, cable fault detection, measurement of cable resistance etc. without the need to open or evacuate the SF6 compartment will be preferred over the conventional design

3.4.5.35 Surge Arresters

3.4.5.35.1 Indoor GIS surge arresters and outdoor GIS surge arresters 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.

3.4.5.35.2 The Contractor shall demonstrate by calculations that the surge arresters will adequately protect the switchgear arrangement proposed.

3.4.5.35.3 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.

3.4.5.35.4 SF6 gas pressure monitors for the surge arresters shall comply with clause 3.8.7 above.

3.4.5.36 Bus bar (GIB)

3.4.5.36.1 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).

3.4.5.36.2 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 currents. To reduce the effect of solar gain, all SF6 insulated bus duct exposed to direct sunlight may be

3.4.5.36.3 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 supporting insulators. The design of the bus ducts shall make full allowance of the thermal expansion

3.4.5.36.4 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

3.4.5.36.5 regards to the differential settlement of the concrete floors of the switchgear room and the bus duct supporting structures

3.4.5.36.6 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 theinduction of over-voltages in the secondary circuits.

3.4.5.36.7 The manufacturer of GIS & GIB shall be same. In case the GIS manufacturer can not supply GIB, the GIB shall be provided from same Origin i.e. Europe/North America/Japan/Korea.

3.4.5.36.8 Outdoor Bushings (HV GIS Equipment)

3.4.5.36.9 In order to ensure good furnishing even in the case of different Suppliers, the switchgear and overhead line Bidders/Contractors will have to cooperate at the gantry area to a maximum possible extend.

3.4.5.36.10 As far as possible, Overhead Transmission Lines (OHTL) shall be connected through air/SF6 gas-insulated bushings. The required clearance in air shall be achieved by means of angled compartments or by provisions of spread bus-ducts with vertically arranged air/SF6 - gas bushings. The connections to the switchgear units shall be established through wall penetrating bus-ducts with extension /compensation bellows which cater for temperature differences between indoor and outdoor equipment.

3.4.5.36.11 Where specified outdoor bushings shall be provided as required. They shall correspond to IEC 60137 and shall be free from defects. Uncovered bushings shall be designed for site pollution severity class "e" (very heavy) in accordance with IEC/TS 60815, unless specified otherwise in the Technical Data Sheets. However, creepage distances as specified in the Technical Data Sheets are to be considered preliminary only and may have to be corrected by the Contractor/Manufacturer in accordance with IEC/TS 60815 dependent on the bushing average diameter.

3.4.5.36.12 Bushings for Um= 72.5 kV and above shall be provided with a compound housing of silicone composite rubber with alternating long and short sheds. The insulators shall be of a uniform shade of light grey.

3.4.5.36.13 Alternatively the insulators may be of top quality electrical grade porcelain, thoroughly vitrified, homogenous and non-porous, and shall be practically in one piece. If insulators are composed of several parts jointed together by synthetic resin, this shall be brought to the attention of Employer/Engineer. The glaze shall not be depended upon for insulation and shall be of a uniform shade of brown, completely covering all exposed parts of the insulator.

3.4.5.36.14 The insulating body shall be of the epoxy resin impregnated paper type with concentrically inserted conductive layers for capacity graded field distribution. Air/SF6 gas insulated bushings are also acceptable. But oil impregnated paper condenser bushings are not acceptable. A test tap at the bushing flange shall be provided for capacitance and dissipation factor measurement, suitable for the dielectric test with a test voltage of 2 kV 50 Hz and duration of 1 min.

3.4.5.36.15 Alternatively a gas-insulated body may be used; in this case a porcelain insulator is not acceptable. Care has to be taken to low ambient outdoor temperatures, a heating of SF6 gas is not applicable.

3.4.5.36.16 All bushing connecting nuts, bolts, washers, rings, caps on the top shall be of non-magnetic material.

3.4.5.36.17 All bushings shall be designed for operation and storage in a horizontal position without any

restriction. All bushings shall be designed for the highest over-current according to the GIS rating.

3.4.5.37 UHF sensors for PD detection

3.4.5.37.1 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.

3.4.5.37.2 However adequacy of number of sensors and their location shall be verified at site as per recommendations of above CIGRE Document No. 654. In case during site testing, additional UHF sensors are required, the same shall also be supplied & installed tocomplete the technical requirement.

3.4.5.37.3 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.

3.4.5.38 Extension of GIS

3.4.5.38.1 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.

3.4.5.38.2 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.

3.4.5.38.3 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.

3.4.5.39 Bus-Ducts (HV GIS Equipment)

3.4.5.39.1 The bus-ducts shall be built-up on rigid supports and structures, which shall be designed under consideration of easy access and maintenance and safe operating. They shall be pre-fabricated, sectionalised and metal enclosed to limit the effects of faults to a minimum of possible parts.

3.4.5.39.2 Bus-duct design shall be over head type only and no duct is acceptable in the cable basement area. It shall respect any necessary clearances on aisles and on transportation roads, if applicable. To remove parts of the bus-duct for servicing and maintenance work as e.g. for circuit-breaker dismantling will not be accepted.

3.4.5.39.3 Sections of bus-duct housings and their associated conductors shall have similar lengths, single phase encapsulated bus-duct assemblies shall be of symmetrical design.

3.4.5.39.4 The Bidder/Contractor shall provide extension and anti-vibration compensators (bellows) to balance out the prevailing climatic and internal load stresses as well as to compensate for maximum different settlements of foundations, floor levels and supporting structures.

3.4.5.39.5 He shall take care of the stable and long-lasting gas tightness of all connections between the switchgear feeders and all parts of the bus-ducts up to its ends at power transformers/shunt reactors and air/SF6 gas-insulated bushings.

3.4.5.39.6 Bus-duct housings shall be directly earthed through tinned copper earth cable to be connected along the full length every 8 m to the earthing grid. The dimensioning shall be appropriate to meet the requirements of operational and protective earth, most notably regarding rated short-circuit currents and electromagnetic interference. Supporting structures to be earthed separately.

3.4.5.39.7 For bus-duct connections the Bidder/Contractor for the switchgear equipment shall also provide all tests applied to the connections.

3.4.5.40 Control Equipment

3.4.5.40.1 Local Control Cubicle

1. Functions

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. 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.

Circuit breaker control position selector and operating control switch shall beinstalled in the local control cubicle, while electrical emergency trip pushbutton is to be provided at GCB mechanism. Circuit breaker control from thisposition will be used under maintenance and emergency conditions only. Theemergency trip push buttons shall be properly shrouded.

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 shallbe blocked.Local manual release facilities shall be provided for closing and tripping thecircuit-breaker. The operation of both releases shall be subject to lockout ifinsufficient stored energy is available. Local manual releases shall beprovided with locking off facilities.

Sufficient electrical terminals shall be provided for the termination andinterconnection of all cabling associated with remote and supervisorycontrol, alarms, indications, protection and local ring main supplies. Where control cabling between the local control cubicle and the switch gear connected by plug and socket boxes, the plugs and sockets shall not be inter-changeable.

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.

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 maximum permitted rise in temperature is not exceeded if the heaters are energized while the apparatus is in operation.

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.
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.

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.

All the control switches shall be internal i.e. installed behind a lockable glass door.

2. Anti -condensation Heaters

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. Auxiliary Switches and Contactors

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.

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.

Direct acting auxiliary switch make before break contacts shall be used in conjunction with busbar protection schemes.

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.

3.4.5.40.2 Control Cables, Wiring and Terminals (Auxiliary Power and Control Cables)

In selecting cable and wire sizes, due regard shall be paid to the appropriate de-rating factors in relation to the climatic conditions at site. All cables and wires shall continuously carry their rated currents under the worst temperature prevailing conditions, and shall also withstand maximum fault currents without damage or deterioration.

1. Control Cables
Control/Signalling cables along the GIS housings and to the points of control and protection cubicles shall be completely installed in properly fixed suitable and robust trays or metallic pipes. Only at sharp bends along the GIS housings and at short runs below 0.5 m to HV control and supervision devices cables may run unsupported and unprotected.

Outer sheath of control/signalling cables shall be of uniform colour, even and free of outlines to achieve a tightness of IP65 with cable glands. The stranding must not become apparent. The printing on the cable sheath shall be repeated in intervals of at least 0.5 m and shall contain

manufacturers name

cable type designation
number and cross sectional area of the cable cores
mark of conformity to RoHS

Cable sheath shall be resistant to oil and grease acc. to VDE 0250 and VDE 0472

Control/signalling cables shall have an overall screen with an optical covering ≥ 85 % and with the screen earthed on both sides, cables running outside of a building shall be additionally armoured and completely laid in covered cable trays, pipes or metallic hoses.

Control/signalling cables shall be of bare copper wires, multi stranded acc. to EN 60228 Class 5. Cable cores shall be stranded concentrically; each cable core layer shall run in the opposite direction to the subjacent one.

The cable core insulation shall be either colour coded or black with white numbering acc. to EN 50334, Arabic numeral, consecutive and starting with #1 from the inner core. Repetition of the numbering shall be in intervals of at least 0.3 m.

The cables shall be designed for nominal voltage (U0/U) of 600 / 1000 V, the test voltage (50 Hz, 1 min) shall be 3 kV between cable cores and between cable cores and screen. Cables having cable cores of a cross sectional area of 1.5 mm² shall be designed for nominal voltage of (U0/U) of 300 / 500 V, the test voltage (50 Hz, 1 min) shall be 2 kV.

To limit the risk to personnel and equipment from smoke and corrosive fumes all auxiliary cabling used indoors shall be flame retardant and self-extinguishing in accordance with IEC 60332-1-2; additionally it shall be of zero emission of toxic or corrosive gases type in accordance with IEC 60754-2.

All types of cable glands required for the termination of the various sizes of Control/Signal Cables shall be part of cable supply.

Cable glands shall be made of non-corrosive material (e.g. nickel-plated brass) and shall be of metric size. They shall provide protection class of at least IP 67 at 5 bar. Cable screens shall be contacted in a circumferential manner for earthing purpose. Gasket material shall not be exposed to sunlight radiation.

2. Wiring
Control wiring shall be of highly flexible stranded copper and must have a cross-sectional area not less than 1.5 mm². VT secondaries shall be wired with a cross-sectional area not less than 2.5 mm²; CT secondaries not less than 4 mm².

Each end of each control wire and cable core shall be terminated with an insulated crimp-type connector sleeve or plug termination of industrial quality, preferably tinned brass shall be used and tinned phosphorous bronze for Fastonconnectors. Correct size crimps and crimping tool shall be used throughout. Any bending of wire lugs by movements of the connected wire shall be avoided.

Each end of each control wire and cable core shall be permanently marked with a securely fitted, non-combustible, thread-on type marking tag or sleeve. Alternatively imprinted or etched into the conductor insulation in more than one position is also acceptable. The tag/sleeve/imprint/etch must

be marked with a non-removable identifying code according to (withdrawn) IEC 391 Figure 11b, dependent local end marking.

The tag/sleeve/imprint/etch must be arranged in a way that it is clearly visible and readable, wiring on more than one level as e.g. with contactors or double layer terminals shall be spaced accordingly.

All wiring shall be installed such that the likelihood of damage during normal operation, maintenance and fault conditions is minimized. The practice of doubling back wires on themselves to absorb slack is not acceptable. Wires not being laid in wire ducts shall be securely fixed without sacking.

Soldered or wire strapped connections shall only be inside electronic systems. Any wire wrapping shall be in accordance with IEC 60352.

3. Terminal Arrangement
Terminal rows of the line-up and expandable type are preferred for all control wiring requiring external connections. They shall be segregated each by function and cabling destination with those going to a common destination allocated to adjacent terminal blocks.

Rows of terminals shall be spaced not less than 100 mm apart. Where plastic channels are used a minimum space of 50 mm shall be left between terminal boards and channel. Terminal boards shall be mounted vertically on TH 35 rails according to IEC 60715. Terminal blocks in the rear shall be angled towards the front. The bottom of each terminal board shall not be less than 200 mm above the incoming cable gland plate.

The arrangements shall be in such a way that it is possible to safely connect or disconnect terminals on live circuits and replace fuse links when the cabinet is live. All terminal blocks shall be arranged straight in the cubicles, a sloped arrangement of terminals is not acceptable.

The connecting terminals shall be provided in such a number that all auxiliary cables running from other sections of the substation can be connected. Minimum ten percent spare terminals, but not less than four spare terminals of each type shall be provided on each terminal block in general.

The terminal block wiring shall be done in such a way that one side of the terminal blocks is kept free for outgoing cable connections. The termination of two conductors at one terminal is not acceptable, suitable bridges and links shall be used.

4. Terminal Marking
The terminal and terminal row designation shall correspond to the wiring diagrams. Terminals shall be provided with marking tags for wiring identification on both sides. One side of the terminals, facing towards the door or upwards, shall be marked with a consecutive numbering, preferably beginning with "1", from left to right or top to bottom. The other side of the terminals shall be marked with potential designations of power supply potentials, CT and VTterminals with the signalling designation.

Terminal strips for different voltage levels must be physically separated from each other and suitably identified, different potentials shall be segregated at least by additional insulation barriers. Terminals carrying dangerous voltages even when the main circuit-breakers are off must be marked with a particular colour and carry suitable warning labels.

3.4.5.40.3 Terminal Design and Material

Terminals for incoming power supply cables shall be suitable for connection of solid conductors with cross-sections from 2.5 mm² up to 35 mm², and they shall be connected directly in series with standard terminals to allow disconnecting and testing of the incoming supply circuit.

Terminals for alarm signals shall have isolation and test facilities.

The CT terminal blocks shall have shorting, isolation and insulated injection test facilities whereas VT terminals shall have isolation and insulated injection test facilities.

- Shorting shall be possible between adjacent terminals by a shorting bridge, being not removable without tool
- Isolation shall be possible by means of links, what can be securely fixed in the open and the closed position
- For injection test two integrated insulated terminal test sockets per terminal shall be available, so that instruments may be connected without opening the secondary circuit

The switching status shall be clearly visible.

To perform the star point of CT windings and VT main windings the relevant electrical connection shall be wired to three consecutive terminals with an adjacent earthing terminal, all being connected by a fixed bridge. The phase connection terminals shall be wired to the next following three consecutive terminals, so that shorting and earthing can be done in a convenient manner.

CT and VT terminal design is subject to a separate approval of the Engineer.

Terminal blocks shall be conforming to IEC 60947-7-1 considering switchgear-specific items of IEC 62271-1 and IEC 61869. The value of the rated insulation voltage shall be at least 800 V, the individual rating and size shall be suitable to their application. They shall be designed to pollution severity degree 3 and material group III.

Terminals must be completely of non-corrosive material like copper alloy, corrosion protection is not applicable. They shall use indirect pressure, captive screw-type mechanisms or, for internal wiring terminations only, Fastontype. Ring-type wire terminations requiring the removal of screws for installation are not acceptable.

The insulating material of the terminals shall be of moulded, toxic free, non-hygroscopic polyamide (PA), inflammability class V0 acc. to UL 94.

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.

3.4.5.40.4 Interlocking

An interlocking scheme shall be provided which takes into account the following basic requirements.

To safeguard maintenance personnel who may be working on one section of the equipment with other sections live.

To prevent incorrect switching sequences which could lead to a hazardous situation to plant, equipment and personnel.

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.

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.

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.

Circuit breakers closing shall be possible irrespective of the busbar and circuit isolator position.

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.

Earthing switches shall be interlocked such that they cannot be operated unless the associated isolator is open.

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.

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.

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.

Interlocking philosophy shall be provided by the switchgear manufacturer and shall be submitted for PGCB's approval.

3.4.5.40.5 Locking Facilities

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.

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.

The following locking facilities shall be provided with common key operated locks.

- Circuit breaker mechanisms in the open position and any associated manual operating device in the neutral position.
- Isolating switches in both open and closed positions.
- Operating cubicle access door

3.4.5.40.6 Synchronous Switching Controller

Synchronous Switching Controller or Pre-insert Resister is to be applied to control switching surge during circuit breaker operation(s) for 400kV Circuit Breaker.

The Synchronous Switching Controller would be designed and manufactured referring to the following function and conditions:

1. Function - Switching Control
   - Compensation of predicted operating time
   - Compensation of predicted operating time of circuit breaker in accordance with the following conditions:
     a. Control voltage of circuit breaker
     b. Ambient temperature of circuit breaker cabinet
     c. Pressure of Hydraulic operating mechanism
     d. Adaptive control
     e. Idle time after idle time of the breaker for next operation
   - Memory storage of operation data
   - Self-diagnostics function
   - Calculation of residual flux
     (In case of switching control for closing transformer)
   - Output alarm

   Operating Condition
   - Temperature: -30 to 60°C
   - Humidity: under 95% RH (60°C)

2. Standard: BS 402, IEC 60255, IEC 61810
3. Mechanical operating characteristics
   - Operating time variation: up to 2ms
   - Operating time variation dependent on 85, 93, 100% and 110% of rated control voltage
   - Operating time variation dependent on 80, 90, 100% and 110% of rated hydraulic pressure
   - Consideration of operating time variation dependent on idle time
4. Electric characteristic RDDS: Rate of decay of dielectric strength

3.4.5.40.7 INTERFERENCE WITH EXISTING EQUIPMENT

Work carried out on site in extending equipment or modifying the existing substation shall be so arranged as to cause minimum interference with existing plant and equipment and interruption to supplies. The Contractor shall include in his price for the provision, erection, commissioning and subsequent dismantling and removal from site of any temporary structures, insulators and connections that may be necessary to maintain continuity of supply whilst certain sections of the plant are out of service to permit the execution of the Works.

If it is necessary to reposition any of the existing substation plant in order to incorporate the specified works or to comply with specific requirements, all costs incurred in dismantling, removing, modifying, repositioning, existing and commissioning of such equipment shall be deemed to have been included in the Bid Price.

The repositioning of any plant is subject to the specific approval of the Employer. Existing plant rendered redundant by this Contract shall remain the property of the Employer and shall be returned to the Employer's store.

Permission for access to existing substations to execute the Works shall be obtained in writing from the Employer. The Contractor shall conform to the Employer's Safety Rules in all respects when working in or near existing plant.

Extensions at the existing substation shall be carried out maintaining the same busbar centres, heights etc., other essential dimensions and interlocking schemes.

Where stated in the Schedule of Requirements, equipment for existing substations shall be of the same type and manufacture as that already in service.

3.4.5.40.8 Portable Partial Discharge(PD) monitoring system

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. The make of the equipment shall be EU, UK, USA or Japan.

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.

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. The equipment shall meet the following requirements

- Measurement shall be possible in noisy environment.

- Stable reading shall be possible in presence of vibrations within complex GIS assemblies, which can produce signals similar to PD.
- Equipment should have necessary synchronizing circuits to obtain PD correlation with power cycle and power frequency.
- The equipment shall be battery operated with built-in-battery charger. It shall also be suitable for 230V AC/50 Hz input.
- 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.
- 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.
- The function of software shall be covering the following:
  a) Data recording, storage and retrieval in computer
  b) Data base analysis
  c) Template analysis for easy location of fault inside the GIS
  d) Evaluation of PD measurement i.e, Amplitude, Phase Synchronization etc.
  e) Evaluation of bouncing/loose particles with flight time and estimation on size of particle.
  f) Expert software system for accurate interpretation of cause of PD.
  g) 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 Bangladesh 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.

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.

Pulse generator, same type as that of used during factory testing for UHF sensor sensitivity test shall be supplied as a standard accessory.

3.4.5.41 Design Review

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

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

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.

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.

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.

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

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 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 substation.
19.	Testing capabilities.
20.	Inspection and test plan.
21.	Transport and storage.
22.	Maintainability.
23.	Site Test

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

a) Study report of VFTO generated for GIS installation for 400 kV and above.
b) Calculation for adequacy of UHF sensors to be provided in GIS Installation as per clause no 5.41.
c) The calculations and documents in support of the average intensity of electromagnetic field on the surface of the enclosure.
d) Calculations to show that there is no Ferro resonance due to capacitance of GIS for the voltage transformers.

e) Calculations in support of touch & step voltages in all enclosures and earthing of complete GIS installation.
f) Measures to mitigate transient enclosure voltage by high frequency currents.
g) 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.

3.4.5.42 Factory Testing

The manufacturer shall carry out routine tests for all GIS bays supplied under this Contract. All tests shall be done in line with as per IEC-62271-203. Complete test report shall be submitted to purchaser after proper scrutiny and signing on each page by the test engineer of the contractor.

3.4.5.43 On Site Testing

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. However, High voltage testing shall be done as per clause 10.2.101.2.3 procedure B of same IEC. Method statement/ procedure of ON SITE high voltage testing, PD measurement and Switching Impulse test shall be submitted by contractor in advance.

3.4.6 HVAC Circuit Breakers

3.4.6.1 This specification of technical conditions and technical requirements for Circuit Breakers covers the ratings, design, equipment requirements, inspection and testing of the equipment.

3.4.6.2 Here are stated only those general aspects that are meant to ensure minimum requirements with respect of quality and performance.

3.4.6.3 Other details and specific data are contained in the Technical Data Schedules.

3.4.6.4 Properties, testing and ratings of the equipment shall at least conform to the latest edition of the relevant IEC and British standards.

3.4.6.5 The Contractor is obliged to provide complete equipment, even if the details are not mentioned specifically in the following specifications.

3.4.6.6 General Design

3.4.6.6.1 Circuit breaker shall be, for outdoor installation. The circuit breaker shall be with SF6 gas as the arc-quenching and insulating medium. The circuit breakers shall comply with the requirements of IEC 60273, IEC 60694, IEC 60815, IEC 62271-100.

3.4.6.6.2 Beside the rated short circuit breaking current, the circuit breakers shall be capable of making and breaking the excitation all currents, without restricting and generating harmful over-voltage.

3.4.6.6.3 Circuit breakers with two breaking chambers shall be constructed to provide voltage distribution per breaking unit not above 55 % of the total voltage, at any circumstances.

3.4.6.6.4 The Contractor shall provide and deliver suitable horizontal and vertical supporting structure that shall be galvanized. The interrupting chamber & Drive mechanism shall be manufactured by manufacturers of European countries, USA, Canada, Korea and Japan.

3.4.6.7 Operating Mechanism

3.4.6.7.1 The operating mechanism shall be of motor wound-spring charged type. Other type operating mechanism is not allowed. Operating mechanism shall be of maintenance free type.

3.4.6.7.2 Operating mechanisms housing shall be made of aluminium or stainless steel. Anticorrosion protection is not anticipated.

3.4.6.7.3 It shall be possible to charge the operating springs with the circuit breaker in either the open or closed positions.

3.4.6.7.4 In normal operation, recharging of the operating springs shall commence immediately and automatically upon completion of the closing operation.

3.4.6.7.5 While a spring charging operation is in progress, closure shall be prevented.

3.4.6.7.6 Release of the springs shall not be possible until they are fully charged.

3.4.6.7.7 Manual spring release shall be provided.

3.4.6.7.8 The operating mechanism shall have hand and electrically charging.

3.4.6.7.9 The operating mechanism shall have hand charging facility and it shall be possible to discharge the operating springs, at site, from a charged condition without difficulty.

3.4.6.7.10 The state of charge of the operating springs shall be indicated by a mechanical device which shows "spring charged" when operation is permissible and "uncharged" when operation is not possible.

3.4.6.7.11 A provision shall be made for remote indication of "spring charge fail" conditions. Therefore, a spare spring-drive limit switch contacts and necessary time delay relays shall be provided.

3.4.6.7.12 The charging motor shall be connected to the a.c. supply.

3.4.6.7.13 The control circuits shall be connected to the d.c. supply.

3.4.6.7.14 The state of charge of the operating springs shall be indicated by a mechanical device which shows "spring charged" when operation is permissible and "uncharged" when operation is not possible.

3.4.6.7.15 At the bottom of each operating mechanism cabinets provide the option of earthing together with the earthing rails, by using the copper wire Cu from the outer side. Connection of Cu earthing rail shall be adopted to Al material of operating mechanism using appropriate material (electrolytically between Cu and Al).

3.4.6.7.16 Detachable plates for cable insertion rings shall be provided at the bottom of each operating

mechanisms cabinet.

3.4.6.7.17 Mechanically endurance of circuit breaker shall correspond to class M2.

3.4.6.8 High Speed Reclosing

3.4.6.8.1 The circuit breakers shall be constructed for high speed reclosure of the three poles simultaneously or of a single pole at a time, as per the Technical Schedules.

3.4.6.8.2 Reclosing applies only to the circuit breakers used for transmission line feeders.

3.4.6.8.3 The operating mechanism shall be suitable for auto-reclosing (cycle 0 - 0.3 s - CO - 3 min - CO).

3.4.6.8.4 After loss of power supply the operating mechanism shall be capable of performing a complete cycle.

3.4.6.9 Control Circuits

3.4.6.9.1 Circuit breaker shall be equipped with one closing coil per phase.The closing coil shall be supplied with anti-pumping devices.Circuit breaker shall be equipped with two electrically independent trip coils per phase.The trip coils shall be suitable for application of trip circuit supervision relays.

3.4.6.9.2 Means shall be provided to prevent the mechanism from responding to a closing signal when the trip coils is energized.

3.4.6.9.3 Circuit breaker shall be designed and equipped with, at least, the following control devices that should be situated in each central control panels:

Open and close push buttons.

Local/remote selector with possibility to be locked in "neutral" position. In neutral position provide appropriate signal.

3.4.6.9.4 The control circuits shall be designed to operate under the following conditions:

Remotely, from a National Load Control Centre,
Remotely, from a substation control building,
Automatically, by the protective relays,
Locally, by electrical push buttons,
Locally, by mechanical arrangement.

3.4.6.9.5 Each pole of the HV line feeder circuit breakers shall have, its own distinct operating mechanism with the controls grouped in a central control cabinet.

3.4.6.9.6 The circuit breaker shall be designed taking into consideration the following points:

3.4.6.9.7 The circuit assigned to the closing coil and the first tripping coil shall be separate from the circuit assigned to the second tripping coil. This means that there are two different d.c. supplies.

3.4.6.9.8 Power supply for the motor operated mechanism shall be protected by moulded circuit breakers. It is not allowed to cut-of neutral conductor.

3.4.6.9.9 Provide enough number of contacts of densimeter to fulfil previous preconditions.

3.4.6.9.10 Protective tripping of the circuit breaker shall not be blocked by the selector switch "Local/Remote".

3.4.6.9.11 A "Manual/Local/Remote" selector switch shall be provided in the central control cabinet.

3.4.6.9.12 A manual operating crank for each circuit breaker mechanism shall be provided.

3.4.6.9.13 Close-Trip" push buttons shall be provided in the central control panel.

3.4.6.9.14 Housing protection shall be at least of IP54.

3.4.6.9.15 A anti-condensation element, shall be provided in each operating mechanism housing and central control panel.

3.4.6.9.16 Provide anti-pumping devices.

3.4.6.9.17 A time delayed adjustable alarm contact for "phase discrepancy" condition shall be provided.

3.4.6.10 Auxiliary Contacts

The Manufacturer shall provide, for each mechanism, the sufficient number of normal close and normal open mechanically operated auxiliary switches, but at least 20 percent spare and not below amount specified in the Technical Schedules.

3.4.6.11 Position Indicator

A visual, mechanical, circuit breaker "Open-Closed" position indicator clearly visible from the ground level and without the opening of any access door, shall be provided. It shall be positively driven (cord drives excluded) directly from the mechanism.

3.4.6.12 Operating Counter

Each operating mechanism is to be equipped with an operation counter.

3.4.6.13 SF_6 Gas

3.4.6.13.1 The circuit breaker shall use SF_6 gas as the arc-quenching and insulating medium.Depending on the design, each pole or complete circuit breaker shall have at least:

3.4.6.13.2 Temperature compensated densimeter. Densimeter should be so designed to allow easy check correctness contacts of densimeter. Pressure device must be temperature compensated.

3.4.6.13.3 Device must so designed to allow easy reading of a gas density, for each pole or complete circuit breaker, without need for opening of operating mechanism housing or control panel housing.

3.4.6.13.4 Sufficient quantity of SF6 gas should be delivered for the first filling and additionally 20 % for eventually refilling.

3.4.6.13.5 One gas leakage alarm signal (S1) and one interlock signal (S2).

3.4.6.14 High-voltage Terminals

High-voltage terminals shall be: horizontal, flat, for aluminium conductor minimum area of 100 x 100 mm, with minimum four holes 14 mm diameter, at 50 mm distance between each other.

3.4.6.15 Cables

3.4.6.15.1 The Contractor must deliver factory-prepared-and-tested all necessary equipment (cables, connectors and similar) for mutual connection all operating mechanisms of circuit breakers and central control panel of a circuit breaker (if exist). Cables must be only for connection between operating mechanisms and central control panel. Cables should be for outdoor installation, equipped with appropriate connectors for fast and reliable erection of circuit breaker.

3.4.6.15.2 Terminals for connection of cables within operating mechanism and central control panel must be equivalent to PHENIX type UK6N and UK10N.

3.4.6.15.3 Provide a sufficient space for cables entrance inside operating mechanism and central control panel.

3.4.6.16 Support Metal Structure

3.4.6.16.1 Circuit breaker must be delivered with factory-prepared horizontal and vertical supporting structure necessary for erection. Metal structures shall be galvanized.

3.4.6.16.2 Final design of construction will be subject of later agreement. Metal structures shall be galvanized with minimum 70μm zinc layer.

3.4.6.17 Environmental Protection

Design of circuit breakers shall be designed to take maximum care of environment.

3.4.6.18 Insulators

3.4.6.18.1 Insulators shall be made of brown porcelain, according to technical specifications. 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. During Acceptance tests Manufacturer shall present a type and routine test report of porcelains.

3.4.6.18.2 Minimum creepage distance is 25 mm/kV.

3.4.6.19 Nameplates

Nameplates should have data written in English language:

Manufacturer name
Country of origin
Applicable standard
Type of circuit breaker
Type of operating mechanism
Rated voltage
Rated lighting impulse withstand voltage
Rated switching impulse withstand voltage
Rated frequency
Rated current
Rated duration of short circuit
Rated short time withstand current
Rated short time withstand current of a no-load OHL
Average making time
Rated operating sequence
Class of CB (Electrical, Mechanical, Capacitive switching)
Rated gas pressure on 20°C
Mass of a SF_6 gases
Weight of a circuit breaker
Year of production
Factory number
Factory number (numbers) of operating mechanisms

3.4.6.20 Special Equipment and Tools

3.4.6.20.1 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.

3.4.6.20.2 A handle for manual winding shall be found in all operating mechanisms.

3.4.6.20.3 SF_6 gas cylinder with valve and instruments for refilling and

3.4.6.20.4 SF_6 leakage detector

3.4.6.20.5 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 and.

3.4.6.21 Spare Parts

Contractor is obliged to enclose with the bid a list of recommended spares required for operation and maintenance necessary for 10 years period.

3.4.6.22 Packing, Shipment and Transportation

3.4.6.22.1 The Contractor is obliged to arrange preparation, packing and transport of the equipment.

3.4.6.22.2 Each circuit breaker shall be separately packed. It is not allowed to pack parts for more circuit breakers in single package.

3.4.6.22.3 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.

3.4.6.22.4 Sufficient quantity of SF_6 gas must be delivered for the first gas filling and eventually refilling.

3.4.6.23 Inspection and Tests

3.4.6.23.1 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.

3.4.6.23.2 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.

3.4.6.23.3 Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.

3.4.6.23.4 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.Acceptance test will be conducted in accordance with the program of routine tests.

3.4.6.24 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:

Dielectric tests
Power frequency withstand voltage test (wet and dry)
Lightning impulse voltage tests
Test on auxiliary and control circuit
Radio interference voltage (r.i.v.) test
Measurement of the resistance of the main circuit
Temperature rise test
Short time withstand current and peak withstand current test
Verification of the degree of protection
Tightness test
Electromagnetic compatibility (EMC) tests
Mechanical operation test at ambient air temperature
Static terminal load test
Short circuit current making and breaking tests, including short line fault tests
Capacitive current switching tests

Magnetizing and small inductive current switching tests

3.4.6.25 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:

Dielectric test on the main circuit including partial discharge measurement
Dielectric test on auxiliary and control circuits
Measurements of the resistance of the main circuit
Design and visual checks
Mechanical operating tests
Tightness test
Measurement of gas condition

3.4.6.26 Documentation

Documentation attached to the bid shall include minimum the following:

Manufacturer's Authorization
Manufacturer's Quality control certificate
Detailed list of type test for each type and class of the specified equipment
Copies of type test reports
Equipment-related catalogues
Reference list for previous five years
Drawings, schematic diagrams and similar
List of special equipment and tools
List of recommended spare parts
Training plan (if any, as required by specification)

For each circuit breaker, in one of the operating mechanisms the following documentation shall be delivered:

Drawings
Schematic diagrams
Instruction manuals for installation, testing and maintenance
Test protocol of acceptance testing

All documents, tables and rating plates attached to the equipment shall be in English language.

3.4.7 HV Disconnectors

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. Other details and specific data are contained in the technical data schedules.
Properties, testing and ratings of the equipment shall at least conform to the latest edition of the relevant IEC and British standards. The Contractor is obliged to provide complete equipment, even if the details are not mentioned specifically in the following specifications.

3.4.7.1 General Design

Disconnectors shall be for outdoor installation, double column, centre break. Disconnectors shall comply with the requirements of IEC 60129, IEC 60265, IEC 60273, IEC 60694, IEC 60815, IEC 62271. Insulators shall be porcelain, brown colour and follow the dimensions ad characteristics defined in the technical specifications.The male-female parts shall be manufactured by manufacturers of European countries, USA, Canada, Korea and Japan.

3.4.7.2 Operating Mechanism

3.4.7.2.1 Disconnectors without earthing blade shall have one operating mechanisms, compliant to the technical specifications.

3.4.7.2.2 Disconnectors with earthing blade shall have two separate operating mechanisms, compliant to the technical specifications. It is not allowed that drive mechanisms of main and earthing blades be located in the same housing.

3.4.7.2.3 Operating mechanisms housing shall be made of aluminium or stainless steel. Anticorrosion protection is not anticipated. Operating mechanism shall be easily accessible constructed for exchange needs.

3.4.7.2.4 All operating mechanisms shall be motor driven, providing the option of manual operation, too. Motor shall be maintenance-free unit. Motor shall be AC, single phase, designed for 230 V, 50 Hz. Motor protection shall be provided with miniature circuit breaker (MCB) having alarm (signalling) contact. Alarm for MCB outage shall be provided. If three-phase MCB is used, the circuit shall be made through all three contacts. Neutral phase shall not be interrupted. After the MCB, the motor circuit shall be positioned with the voltage presence controller (voltage detector relay). Control voltage for electric controls of the disconnector shall be conditioned by the presence of voltage for the motor supply.

3.4.7.2.5 Alarm (signalling) and control voltage shall be 220V, DC. Control over disconnectors shall be two-pole, i.e. both polarities shall be interrupted in control circuits. Selection switch for local/neutral (manual)/ remote controls shall be provided in each operating mechanism. Suitable push buttons shall be provided on all control operating mechanisms.

3.4.7.2.6 Option of mechanical blocking and locking of disconnector at both work positions shall be provided.

3.4.7.2.7 Blockings shall have latches (bolts) for prevention of electric operation in case of manual manipulation, when crank of manual unit is put in work position.

3.4.7.2.8 Provide that the crank for manual operation cannot be inserted if the selection switch has not been put in manual position. When the crank is inserted, the electric control over disconnector shall not be possible regardless to the position of selection switch.

3.4.7.2.9 All operating mechanisms shall be equipped with heater to prevent condensation.

3.4.7.2.10 All operating mechanisms shall have lighting, with automatic switch located at the door of the operating mechanism.

3.4.7.2.11 Heater and lighting shall be for 230 V AC, 50 Hz.

3.4.7.2.12 The circuits for supply of heater and lighting and socket shall be independent from the circuits for motor supply.

3.4.7.2.13 All operating mechanisms shall be equipped with manual control regardless to the type of operating mechanism.

3.4.7.2.14 A crank for manual control shall be found in each operating mechanisms.

3.4.7.2.15 Secondary connections must be made on terminal connections. Terminal connections shall be made of best material. For AC circuits it shall be for 16 mm^2 conductors and for other circuits it shall be for 6 mm^2 conductors.

3.4.7.2.16 All operating mechanisms shall have copper latches at the bottom of the cabinet for earthing of the cable sheath.

3.4.7.2.17 Detachable plates for cable glands shall be provided at the bottom of each operating mechanisms cabinet.

3.4.7.2.18 Housing protection shall be at least IP 54.Operating mechanism housing shall have electric scheme on inner side of the door.

3.4.7.3 Control Circuits

3.4.7.3.1 Disconnector shall be designed and equipped with at least the following control units to be found at all operating mechanisms:

Buttons for manual closing/opening shall be available. Control switch for operation mode local / neutral (manual) / remote, with an option of electric blocking in "neutral" position,

3.4.7.3.2 Control circuits shall be designed to operate under the following conditions:

Remotely
Locally, via electric buttons in operating mechanism
Locally, using crank for manual operation.

3.4.7.4 Blocking

Mechanical and electrical blockings shall ensure to avoid minimum the following conditions:

Concurrent use of closing and opening Contractors
Use of electric motor in the course of manual operation
Electric operation when the crank for manual operation has been inserted.
Activation of main blades when earthing blades are activated and vice versa
Mechanical blocking of the main blades when earthing blades are activated and vice versa

3.4.7.5 Auxiliary Contacts

Manufacturer shall for each mechanism provide sufficient number of mechanical auxiliary contacts for normal closing and normal opening, number specified in the Technical Data Schedules.The auxiliary contacts shall be Class 1 and shall offer the option of time adjustment.

3.4.7.6 High-Voltage Terminals

High-voltage terminals shall be: horizontal, flat, for aluminium conductor minimum area of 100 x 100 mm. with minimum four holes 14 mm diameter, at 50 mm distance between each other.

3.4.7.7 Metal Structure

The Contractor shall provide and deliver suitable horizontal supporting structure. The horizontal supporting structure as well as all other pertinent metal components shall be galvanized with minimum 70μm zinc layer.

3.4.7.8 Environmental Protection

Design of Disconnectors shall be designed to take maximum care of environment.

3.4.7.9 Insulators

Insulators shall be made of brown porcelain, according to technical specifications. 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. Metal parts shall be galvanized with minimum 70 μm zinc layer.

Minimum creepage distance is 25 mm/kV.

3.4.7.10 Special Equipment AND Tools

3.4.7.10.1 The Contractor is obliged to deliver all equipment and tools required for installation, testing and maintenance of disconnectors. Special equipment and tools shall be of the highest quality and suitable for field work. All materials to be used shall be new.

3.4.7.10.2 Special equipment and tools list shall be defined by the Technical data Schedule. Special equipment and tools shall be supplied in a number defined by the Technical data Schedule.

3.4.7.10.3 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.

3.4.7.11 Spare Parts

Contractor is obliged to enclose with the bid a list of recommended spares required for operation and maintenance of disconnectors.

3.4.7.12 Packing, Shipment and Transportation

Each disconnector shall be separately packed. It is not allowed to pack parts for more disconnectors in one package. 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.

3.4.7.13 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.

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.

Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.

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.

Acceptance test will be conducted in accordance with the program of Routine tests.

3.4.7.14 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:

Dielectric tests
Power frequency withstand voltage test (wet and dry)
Lightning impulse voltage tests
Artificial contamination test
Auxiliary and control circuits test
Radio interference voltage test (r.i.v.)
Main circuit resistance test
Temperature rise test
Short circuit withstand current test and impulse withstand current tests
Earthing blade operation performance test
Operation and mechanical endurance tests
Busbar breaking currents test

A detailed list of type tests shall be attached to the bid.

3.4.7.15 Routine Test

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:

Main circuit dielectric test

Auxiliary circuits and control circuits dielectric test
Main circuit resistance measurement
Visual inspection
Functionality check and mechanical operation test

Documentation

Documentation attached to the bid shall include minimum the following:

Manufacturer's authorization
Manufacturer's quality control certificate
Detailed list of type test for each type and class of the specified equipment
Copies of type test reports
Equipment-related catalogues
Reference list for previous five years
Drawings, schematic diagrams and similar
List of special equipment and tools
List of recommended spare parts
Training plan

For each disconnector, in one of the operating mechanisms the following documentation shall be delivered:

Drawings
Schematic diagrams
Instruction manuals for installation, testing and maintenance
Test protocol of acceptance testing

All documents, tables and rating plates attached to the equipment shall be in English language.

3.4.8 HV Instrument Transformers

3.4.8.1 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.

3.4.8.2 Other details and specific data are contained in the Technical Data Schedules.

3.4.8.3 Properties, testing and ratings of the equipment shall at least conform to the latest edition of the relevant IEC and British standards.

3.4.8.4 The Contractor is obliged to provide complete equipment, even if the details are not mentioned specifically in the following specifications.

3.4.8.5 Current transformers in the existing substations shall be carefully chosen. Final characteristics may be different from the characteristics in the single line diagram and/or in the technical schedules. They shall be defined during the design stage and shall be appropriate for busbar protection in the existing substation.

3.4.8.6 General Design- Current Transformers

3.4.8.6.1 The current transformers shall be for outdoor installation, single phase, head type, hermetically sealed, oil-paper immersed. SF6 gas is not allowed. They shall be multi core with appropriate characteristics. They shall be designed to allow secondary reconnection. Primary reconnection is not allowed.

3.4.8.6.2 The winding, capacitor stack & Core shall be manufactured by manufacturers of European countries, USA, Canada Korea and Japan.

3.4.8.6.3 The current transformers shall be supported by a porcelain insulator. They shall comply with IEC 60044 and shall be equipped with:

3.4.8.6.4 Expansion chamber/and internal metal bellows type oil gauge diaphragm.

3.4.8.6.5 Device for determining insulating medium level.

Oil drain cock and sampling device.
tgδ measuring connection
Low voltage terminal box
Enable sealing after accuracy class checks (sealing possibilities).
Overpressure device
Adequate earth terminal connection

3.4.8.6.6 Oil compensation system must be metallic. Other materials won´t be accepted. Moreover, Insulators must be cylindrical or conic shape, with cemented flanges.

3.4.8.6.7 Current transformers must be top core design with aluminum housing. Current transformers must be equipped with a tangent delta tap, in order to take measurements at site. This tangent delta tap must be such that the whole internal insulation must be covered during testing. Details must be given for evaluation and for approval during execution.

General Design - Voltage Transformers

3.4.8.6.8 The voltage transformers shall be for outdoor installation, single phase, hermetically sealed.

3.4.8.6.9 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. SF_6 gas is not allowed.

3.4.8.6.10 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.

3.4.8.6.11 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 porcelain insulator.

3.4.8.6.12 The voltage transformers shall comply with IEC 61869. They shall be equipped with:

Expansion chamber/and internal metal bellows type oil gauge diaphragm.

Device for determining insulating medium level
Oil drain cock and sampling device
tgδ measuring connection
Low voltage terminal box
Adequate earth terminal connection
Enable sealing after accuracy class checks (sealing possibilities)
Terminal connection for anti-ferro-resonance control for capacitive voltage transformers
HF connection terminal for capacitive voltage transformers
Overpressure device

3.4.8.6.13 Oil compensation system must be metallic. Other materials won´t be accepted. Moreover, Insulators must be cylindrical or conic shape, with cemented flanges.

3.4.8.6.14 Voltage transformers must be top core design with aluminum housing. Voltage transformers must be equipped with a tangent delta tap, in order to take measurements at site. This tangent delta tap must be such that the whole internal insulation must be covered during testing. Details must be given for evaluation and for approval during execution.

3.4.8.7 High-Voltage Terminals

High-voltage terminals shall be:

horizontal (or vertical, for voltage transformers only),
flat,
for aluminium conductor,
minimum area of 100 x 100 mm, with four holes, 14 mm diameter, at 50 mm distance between each other

3.4.8.8 Permissible Partial Discharges Level

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.

3.4.8.9 Outdoor Insulation

Outdoor insulation of instrument transformers shall consist of porcelain insulator element.

Insulators shall be made of brown porcelain, according to technical specifications. 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. Metal parts shall be made of aluminium, stainless steel or shall be galvanized with minimum 70 µm zinc layer.

Minimum creepage distance is 25 mm/kV.

3.4.8.10 Environmental Protection

Design of Instrument transformers shall be designed to take maximum care of environment.

3.4.8.11 Mechanical Terminal Loads

Instrument transformers shall fulfil at least mechanical requirements of Class II.

3.4.8.12 Mechanical Protection

Design of instrument transformers shall provide hermetically sealing of active parts. Secondary terminal box shall be mechanical protection level min. IP54.

3.4.8.13 Anticorrosion Protection

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.

It is not allowed to use material with anticorrosion protection, except metal support structure, which shall be galvanized with minimum 70 µm zinc layer.

3.4.8.14 Packing, Shipment and Transport

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.

3.4.8.15 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.

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.

Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.

Special tests shall be performed on each piece of equipment before delivery, during the acceptance test
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.

Acceptance test will be conducted in accordance with the program of routine tests.

3.4.8.16 Type Tests of Current Transformers

The following type tests shall be conducted on each type and class of the specified equipment for the purpose of proving its properties:

Short-circuit withstand capability test

Short-duration current test
Temperature rise test
Lighting impulse tests
Switching impulse test
Wet test
Determination of errors
Test of secondary winding resistance for PR and TPY class
Determination induce characteristic of a secondary winding for TPY class
Determination of remanence factor for PR and TRY class
Determination of a secondary loop time constant for PR and TPY class
Accuracy class test for TPY class
Determination construction factor for TPY class
Radio interference voltage measurement test (RIV)
Seismic test
Wind pressure test.

3.4.8.17 Type Tests of Capacitive Voltage Transformers

The following type tests shall be conducted on each type and class of the specified equipment for the purpose of proving its properties:

Accuracy class test
Temperature rise test
Measurement of capacitance and dielectric dissipation factor
Chopped impulse tests
Radio interference voltage measurement test (RIV)
Short-circuit withstand capability test
Lighting impulse tests
Switching impulse test wet
Transient response test
Ferro-resonance test
Tightness test of liquid-filed electromagnetic unit
Voltage and phase accuracy test

3.4.8.18 Type Test of Inductive Voltage Transformers

The following type tests shall be conducted on each type and class of the specified equipment for the purpose of proving its properties:

Temperature rise test
Short-circuit withstand capability test
Lighting impulse tests
Switching impulse test
Power frequency voltage wet test
Determination of voltage and phase errors
Radio interference voltage measurement test (RIV)
Seismic test
Wind pressure test
Measurement of capacitance and dielectric dissipation factor

Chopped impulse tests
Transient response test
Ferro-resonance test
Tightness test of liquid-filed electromagnetic unit

3.4.8.19 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:

Routine Tests-Current Transformers
Verification of terminal markings
Power frequency withstand tests on primary windings
Partial discharge measurement
Measurement of capacitance
Measurement of dielectric dissipation factor (tgδ)
Power frequency withstand tests on secondary windings
Power frequency withstand tests between sections
Inter-turn overvoltage test
Insulation resistant test
Instrument security factor test
Security factor test
Accuracy class test
Galvanizing test

3.4.8.20 Routine Tests-Capacitive Voltage Transformers

On capacitive divider of capacitive voltage transformers:
- Measurement of capacitance
- Measurement of dissipation factor (tgδ)
- Power frequency withstand tests
- Partial discharge measurement
- Measurement of capacitance (again)
- Measurement of dissipation factor (tgδ)(again)
- Measurement of capacitance separately C1 and C2
- Power frequency withstand tests on low voltage terminals of capacitive divider.

On electromagnetic unit of capacitive voltage transformer:
- Power frequency withstand tests
- Power frequency withstand tests on low voltage terminals of capacitive divider
- Power frequency withstand tests on secondary windings

On complete of capacitive voltage transformer:
- Verification of terminal markings
- Ferro-resonance test
- Accuracy class test
- Galvanizing test

Routine Tests-Inductive Voltage Transformers
Verification of terminal markings
Partial discharge measurement
Measurement of capacitance

Measurement of dissipation factor (tgδ) 2 kV
Power frequency withstand tests on low voltage terminals.
Power frequency withstand tests on secondary windings.
Accuracy class test
Galvanizing test

3.4.8.21 Special Tests-Inductive Voltage Transformers

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:

High frequency transient voltage test
Over pressure device test

3.4.8.22 Documentation

Documentation attached to the bid shall include minimum the following:

Manufacturer's Authorization
Manufacturer's Quality control certificate
Detailed list of type test for each type and class of the specified equipment
Copies of type test reports
Equipment-related catalogues
Reference list for previous five years
Drawings, schematic diagrams and similar
List of special equipment and tools, if any
List of recommended spare parts, if any

For each instrument transformer, the following documentation shall be delivered:

Drawings
Schematic diagrams
Instruction manuals for installation, testing and maintenance
Test protocol of acceptance testing

All documents, tables and rating plates attached to the equipment shall be in English language.
For , 33kV IT (CT & IVT) , there shall be two secondary terminals, one for revenue metering and other for substation metering & protection purpose.

3.4.9 Surge Arresters

3.4.9.1 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.

3.4.9.2 Properties, testing and ratings of the equipment shall at least conform to the latest edition of the relevant IEC and British standards.

3.4.9.3 The Contractor is obliged to provide complete equipment, even if the details are not mentioned specifically in the following specifications.

3.4.9.4 General Design

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.
The metal-oxide blocks shall be manufactured by manufacturers of European countries, USA, Canada Korea and Japan.

3.4.9.5 High-Voltage Terminals

High-voltage terminals shall be as it is defined in a technical schedule:

Vertical,
Flat,
For aluminium conductor,
Minimum area of 100 x 100 mm
With at least four holes 14 mm diameter, at 50 mm distance between each other

3.4.9.6 Insulating Basement

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.

3.4.9.7 Earthing

Surge arresters will be equipped with appropriate earthing connector.

3.4.9.8 Surge Arresters Housing

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 25 mm/kV.

3.4.9.9 Environmental Protection

Design of surge arresters shall be designed to take maximum care of environment.

3.4.9.10 Nameplates

Nameplates should have data written in a English language:

Manufacturer name
Type of surge arrester
Rated voltage of surge arrester Ur

Continuous operating voltage of surge arrester Uc
Nominal discharge current of an arrester (8/20 µs)
Rated short circuit current
Rated frequency
Line discharge class
Number of a unit position in a set (for multi units surge arrester)
Mass of surge arrester
Year of production
Serial number

3.4.9.11 Special Equipment, Tools and Drawings

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.

3.4.9.12 Spare Parts

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.

3.4.9.13 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.

3.4.9.14 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.

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.

Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.

Special tests shall be performed on each piece of equipment before delivery, during the acceptance test

3.4.9.15 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:

Dielectric tests
- -Power frequency withstand voltage test of arrester housing
- -Lightning impulse voltage tests
- -Power frequency voltage wet and dry test

Residual voltage test
- -Steep current
- -Lightning impulse
- -Switching impulse

Test to verify long term stability under continuous operating voltage
Repetitive change behaviour verification
Operating duty tests
Power frequency voltage versus time
Short circuit test
Weather aging test

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.

3.4.9.16 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:

Measurement of reference voltage
Residual voltage test
Partial discharge and contact noise tests
Seal leakage test

Documentation:

Documentation attached to the bid shall include minimum the following:

Manufacturer's Authorization
Manufacturer's Quality control certificate
Detailed list of type test for each type and class of the specified equipment
Copies of type test reports
Equipment-related catalogues
Reference list for previous five years
Drawings
For each surge arrester, the following documentation shall be delivered:

Drawings:
Instruction manuals for installation, testing and maintenance
Test protocol of acceptance testing

All documents, tables and rating plates attached to the equipment shall be in English language.

3.4.10 Post Insulators

3.4.10.1 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.

3.4.10.2 Properties, testing and ratings of the equipment shall at least conform to the latest edition of the relevant IEC and British standards.

3.4.10.3 The Contractor is obliged to provide complete equipment, even if the details are not mentioned specifically in the following specifications.

3.4.10.4 General Design

Post insulators should be solid core type post insulators, made of porcelain, for outdoor installation in the three phase 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.

Post insulators should satisfy the best level of development for this kind of equipment in a field of design, construction and material.

3.4.10.5 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.

3.4.10.6 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.

3.4.10.7 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.

3.4.10.8 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.

3.4.10.9 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.

3.4.10.10 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 25 mm/kV.

3.4.10.11 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.

3.4.10.12 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.

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.
Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.

3.4.10.13 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:

Dielectric tests
- Lightning impulse voltage tests
- Power frequency voltage wet and dry test
- Power frequency withstand voltage test of arrester housing
- Long-duration current impulse withstand test
- Residual voltage test
- Internal partial discharge tests
- Mechanical failing load test

3.4.10.14 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:

Radio interference voltage measurement test (RIV)
Test for deflection under load

3.4.10.15 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:

Routine thermal shock test
Routine visual examination
Routine electrical test
Routine mechanical test

3.4.10.16 Acceptance Tests

The following tests shall be conducted:

Verification of dimensions
Temperature cycle test
Dimension tests
Mechanical test
Puncture test
Porosity test
Galvanizing test

3.4.10.17 Documentation

Documentation attached to the bid shall include minimum the following:

Manufacturer's Authorization
Manufacturer's Quality control certificate
Detailed list of type test for each type and class of the specified equipment
Copies of type test reports
Equipment-related catalogues
Reference list for previous five years
Drawings

Following documentation shall be delivered together with the equipment:

Drawings
Instruction manuals for installation, testing and maintenance
Test protocol of acceptance testing

All documents, tables and rating plates attached to the equipment shall be in English language

3.4.11 Neutral Grounding Resistors

The earthing resistors shall be of the metal grid type with enclosure having degree of protection IP 33 and suitable for outdoor service on the neutral earthing system as specified. The framework and enclosure shall be of galvanised steel. The grids shall be adequately supported on steel rods and porcelain insulators and be designed to withstand the currents flowing under fault conditions. Adequate insulating barriers shall be provided to prevent internal flashover.
The resistor shall be complete with lifting and jacking lugs, access panels, holding down bolts or clamps, earth terminals, connectors and connections.
The bushing shall have a minimum creepage distance of 25mm/kV of rated system phase to neutral voltage.
The specified resistance shall be that at the design ambient temperature and it shall be capable of passing the specified current for 10 seconds with a maximum temperature rise as stated in the Schedule of Guarantees.

3.4.12 Insulators, Bushings, Buses and Hardware

3.4.12.1 Bushings and Support Insulators

General

Bushings shall be manufactured and tested in accordance with IEC-60137 while hollow column insulators shall be manufactured and tested in accordance with IEC-60233. The support insulators shall be manufactured and tested as per IEC-60168, IEC-60273. The insulators shall also conform to IEC-60815 as applicable. All bushings shall be one piece only and no joints shall be accepted.

Constructional Features

a) Porcelain used shall be homogeneous and free from imperfections that might affect the mechanical or dielectric quality.

b) Glazing of the porcelain shall be of uniform brown colour, free from blisters, burns and other similar defects. The ground surface shall not be glazed.

c) Condenser type bushing shall be provided with :

   i) Oil level gauge.

   ii) Oil filling plug and drain valve if not hermetically sealed.

   iii) Tap for capacitance and tan delta test.

d) When bushings have an under-oil end of re-entrant form, the pull through lead shall be fitted with a gas bubble deflector.

e) Where current transformers are specified, the bushings shall be removable without disturbing the current transformers.

f) Bushings of identical rating shall be interchangeable.

g) No arching horns shall be provided on the bushings.

h) All ferrous parts shall be hot dip galvanized or zinc plated and passivated. All joints shall be air tight. Insulator/bushing design shall be such as to ensure a uniform compressive pressure on the joints.

i) Support insulators/bushings/hollow column insulators shall be designed to have ample insulation,

mechanical strength and rigidity for the conditions under which they shall be used.

j) When operating at rated voltage there shall be no electric discharge between conductor and insulators which would cause damage to conductors or insulators by the formation of substances produced by chemical action. No radio interference shall be caused when operating at rated voltage.

k) The design of the insulator shall be such that stresses due to expansion and contraction in any part of the insulator shall not lead to deterioration.

l) The Bidder/Bidder shall define the type of insulator (type A or B) as per IEC-60168.

m) Bushing porcelain shall be robust and capable of withstanding the internal pressures likely to occur in service. The design and location of clamps and the shape and the strength of the porcelain flange securing the bushing to the tank shall be such that there is no risk of fracture. All portions of the assembled porcelain enclosures and supports other than gaskets, which may in any way be exposed to the atmosphere shall be composed of completely non hygroscopic material such as metal or glazed porcelain.

n) Special precaution shall be taken to exclude moisture from paper insulation during manufacture, assembly, transport and erection. The surface of all paper insulation shall be finished with non-hygroscopic varnish which can not be damaged easily.

o) Each porcelain 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. 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 60137:1973.

Parameters

The parameters shall be determined by the Bidder, however the minimum performance parameters for the 420 kV and 132 kV class post insulator shall be as per the stipulation of Schedule-A of Volume 3 of 3(Schedule of Requirements).

Tests

Each type of bushing and insulator shall be subjected to type and routine tests in accordance with applicable standards and acceptance test shall include one minute dry power frequency withstand test and ultrasonic test (except for hollow insulator). The ultra sonic test shall be done on the porcelain before assembly. All sample tests and special tests shall also be conducted.

3.4.11.2 String Insulators & Hardware

General

The insulators for suspension and tension strings shall conform to relevant IEC/Standard. Insulator hardware shall conform to relevant IEC/Standard. The insulation levels shall be determined by the Bidder but the minimum performance characteristics shall be as specified in Schedule A of Volume 3 of 3.

Constructional Features

a) Requirements specified in Clause 3.4.11.1 above shall also be applicable equally to string (disc)

insulators.

b) Suspension and tension insulators shall be wet process porcelain with ball and socket connections. Insulators shall be interchangeable and shall be suitable for forming either suspension or tension strings. Each insulator shall have rated strength markings on porcelain printed and applied before firing.

c) Insulator hardware shall be uniform to the requirements stipulated for clamps and connectors under Clause 3.4.10.3.

d) Insulator hardware shall be of forged steel. Malleable cast iron shall not be accepted except for insulator disc cap. The surface of hardware must be clean, smooth, without cuts, abrasion or projections. No part shall be subjected to excessive localized pressure. The metal parts shall not produce any noise generating corona under operating condition.

e) Insulator hardware assembly shall be designed as per the design requirement but for at least 4000 Kg. tensile load per phase for the switchyard with a factor of safety two (2). Similarly ground wire tension clamp shall be designed for at least 3500 kg tensile load with a factor of safety of two (2).

f) Tension string assembly shall be supplied along with suitable turn buckle (one turn buckle per string).

g) All hardware shall be bolted type.

h) As an alternative to disc insulator string, the Bidder/Bidder can provide a combination of long rod insulators, with suitable hardware. This combination shall be suitable for application specified and should offer the same equivalent parameters as would be available from the insulator string composed of specified disc insulators and hardware combination. Further the complete long rod insulator string shall be subject to the specified tests and the insulator shall also be subject to all tests as per relevant standards. All other constructional features specified above shall also apply to the long rod insulator string.

Parameters

The minimum parameters of insulator discs/complete insulator strings shall be as per the stipulation of Schedule-A of Volume 3 of 3(Schedule of Requirements).

Tests

The insulators for suspension and tension strings and hardware shall be subjected to the following type tests, acceptance tests and routine tests.

a) Type Tests on Insulator Strings:

i) Dry and Wet Power Frequency Voltage withstand test with corona control rings and arcing horns

ii) Dry and Wet Switching surge voltage withstand test with corona control Ring

iii) Dry and Wet Impulse Voltage Withstand test with corona control rings

iv) Voltage distribution test

v) Corona and RIV test (Dry Condition)

vi) Mechanical strength test

b) Type Tests on Disc Insulators:

i) Thermal and Mechanical performance tests

ii) Power frequency puncture withstand voltage

iii) Steep front wave test to be conducted as follows:

- This test shall be performed on five samples taken at random
- The insulators shall be subjected to five(5) positive and five (5) negative impulses with wave fronts of at least 2500 kV/microsecond
- In the case of low flashover values of porcelain puncture, the number of samples shall be doubled or another test shall be performed.

iv) Results of the second test should not show porcelain puncture

c) Acceptance Tests for Disc Insulators:

i) Visual examination

ii) Verification of Dimensions

iii) Temperature Cycle Test

iv) Puncture Test

v) Galvanizing Test

vi) Mechanical performance Test

vii) Test on locking device for ball and socket coupling

viii) Porosity test

ix) Electromechanical test

d) Type Test on Hardware Fittings Only:

i) Magnetic power loss test for suspension assembly (For both suspension and drop clamps)

e) Acceptance Test on Hardware Fitting:

i) Visual Examination

ii) Verification of Dimensions

iii) Galvanizing/Electroplating tests

iv) Slip strength test

v) Shore hardness test for Elastometer (if applicable)

vi) Mechanical strength test for each component (including corona control rings and arcing horns)

vii) Mechanical strength test on corona control rings

viii) Test on locking devices for ball and socket coupling

f) Routine Test on Disc Insulator/Long Rod Insulator:

i) Visual Inspection

ii) Mechanical Routine Test

iii) Electrical Routine Test

g) Routine Test of Hardware Fittings:

i) Visual examination

ii) Mechanical strength test

h) Test During Manufacture on all Components as Applicable on Disc Insulator:

i) Chemical analysis of zinc used for galvanizing

ii) Chemical analysis, mechanical hardness tests and magnetic particle inspection for malleable casting

i) Test During Manufacture on all Components as Applicable on Hardware Fittings:

i) Chemical analysis of zinc used for galvanizing

ii) Chemical analysis, mechanical hardness tests and magnetic particle inspection for forgings.

iii) Chemical analysis and mechanical hardness tests and magnetic particle inspection for fabricated hardware.

Test Procedures

a) Voltage Distribution Test(Dry)

The string shall be energised with 100 kV power frequency voltages. The voltage across each insulator unit shall be measured by using a high impedance voltmeter. The voltmeter shall be calibrated before and after the measurement. The voltage across any disc shall not exceed 9% of the applied voltage for single and double suspension insulator string and 10% for double tension insulator strings.

b) Corona Extinction Voltage Test (Dry)

The sample assembly when subjected to power frequency voltage shall have a corona extinction voltage of not less than 320 kV line to ground under dry conditions. There shall be no evidence of corona on any part of the sample when all possible sources of corona are photographed in a darkened room.

c) RIV Test (Dry)

Under the conditions as specified under b) above the insulator string alongwith complete hardware fittings shall have a radio interference voltage level below 1000 microvolts at one MHz when subjected to 50 Hz AC voltage of 266 kV (rms) line to ground under dry conditions. The test procedure shall be in accordance with IEC-60437-1973.

d) Mechanical Strength Test

The complete insulator string along with its hardware fittings shall be subjected to a load equal to 50% of the specified minimum ultimate tensile strength (UTS) which shall be increased at a steady rate to 67% of the minimum UTS specified. The load shall be held for five minutes and then removed. After removal of the load, the string components shall not show any visual deformation

and it shall be possible to disassemble them by hand. Hand tools may be used to remove cotter pins and loosen the nuts initially. The string shall then be reassembled and loaded to 50% of UTS and the load shall be further increased at a steady rate till the specified minimum UTS and held for one minute. No fracture should occur during this period. The applied load shall then be increased until the failing load is reached and the value recorded.

e) Magnetic Power Loss Test for suspension assembly (for both drop and suspension clamp)

Two hollow aluminium tubes of 32 mm dia. shall be placed 450 mm or 250 mm apart depending upon the voltage level at which test is to be done. An alternating current in the range of 200 to 600 Amps. shall be passed through each tube. The reading of the wattmeter with and without two suspension assemblies along with the line side yoke plate clevis eye shall be recorded. Not less than three suspension assemblies shall be tested. The average power loss for the suspension assembly shall be plotted for each value of current. The value of loss corresponding to 300 Amps shall be read from the graph. The magnetic power loss of the clamp assembly with entire line fitting shall not exceed 4 watts at 600 Amps current (rms).

f) Mechanical Strength Test of each component

The load shall be so applied that the component is stressed in the same way as it would be in actual service and the procedure as given in f) above should be followed.

g) Chemical Analysis of Zinc used for galvanizing

Samples taken for the zinc ingot shall be chemically analyzed as per relevant IEC Standard. The purity of zinc shall be not less than 99.5%.

h) Test for Forgings, Castings & Fabricated Hardware

The chemicals analysis, mechanical hardness tests and magnetic particle inspection, shall be as per the internationally recognized procedures for these tests. The sampling shall be based on heat number and heat treatment batch. The details regarding test shall be mutually agreed to by the Bidder and the Employer.

3.4.13 Interlocking Facilities

Disconnectors, earthing switches, circuit breakers, etc., shall be provided with an interlocking system which ensures safe operation of the equipment under all service conditions.

The interlocking scheme shall be designed for the final substation arrangement. The items of plant supplied under this Contract shall be complete with all interlocking facilities needed for the final arrangement, avoiding the need for future modifications.

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.

Tripping of the circuit-breaker shall not occur if any attempt is made to remove a trapped key from the mechanism. Emergency tripping devices shall be kept separate and distinct from any key interlocking system and shall be clearly labelled, suitably protected from inadvertent operation but readily accessible.

Circuit-breakers shall be interlocked so that, except under maintenance conditions, it is not possible to close a circuit-breaker unless the selected busbar and circuit disconnectors are closed.

Except as stated below, disconnectors shall be so interlocked that they cannot be operated unless the associated circuit-breaker is open. Where power transformers are banked together, the individual transformer disconnectors shall be interlocked so that it is not possible to make or break

load current at the disconnectors.

Provision for on load transfer of feeder circuits from one busbar to another shall be made possible by interlocks which ensure that the section disconnectors, bus coupler and its disconnectors are closed.

All electrical interlocks shall so function as to interrupt the operating supply, and an approved system of interlocks shall be provided which shall cover the emergency hand operation of apparatus which is normally power operated. Failure of supply (or its restoration after an outage) or of connections to any electrical interlock shall not produce or permit faulty operation. Electrical bolt interlocks shall be energized only when the operating mechanism is being operated. Visible indication shall be provided to show whether the mechanism is locked or free. Approved means, normally padlocked, shall be provided whereby the bolt can be operated in the emergency of a failure of interlock supplies.

3.4.14 Auxiliary Switches and Contactors

Circuit-breakers, disconnectors and earthing devices and circuit selector disconnectors shall be provided with suitably rated auxiliary switches and contactors, where permitted, to relay circuit information for the purpose of control, protection, indication and metering at the substation site as required by the relevant section of the Specification. In addition they shall be provided with auxiliary contacts for position indication to the central system control room via the remote supervisory system. Disconnector auxiliary switches are not to be used for current transformer switching circuits.

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 the auxiliary switches except as specifically approved by the Engineer. Auxiliary switches and contactors shall comply with the requirements of this Specification and in particular shall be capable of operation within the same voltage limits as specified for the associated circuit-breaker close and trip coils.

The connections of all auxiliary switches, including spares, and contactors as well as the associated coil connections and interconnections between auxiliary switches, shall be wired to a terminal board located in the operating cubicle or other approved position.

Auxiliary switches and contactors shall be mounted in an approved accessible position clear of the main operating mechanism but with a minimum of additional mechanical linkages and housed in a substantial weatherproof enclosure. Where adjustable linkages are provided to facilitate the timing of the auxiliary switches with respect to the main equipment, approved locking devices shall be fitted.

Auxiliary switch contacts shall be positively operated, make with a wiping action and, where necessary, discharge resistors shall be provided to prevent arcing when breaking inductive circuits.

Except for the contacts employed for control and interlocking, the requirements for auxiliary switches in respect of timing shall be as follows:-

For Circuit-Breakers

Normally open contacts, with the exception of two sets of this type, shall close in about 10 milliseconds after the making of the main circuit-breaker contacts and shall open in about 10 milliseconds before the separation of the main circuit-breaker contacts whilst the two remaining sets shall close in about 5 milliseconds before the making of the main circuit breaker contacts and

open simultaneously with the main circuit contacts.

Normally closed contacts shall close 10 milliseconds after the opening of the main circuit-breaker contacts and open at least 10 milliseconds before the making of the main circuit-breaker contacts.

For Busbar Disconnectors

The operating sequence of any disconnector auxiliary switches used in D.C. circuits for high impedance busbar zone protection shall be such that the auxiliary switches operate:-

a) before reaching the pre-arcing distance on closing the disconnector.

b) after the pre-arcing distance has been exceeded on the opening of the disconnector.

Auxiliary switches shall be adjustable from normally-open to normally-closed or vice-versa.

For Line Disconnectors

As for Busbar disconnector auxiliary switches.

For Earthing Switches

As for Busbar disconnector auxiliary switches.

Any deviation from the above should be stated in the Schedule F of Deviations from Specification.

3.4.15 Interference with Existing Equipment

Work carried out on site in extending equipment or modifying the existing substation shall be so arranged as to cause minimum interference with existing plant and equipment and interruption to supplies. The Bidder shall include in his price for the provision, erection, commissioning and subsequent dismantling and removal from site of any temporary structures, insulators and connections that may be necessary to maintain continuity of supply whilst certain sections of the plant are out of service to permit the execution of the Works.

If it is necessary to reposition any of the existing substation plant in order to incorporate the specified works or to comply with specific requirements, all costs incurred in dismantling, removing, modifying, repositioning, existing and commissioning of such equipment shall be deemed to have been included in the Bid Price.

The repositioning of any plant is subject to the specific approval of the Employer. Existing plant rendered redundant by this Contract shall remain the property of the Employer and shall be returned to the Employer's store.

Permission for access to existing substations to execute the Works shall be obtained in writing from the Employer. The Bidder shall conform to the Employer's Safety Rules in all respects when working in or near existing plant.

Extensions at the existing substation shall be carried out maintaining the same busbar centres, heights etc., other essential dimensions and interlocking schemes.

Where stated in the Schedule of Requirements, equipment for existing substations shall be of the same type and manufacture as that already in service.

3.5 Appendix

APPENDIX A1-1

SCHEDULE OF TECHNICAL REQUIREMENTS OF
420kV, 245kV, 145kV and 33kV GAS INSULATED SWITCHGEAR (GIS)

Refer to schedule-E

APPENDIX A1-2

SCHEDULE OF TECHNICAL REQUIREMENTS OF
420kV, 245kV, 145kV and 33kV AIR INSULATED SWITCHGEAR (AIS)

Refer to schedule-E

PORTABLE EARTHING EQUIPMENT

1	Rated voltage	145kV	245kV	400kV
2	Material type for Hot Stick	Glass fibre, weather resistant Non-conductive,		
3	Material type for grounding lead	Heavy duty with wide range current capacity; Hi-copper conductor lead with Transparent insulated cover.		

4	Min. Short circuit current capacity	(40 kA for 1 sec),	(50 kA for 1 sec),	(63 kA for 1 sec),
5	No.s grounding lead,	3 Nos.(1 for each phase)		
6	length of Grounding lead	Finalized at execution		
7	Height of Hot stick			
8.	Country of origin	USA/UK/Japan/Europe		

SCHEDULE OF TECHNICAL REQUIREMENTS OF
GAS INSULATED LINE (GIL)

A1-2-3 GAS INSULATED LINE (GIL)

Sl No	ITEM	SPECIFICATION
1.	Enclosure Material	Corrosion-Resistant Aluminium Alloy
2	Inner Post Insulator	Cast-Resin
3	Installation Method	Above Ground
4.	Rated Voltage	400kV/230kV/132KV
5	Rated Current	5000/4000A
6	Rated Short Circuit Current	63/50kA 3sec
7	Insulating material for GIB	Composite/Silicon

SCHEDULE OF TECHNICAL REQUIREMENTS OF
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)	120	120	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 withstand 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)	10500	6125	3625

SECTION-4:

POWER TRANSFORMER

Index of Contents

SL No.	Name of Items	Page No.
4.1	Scope	3
4.2	References	3
4.3	Power Transformer	4
4.4	Magnetic Circuit and Windings	18
4.5	Tanks and Ancillary Equipment	23
4.6	Cooling Plant	31
4.7	Voltage Control	33
4.8	Supervisory Control	44
4.9	Terminal Bushing and Connection	44
4.10	Bushing Current Transformer	49
4.11	Auxiliary Power and Control Cables	51
4.12	Shipment & Drying Out	55
4.13	Explosion, Fire Protection/Prevention System	55
4.14	Oil for transformer and tap-changer	76
4.15	Auto-Transformer	80
4.16	Earthing & Auxiliary Transformer	81
4.17	Transformer Online Dissolved Gas Analizer	91
4.18	Inspection and Testing	92
4.19	Shipment , Receiving & Site Testing	100

4. Power Transformers

4.1 Scope

These clauses describe the general technical requirements for power 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 and Operating Conditions

General

The transformers shall be oil immersed and suitable for outdoor installation and shall comply with IEC 60076, Parts 1 to 8 & 10 inclusive.

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.

4.3.2 Drawings & Documentation

All drawings and nameplates shall include measurements in SI Units (millimetres/meters, kilogram, Litres, etc.), unless otherwise specified.

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:

- Customer's name
- Manufacturer's name with country of origin
- Name of substation
- 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:
    - AutoCAD drawings in dwg format
    - Word Documents in PDF format
    - Photographic files in JPEG format and of appropriate resolution to print an 8"x10"image at 300 dpi with no loss of detail.

- 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:

1. Rating of Transformer
2. The following weights:
    - Core and Coil assembly
    - Tank and Accessories
    - Total mass excluding oil
    - Oil mass in main tank
    - Oil mass in OLTC
    - Oil mass in radiator
    - Oil mass in main conservator
    - Oil mass in OLTC conservator
    - Fully assembled transformer including oil (Total)
    - Shipping (W/O oil)
3. Overall size & dimensions, shipping dimensions, space requirements (including that for dismantling and maintenance) and the interrelationship of the various components.
4. Component list with OEM part numbers, voltage ratings and current ratings.
5. The sizes of tubing, cables, and bus bars shall be indicated on this drawing.
6. Location of the impact recorder, pressure-vacuum relief/gauge.
7. Location of items to be removed for shipment.
8. The location of series autotransformers, preventive autotransformers, regulating transformers and core grounds.
9. 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.
10. The number of radiators, and fans utilized on the transformer.
11. The outline drawing(s) shall include plan view as well as elevation views of all four sides.
12. 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.
13. Where applicable, details of field erection indicating all field welds, sequence of welding, length of weld, etc. shall have to be provided.
14. Torque specification table for all components requiring field assembly.
15. 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) Certified seismic outline drawings – shall include the following information:

1. All dimensions of each component, break down weights, the center of gravity of the transformer, loads and accelerations used in the design.
2. 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.
3. Controlling reactions at the base of the equipment for seismic, wind, and normal operating loads.
4. Controlling forces used for designing anchors.

E) Schematic Diagrams – shall include the following information:

1. A list of devices with manufacturer and OEM model number shall be included
2. 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.
3. Terminal points shall be identified on the schematics.
4. A typical paralleling diagram shall be provided.
5. The alarm schematic drawing shall show the annunciator with all alarm inputs and associated field contacts on one sheet.
6. Set-points shall be identified for devices performing alarm or control functions.
7. Total kVA demand shall be shown for all auxiliary equipment.
8. 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.
9. Wiring Diagrams for all components shall be provided, including internal wiring of the LTC.
10. Accessory drawings and documentation:
    - Outline drawings and details of bushings, showing stud size, connections, and dimensions.
    - Bushing stud connector cut sheets shall be provided and shall include ampacity of connectors.
    - A drawing showing dimensions and quantities of all gaskets.
    - Outline drawings of arresters, showing connections, height, and mounting details.
    - saturation curves and ratio correction factor curves.

F) Drawings Sizes. Drawings shall conform to standard drawings sizes. (Plus or minus two mm in either dimension)

• 594 x 841mm(A1 Size)

• 420 x 594mm(A2 Size)

- 297 x 420mm(A3 Size)
- 210 x 297mm(A4 Size)

G) 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.

4.3.3 Design review

The Employer shall have the option of conducting a review of the transformer.

The Customer's Engineers and the Manufacturer's Engineers shall meet for a design review at such time after the design has been completed but before any materials that cannot be used by the Manufacturer on other orders have been procured. The Customer 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. 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.

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 Final Documentation

Final documentation shall be provided within 2 weeks of shipment, and shall include the following:

- One (1) CD with AutoCAD drawings, test reports, SFRA data files, and photographs.

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” color 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

4.3.5 Short-Circuit Design

The entire transformer shall be capable of withstanding without injury the mechanical and thermal stresses caused by short circuits (single phase, phase-to-phase, or 3-phase) on the external terminals of any winding

or windings with rated voltage maintained across the o the run-faulted windings all in accordance with IEC Standard 60076-5. In addition, the transformer shall be designed to withstand short circuit stresses for at least the time period durations indicated in the above-mentioned IEC Standard.
For this purpose, the design short circuit level for each system voltage shall be as per follows or as stated in the Schedule of Requirements.

kV level	System Short Circuit MVA (3-p) symmetrical	Remarks
400kV	45775	63kA SCC
230kV	21192	50kA SCC
132kV	10034	40kA SCC
33kV	1961	31.5kA SCC

- System fault capability shall be assumed to be infinite (zero impedance).
- The pre-fault voltage shall be assumed to be 1.10 per unit.
- For transformers with a delta tertiary, the tertiary shall be sized to provide sufficient mechanical strength for a short circuit involving ground at the terminals of the transformer. For the purposes of the mechanical and thermal attributes of the tertiary winding, an infinite source shall be assumed on the primary and the current for a fault on the secondary side shall be limited only by the impedance of the transformer.

Calculations and Tests:

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. *The test is applicable for a reference transformer and calculation is for the offered transformer.*

The Bidder shall provide with his bid a brief description of the transformers, or parts thereof, which have been subjected to short circuit test. 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. The offered transformer must be same or have comparable design to that of the reference transformer. 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. The contractor must redesign or modify his offered transformer design based on the observation of Employer. 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. 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)

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.

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.

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.

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.

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.

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)

4.3.6 Service conditions

Usual service conditions:

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

Loading other than rated conditions:

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.

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.

Unusual service conditions:

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.

4.3.7 Rating

4.3.7.1 Cooling class

Transformers shall be filled with a dielectric fluid as identified in the specific transformer Technical Data Sheets.

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.

Where a combination of two methods of cooling is applied to one transformer, as for ONAN/ONAF units, the transformer shall be capable of operating under the ONAN condition up to 70 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 ONAF unit.

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.

Failure of one fan in each group of blowers shall not reduce the continuous maximum rating of the transformer. Design shall confirm this requirement.

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.

4.3.7.2 Frequency

All transformers shall be designed for operation at 50 Hertz.

4.3.7.3 Phases

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.

4.3.7.4 Rated MVA

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.
Specific MVA rating requirements are provided in the specific transformer Data Sheets.
All 3-winding transformers shall be designed for simultaneous loading unless otherwise specified. Design shall be such that, when three windings are loaded simultaneously for the rating specified in the datasheet, the transformer is not de-rated; 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.

4.3.7.5 Voltage ratings and taps

Voltage ratings for all windings shall be as specified in the specific transformer Data Sheets. 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. A On Load Tap Changer shall be provided in accordance with clause 4.7.2 of this specification, and with tap voltages as identified in the specific transformer Data Sheets.

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.

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 Winding terminal markings and connections

It shall be in accordance with IEC standard 60076, unless specified otherwise in the specific transformer Data Sheets.

4.3.7.7 Winding configurations and phase relationship

It shall be as identified in the specific transformer Data Sheets.

4.3.7.8 Impedance

Positive and Zero Sequence Impedance shall be as specified in the Data Sheets.

For Wye-Wye Transformers 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.

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%).

4.3.7.8.1 Parallel Operation

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. 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.

4.3.7.9 Insulation Levels

Insulation levels for line and neutral terminals shall be provided as identified in the Specific Transformer Data Sheets. Refer also to Section 13 of this specification for specific dielectric test requirements. Specified insulation levels shall apply to all leads and ancillary equipment associated with each terminal.

BIL requirements shall be met without the use of internal arresters.

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".

4.3.7.10 Temperature rise and loading conditions:

Temperature rise to be as stated in the Data Sheets.

4.3.7.11 Power Factor

Permissible range for power factor shall be as per Table below, 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]

4.3.7.12 Internal clearance

4.3.7.12.1 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).

4.3.7.12.2 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 brought 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.

4.3.7.13 General Arrangement

Unless otherwise specified, the physical arrangement shall be such that:

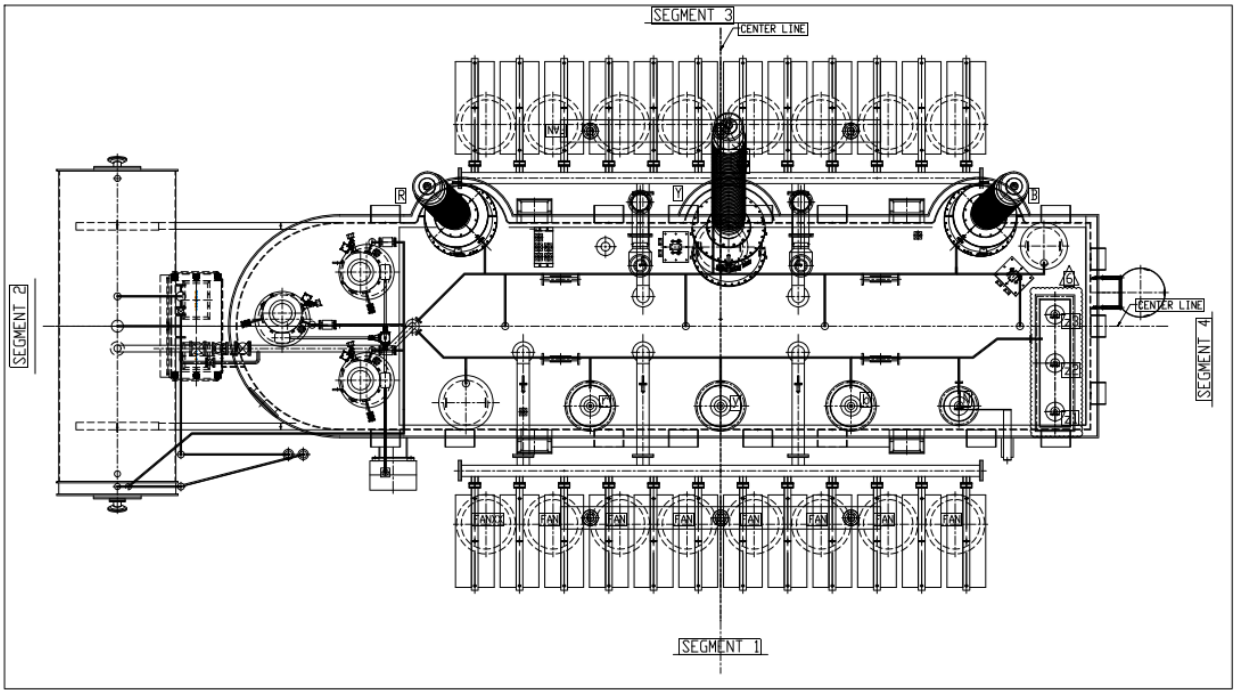


Figure 01: GA & Equipment Layout

Segment 01: LV bushing
Segment 02: OLTC/Conservator
Segment 03: HV bushing
Segment 04: TV bushings

4.3.7.14 Nameplate:

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, booster,…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:
    - Core and Coil assembly
    - Tank and Accessories
    - Total mass excluding oil
    - Oil mass in main tank
    - Oil mass in OLTC
    - Oil mass in radiator
    - Oil mass in main conservator
    - Oil mass in OLTC conservator
    - Fully assembled transformer including oil (Total)
    - 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 Continuous Maximum Rating

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. To allow for high atmospheric temperatures, the allowable temperature rises shall be reduced in accordance with IEC 60076-Part 2.

The overload capability shall be in accordance with IEC 60354.

4.3.9 Electrical Connections

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).

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.

4.3.10 Stabilizing Windings

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.
When required by the Schedule of Requirements, the stabilizing winding shall be capable of carrying continuously the load specified therein.
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

4.3.11 Losses and Evaluation of Losses

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.

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 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

The acceptance of transformers (after Factory Acceptance Test) yielding component losses higher than the guaranteed values shall be governed by either of the following:

(a) Component losses in excess of guaranteed values but within the tolerance permitted under IEC 60076 Part 1:
Transformers shall be acceptable subject to full compliance with all technical particulars, including temperature rises at CMR 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.

(b) Component losses in excess of guaranteed values and exceeding the tolerance permitted under IEC 60076 Part 1:

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.

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.

4.3.12 Impedance

The value of impedance measured on normal and extreme tapping shall be as stated in the Schedule and minimum and maximum values where stated in the Schedule of Requirements (Technical Data Sheets) shall not be subject to tolerance.

4.3.13 Noise

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).

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.

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.

The total unloaded depth of anti-vibration material (excluding load spreading plates) in the mountings shall not exceed 40mm.

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).

Representative samples of anti-vibration material for the mountings shall be subjected to sample tests.

4.3.14 Harmonic Suppression

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

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.

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.

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

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. 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

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

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.

At the maximum forced-cooled rating, the maximum flux density in magnetic shunts shall not exceed 1.2 Tesla.

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 positionin 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.

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.

The induction level shall be such that the ratio of induction current at 110% and 100%voltages shall not be >3.

4.4.2.4 Core design

The core shall be a three-legged core-form construction using mitered step lap design, unless otherwise specified in specific transformer Data Sheets in the Appendix. 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. 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. 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. 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. 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.

4.4.2.5 Core insulation

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. A minimum material thickness of 2 mm shall be provided.

4.4.2.6 Core Grounds

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. 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.

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. 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.

4.4.2.7 Frame Ground

A frame ground bushing shall be provided.

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. Frame ground bushings shall be separately grounded outside the main tank. Audible Sound Level:

The guaranteed sound level for operation at the rated voltage shall be described in the Specific Transformer Data Sheets.

4.4.3 Windings and internal leads

All conductors of transformer shall be copper unless otherwise specified in the Requirement .Transformer HV and MV 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.

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.

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.

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.

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.

4.4.3.1 Winding Design

Self-supporting coil design is encouraged, but windings must still be fully supported backto the core.Circular disc and/or helical type windings shall be provided for all windings, includingseries transformer if provided.Rectangular winding design will only be accepted for preventive autotransformers for areactance-type LTC.

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.

Spring or isostatic pressure (preferred) shall be applied during the winding sizing process.

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.

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.

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.

Where needed for pack-out, solid tapered insulating material shall be used in a disk orturn instead of duct-strip.

4.4.3.2 Winding and lead insulation

The winding insulation system shall be thermally upgraded to meet the operating conditions for 65°C rise.

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.

Excluding lead supports and clamping rings, all insulation material shall be thermally upgraded (suitable for continuous operation at 110°C).

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.

All lead support distances shall be less than 24 inches. 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.

Internal non-metallic support structures provided for support of leads and other internal devices shall be bolted together using nonmetallic 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.

4.4.3.3 Connections

Soldered connections shall not be used internal to the tank. Brazed connections are acceptable.

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.

4.4.4 Internal Earthing

General

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.

Earthing of Core Clamping Structure

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:

(a) by connection through vertical tie rods to the top structure;
(b) by direct metal-to-metal contact with the tank base maintained by the weight of the ore and windings;
(c) by connection to the top structure on the same side of the core as the main earth connection to the tank.

Earthing of Magnetic Circuits

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. 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.

All insulating barriers within magnetic circuits shall be bridged by means of aluminium or tinned copper strips, so inserted as to maintain electrical continuity.

Earthing of Coil Clamping Rings

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.

Size of Earthing Connections

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

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.
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

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.

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.

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.

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.

A leak test of the welded joints at the factory is required before the transformer is accepted for shipment.

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. 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.

The tank shall be provided with jacking lugs with stenciled 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.

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.

All joints, other than those that may have to be broken, shall be welded.

Where cooling tubes are used, each tube shall be of heavy gauge steel welded into the tank sides, top and bottom.

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 and shall be provided with suitable flanges having sufficient and properly spaced bolts. 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.

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.

Manholes:

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. 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.

Manhole locations shall permit the proper use of confined space retrieval equipment for personnel inside the tank.

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.

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.

The tank shall be mechanically strong and designed for both full vacuum filling and 10 psig (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.

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.

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.

Lifting, moving and jacking facilities shall be provided in accordance with IEC60076 and for any covers over 20 kg. Covers under 20 kg shall 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.

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.

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.

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.).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.

It must be possible to remove any bushing without removing the tank cover.

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.

Where called for in the Schedule of Requirements, accommodation shall be provided for outdoor weather proof neutral current transformers.

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.

4.5.3 Conservator Tanks, Breathers and Air Dryers

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.

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.

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.

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.

Appropriate membrane has to be provided inside the conservator for ‘’breathing’’ of the transformer.

Breather

Each conservator shall be fitted with an air cell that shall be connected to a silica gel regenerative dehydrating breather.

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.

Alpha-control: The maintenance-free breather shall be equipped with a state-dependent control of the heating process by monitoring the
humidity

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.

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.

All breathers shall be mounted at a height of approximately 1400 mm above ground level.

4.5.4 Valves

Each transformer shall be fitted with the following valves as a minimum requirement:

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.

Conservator

(E) 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.

(F) One drain valve for oil conservator tank so arranged that the tank can be completely drained of all oil.

Tap Changer

(G) 50mm filter and 50mm drain valve where selector switches are contained in a separate tank.

Diverter Switch

(H) One drain valve to be fitted to each tank.

Radiators and Cooler Banks

(I) Valves at each point of connection to the tank and in accordance with Clauses 4.6.2 and 4.6.3.

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.

Blank flanges, plates or captive screw caps shall be fitted to all valves and pipe ends not normally connected in service.

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.

4.5.5 Joints and Gaskets

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.

Gaskets shall be of nitrile rubber. Oil resisting synthetic rubber gaskets are not permissible.

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.

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.

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.

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.

Final drawings shall include a gasket dimension sheet which identifies quantities and dimensions of all gaskets associated with the tank pressure boundary.

One full set of gaskets shall be provided, along with drawings identifying all gasket dimensions and quantities.

4.5.6 Pressure Relief Device

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.

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.

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.

The contacts shall have the protection class IP65 according to IEC 60529 and must be directly activated by a self-locking pin.

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 l/sec or below and test report of each device shall be submitted.

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

4.5.7 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.

4.5.8 Rating, Diagram and Valve Plates

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.

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

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.

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

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.

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.

A valve shall be provided on the tank at each point of connection to the tank.

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.

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.

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.

Radiators shall be designed to permit removal and installation without additional special bracing.

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

Each cooler bank shall be provided with:

(A) A valve at each point of connection to the tank.
(B) A valve at each point of connection of radiators.
(C) Loose blanking plates for blanking off the main oil connections.
(D) A 50mm filter valve at the top of each cooler bank.
(E) A 50mm drain valve at the lowest point of each interconnecting oil pipe.
(F) A thermometer pocket, fitted with captive screw cap, in the inlet and in the outlet oil pipes.
(G) Air release and drain plugs on each radiator.

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 Forced Cooling

The type of forced cooling shall be as stated in the Schedule of Requirements.

Forced cooling equipment for transformers of similar rating and design shall be completely interchangeable, one with the other, without modification on site.

4.6.5 Oil Pipes and Flanges

All oil piping necessary for the connecting of each transformer to its conservator, cooler banks etc. shall be supplied and erected under this contract.

The oil piping shall be of approved material with machined flanged joints. Copper pipework is to comply with BS 61.

Dimensions of steel pipes shall be in accordance with BS 3600 and the drilling of all pipe flanges shall comply with BS EN 1092.

An approved expansion piece shall be provided in each oil pipe connection between the transformer and each oil cooler bank.

All necessary pipe supports, foundation bolts and other attachments are to be provided.

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.

4.6.6 Air Blowers

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.

To reduce noise to the practical minimum, motors shall be mounted independently from the coolers or, alternatively, an approved form of anti-vibration mounting shall be provided.

It shall be possible to remove the blower, complete with motor, without disturbing or dismantling the cooler structure framework.

Blades shall be of material subject to approval.

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.

Galvanised wire guards with mesh not exceeding 12.5mm shall be provided to prevent accidental contact with the blades. Guards shall also be provided over all moving parts. Guards shall be designed such that blades and other moving parts cannot be touched by test fingers to IEC 60529.

4.6.7 Cooler Control

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.

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.

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.

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.

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.

All contacts and other parts that may require periodic renewal, adjustment or inspection shall be readily accessible.
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.

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.

4.7 Voltage Control

4.7.1 General

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.

Winding taps as called for in the Schedule A of Requirements shall be provided on the high voltage winding.

All terminals shall be clearly and permanently marked with numbers corresponding to the cables connected thereto.

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

General

On-load tap changers shall be from **MR Germany** or **ABB Sweden** make, vacuum type, 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.

Only designs that have been type-tested in accordance with these standards will be accepted. Tap changers in auto-transformers shall be located 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.**

The OLTC shall be installed inside the main tank.

Current making and breaking 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 completely independent of that on the transformer itself. 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.

Capabilities and Ratings

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. All voltages listed on the nameplate shall reflect the actual design voltages, rounded to the nearest 10 volts.

All taps shall be full capacity taps.

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.

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.

LTC’s shall be capable of parallel operation with circulating currents not to exceed 20% of rated current.

All components of the transformer shall be capable of carrying maximum rated current at all tap positions.

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.

Tap changer operation mechanism

A mechanism for hand operation shall be provided. A permanently legible lubrication chart shall be provided and fitted inside the tap change mechanism chamber.

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.

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.

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).

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.

Tap changer controls

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

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.

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.

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.

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.

Suitable test terminals for measuring regulated voltage shall be provided.

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.

Three limit switches, SPDT suitable for 0.5A at 125VDC 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.

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.

Indications

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.

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.

OLTC alarms

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)

Provisions shall be made to block OLTC operation by a normally closed contact of the Employer's transformer lockout relay.

Paralleling facilities

Transformers supplied against each item shall be designed to operate satisfactorily, one with the other, when operating on the same tap position.

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.

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.

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.

A 52Y (Interposing relay) with (2 NO and 2NC) contacts shall be provided for use by the Customer in the paralleling scheme.

Provisions shall be made to permit either phase-to-neutral or phase-to-phase voltage input along with corresponding CT connections.

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.

OLTC Accessories:

Local Control Switch with pistol grip handle, spring return to OFF, for LTC controls. Switch shall be labeled Lower-OFF-Raise (Operable from ground with doors open).

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.

Pressure relief device, temperature indication equipment, and fault pressure relay as per relevant Section below:

- 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.

- The LTC pressure relief alarm will be connected to an LTC PRESSURE RELIEF alarm point on the local annunciator.

- Semaphore for LTC compartment shall be visible from the ground.

- Discharge of pressure relief device(s) shall be baffled to control direction and extent of spray and to facilitate clean-up.

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.

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.

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.

Space heater(s) with protective guard(s), located to prevent overheating wiring or equipment or accidental contact by personnel checking wiring.

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.

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.

Rated voltage of space heaters shall be at least 67% higher than the applied voltage.

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.

A Non-GGCI outlet (refer to section below for rating) to be provided.

LTC compartments shall meet the following requirements:

- 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.

- Tap changer shall be free-breathing with a suitable desiccant breather located approximately 5 feet from the transformer base for ease of replacement.

Each separate LTC oil-filled compartment shall have the following minimum accessories:

i. One -Upper vent connection with pipe cap.
ii. One -Lower fill and drain valve with pipe plug.
iii. Valve to have sampling valve located outside the disk of the main valve.
iv. The valve shall be on the bottom of the compartment.
v. One -Oil level indicator with high and low level alarm contacts.
vi. All LTC level alarms will be connected to a single LTC OIL LEVEL alarm point on the local annunciator.
vii. Indicators for all compartments shall be readily visible from a single location.
viii. 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.
ix. One -Pressure relief device shall be provided for the common LTC compartment, with alarm contacts and readily visible semaphore. And baffle and discharge pipe.

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.

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.

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.

Each LTC control cabinet shall be weather proof, with hinged access doors as follows:

i) Locking facilities, suitable for padlocks with shanks
ii) Doors shall have suitable gaskets completely around each opening and a weather shield on the top horizontal surface.
iii) Each door shall be equipped with a holding bar or other mechanism to securely hold the door open at least 110° from the cabinet against winds gusting to 40 kph.

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.

The following equipment shall be housed in all LTC control cabinets. No control or indicating devices shall be mounted on the outer cabinet doors.

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)

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

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.

All wiring associated with tripping, including lockout relays and initiating devices, shall be unfused.

All Manufacturer's LTC control wires shall be provided with indelible marker sleeves at each termination designating the location of the opposite end termination.

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.

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.

Line drop compensator, control relays, time delay relays and facilities for readily reversing polarity of reactance compensation. See Data Sheets for specific transformer.

High loads on the change-over selector, caused by large breaking currents and large recovery voltages, result in the formation of more gas. Use of proper measures is recommended when average gas volumes of 7 – 10 ml and more are being created per change-over selector connection. Mechanism shall be provided in Tap-changer compartment for reducing the amount of gas produced during a change-over selector connection (reducing gas to <0.5ml per change-over selector connection). Thereby the volume of gas to be reduced by around 80-90%.

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.

Oil Filter

Each 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

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.

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

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.

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.

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.

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

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 hanging cabinet 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 110° 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 bulbto be supplied.

One (1) 20 Amp, 230 VAC, single phase, wire grounded duplex convenience receptacle(GFI protected) shall be provided in the control cabinet.
Weather-shielded, screened breather holes shall be furnished at the top and bottom of the cabinet.

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 center line location of this plate shall be clearly shown on the outline drawing.

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:
  - 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

An externally operated DETC shall be provided for the high voltage winding taps.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.

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.

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.

4.8 Supervisory Control

Requirements

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.

The following supervisory facilities are required:

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.

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) Tap change control on Local/Supervisory.
v) Parallel/independent, master/follower.
vi) Tap change blocking on/off.
vii) Tap change control on automatic/manual.

All contacts for supervisory alarms and indications shall be potential free.

4.9 Terminal Bushings and Connections

4.9.1 General

Where stated in the Schedule of Requirements, transformers are to be provided with outdoor type bushing insulators.

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.

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.

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.

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.

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.

On all bushings a tapping shall be brought out to a separate terminal for testing purposes on site.

Special precautions shall be taken to exclude moisture from paper insulation during manufacture, assembly, transport and erection.

4.9.2 Type, rating & Construction of Bushings

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.

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.

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.

Approved suppliers of bushings are: *ABB (Sweden)*, *Trench (France/USA), HSP (Germany), (and as specified in Technical data sheets).*

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.

Bushings for Buried Z-Terminals

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 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.

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.

4.9.3 Porcelain (Not used)

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.

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.

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.

All porcelain insulators shall be designed to facilitate cleaning.

4.9.3A Silicone Rubber

Resin Impregnated Paper (RIP) Condenser Bushing shall use Silicone Rubber composite insulator as housing of the bushing.

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.

The electrical and mechanical characteristics of bushings shall be in accordance with IEC: 60137/DIN 42530. All details of the bushing shall be submitted for approval and design review during contract stage.

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.

Where current transformers are provided, the bushings shall be removable without disturbing the current transformers.
Bushings of identical rating shall be interchangeable to optimise the requirement of spares.

Polymer / Composite Insulator
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.

The hollow silicone composite insulators shall comply with the requirements of the IEC publications IEC 61462 and the relevant parts of IEC 62217.

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.

The SiR generally have the following component –
• Basic polymer
• Filler, normally AluminiumTriHydrate, ATH
• Catalyst
• Other additives, for instance mould release agent

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.

The design of the composite insulators shall be tested and verified according to IEC 61462 (Type & Routine test).

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.

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.

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.

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.

Different formulations of silicone rubber require different processing when producing high voltage insulators. For example –

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.

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.

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.

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.

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.

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.

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.

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.

Lifetime
The bushings shall be designed to withstand service for the life of the equipment it serves, normally at least 30 years.

Plug-In Type Bushing
Where possible, Tertiary Bushing shall be Plug-In type.

4.9.4 Marking

Each porcelain 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.

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.

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 60137:1973.

4.9.5 Mounting of Bushings

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.

The clearances from phase to earth must not be less than those stated in the Schedule of Requirements.

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.
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.

The bushing flanges must not be of re-entrant shape that may trap air.

Clamps and fittings made of steel or malleable iron shall be galvanised and all bolt threads are to be greased before erection.

4.10 Bushing Current Transformer

Except where otherwise specified, each terminal bushing, including neutral, shall be equipped with bushing-type current transformers that meeting the following requirements:

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.

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.

CT wiring

All secondary wiring for CTs shall be at least 2.5 mm^2 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.

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.

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.

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.

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:

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 2.5mm^2 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 centerline location of this cabinet shall be clearly shown on the outline drawing. Wire-ways shall be provided for customer wiring.

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).

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 Scope of Supply

This Contract includes the supply, installation and termination of the necessary auxiliary power and control cables within items of plant supplied under the contract.

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.

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.

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.

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.

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.

Intermediate terminal blocks between external devices and the control cabinets shall be barrier type. No splices shall be used.

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.

All wiring inside control cabinet shall be run in wire duct with snap on covers topermit easy tracing of circuits.

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.

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.

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.

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.

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.

All relay and control devices shall be identified by engraved nameplates.

4.11.2 General

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.

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.

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.

4.11.3 Temperature-Indicating Devices and Alarms

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.

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.

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.

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.

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.

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.

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.

Connections shall be brought from the device to terminal boards placed inside the marshalling cubicle.

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.

4.11.4 Fiber Optic Based Temperature Sensing System

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 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

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.
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.

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.

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.

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

4.11.5 Gas and Oil-Actuated Relays

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.

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.

Each relay shall be fitted with a calibrated glass window for indication of gas volume.

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.

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.

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.

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.

The clearance between oil pipework and live metal shall be not less than the minimum clearances stated in the Project Requirements of Section 1.

4.12 Shipment & Drying Out

4.12.1 Shipment

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.

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.

All earthing transformers shall be shipped full of oil.

4.12.2 Drying Out

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.

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

4.13 Explosion, Fire Protection/Prevention System

4.13.1 Fire Protection/Prevention System

General

The new power (auto) transformers shall be provided with Fast Depressurization System (FDS). General description, design and performance requirements of the FDS is 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.

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:

BS Standards

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

The fire prevention & protection system shall have been in successful operation in for at least last three years for protection of transformers of 400/230kV and higher voltage class. The reference list along with performance certificate from end users of the system shall be submitted with the bid.

The system shall be reliable without making any mal operation.

In case of an event of the control power failure, the system shall be able to be operated manually. Various equipment to perform the required fire prevention & protection shall be provided under this contract.

4.13.2 Transformer Explosion and Fire Prevention system

When required by schedule of requirement, the Contractor shall provide the transformer explosion and fire prevention system as specified below for each of the transformer:

Transformer or reactor explosion and fire generally result from a fault inside the tank. This may be caused by overloads, short-circuits, or failure of the associated equipment such as On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT).

For an electrical arc, a huge volume of explosive gas is created during the first millisecond for the first mega joule. This gas generation creates one dynamic pressure peak and the transformer or reactor tank is violently shaken by accelerations. This shockwave is travelling in the tank at a speed of the sound inside oil. The first pressure peak of the resulting shockwave, initial amplitude greater than 10 bars. The transformer needs to be prevented from fire and the tank from permanent deformation. The proposed Transformer Explosion and Fire Prevention system shall be capable of doing the same.
The Contractor has to make necessary provisions for the satisfactory operation of the nitrogen fire-prevention system without affecting the overall performance of the transformer.

Operating Principle

The Fast Depressurization System shall allow the depressurization of the transformer or reactor after a few milliseconds from the time the electric fault has occurred. The Depressurization process shall include taking transformer oil out of transformer tank, take out the dynamic pressure out of tank. In order to avoid delays that will caused a transformer or reactor explosion, the Fast Depressurization System (FDS) shall not depend on any sensor or electrical actuators coming from other protection. During, the depressurization the system shall inject inert gas, like nitrogen, to avoid fire and to ensure personnel and equipment safety.

Equipment Description

The Fast Depressurization System shall be made of several sets, each playing a different role:

- The Depressurization Set (DS) with Rupture Disk (RD) shall prevent a Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) explosion following a short circuit. Each Depressurization Set (DS) shall relieve the dynamic pressure within milliseconds and a Decompression Chamber (DC) favors high-speed depressurization.

- The Inert Gas Injection Set (IGIS) is required for personal safety to avoid the bazooka effect caused by the explosive gas in contact with air (oxygen) when the tank is opened after the incident. The

IGIS creates a safe environment in the Transformer or Reactor and the On Load Tap Changer (OLTC) after the depressurization process by injecting an inert gas flow, which also cools the tank.

- An Oil-Gas Separation Tank (OGST) shall collect the depressurized oil and explosive flammable gas to dissociate oil from gases. It is recommended to locate the OGST in the transformer or reactor conservator where a slice shall then be devoted for the OGST as often done for the On Load Tap Changer (OLTC) oil conservator.This transformer conservator slice shall have a volume of 0.5 m^3 - 17.6 ft3.

- The Explosive Gas Evacuation Pipe (EGEP) shall then channel the gas to a safe and remote area.It is possible to separate the OGST from the transformer. In this case, the top of the OGST must always be located 10 cm - 4 inches above the top of the conservator.

- The Inert Gas Injection shall have both automatic & manual, and including as an option the Inert Gas Injection Quick Connector.

For the vendors with customized solution, the equipment component requirement may be relaxed provided they must serve the same function of prevention of Explosion & Fire.

Requirement

To avoid Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) explosion and fire, the supplier shall have specified likely locations of dielectric failure and subsequent arcing events inside the oil-filled tank. Using a physical model capable of describing a multi-phase compressible fluid, quantitative predictions should be made for the gas volume generation as a function of arc energy, the resultant pressure waves' speed and amplitude, and the subsequent increase in static, or average, pressure throughout the tank prior to the activation of the Fast Depressurization System.

The physical model should accurately model the opening of the Rupture Disks (RD), the oil-gas mixture outflow, the time-dependent transformer tank pressure drop, and the resultant stresses and deformations on the transformer tank.

The Fast Depressurization System supplier shall provide Computerized Fluid Dynamic (CFD) and Fluid Structure Interactions (FSI) simulations for the transformer most probable low impedance energy fault (Mega Joule).

The Fast Depressurization System must comply with the description for all Power Plants and Substations of the National Fire Protection Association, Code NFPA 850, 2015 edition. Therefore, the Fast Depressurization System must be "passive – mechanical" and activated without sensors or electrical actuator.

Experience and Tests

The supplier shall prove that the Fast Depressurization System:

- 10 years of experience with increased sales to 1,000 units.

- A Test Certificate showing a campaign of at least 20 successful live tests of electric arcs events inside the transformer or reactor tank closed and full with oil, from which at least 5 have been done with arcs of more than 1 Mega Joule.

  This Test Certificate must be granted by a recognized and independent high voltage laboratory from a country different than the country of manufacture of the explosion and fire prevention system.

- Evidence that the explosion and fire prevention system has prevented the explosion of at least 2 transformers or reactors over 50MVA in 2 different countries with 2 Certificates of Successful Activation signed by the transformer or reactor owner.

- Insurance Policy over USD 10 million dollars to cover damages in case of transformer or reactor Explosion/Fire with the Fast Depressurization System installed.

Automation Requirement

The FDS 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.

Site Tests

Commissioning of the system shall be performed in supervision of OEM of the transformer Protector system. Detailed layout drawings, equipment drawing along with 4 sets of the operation and maintenance manual along with soft copies (on CDs) shall be submitted by the Contractor.

4.13.3 Water Spray System (WSS)

When required by schedule of requirement, the Contractor shall provide the water spray system arrangements specified below for each of the transformer:

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.

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

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.

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.

The pressurizing air vessel is to be installed above ground.

Two air pressure units, rated pressure 10 bar, each provided with the following main equipment:

- 1 air compressor
- 1 415/240V three-phase motor
- 1 flexible coupling
- 1 oil and water separator
- 1 non-return valve
- 1 vent and drain valve
- 1 pressure gauge

Installed completely on a sturdy base frame with all necessary anti-vibration mounts and fixing material.
One compressed air container, vertical type, welded with manhole, rated pressure matched to the water spray system, including the following main fittings:

- 1 contact type pressure gauge
- 1 relief valve
- 1 pressure switch
- 1 drain valve

Assembled completely and ready for operation, the volume of air being matched to the time sequence of the transformer extinguishing operation.

The necessary control cabinet, enclosure type IP55, completely equipped with the following main items:

- 2 motor 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

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.

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.

For, quality and maintenance requirement, the Watery Spray System (WSS) shall be from Europe/USA/Canada/Japan origin.

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.

4.13.4 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 origin.

General

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

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.

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

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

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.

Note that, the fine (that is smaller than 400 microns) droplets are essential for extinguishment of Class B (flammable liquid) fires.

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.

System Operation

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).

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.

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.

PRINCIPLE OF EXTINGUISHMENT

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.

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.

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.

Water mist shall be sprayed at high pressure (500-4000 psi) & water mist (droplet size 10-100μm) shall be created before spraying.

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.

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.

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).

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.

System design

1) Fire detection system

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.

a) 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.

b) 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.

c) Linear Heat Detector

A line-type form of fixed temperature heat detection. Fiber optic type heat detector shall be used for effective heat detection.

d) 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.

2) 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

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.

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.

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.

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.

STRAINERS AND FILTERS

Comply with the requirements in NFPA 750 for filters and strainers on the water supply connection.

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.

3) 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.

4) 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.

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.

Drawings 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.

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.

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.

Automation

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.

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.

Tubing and Supports

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.

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.

System 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.

4.13.5 Nitrogen Fire Protection System (NIFPS)

When required by schedule of requirement, the Contractor shall provide the transformer Nitrogen Fire Protection System (NIFPS) as specified below for each of the transformer:

4.13.5.1 General

The new auto transformers and power transformers shall be provided with Nitrogen Injection Fire Protection System (NIFPS). General description, design and performance requirements of the NIFPS is 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.

The system design shall also conform to TAC / NFPA norms. 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:

4.13.5.2 BS Standards

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

The fire protection system shall have been in successful operation in for at least last three years for protection of transformers of 400/230/33 kV and higher voltage class. The reference list along with performance certificate from end users of the system shall be submitted with the bid.

The system shall be reliable without making any mal operation. Even if undesirable nitrogen gas injection is made into the transformer tank under normal transformer condition without the internal faults, restoration of transformer by vacuum oil purification up to re-energizing shall complete as soon as possible after the undesired gas injection.

In case of an event of the control power failure, the system shall be able to be operated manually. Various equipment to perform the required fire protection shall be provided under this contract.

4.13.5.3 Nitrogen Fire Fighting System

The Contractor has to make necessary provisions (in consultation with the Supplier of the NIFPS) for the satisfactory operation of the nitrogen fire-fighting system without affecting the overall performance of the transformer. Oil filled autotransformers shall be provided with an appropriate NIFPS for the required specific ratings.

The fire protective system shall prevent the explosion of the transformer oil tank and a possible fire in case of internal faults. In the event of fire by external causes such as bushing fire, OLTC fires, fire from surrounding equipment etc., it shall act as a fast and effective fire fighter. It shall accomplish its role as fire preventer and extinguisher without employing water and/or carbon dioxide.

Fire shall be extinguished within 3 minutes (maximum) of system activation and within 30 seconds (maximum) of commencement of nitrogen injection.

4.13.5.4 Activation of the Fire Protective System

Mal-functioning of fire prevention/ extinguishing system could lead to an interruption in power supply. The Bidder shall ensure that the probability of malfunctioning of the fire protective system is practically zero. To achieve this objective, the Bidder shall plan out his scheme of activating signals which should not be too complicated to make the fire protective system inoperative in case of actual need. The system shall be provided with automatic control for fire prevention and fire extinction. Besides automatic control, remote electrical push button control at the control box and local manual control in the fire extinguishing cubicle shall also be provided. The following electrical signals are required for activating the fire protective system under prevention mode / fire extinguishing mode:

Auto Mode

- For prevention of fire:
  - differential relay operation
  - Buchholz relay paralleled with pressure relief valve or RPRR (rapid pressure rise relay)
  - tripping of all circuit breakers (on HV &LV/IV side) associated with transformer is the pre-requisite for activation of system

- For extinguishing fire
  - fire detector
  - Buchholz relay paralleled with pressure relief valve or RPRR (rapid pressure rise relay)
  - tripping of all circuit breakers (on HV &LV/IV side) associated with transformer is the pre-requisite for activation of system.

Manual Mode (Local / Remote)
- Tripping of all circuit breakers (on HV &LV/IV side) associated with transformer is the pre-requisite for activation of system

Manual Mode (Mechanical)
- The system shall be designed to be operated manually in case of failure of the power supply to the fire protection system

4.13.5.5 Description

The nitrogen injection fire protection system should be a dedicated system for each oil-immersed transformer. It should have a fire extinguishing cubicle (FEC) placed on a plinth at a distance of 5-10 m from transformer / reactor or placed next to the fire wall (if a fire-fighting wall exists).

The FEC shall be connected to the top of the transformer/reactor oil tank for depressurization of the tank and to the oil pit (capacity is approximately equal to 10% of the total volume of the oil in the transformer /reactor tank) from its bottom through oil pipes.

The fire extinguishing cubicle should house a pressurized nitrogen cylinder(s) which is connected at to the bottom of the transformer oil tank. The transformer conservator isolation valve (TCIV) is fitted between the conservator tank and the Buchholz relay. Cable connections are to be provided from the signal box to the control box in the control room, from the control box to the fire extinguishing cubicle and from the TCIV to the signal box. Fire detectors placed on the top of the transformer/reactor tank are to be connected in parallel to the signal box by fire-survival cables. The control box is also to be connected to the relay panel in the control room for receiving system activation signals.

4.13.5.6 Operation

On receipt of all activating signals, the system shall drain a pre-determined volume of hot oil from the top of the tank (i.e. top oil layer) through an outlet valve to reduce the tank's pressure by removing top oil and should simultaneously inject nitrogen gas at high pressure for stirring the oil at a pre-set rate, thus bringing down the temperature of the top oil layer.

The transformer conservator isolation valve blocks the flow of oil from the conservator tank in case of tank rupture / explosion or bushing bursting. Nitrogen occupies the space created by the drained out oil and acts as an insulating layer over the oil in the tank, thus preventing an aggravation of the fire.

4.13.5.7 System Components

The nitrogen injection fire protection system shall broadly consist of the components mentioned below. However, all other components which are necessary for fast, reliableand effective operation of the fire protection system are deemed to be included in the scope of supply.

- Fire Extinguishing Cubicle (FEC)
  The FEC shall be made of CRCA sheets of a minimum thickness of 3 mm, complete with the base frame, painted inside and outside with post office red colour (shade to be in line with BS: 381 C: 1988 - Colours for Identification, Coding and Special Purposes). It shall have hugged split doors fitted with high-quality tamper proof lock. The degree of protection shall be IP55. The following items shall be provided in the FEC.
  - a nitrogen gas cylinder with regulator and falling pressure electrical contact manometer
  - oil drain pipe with mechanical quick drain valve
  - electro-mechanical control equipment for draining of a pre-set volume of oil and for injecting a regulated volume of nitrogen gas
  - a pressure monitoring switch for back-up protection for nitrogen release
  - limit switches for monitoring of the system
  - a butterfly valve with flanges on the top of the panel for connecting the oil drain pipe and the nitrogen injection pipes for transformers
  - panel lighting (CFL type)
  - oil drain pipe extensions of suitable sizes for connecting the pipes to the oil pit
  - space heater
  - other items, if necessary

- Control box
  The control box shall be placed in the control room for monitoring system operation, automatic control and remote operation. The following alarms, indications, switches, push buttons, audio signal etc. shall be provided.
  - system on
  - TCIV open
  - oil drain valve closed
  - gas inlet valve closed
  - TCIV closed*
  - fire detector trip *
  - Buchholz relay trip
  - oil drain valve open*
  - extinction in progress *
  - cylinder pressure low *
  - differential relay trip
  - PRV / RPRR trip
  - transformer/reactor trip
  - system out of service *
  - fault in cable connecting fault fire detector
  - fault in cable connecting differential relay
  - fault in cable connecting Buchholz relay
  - fault in cable connecting PRV / RPRR
  - fault in cable connecting transformer /reactor trip
  - fault in cable connecting TCIV

- auto/ manual / off
- extinction release on / off
- lamp test
- visual/ audio alarm*
- visual/ audio alarm for DC supply fail *
- space heater
- others, if necessary

Suitable provisions shall be made in the control box for monitoring of the system from a remote substation using the substation automation system.

- Transformer Conservator Isolation Valve
  A transformer conservator isolation valve (TCIV) shall be fitted in the conservator pipeline, between the conservator and the Buchholz relay.It shall isolate the conservator during abnormal flow of oil due to rupture / explosion of tank or bursting of bushing. The valve shall not isolate the conservator during normal flow of oil during filtration or filling or refilling. Locking plates shall be provided with handle for pad locking. It shall have a proximity switch for remote alarm; indication shall be with visual position indicator.

- Fire Detectors
  The system shall be complete with an adequate number of fire detectors (quartz bulb) fitted on the top cover of the transformer / reactor oil tank.

- Signal Box
  The signal box shall be mounted away from the transformer's main tank, preferably near the transformer marshalling box, for terminating cable connections from TCIV & fire detectors and for further connecting them to the control box. The degree of protection shall be IP55.

- Cables
  Fire-survival cables (capable to withstand 750°C) of 4 core x 1.5 mm² size for parallel connection of the fire detectors shall be used. They shall conform to BS 7629-1, BS 8434-1 and BS 5839-1, BS EN 50267-2-1 or relevant International standards.
  Fire-retardant low smoke (FRLS) cables of 12 core x 1.5 mm² size shall be used for connection of the signal box / marshalling box near the transformer and the FEC mounted near the transformer with the control box mounted in the control room. Such cables shall also be used for the connection between the control box and the DC and AC supply source, the fire extinguishing cubicle and the AC supply source, the signal box/ marshalling box and the transformer conservator isolation valve connection on the transformer.

- Pipes
  Pipes complete with connections, flanges, bends and tees etc. shall be supplied alongwith the system.

- Other items
  - Oil drain and nitrogen injection openings with gate valves on transformer tank at suitable locations.
  - Flanges with dummy piece in conservator pipe between Buchholz relay and conservator tank for fixing TCIV.
  - Fire detector brackets on transformer / reactor tank top cover.
  - Spare potential free contacts for activating the system i.e. in differential relay, Buchholz relay, Pressure Relief Device / RPRR, Circuit Breaker of transformer/reactor

- Pipe connections between transformer / reactor and FEC and between FEC and oil pit required for collecting top oil.
- Cabling for fire detectors mounted on transformer /reactor top cover
- Inter cabling between signal box, control box and Fire Extinguishing Cubicle (FEC).
- Butterfly valves /Gate valves on oil drain pipe and nitrogen injection pipe which should be able to withstand full vacuum.
- Supports, signal box etc. which are to be painted with enamelled paint.

4.13.5.8 Technical Particulars

- Fire extinction period from commencement of nitrogen injection: 30 s. (max.)
- Total duration from activation of fire protection system to complete cooling: 30 minutes (max.)
- Fire detectors' heat sensing temperature: 141 °C
- Heat sensing area per detector: Up to R = 800 mm
- Transformer Conservator Isolation valve setting (minimum): 60 litre / min
- Capacity of nitrogen cylinder (minimum water capacity): 68 litre
- Capacity of nitrogen cylinder (minimum gas capacity, at 150 kg/cm^2 pressure: 10 m^3
- Power supply, for control box and for fire extinguishing cubicle for lighting: 110 V DC / 240 V AC

4.13.5.9 Mandatory Spare Parts per Substation

- Cylinder filled with nitrogen of required capacity per substation: 1 piece
- Fire detectors: 3 pieces
- Regulator assembly: 1 piece

4.13.5.10 Tests

Reports of all type tests conducted as per relevant IEC standards including test reports for the degree of protection for FEC / control box / signal box shall be submitted with the bid.

The performance test of the complete system shall be carried out after installation of the system on site. Detailed layout drawings, equipment drawing along with 4 sets of the operation and maintenance manual along with soft copies (on CDs) shall be submitted by the Contractor.

4.13.6 Compressed 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.

4.13.6.1 CAFS Package includes:

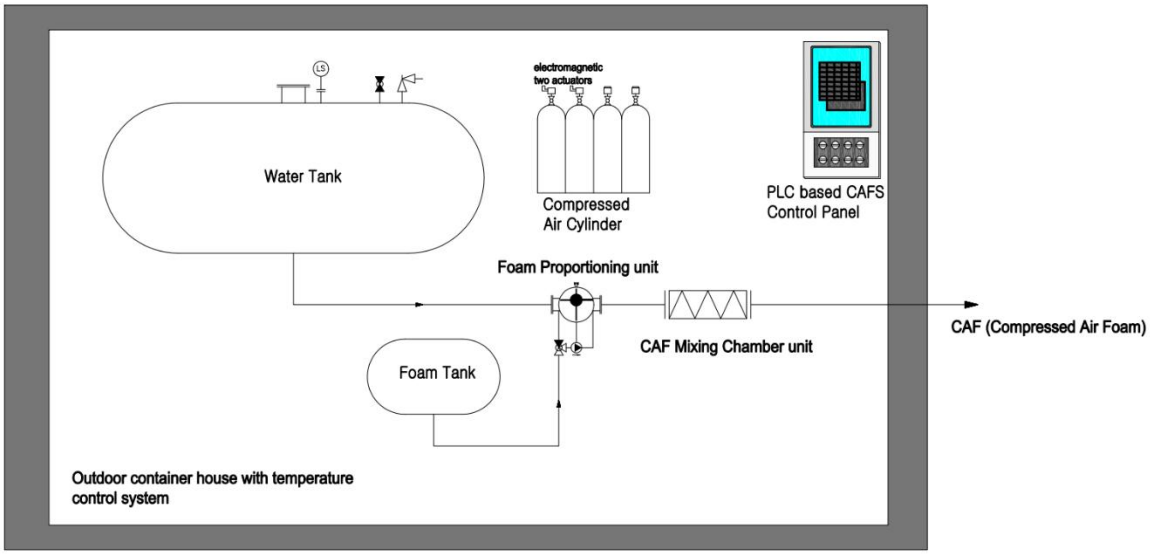
- PLC based CAFS Control Panel
- Foam Proportioning unit : water turbine drives a positive displacement foam concentrate pump. Ratio 3%
- CAF Mixing Chamber Unit : Foam Solution to Air Ratio = 1:7
- Compressed Air Cylinder Unit : Compressed air cylinders pressurized to 200 bar. Each cylinder is supplied 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.

4.13.6.2 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>



4.13.7 Fire Wall

A fire wall of suitable height shall be installed on both sides the transformers to prevent transformers from the spread fire. The wall shall be made of reinforced concrete.

4.14 Oil for transformer and tap-changer

The transformer oil shall be new, inhibited, naphthenic based mineral oil, free from additives. It shall be acid-refined and pre-treated and shall have properties complying with IEC 60296-class II. The Contractor shall supply the first filling of all insulating oil required for the operation of the Plant and, after treatment, a test shall be made in the Engineer's presence to prove that the breakdown voltage is at least 50kV at 2.5mm electrode gap. For further detail, please refer schedule of requirement.

Transformer Oil Specification & Scope:

This Specification covers electrical insulating oil for substation and transmission class equipment.

4.14.1 Type and quality

4.14.1.1 Only new naphthenic-based mineral oils, which must be certified as such prior to filling, shall be used.

4.14.1.2 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.

4.14.1.3 Under no circumstances shall poor quality oil be filled into the transformer and subsequently bringing up to specification by circulation within the transformer.

4.14.1.4 The transformer oil shall be power grade and shall be from approved manufacturer. Acceptable manufacturer are Nynas AB, Midel, Cargil, Eargon Inc. or equivalent.

4.14.2 Dielectric strength

4.14.2.1 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 60kV / 2.5 mm for virgin oil prior to filling, and not be less than 50kV/2.5 mm at time of take over.

4.14.2.2 Dielectric strength shall be determined in accordance with the method prescribed in IEC 60156.

4.14.3 Moisture content

4.14.3.1 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.

4.14.3.2 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.

4.14.4 Degree of polymerisation

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.

4.14.5 Oil sampling and testing

4.14.5.1 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).

4.14.5.2 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.

4.14.6 Oil-filling/impregnation under vacuum

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.

All transformers installed in vacuum-proof tanks shall be oil impregnated and filled under vacuum.

Oil impregnation or drying under vacuum shall be done with the transformer and oil at a temperature of at least 60°C.

The duration of the treatment shall be such that is results of the in moisture content is as specified in clause of Moisture content.

Procedures shall be submitted for approval and full instructions shall be included in the transformer manual.

4.14.7 Preservation system

See clause for the detail requirements of the conservator systems.

4.14.8 Poly Chloride Biphenyls (PCB) content

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.

4.14.9 Contact with bare copper

Bare copper in contact with transformer oil shall be minimised by using appropriate paper covering or painting.

4.14.10 Oil Treatment 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.

4.14.11 Oil Storage (Tanks and Bags)

As required by Clause 4.14.1, 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, 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 fabrics, 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.

4.14.12 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)

4.14.13 Test Requirements

a) A certified test report identifying the name brand, type of oil, and conformance with tests identified in the attached table is to be forwarded by the supplier prior to shipping of oil.

b) A test report certifying conformance with the tests identified by an asterisk (*) on the attached table shall accompany each shipment.

c) Any or all of the tests identified in item 2 may be performed as acceptance tests by The Power Grid Company of Bangladesh personnel upon receipt of the shipment.

Failure to comply with any of the above requirements, or failure of any acceptance test, will result in rejection of the shipment at the supplier's cost.

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	60 kV Minimum
Or			
Dielectric Strength		D1816 (0.04'' Gap)	50 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		D2112	220 Minutes Minimum
Or			
Oxidation Stability		D2440	
72 Hrs:	Percent Sludge by Mass		0.1 Percent Maximum
	Total Acid No.		0.3 mg KOH/g Maximum

Type of Test		**ASTM Designation**	**Test Limits**
164 Hrs:	Percent Sludge by Mass		0.2 Percent Maximum
	Total Acid No.		0.4 mg KOH/g Maximum
. PCB Content *		D4059	Non–Detectable (Less than 2 ppm PCB)
Pour Point		D97	–40 °C Maximum
Power Factor	100°C	D924	0.30 Percent Maximum
	25°C		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.

4.15 Auto-Transformers

4.15.1 General

Auto-transformers for interconnection between the 400kV & 230kV and 230kV and 132kV system shall comply with the general requirements of the Specification and the particular requirements of this Section.

The auto-transformers will be star connected and the system will be solidly earthed at each auto transformer neutral.

A delta connected stabilising winding shall be provided.

4.15.2 Continuous Maximum Rating

The auto-transformers shall have the continuous maximum rating stated in the Schedule of Requirements (Technical data schedule) and be provided with a delta connected tertiary winding capable of supplying the load stated in the Schedule of Requirements. No compensation shall be made to the rating of the series or common windings of the auto-transformer for any limitation in output consequent on the tertiary load but Schedule E shall be completed showing any restriction in 132 kV output, for conditions of input from the 230 kV system, with the tertiary power factors of their respective loads down to 0.8 lagging.

4.15.3 Impedance

Auto-transformers shall have an impedance between HV and LV/MV windings as stated in the Schedule of Requirement & Appendix thereto. The impedance on other tappings and between other windings (HV-TV/ LV-TV etc.) shall be stated in the Schedule E of Particulars and Guarantees.

It is preferred that the equivalent zero sequence impedance of the auto-transformer, when viewed from the HV terminals and feeding a fault at the MV terminals, is not less than the positive sequence impedance

between HV and MV terminals at normal ratio and normal rating. The value shall be stated in the Schedule of Particulars and Guarantees on the basis of system short circuit levels stated in the Schedule of Requirements.

4.15.4 Winding Terminations

Terminations of stabilising windings and neutral ends of windings shall be as follows:

i) Neutral ends of the three phase windings shall be connected at a point accessible from a hand hole in the cover and brought out via one bushing insulator.
ii) Stabilising winding terminations shall be brought out via oil/air bushings for connections in delta formation by means of busbar arrangement mounted on firewalls between transformers.

4.15.5 Tap Changing

Tap-changers are required between the HV and MV transformer windings. Tap-changers shall comply with Clauses described here in.

4.16 Earthing & Auxiliary Transformer

4.16.1 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.

4.16.2 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

4.16.3 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.

4.16.4 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.

4.16.5 Design & Construction

4.16.5.1 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.

4.16.5.2 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.

4.16.5.3 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.

4.16.5.4 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.

4.16.5.5 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

4.16.5.6 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.

4.16.5.7 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.

4.16.5.8 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.

4.16.5.9 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.

4.16.5.10 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.

4.16.5.11 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.

4.16.5.12 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.

4.16.5.13 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.

4.16.5.14 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.

4.16.5.15 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.

4.16.5.16 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.

4.16.6 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.

4.16.7 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 Transformer.

4.16.8 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)

4.16.9 Transport & Shipment

All earthing transformers shall be shipped full of oil.

4.16.10 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.

4.17 Transformer Online Dissolved Gas Analyser (DGA)

Online Dissolved Gas (Multi-gas) and Moisture Analyser

a) Online Dissolved Gas (Multi-gas) and Moisture Analyzer (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 analyze the following gases:

SL	Gases & Moisture Parameters	Typical Detection Range
1	H2	5 – 3,000 ppm
2	CH4	5 – 5,000 ppm
3	C2H6	5 – 5,000 ppm
4	C2H4	3 – 5,000 ppm
5	C2H2	1 – 3,000 ppm
6	CO	10 – 10,000 ppm
7	CO2	20 – 30,000 ppm
8	O2	500 – 25,000 ppm
9	H2O	2 – 100 % RS should have facility for measurement of moisture in oil in ppm

c) The analyzer should measure (not calculate) all above gases and should have100% 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 IP55Stainless 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 + 10%
Repeatability +3% to 10% depending upon gases
Oil temperature range - 20^0 C to + 120^0 C
External Temp. Range - 20^0 C to + 55^0 C
Humidity range 10 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 carryingout DGA of oil sample complete in all respect as per the technical specification. Thefollowing 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 & Troubleshootinginstructions.
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.

4.18 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.

4.18.1 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.

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

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:

- Visual inspection and dimension verification
- Power transformer tank oil leakage test
- Corrosion protection check
- Autotransformer tank vibration test
- Jacking pad test - checking of tank by lifting of power transformer
- Welding check after jacking pad test
- Oil dielectric strength
- Winding resistance measurement
- Transformation ratio measurements and winding connection verification
- Measurement of winding insulation resistance (before and after dielectric tests)
- Core insulation measurement (before and after dielectric tests)
- Switching impulse withstand voltage (SI)
- Impulse voltage test; primary voltage, secondary voltage, tertiary, including neutral point (LI)
- Impulse chopped voltage (LIC)
- Power frequency withstand voltage test, 50 Hz , 1 min (winding, core and secondary equipment)
- Short-duration induced AC withstand voltage test (ACSD) with monitoring of partial discharges.
- Long-duration induced AC withstand voltage test (ACLD) with measurement of partial discharges.
- Measurement of no load losses and no-load current at rated frequency before and after impulse test.
- Dissolved gas-in-oil analysis by chromatography prior to dielectric tests, after completion of dielectric tests and prior and after the temperature rise tests.
- Tap changer test for no load and short circuit conditions.
- Functional tests of protection devices and related equipment.

Special Tests

Within the factory acceptance test, the following special tests shall be performed:

- Measurement of zero-sequence impedance.
- Measurement of no-load current harmonics.
- Measurement of magnetizing current.
- Measurement of power consumption for cooling system.

- Measurement of capacitance (C), factor of dielectric losses (tgδ), (before and after dielectric testing).
- Measurement of the mutual inductance of the winding.
- Sweep frequency response analysis (SFRA).
- Measurement of transferred over voltages.

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.

4.18.2 Detailed Testing Requirements

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.
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.

All test results, measurements, and calculated values shall be recorded on the supplier's certified test report.

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.

In the event of a test failure, no corrective action shall be taken until authorized by the Employer.

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.

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.

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 65°C by resistance measurement and 80°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 beperformed 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.

4.18.3 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 notexceed 100 microvolts and 300 picocoulombs during the one-hour level.

c) The measured levels of gasses generated during the preliminary and dielectrics testsshall 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

4.19 Shipment , Receiving & Site Testing

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.
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.

No transportation media transfers are to be made without written approval from the Employer.

The Seller shall provide satisfactory trip lease arrangements where rail shipments to private rail sidings are used.

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.

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.

All earthing transformers shall be shipped full of oil.

4.19.2 Drying Out

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.

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.

4.19.3 Receiving

After the Employers's representatives have been notified of the transformer's arrival at the specifiedshipping destination, they and the Seller's representatives will inspect the transformer for apparent damage or loss. In the event there is evidence of loss, damage, or rough handling, the Seller's representative will be responsible for noting such on the carrier's delivery receipt. If the Seller 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 Seller 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 Seller 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.

The Seller 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.

The Seller shall provide receipt inspection criteria.

Field supervision by a qualified employee of the Manufacturer is to provide technical assistance during the initial field assembly of the transformer.

4.19.4 Site Tests

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.

Commissioning Tests

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.

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.

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.

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 this section. 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

Handling on Site

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.

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.

5. Protection, Metering &Control and Substation Automation System

Protection, Metering & Control and Substation Automation System 5/1

5.1General 5/2

5.2Protection Relay - General 5/2

5.3Fault Clearance Times 5/3

5.4Arrangement of Facilities 5/3

5.5Multi-Core Cable Diagrams 5/4

5.6Test and Earthing Facilities 5/4

5.7Protection Devices 5/5

5.8Relays 5/5

5.9Overhead Line Protection 5/7

5.10 Busbar Protection 5/11

5.11 Circuit Breaker Failure Protection 5/13

5.12 End Fault Protection 5/14

5.13 Auto-Reclosing Scheme 5/14

5.14 Overcurrent and Earth Fault Protection 5/16

5.15 Coupling Bay Protection 5/16

5.16 Transformer Protection 5/16

5.17 DC Auxiliary Voltage Operating Range 5/19

5.18 Tele-protection Signaling 5/20

5.19 Digital Fault and Disturbance Recorder (DFDR) 5/20

5.20 Travelling Wave Fault Locator (TWFL) 5/23

5.21 Tripping Relays 5/23

5.22 Protection Settings 5/24

5.23 Substation Automation System 5/24

5.24 Trip Circuit and Power Supply Supervision 5/43

5.25 Busbar Voltage Selection 5/43

5.26 Synchrocheck 5/44

5.27 Interlocking and Control Authority 5/44

5.28 Diagrams 5/44

5.29 Current Transformer Calculations 5/45

5.30 Energy Meter (Tariff Metering) 5/45

5.31 Annexure 5/50

5.1 General

This specification covers the design, manufacturing, factory tests, delivery to sites, erection, setting, parameter setting, and architecture configuration, field testing, commissioning, warranty, and lifetime support of 230/132/33kV substation 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 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 the 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 and control facilities shall be suitable for the power system arrangement as shown on the Single Line Drawing and Trip Logic provided with the bid document. For each substation, the Contractor has to foresee one (or more) separate cubicle(s) for:

- Control system – SCADA Server (Control, SCADA, SAS, etc.)
- Operator's Working Station
- Gateway server
- DFDR (Digital Fault and Disturbance Recorder)
- AVR
- Protection system
- Metering
- 33 kV Control cubicle(s)

During the Design stage, the Contractor has to propose the final solution, which will be subject of the Employer's final approval.

5.1.1 For the entire system, the following protection philosophy shall be applicable for OHL (Over Head Line Protection):

	Main Scheme		Communication Scheme	Reclosing	Remarks
	Relay	Comm. Ch			
Main 1 for Overhead Lines	Line Differential (87L)-based on application, Distance (21), 67/67N, 68, 46BC, VTFF, 50 Stub, SOTF, 27, 59, 51/51N, 50/50N, 21FL, DDR	Optical	Transfer Trip (PUTT, POTT, DTT, CB Echo, WEI Echo, Current Reversal Blocking, Z1 extension etc.) for 21 as well as 67N	Multiple 1ph, 3ph, 1+3ph (Selectable)	Full scope of Distance and Multiple OC Function
Main 2 for Overhead Lines	Line Differential (87L)-based on application, Distance (21), 67/67N, 68, 46BC, VTFF, 50 Stub, SOTF, 27, 59, 51/51N, 50/50N, 21FL, DDR	Optical	Transfer Trip (PUTT, POTT, DTT, CB Echo, WEI Echo, Current Reversal Blocking, Z1 extension etc.) for 21 as well as 67N	Multiple 1ph, 3ph, 1+3ph (Selectable)	Full scope of Distance and Multiple OC Function

	Main Scheme		Communication Scheme	Reclosing	Remarks
	Relay	Comm. Ch			
Backup	67/67N, 51/51N, 50/50N, 27, 59, DDR	N/A	N/A	N/A	As applicable in PSLD & Trip logic

5.1.1.1 The Main 1 & Main 2 relay shall be for 245kV & higher voltage system and for 145kV system, only Main 1 & backup relay shall be applicable. The Main 1 & Main 2 relays of the same protected object shall be from different manufacturers.

5.1.1.2 During the Design stage, the Contractor can propose different arrangements 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 & Lowers
- The final solution will be subject of the Employer's final approval.

5.1.1.1 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.

5.1.1.2 During the design and execution stage, the contractor shall submit the GTP of the panel (annexure 1) for approval and must also adhere to the employer's requirements for manufacturing all panels as per annexure 2.1 and annexure 2.2.

5.1.1.3 However, the bidder/manufacturers of relay shall provide at least 5 years of warranty for its product, i.e., for complete Protection system.

5.2 Protection Relay - General

5.2.1 For standardization of operating performance, facilities and spare requirements, the protection relays and control systems, together with complete panels to be supplied under this project shall be manufactured by ABB (Switzerland/Sweden/USA), Alstom/GE (France / UK/USA/Canada), Siemens (Germany), or SEL (USA). Upto 132kV system, the CRP system together with complete panels manufactured by NR (China) is also acceptable.

5.2.2 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 current transformer design shall be based on these fault levels.

5.2.3 All relays shall operate correctly within system frequency limits of 47Hz to 53Hz.

5.2.4 Installation, testing, and commissioning of Control, protection and metering system shall be done by the Manufacturer(s) Engineer(s).

5.2.5 All the Auxiliary relays (Contactor, TCS, Tripping relays, thermostat, humidity controllers etc.) used for the protection scheme shall be of EU/USA/UK/Japan/Canada origin.

5.3 Fault Clearance Times

5.3.1 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	msec.	80	100	120	300
Line faults:					
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	300
72% of 100% of the line length where (@) plus protection signalling time	msec.	100	130	150	300

5.3.2 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

5.4.1 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. Sufficient protection from external disturbances must be established for the Control, Protection and SAS equipment. Control cables should be properly armoured; sealing must be provided at the entrance of the respective panel.

5.4.2 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 likewise 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.

5.4.3 Backup Control panels shall incorporate all necessary control and indication facilities along with hardware-based interlocks (for AIS) for the operation of the devices at the associated substation even in the case of failure of Substation Automation System. In addition, the substation may be remotely controlled and supervised from the National Load Dispatch Centre (NLDC) in Dhaka. Necessary NLDC integration must be performed by the contractor.

5.4.4 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.

5.4.5 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.

5.4.6 Protection facilities have to be arranged as shown in the Trip Matrix provided in the Bid

document.

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

5.6.1 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.

5.6.2 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 mm².

5.6.3 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.

5.6.4 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.

5.7 Protection Devices

5.7.1 Simplified arrangements of the main connections and protection for the various items of the substation are shown in Bid Drawing.

5.7.2 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.

5.7.3 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.

5.7.4 Transformer Buchholz, winding temperature, oil temperature, tap changer protective devices and pressure relief devices are to be supplied under this contract, and all necessary interposing relays, tripping relays and cabling associated with these devices shall be supplied and mounted under this contract.

5.8 Relays

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 designed identical 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.

5.8.2 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.

5.8.3 Relays shall be of approved construction and shall be arranged so that adjustments, testing and replacement can be affected with the minimum of time and labour. Relays of the hand reset type shall be capable of being reset without opening the case.

5.8.4 Electrically reset tripping relays shall be provided where necessitated by the system of control, such as for those circuits subject to remote supervisory control.

5.8.5 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 provided. 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.

5.8.6 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.

5.8.7 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.

5.8.8 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.

5.8.9 Relays which rely for their operation on an external DC supply shall utilise 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.

5.8.10 Any auxiliary supplies needed shall be drawn from the main station batteries and not from separate internal batteries in the protection equipment.

5.8.11 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.

5.8.12 Attention is practically drawn to the tropical climate and relay designs should be entirely suitable for duty under full tropical conditions.

5.8.13 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.

5.8.14 Relay shall be suitable for operation on 110 V nominal, 121 V float DC systems without the use of voltage dropping resistors or diodes

5.8.15 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.

5.8.16 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 programme/ parameterize 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.

5.8.17 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.

5.8.18 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.

5.8.19 Electromagnetic Compatibility

5.8.20 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.

5.8.21 Where such devices are required, they and the ancillary circuits connected to them, such as power supplies, current and voltage transformer secondaries, status or tripping or alarm circuits shall be designed to ensure that they are compatible for use in the hostile electrical environment found in an EHV substation.

5.8.22 Adequate steps, by means of suitable design, shall be taken to prevent Electromagnetic Interference (EMI) (generated by sources such as circuit breakers, disconnectors, lightning, radio or radar emissions, switching contactors in dc circuits etc.) or Electrostatic Discharges (ESD) from affecting relay performance or causing damage to components.

5.8.23 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.

5.8.24 OEM of the protective relays shall declare the following RAM DATA for each offered relay in the following format:

ITEM	MTTF (Yrs)	EOL (Yrs)	MTTR (Hrs)	MTBPM (Yrs)	MTTPM (Hrs)

RAM: Reliability, Availability, Maintainability
MTTF: Mean Time to Failure
EOL: Expected Operating Life
MTTR: Mean Time to Repair
MTBPM: Mean Time to Perform Preventive Maintenance
MTTPM: Mean Time Between Preventive Maintenance

Field demonstrated RAM DATA should also be provided for the proposed relays

Relay Make and Model Number:

FIELD RAM DATA	2016	2017	2018	2019	2020
Total number installed					
Total number replaced (for any reasons)					
Failure due to wrong design					
Failure due to faulty production					
Failure due to bad use/ handling					
Random failure					
Mean Time to Repair/ Replace					

[Reference to the data given above is to be mentioned]

5.8.25 In addition to the mentioned requirements, the OEM of protective relays should have registered office in the employer's country.

5.9 Overhead Line Protection

5.9.1 400kV, 230kV and 132 kV Transmission Line Protection:

Protective devices for Main 1 and Main 2 overhead line protection are shown on Bid Drawing. These devices shall comply with the following.

5.9.1.1 Main 1 and Main 2 protection of 400 & 230 kV line shall be of Line differential protection with back-up distance protection for short length lines. Line differential protection 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. The Main & Back-up protection of 132 kV line shall be Line differential with back-up distance or Distance protection alone (based on the criteria above) and Directional overcurrent & Earth fault protection respectively. Both Main-1 and Main-2 protections should operate in conjunction with tele-protection channels over optical fibre 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.

5.9.1.2 Each set of protection will be energised 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 reclose relay.

5.9.1.3 Two sets of protection shall consist of relays from different Manufacturers among the ones mentioned in the document. 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.

5.9.1.4 The relay scheme offered shall be suitable for use in the permissive under-reaching, permissive overreaching, direct transfer trip, CB Echo logic, Weak End Infeed Echo logic, blocking and unblocking modes for Distance (21) and Directional Earth Fault (67N) functions. 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, medium or short overhead lines or cables, double circuit lines, heavily loaded lines, lines with weak infeed etc.

5.9.1.5 The permissive overreach scheme shall operate in a permissive underreach/overreach transfer tripping mode with underreaching 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.

5.9.1.6 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 disconnector is open, or when the associated circuit breakers are open.

5.9.1.7 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.

5.9.1.8 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 signalling 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.

5.9.1.9 The Zone 3 elements shall provide a further time delayed back-up zone.

5.9.1.10 Distance protection back-up zones shall also have the facility to trip the remote end circuit breaker(s) via a direct intertripping channel.

5.9.1.11 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 underreach 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 if the protection zone is selected for forward region. Details of methods used for polarising 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.

5.9.1.12 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.

5.9.1.13 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.

5.9.1.14 Single pole tripping and auto-reclosing are being employed and the auto-reclosing scheme requirements are given in relevant sections. 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.

5.9.1.15 Auto reclosing shall be capable of being blocked for

i. any multi-phase fault

ii. any Zone 2 or Zone 3 time delayed trip
iii. Tele-protection channel out of service
iv. DEF back up time delayed trip without tele-protection aided scheme.
v. Switch on to fault.

5.9.1.16 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.

5.9.1.17 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

5.9.1.18 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.

5.9.1.19 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.

5.9.1.20 Under no circumstances shall any line protection operate because of normal system switching including de-energisation of the line.

5.9.1.21 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-energised line.

5.9.1.22 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.

5.9.1.23 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.

5.9.1.24 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.

5.9.1.25 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

5.9.1.26 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 signalling 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.

5.9.1.27 The directional relays shall be dual polarised i.e. polarised 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 230 kV system zero sequence source is an auto transformer with a delta tertiary winding, that current polarising of a dual polarised 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 polarising the relay within three months of being advised of all transformer impedance parameters.

5.9.1.28 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.

5.9.1.29 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.

5.9.1.30 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.

5.9.1.31 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.

5.9.1.32 The distance protection time delayed back-up Zones 2 and 3 and the directional earth fault back-up stage shall inter-trip the remote station circuit breakers over direct inter tripping channels.

5.9.1.33 Auto reclosing shall not be initiated on receipt of direct inter-tripping signal. Direct inter-tripping shall also be initiated in the event of a 3 phase fault in any zone, or following a switch on to fault trip.

5.9.1.34 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.

5.9.1.35 Facilities shall be provided to block zones 1, 2 and 3 of the distance relay from the power swing blocking logic as required.

5.9.1.36 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.

5.9.1.37 The associated time delay relay shall have a setting range of 50-250 ms.

5.9.1.38 Relays shall be of numerical or static 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 fibre 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.

5.9.1.39 Reset times shall be low to ensure the associated distance relay reverts to its normal role as soon as possible following a power swing.

5.9.1.40 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.

5.9.1.41 If the associated VT supplies are lost due to VT fuse failure the power swing blocking relay shall not operate.

5.9.1.42 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.

5.10 Busbar Protection

5.10.1 The busbar protection for 400kV (1 & 1/2 Breaker and Double Busbar scheme), 230kV & 132kV shall be low impedance type numerical relay capable of detecting all types of phase and earth faults under all system generation conditions. Busbar protection system should be distributed in principle. The protection shall be extensible to cover the final substation arrangements and Bidders shall state what extra material is required.

5.10.2 Each busbar having voltage levels of 400kV and above shall be protected with 2 (two) sets of Main and Redundant busbar protection system. Two sets of busbar protection should be from two different manufacturers.

5.10.3 The busbar protection shall meet the fault clearance time of 80ms for 400kV under all conditions and have the following features:

5.10.1.1 In case of 400kV busbar protection, two independent measurement, protection & tripping criteria shall be applied.

5.10.1.2 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.

5.10.1.3 Tripping logics and close blocks for Busbar protection operation will be implemented as shown in PSLD & Trip logic and associated trip matrix.

5.10.1.4 The operating time of the measuring relays shall not exceed 30msecs at five times the relay current setting.

5.10.1.5 The busbar protection should be capable of feeding from different ratio of current transformers in different feeders. The working ratio will be selected on the basis of

maximum load transfer in the same manner as the line current transformer ratios.

5.10.1.6 The rated stability limit of the protection shall not be less than the switchgear short circuit rating.

5.10.1.7 Stability against all external faults must be confirmed even in case of severe CT saturation.

5.10.1.8 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 differential current supervision element should take the defective protection zone out-of-service.

5.10.1.9 The Contract shall include for all necessary current transformers, relay panels, marshalling boxes, isolating and shorting links, etc. 5 (five) nos. selector switches have to be provided for enabling and disabling BBP (Busbar Protection), BFP (Breaker Failure Protection), EFP (End Fault Protection), Output contacts and All functions.

5.10.1.10 Suitable voltage limiting devices shall be provided as necessary, including across the unused part of the CT secondary when tapings are employed.

5.10.1.11 Full details of the scheme offered, together with performance figures for stability and sensitivity shall be provided.

5.10.1.12 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 initialisation of trip commands. 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.

5.10.1.13 If the intercommunication between the bay unit and central unit by fibre optic cables, the required fibre optic cable and all necessary items shall be supplied, connected and commissioned by the Bidder. Fibre optic cables connected between panels have to be appropriately armourd, sealed and protected from external disturbances.

5.10.1.14 Front mounted HMI should be provided with Central Unit and each Bay Unit of busbar protection system having facility of accessing all relevant measurements, alarms, tripping information and switching device information without connecting external computers.

5.10.1.15 Complete configuration including software and hardware capabilities should be available in BBP system for accommodating existing feeders as well as future feeders. No further engineering would be required during extension of future feeders, only installing new Bay Units should be sufficient.

5.10.4 Extension of existing busbar protection: The scope of work under this contract is to extend the existing busbar protection for new bays with the same equipment.

5.10.5 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:

i) The rated stability limit shall be no less than the three-phase symmetrical breaking capacity of the associated switchgear.

ii) Current transformer knee point voltages shall not be less than twice the relay circuit setting voltage.

iii) The maximum peak voltage across current transformer secondary wiring shall not exceed 3 kV under maximum internal fault conditions.

iv) Associated current transformers shall be Class X or 5P, low reactance type. Split core type current transformers will not be accepted.

v) 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

5.11.1 Breaker failure protection shall be fitted to all 400kV, 230 kV and 132 kV circuit breakers of the substation. Each CB having voltage level of 400kV and above will be equipped with 2 (two) nos main and redundant Breaker Failure Protection. 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 inter-tripping 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 issue a re-trip to the same Circuit Breaker through an alternative path of the initially issued trip signal. If the Circuit Breaker fails to open even after receiving the re-trip signal, the BFP will initiate tripping to all adjacent circuit breakers of all connected sources. It shall also incorporate provision for initiating tripping of any remote infeeds, via direct inter-tripping channels over optical fibre communication link or power line carrier circuits.

5.11.2 On the other hand, BFP remote tripping from the remote infeeding end will be received by the local end relays to issue tripping to local end CBs.

5.11.3 In the case of 400kV, 230 kV and 132 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 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.

5.11.4 The operating time from initiation to back-up tripping output shall be selected by means of duplicated timers with a setting range of 50-500 msec.

5.11.5 The timers shall be of a modern design to minimise overtravel. With the approval of the Engineer the busbar protection trip circuits may be employed for circuit breaker fail back-up tripping.

5.11.6 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.

5.11.7 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.

5.11.8 Breaker Failure Protection will be implemented as a built-in function of Busbar Protection system for Double Busbar bus arrangement. Same will be applicable for Bus side Circuit Breakers of 1 and half CB bus arrangement. Stand-alone Breaker Failure Protection relay can be provided for Tie CB of 1 and half CB bus arrangement depending on manufacturer's practice.

5.12 End Fault Protection

5.12.1 Blind zone between Circuit Breaker and Current Transformer needs to be protected with End Fault Protection where overlapping protection zones are not formed due to CT location.

5.12.2 End Fault Protection will be implemented as a built-in feature of busbar protection system.

5.12.3 Tripping will be issued to remote infeeding end either through direct inter-tripping (in case of transformer) or through Tele-protection channel (in case of OHL) with selectable time delay if EFP is detected.

5.13 Auto-Reclosing Scheme

5.13.1 Three pole and/or single pole, single shot repetitive auto-reclosing equipment, shall be provided for the overhead line circuit breakers.

5.13.2 Reclosure shall be initiated following tripping by either main protection operating in Zone 1 or in conjunction with a tele protection receive signal or DEF with tele-protection aided scheme. 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. Re-closure 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 inter-tripping signal is received, nor when the circuit breaker is closed onto a fault on a previously de-energised line, nor when the DEF back-up protection operates nor if the carrier channel is out of service nor O/C & E/F protection operated nor voltage protection operated.

5.13.3 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 phases 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.

5.13.4 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.

5.13.5 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 poles reclose dead time: 3 to 30 seconds.

Bidders shall state available ranges.

5.13.6 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).

5.13.7 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 energised.

5.13.8 A counter shall be provided to record the number of reclosures and lockout after a pre-selected number of reclosures has been reached.

5.13.9 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 3 mins.

5.13.10 Auto-reclose functions have to be provided in Main-1 and Main-2 relays for voltage levels of 230kV and above. Main-1 line protection relay has to be selected as master for auto-reclose. A/R function of Main-2 relay will be active in case of unhealthiness of Main-1 relay for avoiding duplicated command. In case of 1 and half CB bus arrangement, A/R will be issued to Bus side CB initially. A/R reclose of Tie CB will be issued after successful reclosing of Bus side CB. Alternatively, A/R will be issued to Tie CB initially if the Bus side CB remains open beforehand.

5.13.11 Auto-reclose function will be activated in Main relay only for 145kV.

5.13.12 Reclosing schemes shall include voltage monitoring and check synchronising relays as appropriate.

5.13.13 Dead line check relays shall monitor the condition of the line and busbar and permit three pole reclosing only when the line is de-energised and the busbar is energised. The line is considered to be de-energised when the voltage is less than twenty percent of rated voltage, and the busbar is considered to be energised 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).

5.13.14 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.

5.13.15 Check synchronising relays shall comply with the requirements of relevant clauses of section 5.26. The same relays may be used as for manual closing.

5.14 Overcurrent and Earth Fault Protection

5.14.1 The overcurrent and earth fault relays shall be fully Numerical and have multi characteristics (inverse, very inverse, extremely inverse) to IEC 60255. Over-current and Earth-fault protections will be implemented as back-up protection of the main feeder protections for line and transformer feeders. The functions will act as main protection for Bus Coupler feeders.

5.14.2 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.

5.14.3 Over-current and earth fault relays shall trip via the CB duplicate trip coils.

5.14.4 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.

5.14.5 Directional back up over-current and earth fault relays shall be provided for Line and Transformer feeders and the directional elements shall be voltage polarised.

5.14.6 Directional units for directional overcurrent protection shall be quadrature connected with a relay characteristic angle setting of 30° or 45° current leading voltage.

5.14.7 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.

5.14.8 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.

5.14.9 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.

5.14.10 The residual polarising 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.

5.15 Coupling Bay Protection

5.15.1 The Coupler bay shall be provided with overcurrent instantaneous trip relay protection (50/50N) and overcurrent time delay relay protection (51, 51N). Relays shall comply with the requirements of clause 5.14.

5.15.2 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.

5.16 Transformer Protection:

5.16.1 Biased Differential Protection:

5.16.1.1 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-supervision 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 fibre optic connection.

5.16.1.2 Overall differential protection shall be of the biased differential type and capable of detecting phase and earth faults.

5.16.1.3 Separate facilities shall be provided to enable bias and operating settings to be adjusted.

The minimum operating setting shall not be greater than 20 per cent of the rated full load current of the transformer.

5.16.1.4 The protection shall be designed to ensure stability on any transformer tap position under maximum through fault conditions with maximum d.c. offset even in case of severe CT saturation. An infinite source is to be assumed and the through fault current calculated using the transformer impedance only.

5.16.1.5 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.

5.16.1.6 The relay characteristics should include unrestrained tripping without checking any restraining quantities or harmonics.

5.16.1.7 The relays shall have magnetising inrush current restraint of the second harmonic or other approved means. All necessary interposing current transformers shall be provided under the contract.

5.16.2 Restricted Earth Fault Protection:

5.16.2.1 Where specified, or shown on drawings, transformer windings and connections shall be protected by restricted earth fault protection.

5.16.2.2 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.

5.16.2.3 The 2nd REF protection will be of ~~the~~ 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.

5.16.2.4 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.

5.16.2.5 33kV winding of Earthing transformer (if any) will also be protected with low impedance type REF protection.

5.16.2.6 Relays shall have maximum sensitivity and minimum operating times consistent with stability for faults outside the protected zone and on magnetising inrush surges.

5.16.2.7 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.

5.16.2.8 For the purpose of calculations it shall be assumed that any neutral earthing impedance is short circuited.

5.16.2.9 The Contractor shall prepare for approval calculated performance for instantaneous high impedance restricted earth fault protection in lieu of heavy current tests, except:

i) The rated stability limit shall be as specified above.
ii) The fault setting shall be as specified below:

(a) 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.

(b) 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.

5.16.3 Transformer Back-up Over-current 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 5.14 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.

Over-current and earth-fault elements should have selectable operating characteristics as shown in PSLD & Trip logic.

5.16.4 Gas Pressure (Buchholz) Protection:

5.16.4.1 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.

5.16.4.2 All necessary flag indication, tripping relays and alarm relays associated with this protection shall be provided, mounted and connected under this contract.

5.16.5 Oil and/or Winding Temperature:

5.16.5.1 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.

5.16.5.2 All necessary flag indication, tripping relays and alarm relays associated with this protection shall be supplied and connected under this contract.

5.16.6 Low Oil Level and Pressure Relief Devices:

5.16.6.1 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.

5.16.6.2 The alarm relays associated with these devices shall be supplied and connected under this contract.

5.16.7 Tap Changer Oil Surge:

5.16.7.1 Transformers will be provided with an oil surge or pressure operated device having contacts for purposes of remote alarm and trip.

5.16.7.2 A relay associated with this device shall be supplied and connected under this contract.

5.16.7.3 All necessary flag indication, tripping and alarm relays associated with tap change oil surge shall be provided.

5.16.8 Transformer Mechanical Protection arrangements:

All mechanical protection of Transformer will be established either through Main-1 and Main-2 protection relays or through Lock-out type tripping relays with necessary flag and indication. The protections which are established with Main-1 and Main-2 relays, tripping and alarm signals from all devices have to be terminated to both relays for assuring redundancy.

5.16.9 Tripping Relays:

5.16.9.1 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

5.16.9.2 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.

5.16.9.3 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.

5.16.9.4 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

5.16.9.5 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.

5.17 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 suitable for operation over a voltage range of 66V to 143V. i-e. 110 - 40% + 20%.

DC automatic changeover scheme has to be provided in each control & protection panel. Main-1 relays, Trip Circuit-1, Lock-out relay-1 should be connected to DC-1 and Main-2 relays, Trip Circuit-2, Lock-out relay-2 should be connected to DC-2 in normal condition. In case of failure of one DC system, the other system will automatically take care of the devices under the failed one.
Similarly for Control Panel, BCU will be supplied from DC-1 and Mimic/Emergency Control will be supplied from DC-2 in normal condition. DC changeover will be implemented as stated above.
DC supply of each panel will be taken directly from DCDB through separated MCB. DC looping among panels will not be accepted.

5.18 Tele-protection Signalling

Details of protection initiation and various permissive and direct inter-tripping signals are as specified in Section-14 & 15, of Vol. 2 of 3.

5.19 Digital Fault and Disturbance Recorder (DFDR)

5.19.1 The DFDR shall be delivered only for all new 400/230/33kV, 400/230/132kV, 400/132 kV and strategically important 132/33kV substations.

5.19.2 For the purpose of standardization, the DFDR to be supplied under this project shall be from Qualitrol (Belgium/UK), SIEMENS (Germany), SEL (USA).

5.19.3 Installation, testing & commissioning of the DFDR shall be done by the DFDR Engineer(s) of the DFDR Manufacturer(s).

5.19.4 **The DFDR shall have the following features:**

5.19.9.1 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 and bus coupler bays that require to be monitored.

5.19.9.2 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, accompanied by the customer's recommendations and type test reports from internationally acclaimed laboratories.

5.19.9.3 The DFDR system shall be modular in design for easy expansion, upgrade and maintenance.

5.19.9.4 The acquisition system or its storage unit shall not be based on a PC platform.

5.19.9.5 The independent DFDR system shall be equipped with a minimum of sufficient numbers of signals per bay as tabled below and shall be suitable for AC/DC measurement without any hardware changes.

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

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
		Bus Coupler feeder (for Double Busbar)	12
		Busbar Protection System	8
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

5.19.9.6 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.

5.19.9.7 DFDR must comply all requirements stated in attached GTP of DFDR.

5.19.9.8 The graphical data should be recorded for all feeders simultaneously (snap shot image). The recording should contain the data prior to the event and afterthe event, including the dynamic length of the event / fault without any alterations.

5.19.9.9 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.

5.19.9.10 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.).

5.19.9.11 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 remotely to download the recorded data, to ascertain the system's operational status, to change parameters, etc.

5.19.9.12 Master communication should be able to communicate via RS 232 (direct connection),

through modem (dial-up telephone line) and LAN (Ethernet (TCP / IP) - IEEE 802.3) networking.

5.19.9.13 The DFR shall perform the following functions:

- fault location (including impedances and report),
- graphical display of data,
- phase measurement & display,
- transient fault recording,
- dynamic swing recording,
- harmonics' measurement & display,
- integrated SER function,
- calculated channels etc.

5.19.9.14 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.

5.19.9.15 The system shall be equipped for time synchronization by the external GPS clock receiver for real time synchronizing (including antenna).

5.19.9.16 Local printing facility shall be provided with the system.

5.19.9.17 The master station (a latest version of PC) and the relevant software shall be supplied with the equipment for analysis and communication.

5.19.9.18 Power quality monitoring or continuous monitoring (periodical recording) shall be made available for at least 4 feeders.

5.19.9.19 If more than one Central Processing Unit is used for DFDR, configuration has to be done in such a way that records from all feeders will be stored in case of triggering any signal.

5.19.9.20 All analog and digital signals of a single feeder have to be displayed in a single page of the HMI and separate pages have to be configured for separate feeders.

5.19.9.21 In addition to above, manufacturer shall provide warranty for its product at least for 5 years.

5.19.5 Extension of the existing DFDR: The scope of work under this contract is to extend the existing DFDR system for new bays. All necessary input and output (both digital & analogue) shall be provided as per the existing bays.

5.19.6 TYPICAL SIGNAL LIST OF DFDR is as below:

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)*

Sl No.	***Signal Description***
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*
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*

Sl No.	*Signal Description*
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*
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*

Sl No.	***Signal Description***
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*
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*
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*

Sl No.	***Signal Description***
9	*Main-1 Relay A/R blocked*
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 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*

Sl No.	***Signal Description***
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*

Sl No.	***Signal Description***
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*
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*

Sl No.	***Signal Description***
2	*BBP Panel DC-2 Fail*
3	*BBP Relay Faulty*
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*

Sl No.	***Signal Description***
19	*Back-up Protection Relay Faulty*
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*

5.20 Travelling Wave Fault Locator (TWFL)

5.20.1 All line of 400kV voltage level or above shall be equipped with Travelling Wave Fault Locator (TWFL) for determining accurate fault location. The TWFL shall be suitable both for Single ended & Double ended application. The TWFL shall comply with the attached GTP of TWFL.

5.21 Tripping Relays

5.21.1 All tripping relays, where specified, shall be of high-speed (preferably 5 ms), high-burden, heavy-duty (larger than 150W) type and shall be suitable for panel mounting. Relays shall comply with the requirements of attached GTP. The relay used shall be of USA/Europe/Japan origin.

5.22 Protection Settings, Testing & Inspection

5.22.1 Protection setting:

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. 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.

All relay setting calculation and co-ordination have to be performed by the engineers of OEM.
Site Acceptance Test of the relays have to be performed by the engineers from OEM or the engineers certified/authorized by OEM.

5.22.2 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.

5.22.9.1 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 recognized laboratory, which should issue the relevant type test certificates upon successful completion of all tests.

Type test to be carried out for each offered protective relay (IEC 60225, IEC 6100-4-3, IEC 6100-4-8, IEC 6100-4-9, IEC 6100-4-10, ANSI/IEEE C37.90, C37.90.1, C37.90.2 etc.) and report shall be submitted.

[**Typical Test List:** *Insulation Resistance/ Dielectric withstand / High Voltage Impulse/ Surge Withstand Capability/ Electromagnetic Compatibility/ High frequency disturbance test class III/ Electrostatic disturbance test (ESD) class 4 and class 3/ Immunity to radiated electromagnetic energy/ Immunity to radio frequency interference (RFI)/ Radiated immunity from digital communications/ Power Frequency Magnetic Field Immunity/ Radiated Immunity from Digital Radio Telephones/ EMC compliance test/ AC ripples on DC supply (Power supply)/ Power supply interruption* (the protective relay must withstand 40msec interruption in DC auxiliary supply)*/ Mechanical vibration, shock/ Seismic qualification , ground acceleration 0.5g/Relative humidity annual average 75%/ High relative humidity 30 days 95%/ Power consumption and overload test/ Contact performance test*.]

5.22.9.2 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.

5.22.9.3 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.

5.22.9.4 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.

5.23 Substation Automation System

5.23.1 Scope of Supply:

5.23.1.1 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.

5.23.1.2 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.

5.23.1.3 The substation automation system (SAS) shall comprise full station and bay protection as well as control, monitoring and communication functions; it shall provide all functions required for the safe and reliable operation based on IEC 61850 standards. It shall enable local station control via PC 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 two (2) communication gateways to NLDC, inter-bay bus, intelligent electronic devices (IED) for bay control and protection as shown in the enclosed general system architecture drawing.

5.23.1.4 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.

5.23.1.5 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 fibre optics.

5.23.1.6 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.

5.23.1.7 The system shall be capable of having its computing power increased in the future through the addition of additional computing systems.

5.23.1.8 The system design life shall be not less than 20 years.

5.23.1.9 The capacity of the SA system shall be sufficient for the ultimate development of the substation as set out in the project requirements.

5.23.1.10 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.

5.23.1.11 The SAS shall have option for integration of Transformer Fire Prevention/Protection system integration. Necessary system configuration and switches shall be available for the said work.

5.23.2 Extension of existing SAS: The scope of work under this contract is to extend the existing SAS system for new bays. All necessary input and output shall be provided as per existing

bays.

5.23.3 Compliance with Standards

For design and type-testing of the protection and control equipment, the following standards shall apply:

5.23.3.1 General List of Specifications

• IEC 60255:	Electrical Relays
• IEC 60038:	IEC Standard voltages
• IEC 68068:	Environmental testing
• IEC 60664:	Insulation co-ordination for equipment within low-voltage systems
• IEC 61850:	Standard for Substation integrated protection and control data communication

5.23.3.2 Detailed List of Specifications

• 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 energising 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

5.23.4 Design and Operating Requirements:

5.23.4.1 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.

5.23.4.2 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.

5.23.4.3 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.

5.23.4.4 Failure behavior 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).

5.23.4.5 400kV, 230 kV and 132 kV substations, 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.

5.23.5 Architecture & Components:

5.23.5.1 The SAS design shall consider Rapid Spanning tree Protocol (RSTP) for 230kV & 132kV level. For 400kV or Higher voltage level, Parallel Redundancy Protocol (PRP) shall be applicable in all aspects.

5.23.5.2 Following components have to be provided in the SAS architecture:

- Server cum operating workstation- 02 Nos
- Gateway computers with hardware-based firewall including cyber security- 02 Nos
- Engineering workstation- 01 Nos
- Laser printer- 02 Nos
- Programmable Ethernet switches- as required
- GPS receiver- 01 Nos, 02 Nos (for PRP)
- Monitors- as per scope of supply
- Other accessories as shown in SAS architecture, scope of supply and as per system requirement

5.23.5.3 Operator workstations should have the teaming facility in the Ethernet LAN cards. Moreover, automatic stand by to hot conversion facility have to be available for both operator workstations. N-1 contingency criteria should be satisfied for all workstations, gateway computers, Ethernet switches and optical fiber links.

5.23.5.4 Common alarm unit shall be provided for notifying about important signals such as MCB status, device healthiness and tripping incidents of the feeders. The Unit should be capable of communicating with SAS.

5.23.5.5 NLDC provided Device ID should be used for the Identification of Switching Devices in the process display.

5.23.5.6 Audible alarm and buzzers must be provided with the SAS for important alarms and trip signals for the notification of the operators.

5.23.5.7 All devices of SAS workstations and gateway computers should be directly DC operated; alternatively, AC operated devices supplied from substation DC sources through inverter may be provided with redundancy and sufficient capacity. Necessary inverter have to be supplied by the contractor is such case.

5.23.5.8 Energy meters need to be connected to SAS and energy values displayed in SAS have to be extracted from Energy meters.

5.23.5.9 Automatic Voltage Regulator (AVR) should be directly IEC 61850 protocols supported and connected to SAS. Complete tap changing facility with parallel operation should be available in SAS for the Transformers of the substation.

5.23.5.10 In case of Parallel Redundancy Protocol- Engineering workstation, AVR will be connected to both networks of the topology.

5.23.5.11 Separate GPS receivers have to be provided for individual ring of the PRP network.

5.23.5.12 Status of Ethernet Switches, GPS Controllers, and Gateways shall be monitored and available on Operators Work stations.

5.23.5.13 DC changeover scheme should be established for all components of the architecture.

5.23.5.14 Status of DFDR and IED healthiness should be available in SAS.

5.23.5.15 33kV transformer incoming feeders of all substations should be operable from SAS.

5.23.5.16 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 55'' LCD monitor, Printers, Hot & standby Gateway with redundant switch & hardware firewall, cables (Fiber optic, Ethernet, copper) & connector, panels etc.

5.23.5.17 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. 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, 500GB Hard Disk, 22'' display, touch screen facility etc.

5.23.6 Modes of Operation:

5.23.6.1 The operator stations and specified remote users shall have the following operational modes, each password protected.

5.23.6.2 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.

5.23.6.3 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.

5.23.6.4 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.

5.23.6.5 System Manager To provide access to all system functions, including assignment of passwords and system maintenance activities.

5.23.6.6 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.

5.23.6.7 A series of passwords shall be personally assigned to operators in each of the above categories.

5.23.6.8 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.

5.23.6.9 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.

5.23.6.10 Similarly, an operator's manual entry applied at one workstation shall be immediately displayed at other workstations where this data is presented.

5.23.7 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

5.23.8 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 spares during the lifetime of the SAS equipment (not less than 10 years).

5.23.9 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.

5.23.10 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 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:

1) Acquisition and plausibility check of switchgear status
2) Control of switchgear
3) Remote checking of device parameters and activation of alternative parameter sets in the connected protective relays
4) Display of actual measured values (U, I, P, Q, f)
5) Display of events
6) Display of alarms
7) Display of trends
8) Sequence control functions
9) Disturbance records and fault location
10) System self-supervision
11) Hard copy printing
12) Dynamic busbar colouring

5.23.11 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.

5.23.12 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.

5.23.13 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.

5.23.14 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.

5.23.15 The SAS shall contain the following main functional parts:

1) Human Machine Interface (HMI) with process database
2) Gateway function for remote control via an industrial grade hardware
3) Dial-in facility / laptop workstation for protection relay parameterization, disturbance analysis and SAS fault analysis.
4) Data exchange between the different system components via high speed bus
5) Bay level devices for control, monitoring and protection
6) Bay-oriented local control and protection panels with mimic inserts
7) Facility for emergency operation of all the switchgear, if the bay controller fails (key / master key system).

5.23.16 The main process information of the station shall be stored in distributed databases. The system shall be based on a decentralised concept with bay-oriented distributed intelligence for safety and availability reasons. Functions shall be decentralised, object-oriented and located as close as possible to the process.

5.23.17 The substation monitoring/protection system shall supply data for maintenance, repair and remote parameter setting of protection and control devices in the switchyard.

5.23.18 In 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.

5.23.19 The monitoring system shall be suitable for the supervision and monitoring of all the secondary (IED) and primary devices in a substation including future extensions.

5.23.20 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.

5.23.21 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.

5.23.22 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 CDs.

5.23.23 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 microwave channel.

5.23.24 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.

5.23.25 System Hardware

5.23.25.1 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.

5.23.25.2 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.

5.23.25.3 Disturbance records shall be analysed using the installed disturbance record analysis programmes. 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.

5.23.25.4 Each uploaded data report file shall be reported on one line that shall contain:

1) The event date and time
2) The name of the event object
3) A descriptive text
4) The state or value of the object

5.23.25.5 The information fields above shall be structured in columns for maximum readability.

5.23.25.6 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.

5.23.25.7 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.

5.23.25.8 A 16-window annunciator unit shall be directly connected to the main station PCs to monitor the same and also to annunciate common station abnormal/fault conditions.

5.23.25.9 Station Inter-bay Bus: The LAN connecting the industrial computer-based operator workstations and printers shall be Ethernet 802.3 LAN, protocol TCP/IP (10 Mbit./ sec or higher), and the physical medium shall be thin Ethernet or fibre optic bus, provided this LAN is kept within the confines of the control room.

5.23.25.10 The bay control and protection units shall be connected via glass fibre optic cables to a station inter-bay bus using 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 fulfill 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 reconfiguration 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.

5.23.25.11 Protection and Control IEDs and Local Back-up Control Mimic on 400kV, 230 kV Level:

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.

5.23.25.12 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.

5.23.25.13 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.

5.23.25.14 The 400kV, 230 kV and 132kV bay control & protection IED shall have the following features:

1) a minimum of 9 configurable analogue channels
2) at least 32 binary inputs, 24 signal relays and 2 command relays
3) 16 LEDs on the front of the unit for indication
4) auto-reclose function
5) Synchrocheck function
6) power function which can be configured to measure forward or reverse, active or reactive power
7) four (4) independently settable parameter setting groups, settable/selectable locally or remotely via the HMI programme
8) 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.
9) High-speed bus serial communication port as per IEC 61850 standards.
10) a 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.
11) 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.
12) comprehensive self-supervision
13) battery-free memory back-up of event and disturbance records
14) logic functions (AND, OR, bistable flip flop, etc.)
15) delay/integrator function

5.23.25.15 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.

5.23.25.16 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.

5.23.25.17 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.

5.23.25.18 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.

5.23.25.19 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.

5.23.25.20 Deleted.

5.23.25.21 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.

5.23.26 Software Structure:

5.23.26.1 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.

5.23.26.2 Confirmation that the software programs will be supported for a minimum of 20 years is required to be submitted with the bid.

5.23.26.3 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.

5.23.26.4 Station Level Software:

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.

Operating System:
A Windows Server 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, multitasking, security levels, data exchange mechanisms (DDE, OLE), open data base communication standards (ODBC) and a standardized, user-friendly look & feel HMI.

5.23.26.5 Bay Level Software

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.

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.

5.23.27 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).

5.23.28 System Functions

5.23.28.1 Control Unit Functions

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:
1) Commands from different operator places, e.g. from the associated control centre (NLDC), station HMI, or the control panel (in control room) according to the operating principle
2) Select-before-execute commands
3) Operation from only one operator place at a time.
4) Operation depending on conditions from other functions, such as interlocking, synchro check, operator mode, or external status conditions.

The control function shall also include:
1) Prevention of double operation
2) Command supervision
3) Selection of operator place
4) Block/de-block of operation
5) Block/de-block of updating of position indications
6) Manual setting of position indications
7) Overriding of the interlocking function (Second key switch.)
8) Switchgear run time supervision

5.23.28.2 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.

5.23.28.3 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 interlocking shall take place via bay communication system.

An interlock diagram/interlock page shall be displayed for each operation of any device in Substation Automation 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.

5.23.28.4 Measurement

Analogue inputs for voltage and current measurements shall be connected directly to the voltage transformers (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.

5.23.28.5 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.

5.23.28.6 Time Synchronisation

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 fibre bus. An accuracy of ±1 ms within the station is required.

5.23.28.7 Synchronism and Energising Check

The synchronism and energizing check functions shall be distributed to the control and/or protective devices and shall have the following features:

1) Adjustable voltage, phase angle, and frequency difference.
2) Energizing for dead line - live bus, or live line - dead bus.
3) Settings for manual close command and auto-reclose command shall be adaptable to the operating times of the specific switchgear.

5.23.28.8 Voltage Selection

The voltages, which are relevant for the synchro check 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.

5.23.28.9 HMI Functions

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:

1) single-line diagram showing the switching status and measured values
2) control dialogues
3) measurement dialogues
4) blocking dialogues
5) alarm list, station / bay oriented
6) event list, station / bay oriented
7) system status
8) checking of parameter setting

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:

1) selected object under command
2) selected on the screen
3) not updated, obsolete value, not in use or not sampled
4) alarm or faulty state
5) warning or blocked
6) update blocked or manually updated
7) control blocked
8) normal state
9) busbar colouring to show live & dead bus.

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-execute" 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.

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.

Reports
The SAS shall generate reports that provide time-related information on measured values and calculated values. The data displayed shall comprise:

Trend reports:

1) day (mean, peak)
2) month (mean, peak)
3) semi-annual (mean, peak)
4) year (mean, peak)

Historical reports:

1) day
2) week
3) month
4) year

5.23.28.10 There must be provision of automatically generated periodic reports (such as, 15mins/30mins/1hr etc.) of all analog data (such as Current, Voltage, Real Power, Reactive Power, Power Factor, and Frequency).

5.23.28.11 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.

5.23.28.12 This report shall be printed automatically at pre-selected times. It shall also be possible to print this report on request.

5.23.28.13 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.

5.23.28.14 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.

5.23.28.15 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:

1) position changes of circuit breakers, isolators and earthing devices
2) indication of protective relay operations
3) fault signals from the switchgear
4) violation of upper and lower limits of analogue measured value
5) 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:

1) date and time
2) bay
3) device
4) function
5) alarm class

5.23.28.16 Alarm List

Faults and errors occurring in the substation shall be listed in an alarm list and shall be immediately transmitted to the control centre. 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:

1) The alarm date and time
2) The name of the alarming object
3) A descriptive text
4) 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.

5.23.28.17 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

1) type of blocking,
2) authority
3) local / remote control
4) NLDC/SAS control
5) errors,
6) etc.,

shall be displayed.

5.23.28.18 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.

5.23.28.19 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.:

1) Display only
2) Normal operation (e.g. open/close apparatus)
3) Restricted operation (e.g. by-passed interlock)
4) System administrator

For maintenance and Engineering purposes of the station HMI, the following authorization levels shall be available:

1) No Engineering allowed
2) Engineering/configuration allowed
3) 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.

5.23.28.20 Controlling authority should be provided of NLDC control, Control from SAS HMI, Bay Controller, Mimic and Local Control Cubicle. Selected authority control must be displayed in the SAS monitor.

5.23.29 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

5.23.30 System Reliability

The SAS system shall be designed to satisfy very high demands for reliability and availability concerning:

1) Solid mechanical and electrical design
2) Security against electrical interference (EMI)
3) High quality components and boards
4) Modular, well-tested hardware
5) Thoroughly developed and tested modular software
6) Easy-to-understand programming language for application programming
7) Detailed graphical documentation, according to IEC 61131-3, of the application software
8) Built-in supervision and diagnostic functions
9) After sales service
10) Security
11) Experience of security requirements
12) Process know-how
13) Select before execute at operation
14) Process status representation as double indications
15) Distributed solution
16) Independent units connected to the local area network
17) Back-up functions
18) Panel design appropriate to the harsh electrical environment and ambient conditions
20) Panel grounding to provide immunity against transient ground potential rise

5.23.31 Configuration Tools

5.23.31.1 The configuration of the station HMI shall be made using the operator station working in Windows NT/Server environment. The various functions shall be customised by easy to use interactive configuration tools. Configuration shall include the visual presentation of the object, adaptations needed in process database and adaptations of the communication configuration data.

5.23.31.2 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.

5.23.31.3 The PC based service & support system shall be used for the following purposes:

1) System configuration
2) System testing
3) Help functions
4) Program documentation
5) Down- and up-loading of programs
6) System commissioning
7) Data base management
8) Changing peripheral parameters

5.23.31.4 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.

5.23.32 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:

1) List of drawings
2) Control room layout
3) Assembly drawing
4) Single line diagram
5) Block diagram
6) Circuit diagram
7) List of apparatus
8) List of labels
9) Functional design specification (FDS)
10) Test specification for factory acceptance test (FAT)
11) Logic diagram
12) List of signals
13) Operator's manual
14) Product manuals
15) Calculation for uninterrupted power supply (UPS) dimensioning
16) High-quality SCD file.

(Please refer to chapter 5.23.25.11 which 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.)

5.23.33 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.

5.23.34 Availability Calculations

The Contractor shall submit availability calculations for the offered substation automation system.

5.23.35 Testing and Commissioning

Testing and commissioning of the SAS must be performed by the engineer from manufacturers. Site Acceptance test shall be carried out as per the approved list from PGCB and any requirement from site shall be complied by the commissioning engineer. The contractor may have to provide evidence of the manufacturer’s authentication regarding the commissioning engineer/personnel and his experience in the relevant field.

5.24 Trip Circuit and Power Supply Supervision

5.24.1 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.

5.24.2 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.

5.24.3 **The trip circuit supervision scheme shall operate satisfactorily and correctly under such conditions.**

5.24.4 **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.**

5.24.5 **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.**

5.24.6 **Relay alarm elements should be equipped with self-resetting flag indicators.**

5.24.7 **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 origin.**

5.25 Busbar Voltage Selection

Where required, selected voltage references, one for each busbar, shall be employed for all indications, metering, protection and synchrocheck where appropriate. The correct voltage selection for the requirements of each circuit according to the busbar to which it is connected shall be obtained internal selection in the BCU or Relay by directly connecting voltage transformers. External busbar VT selection through auxiliary relays will not be accepted.

5.26 Synchrocheck

5.26.1 **Synchrocheck Scheme: Synchrocheck facilities are required at all circuit breakers controlling feeder circuits and bus coupler circuits, and LV circuit breakers controlling transformers.**

5.26.2 **The system provided under the Contract is to be to the approval of the Engineer and is to be such that the synchrocheck circuit must be established before the circuit breaker can be closed. Synchrocheck function will be performed by BCU (Bay Control Unit) for controlling from SAS or BCU. Synchrocheck function will be checked by Protective relays as shown in attached interlocking logics for controlling from Mimic.**

5.26.3 **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.**

5.26.4 **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 synchrocheck 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.

5.26.5 **It shall only be possible to operate on one circuit at a time.**

5.27 Interlocking and Control Authority

5.27.1 **Independent and identical interlocking/blocking conditions have to be established for Mimic and BCU control. Interlocks in Local Control Cubicle (LCC) will also be same in case of GIS.**

5.27.2 **For mimic control, interlocking/blocking conditions will be hardware based and established in CRP by taking the statuses of relevant devices to CRP in case of AIS. Contact multiplier relays can be used for the purpose. Wiring in the switchyard among the devices will not be accepted.**

5.27.3 **For controlling from BCU, interlock will be software based and established in BCU. Hardware based interlocks will never be bypassed in any mode of operation.**

5.27.4 **Interlock for maintenance mode will be established in LCC for GIS.**

5.27.5 **Interlock bypassing option should be available in Control Panel; should also be available in LCC in case of GIS.**

5.27.6 **More than one device will not be allowed for operation at the same time.**

5.27.7 **CB internal blocking such as Gas pressure lock-out, spring discharge etc will be applicable for all modes of operations.**

5.27.8 **Control Authority Switch shall be installed in Control Panel having 4 (four) independent positions: Off, Mimic, BCU and Remote. The switch can be in only one position at any given time.**

5.27.9 **Interlocking logics and control authorities must comply with the attached Interlocking Logic drawings.**

5.28 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 in order to agree the circuit schemes and operating modes.

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.

Protection SLD, Trip matrices and Interlocking logic block diagrams have to be integral part of schematic drawings of each Control and Protection panel.

5.29 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.

5.30 Energy Meter (Tariff Metering)

5.30.1 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

SL. No.	Description	Unit	PGCB's requirements	Bidder's data
1	Manufacturer's name		CEWE/Elster/Landis+Gyr/EDMI/SEL	
2	Country of Manufacturing		France/UK/USA/Switzerland/Sweden/Germany/EU/Canada	
3	Model		Should be filled up by bidder	
4	Meter type		Numerical, programmable, multi-function tariff meter	
5	Housing & mounting		Flush/surface mounting housing and capable of sustaining in harsh environmental condition	
6	Panel mounting kit		Should be supplied	
7	Display language		English	
8	Connection type		CT/VT operated, 3-phase, 4 wires, solidly grounded neutral	
9	Installation		Indoor installation	
10	Type of socket		To be mentioned	
11	Number of elements	Nos	3 (three)	
12	Number of terminals	Nos	At least 10 (ten)	
13	Current range	A	1 to 10, user programmable	
14	Starting Current	A	0.1% of nominal	
15	Continuous Thermal current rating	A	1.5*In or higher	
16	Short time thermal rating	A	10*In or higher for 1sec	
17	Voltage range	V AC	50 to 82.5 (P-N) or higher range, Burden-10MΩ	
18	Overload voltage	V AC	1.2*Vn, continuous	
19	Meter constant	Imp/	Shall be mentioned	

SL. No.	Description	Unit	PGCB's requirements	Bidder's data
20	Multiplication factor		The following shall be inscribed on the mater. Display reading X CT ratio X PT ratio = Actual reading in KWh	
21	Visual indication of operation		Pulse indicator on the front of meter as per meter constant.	
22	Burden			
	22.1 Current Circuit	VA/phase	< 0.1 @ 1A, < 0.5 @ 5A	
	22.2 Voltage Circuit (with auxiliary power)	VA/phase	< 0.1	
	22.3 Voltage Circuit (with self power)	VA/phase	< 6VA	
23	Auxiliary supply range		Dual Power Supply: i. 80V to 240V AC/DC or higher range ii. Self Power with VT voltage (80V to 130V AC)	
24	Operating frequency		50Hz (±5%)	
25	Measuring mode		True 4 quadrant	
26	Accuracy class		0.2S for kWh, 0.5 for kVARh	
27	Losses at nominal load		To be mentioned	
28	Remote communication		Standard metering protocol, MODBUS; Communication facility to Network Control Center should be available	
29	Communication port		• The meter must be provided with a suitable communication port to allow down loading of desired information stored in the meter to a PC via hand held data logger as per IEC 1107 or equivalent standard. • Following communication ports have to be available: ○ Optical 1107 Port (front mounted): supporting DLMS protocol ○ RS485: supporting MODBUS protocol ○ RS232: Optional ○ Ethernet: Optional	
30	Software requirement		• Should be able to configure and monitor with user-friendly PC-based tool. • Necessary software for configuration and parameterization has to be supplied free of cost and without any time-bound license	

SL. No.	Description	Unit	PGCB's requirements	Bidder's data
			• The parameterization software must run on Windows operating environment. • The software must be protected by software keys to control duplication and installation. • The software should have a customizable printing feature by task list. • The meter must be able to display or record meter ID, Program, Programmer ID, C. T. ratio, V. T. ratio, Total (KWh, KVarh, KVAh, KW, KVar, KVA, P.F); per phase (voltage, current, KW, KVar, KVA, P.F, phase voltage angle, phase current angel); Load profile having minimum 8(eight) Channels data stored in different interval for 90 days. • Tamper feature: The meter must have Errors & Warnings codes, History log and Event log (minimum 400events) to record date & time of all power outages, demand resets, time change. • The Meter should be able to display the phasor diagram.	
31	Meter sealing condition		Hermetically or Ultrasonic welded	
32	Display options		Built-in HMI LCD display, configurable display, including meter ID, power quadrant display	
33	Integration period		30 (thirty) minutes	
	Resetting period		1 (one) month	
	Cumulative MD transfer		Built-in	
	Cycle Timing device		Built-in	
34	Normal display list		• Complete LCD test, Present date, Present time • Current billing total kWh-Del, Current billing total kWh-Rec • Current billing total kVARh-(Q1+Q4), Current billing total kVARh-(Q2+Q3) • Current billing maximum kW-Del, Current billing maximum kW- Del Date, Current billing maximum kW-Del Time, Current billing cumulative kW-Del • Current billing maximum kW-Rec, Current billing maximum kW-Rec Date, Current billing maximum kW-Rec Time, Current billing cumulative kW-Rec	

SL. No.	Description	Unit	PGCB's requirements	Bidder's data
			• Phase A voltage, Phase B voltage, Phase C voltage • Phase A current, Phase B current, Phase C current • Phase A voltage angle, Phase B voltage angle, Phase C voltage angle • Phase A current angle, Phase B current angle, Phase C current angle • System PF-arithmetic, Line frequency	
35	Alternate mode display list		• Complete LCD test, Present date, Present time • Current billing total kWh-Del, Current billing total kWh-Rec • Current billing total kVARh-(Q1+Q4), Current billing total kVARh-(Q2+Q3) • System PF-arithmetic, Line frequency	
36	Data storage		The meter shall have sufficient capacity (minimum 400 KB) to store the following readings and data in non-volatile memory even in case of power failure. • Equipment identification codes, security codes and access codes. • Number of power interruption with date & time (minimum 100 events). • Latest power failure time & date • Date & time of meter tempering. (Voltage & Current missing, demand reset, time change). • Event logs • Current & Previous registered in month KWh (Peak & off-peak), Total KVarh (Q1+Q4) • Current & Previous month registered with maximum KW demand since last MD reset with time and date of its occurrence. The meter must have sufficient capacity to store data at 30 (thirty) minutes interval for at least 90 (ninety) days. • Load Profile data [kWh, KVarh (Q1+Q4) • Phase voltage • Phase amps	
37	Data logging and event recording		Should be available	
38	In built clock		Should be available	
39	Provision of GPS synchronization		Should be available	
~~**40**~~	Additional Features		Insert	
41	Construction		The meter shall be completely self-contain round socket or enclosure type. The meter cover shall be made of polycarbonate/acrylic /phenolic /resin and	

SL. No.	Description	Unit	PGCB's requirements	Bidder's data
			socket cover shall be made of metal polycarbonate/ acrylic /phenolic /resin. The meter cover and socket /enclosure shall be provided with security sealing provisions to prevent unauthorized access to the internal meter works and socket /enclosure sealing shall be designed to accommodate both padlock and wire type seal.	
42	Terminal		Socket connected type/ Non-symmetrical, bottom entry, front connection, and connection type with extended terminal cover: Minimum 10 Terminals to accommodate up to 06 sq. mm size of cable. The terminal cover for the offered energy meter shall be extended type, and which can be sealed independently. There shall be free space between bottom of the terminal and the bottom of the terminal cover.	
43	Environment requirement			
	43.1 Ingress protection		IP54 or better	
	43.2 Operating temperature		-10^0C to $+60^0$C	
	43.3 Storage temperature		-40^0C to $+80^0$C	
	43.4 Humidity range		0% to 95%, non-condensing	
44	Weight of the meter		To be mentioned	
45	Dimension of the meter		To be mentioned	
46	Outline, drawing and leaflets		To be provided	
47	Performance curves for balanced and unbalanced load		To be mentioned	
48	Year of manufacture		To be mentioned	
49	Minimum Battery Service life and shelf life	Years	10 (ten) & 15 (fifteen) respectively	
50	Meter service life	Years	15 (fifteen)	
51	Reference standard		Relevant ANSI/IEC standard	
52	Warranty	Days	540	
53	Type test certificate		Should be provided	

5.30.2 Software keys (without any time bound license) have to be provided for the supplied meters against each substation covering full administrative control.

5.30.3 01 (one) Nos Optical communication cord (supporting 1107 protocol) have to be supplied with the meters against each substation for allowing full control and configuration. The communication cord should be with USB connection terminal at the end of PC connection.

5.30.4 On-site accuracy test has to be performed for all Tariff/Energy Meters prior to the

commissioning.

APPENDIX A1

(Technical Requirements) Refer to Schedule-E

APPENDIX A2 (If required by BoQ)

PHASOR MEASUREMENT UNIT

1. *General*

The Bidders are encouraged to offer their standard products that meet or exceed the specification requirements. Although the bidder is encouraged to use as much standard hardware and software as possible, the proposal will be judged by its conformance to the Specification. The proposal shall clearly identify all deviations from the Specification to help EMPLOYER evaluate the degree of conformance of the Bidder's offering.

The substations /Generating stations normally are provided with CTs on each bay of the switchyard and CVTs in each transmission line bay and on each bus. Generally CTs have one metering core and four protection cores. The CVTs are provided with three cores, one for metering and other two for protection. The PMUs to be supplied shall be connected to either of these CT and CVT cores.

The specification identifies some minimum requirements for each of the major component which are essentially required for measurement of complex quantities and transmitting the same to the PDC (Phasor Data Concentrator) at control center. The delivered system is expected to provide meaningful measurement of the acquired data so that it is useful to the operators in assessing the current state of grid and can also be used for carrying out the post- facto analysis. The offered PMU must be in operation at least for one year as on date of bid opening.

1.1. Intent of Specification

The intent of this Specification is to describe the technical requirements for supply installation, testing, commissioning & integration of PMUs. The PMUs to be supplied under this Specification shall be installed at the Substations/Power stations and shall communicate to the Phasor Data Concentrator (PDC) at the Control Centre on IEEE C37.118 format.

1.2. Scope of Work

The scope of work shall include site survey, planning, design, engineering, testing, supply, integration, transportation & insurance, delivery at site, storage, installation, training, commissioning, demonstration for acceptance and documentation of:

a) Phasor Measurement Units (PMUs) along with GPS

b) All cabling, wiring, terminations and interconnections to the equipment including necessary trench/surface conditioning to interconnect the PMUs to the installed or being installed communication equipment by the Owner.

c) Integration of supplied PMUs to PDC conforming to IEEE C37.118 standard.

d) Cable connection / interfacing with communication equipment.

e) In case of multiple PMU at a substation/power plant the Router with firewall shall be provided which shall interface PMUs on one side and communication equipment on the other side.(

f) Any other work which is not identified in the specification but is required for completion of the work within intent of the specification shall also be in the scope of the Bidder.

g) On-site training of the Employer personnel.

h) Maintenance of the supplied equipment for 4 years after the one year warranty period.

The list of substations/power plants where PMUs are to be installed are indicated at Table-I and BOQ is specified at Table-2. The Data Requirement Sheet (DRS) to be submitted along with the Bid is attached at **Annexure-I**.

The Bidder shall indicate the Communication speed required for single PMU at 25 samples/second in their offer.

1.3. PMU Requirements

The offered PMUs shall be complete in all respect so that they can be installed at the substation/power plant and can communicate with Control centre having Phasor Data Concentrator (PDC). The necessary cable and connector and installation hardware shall also be supplied by the bidder. The PMUs shall normally be installed near to the control & relay panels and CT/CVT connections to the PMU shall be extended from the control & relay panels. The PMUs shall conform to IEEE C37.118 standard and shall be designed to meet the following requirements:

a. The PMUs shall be designed to measure the electrical parameters in the power system frequency band of 45-55 Hz.

b. The supplied PMU will be standalone in the substation control rooms /relay panel room.

c. The auxiliary power supply to PMUs will be provided from the station DC

which is used for control and protection of substation devices. Accordingly the PMUs shall be suitable to operate on unearthed 220 V or 110V (+10%, -15%) DC power supply depending upon the station DC supply available.

d. The minimum offered configuration of PMUs shall have at least 9 analog input channel (1 set of 3-phase voltages, two set of 3-phase current) and 8 digital inputs. In case of substations & power plants where all the control & relay panels are installed in a single room, the Bidder may offer higher configuration to meet the requirement of multiple feeders and BOQ may be adjusted accordingly. Typical configuration diagram is shown in **Annexure- II.**

e. The PMUs shall be used to measure the following:

- 3 phase positive sequence voltages as magnitude and angle (polar form) quantities
- 3 phase positive sequence currents magnitude and angle (polar form) quantities

f. All the measurements shall be tagged with UTC (Coordinated Universal Time). The time tagging accuracy shall be at least one micro-second.

g. The PMU output shall be in IEEE C37.118 format and shall communicate with the PDC in the same format. The accuracy of the measurements shall be as per the IEEE C37.118 standard level 1.

h. The PMUs shall be suitable for configuring the data sampling rate of 10, 25, 50 samples per second. Actual rate shall be user selectable.

i. The PMUs shall have continuous self monitoring ,diagnostic feature and capable to identify & communicate problems and shall generate alarm in case of any abnormality which shall be displayed locally as well as shall be transferred to the PDC.

j. The PMU design shall ensure that the impact of frequency fluctuation (45-55 Hz) on accuracy is within permissible limit as per prevailing standards.

k. Testing & configuration accessories such as test switch, connector ,software etc which are not in-built to the PMUs but are required for testing and configuration changes, at least one set of such testing & configuration accessories shall be supplied complete with necessary hardware.

l. The PMUs shall communicate with PDC on Ethernet interface over the communication link provided by the employer. One communication port of 10/100/1000 Base Tx for TCP/IP for streaming data in IEEE C 37.118 format shall be provided in the PMU. Additional optical remote communication ports 10/100/1000 Base Tx for TCP/IP shall also be available for streaming data in IEEE C37.118 format.

m. There shall be provision for HMI (Human Machine Interface) in PMU to perform setting changes. In addition HMI should display the measured quantities for ease during testing. The Operation indications and time tagged events shall be available by the Local HMI. Alternatively Portable configuration device for PMUs at end can be provided for configuring the PMUs.

n. Remote configuration facility shall be provided in PMU and the supplier shall supply the software required for remote configuration of PMU.

o. Remote firmware upgrade feature shall be made available.

p. PMU shall be capable of sending data in Unicast and multicast both.

1.4. GPS based Time Facility

GPS based time facility to synchronize PMU clock with UTC source, shall be provided for each PMU. The time receiver shall include propagation delay compensation and shall also include an offset to permit correction to local time to achieve time accuracy of at least 1 microsecond. The time receiver shall detect the loss of signal from the UTC source and a loss-of-signal event shall be sent to the PMU which will be transferred to PDC and shall result in an alarm at PDC. Upon loss of signal, the PMU time facility shall revert to an internal time base. The internal time base shall have minimum stability of 1pps. Within five minutes of reacquisition of signal, the time shall return to within 1.5 micro-second of UTC. Proper correction of leap second shall be provided.

1.5. Phasor Data Concentrator (PDC) Requirements

The PMU to be supplied shall communicate to the PDC. The PDC is not in the scope of the present specification. However, the PDC to which PMUs to be integrated shall meet atleast the following features.

- Shall support data streaming in IEEE C37.118 format.
- Shall be capable of receiving data in Unicast and Multicast.
- PDC shall be able to receive the loss of signal event of the time receiver from PMU and shall result in an alarm at PDC.
- PDC shall support Remote configuration of PMU.

1.6. Environmental Requirements

The PMU will be installed inside buildings without temperature or humidity control. The PMU shall be capable of operating in ambient temperatures from -10 deg C to +55 deg C and relative humidity up to 10-90% non-condensing.

1.7. PMU Panel Construction

a) The PMUs shall be installed at the substation control room where the space in the existing panels may be available. The supplied PMU may be mounted in the existing panel wherever the space in the panel is available. The stand alone panel shall be provided, if space in the existing panel is not available.

b) Panels shall be free standing surface or flush type and shall comprise structural frames completely enclosed with specially selected smooth finished, cold rolled sheet steel of adequate thickness for weight bearing members of the panels such as base frame, front sheet and door frames, as well as for sides, door, top and bottom portions.

1.8. PMU Panels

The panel enclosures shall meet the following requirements:

a) The enclosures shall be finished inside and out. All cabinet metal shall be thoroughly cleaned and sanded, and welds chipped to obtain a clean, smooth finish. All surfaces shall be treated to resist rust and to form a bond between the metal and the paint. Enclosures (except for server racks) shall confirm to IP-31 degree of protection in accordance with IS-2147. All the louvers shall be provided with suitable wire mesh.

b) Enclosures shall be floor mounted with front and rear access to hardware and Wiring.

c) Moving assemblies within the enclosure, such as swing frames or extension slides, shall be designed such that full movement of the assembly is possible without bending or distortion of the enclosure or the moving assembly. Enclosures shall not require fastening to the floor to preclude tipping of the enclosure when the moving assembly is extended.

d) Cable entry shall be through the bottom. No cables shall be visible, all cables shall be properly clamped, and all entries shall be properly sealed to prevent access by rodents.

e) Cooling air shall be drawn from the conditioned air within the room. Ducted or directed cooling air to the enclosures will not be supplied by Employer.

f) All wiring shall use copper conductors. Conductors in multi core cables shall be individually colour coded.

g) Wiring within the enclosures shall be neatly arranged and securely fastened to the enclosure by non-conductive fasteners. Wiring between all stationary and moveable components, such as wiring across hinges or to components mounted on extension slides, shall allow for full movement of the component without binding or chafing of the wire.

h) All materials used in the enclosures including cable insulation or sheathing, wire troughs, terminal blocks, and enclosure trim shall be made of flame retardant material and shall not produce toxic gasses under fire conditions.

i) All enclosures shall be provided with suitable internal lighting lamp, 230 VAC 15/5A duplex type power socket & switch for maintenance purpose.

j) The finish colours of all enclosures/panels shall be finalized during detailed Engineering.

1.9. Earthing

a) All panels shall be equipped with an earth bus securely fixed. Location of earth bus shall ensure no radiation interference for earth systems under various switching conditions of isolators and breakers. The material and the sizes of the bus bar shall be at least 25 X 6 sq.mm perforated copper with threaded holes at a gap of 50mm with a provision of bolts and nuts for connection with cable armours and mounted equipment etc for effective earthing provision shall be made for extending the earth bus bars to adjoining panels on either side.

b) Provision shall be made on each bus bar of the panels for connecting substation earthing grid. Necessary terminal clamps and connectors for this purpose shall be included in the scope of supply of Bidder.

c) Panels shall be connected to the substation control room earth system at least at two places separately.

d) All metallic cases of PMUs shall be connected to the earth bus by copper wires of size not less than 2X2.5 sq. mm. The Colour code of earthing wires shall be green.

e) Looping of earth connections which would result in loss of earth connection to other devices when the loop is broken, shall not be permitted. However, looping of earth connections between equipment to provide alternative paths to earth bus shall be provided.

1.10. Interconnections

The bidder shall be responsible for laying and termination of all cables at required under the project which includes interconnections among bidder supplied equipment and their interconnection with employer's panels. Testing and commissioning of these interconnections shall also be done by the bidder.

The signals cables for communication shall be shielded type to provide suitable protection against noise and electromagnetic interference. All the cables shall be suitably sized to meet the functional requirements. Shielded/Armored cables shall be used for other requirements. These external cables (except communication cables) shall have the following characteristics:

- Minimum core cross-section of 2.5/4 mm^2 (depending upon site requirements) for PT cables and 2x2.5 mm2 for CT cables, 2.5 mm2 for Power & Control outputs and 1.5 mm2 for Digital Status inputs shall be provided.
- Rated voltage of cables shall be Uo/U of 0.6/1.1KV

The Communication cable shall be of shielded, twisted pairs and of minimum 0.22sq mm size as per IS 1554 Part- I.

1.11. Router

In case of multiple PMUs at a substation/power plants all the PMUs shall be connected to the communication equipment through router. The router shall interface PMUs on one side and communication equipment on the other side. Router shall be provided with following features.

S.No	Description of the	Minimum Quantity of the features
1.	Functions	High performance Routing for data
2.	Routing Capability	Static & Dynamic routing
3.	Processing capacity	Minimum 2Mpps
4.	IPSec VPN tunnels	Minimum 10
5.	Features to support	QoS, MPLS, Security, Broadband, Multiservice, Voice, IP to IP Gateway
6.	Routing protocols	EIGRP, IGRP, IS-IS, OSPF, BGP, ARP, IPCP, IP forwarding, VLAN & MPLS etc.
7.	Network protocols	TCP/IP, IPv4,IPv6, OSI, Telnet, UDP, DHCP
8.	Network management	Using SNMP Protocol
9.	Minimum inbuilt software firewall features required	a) Data encryption supported DES (56 BITS) 3des (168 bits) and hashing algorithm like MD5 and SHA-1 b) Filtering of packets based on Source address, Destination address, Protocol type, User, Port number, URL c) Filtering of Protocols such as FTP, SMTP,

		HTTP, SNMP, UDP, ICMP, RPC, DNS, DHCP, ARP d) Detailed system logging
10.	Speed configurability at each port	All ports shall be configurable from 64kbps to 2Mbps
11.	Interface ports	a) For connecting to communication equipment on 1Gbps Ethernet port or G.703 Port. b) 1Gbps Ethernet port for each PMU
12.	Mounting	Rack mountable
13.	Minimum no. of concurrent TCP sessions	10

1.12. Training

Training shall be conducted by contractors personal who are experienced instructor. All necessary training material shall be provided by the contractor. Each trainee shall receive individual copies of all technical manuals and all other documents used for training. The training courses, and their duration in each courses are identified in Table-1

Table-1: Training Requirements

S.No	Training Course	Total No. of days	Participation
1	PMU– Technical internals	3	Persons responsible for Installation and commissioning

1.13. Spares

One spare PMU identical to PMU in Main items as a spare shall be supplied by the contractor, under the contract as indicated in **Table-2 (BOQ).**

1.14.Maintenance

Contractor shall be responsible for providing "Maintenance on call" of the system under warranty including supply of spares for ensuring the successful operation of the system. The maintenance period shall be for 4 years after one year of warranty period. The maintenance period shall be extended for a further period of 3 years at the same price in the final offer of the vendor with same terms & conditions. During this period, the contractor shall have prime maintenance responsibility for the system. The response time for the maintenance shall be less than 24 hours excluding the journey period.

1.15. Documentation

Complete documentation is required to support PMU setup, operation and maintenance. The documentation shall include following:

a) Procedures for PMU setup and use with regards to all features.

b) Documentation of procedures regarding routine maintenance including use of system diagnostics.
c) Detailed connection diagrams showing how the PMUs are installed at site.
d) A complete copy of PMUs functional design
e) Details of PMU database.
f) Details of hardware/software and as built system.

All documentation shall be delivered in both electronic format (e.g. PDF, MS WORD, Hypertext, etc.) on CDs/DVDs/USB drive, and in hardcopy format. Sufficient on-line, documentation, such as help screens, user guidance messages, context-sensitive help information links, etc., shall be included with the system to minimize the need for users to consult the hardcopy documentation**.**

1.16. Testing of PMUs

The offered PMUs shall conform to the type tests as per applicable standard and the bidder shall supply type tested PMU. The bidder shall submit PMU type test reports along with the bid for the offered make and model. The type test report shall include at least these tests indicated as follows:

A. Level-1 accuracy test as per IEEE C37.118 standard
B. Electromagnetic compatibility (EMC), Immunity conforming to the requirements of IEC-60255/IEC 61000.
C. Emission test conforming to the requirements of EN 55011
D. Insulation Test per IEC 60255-5
E. Environmental Test as per IEC 60068-2-2

In case the type tests are conducted after placement of order, the Bidder shall get the Type Test procedure approved by the Employer/Owner and then these tests shall be conducted at bidder's own cost in presence of owner representative. The Bidder shall offer the PMUs for inspection & Factory acceptance Tests (FAT). During FAT the supplier shall demonstrate all the functions of PMU. The compatibility to integrate with PDC in accordance to IEEE C37.118 shall also be demonstrated. These functionalities shall also be demonstrated at site at the time of commission of PMUs at site. The procedure for all the testing shall be agreed between the supplier and purchaser before proceeding for the testing.

Locations for Installation of PMU

Table-1

S.No.	Name of Station	Owner Utility	Voltage Level	Communication type
1				
2				
3				
4				
5				

Table-2

Typical BOQ (Bill of Quantity)

S.No	Name of the item	Unit	Qty
1	PMU (complete with all necessary accessories, cables etc. as per specification) with minimum 1 three phase voltage & 2 three phase currents	Nos	--
2	Panel for mounting PMUs and other equipment	Nos	--
3	GPS (complete with all necessary accessories, cables etc. as per specification)	Nos	--
4	Router (In case of multiple PMUs)	Nos	--
	Spares		
5	PMU (complete with all necessary accessories, cables etc. as per specification)	Nos	--
	Services		
6	Installation and commissioning of PMUs and associated items at site along with all interconnections with CT, PT and communication equipment complete in all respect as per technical	Nos	--
F	**Training**	Lot	1
G	**Maintenance**		
1	AMC of the equipment being supplied for 1 year during warranty period	Lot	1
2	AMC of the equipment being supplied for 4 years after warranty period	Lot	1

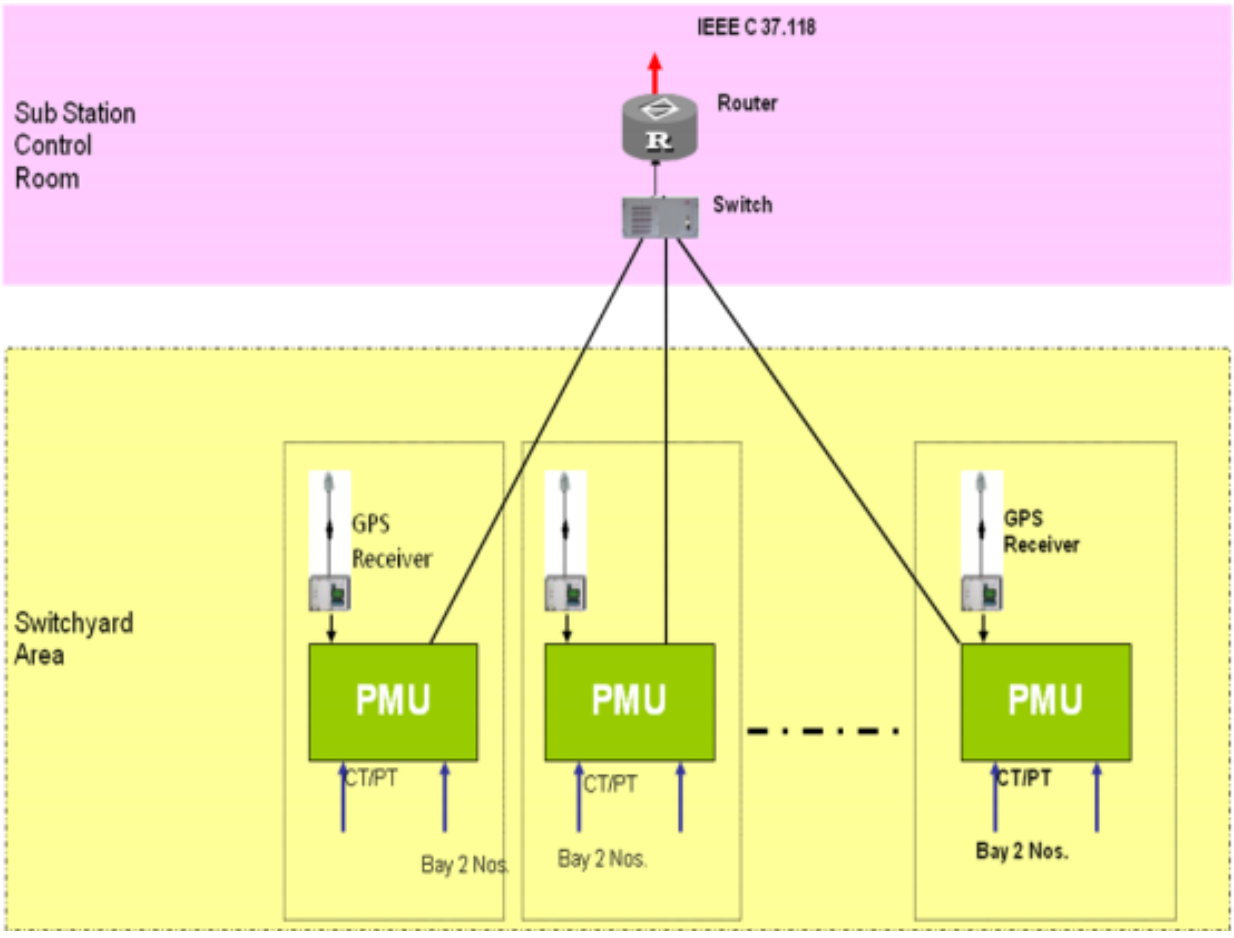
Annexure –I

Data Requirement Sheet to be submitted by the Bidder along with Bid:

S.No	Item Description	Offering as per Bidder
1.	Make & Model of PMU	
2.	Compliance to IEEE C37.118	Yes / No
3.	No of 3 phase Current input	
4.	No of 3 phase Voltage input	
5.	Accuracy of measurements	
6.	Data Sampling Rates provided	
7.	Power Frequency measuring range	
8.	PMU configuration feature	
9.	DC Supply operating range	
10.	Baud rate required at 25 samples/second for Communicating with PDC	
11.	Make & Model of Router	
12.	Make & Model of GPS	

Annexure –II

Typical Hardware configuration Diagram for Multiple PMUs



Guaranteed Technical Particulars (GTP) of Protection, Control & Metering Cubicle

SN	Description	Unit	Requirement	Guaranteed Data
1	**General**			
1.1	Enclosure Standard of reference		IEC 61439-1-2	
1.2	Installation		Free Standing Floor Mounted	
2	**Cubicle**			
2.1	Frame and Door Manufacturer		Rittal/Equivalent	
2.2	Origin of Frame and Door		Germany/Italy/ EU/Equivalent	
2.3	Origin of Screws, Bolts and Hinges		Germany/Italy/ EU/Equivalent	
2.4	Steel Grade of Sheet, Frame and Door		Cold Rolled Sheet Steel, SAE 304	
2.5	Panel or Cubicle Type		Swing Frame Type and Welding Free	
2.6	Sheet Thickness	mm	≥ 3mm for weight bearing members, ≥ 2mm for others	
2.7	Ingress Protection		IP54 or Better	
2.8	Gasket		NEMA 12/13, UL 50 and IEC 60529	
2.9	Gasket Material			
2.10	Enclosure Door Type		Glass for Front Door	
2.11	Panel Interior & Exterior Color		RAL7032	
2.12	Swing Frame Swing Angle	deg	≥ 120	
2.13	Glass Door Swing Angle	deg	180	
3	**Terminal Block**			
3.1	Country of Origin		Germany/Italy/EU/Equivalent	
3.2	Manufacturer's Name		Phoenix Contact/WAGO/Equivalent	
3.3	Standard		IEC 60947-7-1, IEC 60998, and utility best practices	
3.4	**Terminal Block for Grounding**			
3.4.1	Type		Pick-off terminal	
3.4.2	Connection Method		Screw connection	
3.4.3	Nominal cross section	mm^2	35	
3.4.4	Model		AZK 35 or Equivalent	
3.4.5	Current Rating	A	100	
3.4.6	Spare Terminal	%	20	
3.5	**Terminal Block for Main AC & DC**			
3.5.1	Type		Feed-through	
3.5.2	Connection Method		Spring-cage	
3.5.3	Nominal cross section	mm^2	10	
3.5.4	Model		ST-10 or Equivalent	
3.5.5	Voltage Rating	kV	0.8/2	
3.5.6	Current Rating	A	50	
3.6	**Terminal Block for Distribution AC & DC**			
3.6.1	Type		Feed-through	
3.6.2	Connection Method		Spring-cage	
3.6.3	Nominal cross section	mm^2	2.5	
3.6.4	Model		ST-2.5 or Equivalent	
3.6.5	Voltage Rating	kV	0.8/2	
3.6.6	Current Rating	A	10	
3.6.7	Spare Terminal	%	20	
3.7	**Terminal Block for CT & VT**			

Guaranteed Technical Particulars (GTP) of Protection, Control & Metering Cubicle

SN	Description	Unit	Requirement	Guaranteed Data
3.7.1	Type		Disconnect with shorting facility	
3.7.2	Connection Method		Screw connection	
3.7.3	Nominal cross section	mm^2	6	
3.7.4	Model		URTK/S or Equivalent	
3.7.5	Voltage Rating	kV	0.8/2	
3.7.6	Current Rating for CT TB	A	10	
3.8	**Terminal Block for Control**			
3.8.1	Type		Knife-disconnect	
3.8.2	Connection Method		Screw connection	
3.8.3	Nominal cross section	mm^2	4	
3.8.4	Model		UDK 4-MTK-P/P or Equivalent	
3.8.5	Voltage Rating	kV	0.6/1	
3.8.6	Current Rating	A	10	
3.8.7	Spare Terminal	%	20	
4	**Wiring Cable**			
4.1	Local Manufacturer's Name		Poly Cables/Equivalent	
4.2	Global Manufacturer's Name		Nexans/Helukabel/Far East/Baosheng/Equivalent	
4.3	Country of Origin		Bangladesh/China/Germany/Equivalent	
4.4	Standard		IEC 60228 Class 5, IEC 60332	
4.5	Conductor Material & Type		Flexible Copper	
4.6	Insulation Material		FRLSH(preferable)/FRLS/LSZH	
4.7	Temperature Rating	°C	90	
4.8	Flame Retardance		IEC 60332-1, IEC 60332-3, IEEE 1202, BS 4066	
4.9	Smoke & Halogen Emission		IEC 61034, IEC 60754	
4.10	**Wiring Cable for Grounding**			
4.10.1	Voltage Rating	V	300/500	
4.10.2	Conductor Size	mm^2	6.0	
4.10.3	Color Code		Green+Yellow	
4.11	**Wiring Cable for Main AC & DC**			
4.11.1	Voltage Rating	V	600/1000	
4.11.2	Conductor Size	mm^2	6.0	
4.11.3	Color Code		Brown-Blue	
4.12	**Wiring Cable for Distribution AC & DC**			
4.12.1	Voltage Rating	V	600/1000	
4.12.2	Conductor Size	mm^2	2.5	
4.12.3	Color Code		Brown-Blue	
4.13	**Wiring Cable for CT & VT**			
4.13.1	Voltage Rating	V	600/1000	
4.13.2	Conductor Size for CT Circuit	mm^2	2.5	
4.13.3	Conductor Size for VT Circuit	mm^2	2.5	
4.13.4	Color Code		Red-Yellow-Blue-Black	
4.14	**Control Cable**			
4.14.1	Voltage Rating	V	600/1000	

Guaranteed Technical Particulars (GTP) of Protection, Control & Metering Cubicle

SN	Description	Unit	Requirement	Guaranteed Data
4.14.2	Conductor Size	mm^2	1.5	
4.14.3	Color Code		Grey	
4.14.4	Color Code for TRIP		Orange	
5	**Mimic Indicator**			
5.1	Type		Whole Supply / Custom Made with Components	
5.2	Country of Origin		Germany/Italy/EU/Equivalent	
5.3	**Indication Lamp**			
5.3.1	Type		LED Type	
5.3.2	Manufacturer's Name		Schneider/ABB/ComElectric/Domo/Gave/ Equivalent	
5.3.3	Country of Origin		EU/Equivalent	
5.3.4	Voltage Rating		As per design requirement	
5.4	**Push Button**			
5.4.1	Manufacturer's Name		Schneider/Siemens/ABB/Eaton/Honeywell/Equival ent	
5.4.2	Country of Origin		EU/Equivalent	
5.4.3	Voltage Rating		As per design requirement	
5.4.4	Spare Contact	%	10	
5.5	**Control Switch**			
5.5.1	Type		Discrepancy Type	
5.5.2	Manufacturer's Name		Schneider/Siemens/ABB/Eaton/Honeywell/Equival ent	
5.5.3	Country of Origin		EU/Equivalent	
5.5.4	Voltage Rating		As per design requirement	
5.5.5	Spare Contact	%	10	
5.6	**Selector Switch**			
5.6.1	Selector Positions		As per design requirement	
5.5.2	Manufacturer's Name		Schneider/Siemens/ABB/Eaton/Honeywell/Equival ent	
5.5.3	Country of Origin		EU/Equivalent	
5.5.4	Voltage Rating		As per design requirement	
5.5.5	Spare Contact	%	10	
5.7	**Muti Function Meter (MFM)**			
5.7.1	Type		3P4W 3 Line Display	
5.7.2	Manufacturer's Name		As per design approval	
5.7.3	Country of Origin		Reputed Country	
5.7.4	Accuracy Class		0.5	
5.7.5	Current Rating		1A/5A	
5.7.6	Voltage Rating	V	100-200	
5.7.7	Communication		Modbus RTU/TCP-IP	
5.8	**Volt Meter**			
5.8.1	Type		1/3 Line Display	
5.8.2	Manufacturer's Name		As per design approval	
5.8.3	Country of Origin		Reputed Country	

Guaranteed Technical Particulars (GTP) of Protection, Control & Metering Cubicle

SN	Description	Unit	Requirement	Guaranteed Data
5.8.4	Accuracy Class		0.5	
5.8.5	Voltage Rating	V	100-200	
5.9	**Ammeter**			
5.9.1	Type		1/3 Line Display	
5.9.2	Manufacturer's Name		As per design approval	
5.9.3	Country of Origin		Reputed Country	
5.9.4	Accuracy Class		0.5	
5.9.5	Current Rating		1A/5A	
5.10	**Annunciator**			
5.10.1	Type		Test, Set, Reset, Acknowledgement with Buzzer	
5.10.2	Manufacturer's Name		Omniflex/ABB/Mikro/Equivalent	
5.10.3	Country of Origin		Reputed Country	
5.10.4	Voltage Rating		110V/220V DC	
5.10.5	Window Size		As per design requirement	
6	**Panel Accessories**			
6.1	**AC and DC Breaker**			
6.1.1	Manufacturer's Name		ABB/Siemens/Schneider/Equivalent	
6.1.2	Country of Origin		Germany/EU/Equivalent	
6.1.3	Rated Current		As per design requirement	
6.1.4	Auxiliary Contact		≥ 1	
6.2	**Lockout Relay**			
6.2.1	Type		Heavy Duty Electrical Reset with Indication	
6.2.2	Manufacturer's Name		ABB/Siemens/Schneider/Arteche/Equivalent	
6.2.3	Country of Origin		Germany/France/Spain/EU/Equivalent	
6.2.4	Tripping Time	ms	≤ 10	
6.2.5	Making Current	A	≥ 20	
6.2.6	Breaking Current	A	≥ 5	
6.2.7	Spare Contact	%	≥ 10	
6.2.8	Voltage Rating		As per design requirement	
6.3	**Trip Relay**			
6.3.1	Type		Heavy Duty	
6.3.2	Manufacturer's Name		ABB/Siemens/Schneider/Arteche/Equivalent	
6.3.3	Country of Origin		Germany/France/Spain/EU/Equivalent	
6.3.4	Tripping Time	ms	≤ 10	
6.3.5	Making Current	A	≥ 20	
6.3.6	Breaking Current	A	≥ 5	
6.3.7	Spare Contact	%	≥ 10	
6.3.8	Voltage Rating		As per design requirement	
6.4	**DC Changeover Relay**			
6.4.1	Type		Heavy Duty	
6.4.2	Manufacturer's Name		ABB/Siemens/Schneider/Arteche/Equivalent	

Guaranteed Technical Particulars (GTP) of Protection, Control & Metering Cubicle

SN	Description	Unit	Requirement	Guaranteed Data
6.4.3	Country of Origin		Germany/France/Spain/EU/Equivalent	
6.4.4	Operating Time	ms	≤ 10	
6.4.5	Spare Contact	%	≥ 10	
6.4.6	Voltage Rating	V	As per design requirement	
6.4.7	Voltage Operating Range	%Un	As per design requirement	
6.5	**Trip Circuit Monitoring Relay**			
6.5.1	Type		Pre Close and Post Close with internal resistor	
6.5.2	Indication		Phase wise LED	
6.5.3	Manufacturer's Name		ABB/Siemens/Schneider/Arteche/Equivalent	
6.5.4	Country of Origin		Germany/France/Spain/EU/Equivalent	
6.5.5	Spare Contact	%	≥ 10	
6.5.6	Voltage Rating	V	As per design requirement	
6.6	**Auxiliary Relay**			
6.6.1	Type		High Burden	
6.6.2	Purpose		Changeover, Supervision, Signal Multiplication	
6.6.3	Indication		LED or Mechanical Flag	
6.6.4	Manufacturer's Name		Phoenix Contact/ABB/Siemens/Schneider//Equivalent	
6.6.5	Country of Origin		Germany/France/Spain/EU/Equivalent	
6.6.6	Operating Time	ms	≤ 15	
6.6.7	Spare Contact	%	≥ 10	
6.6.8	Voltage Rating	V	As per design requirement	
6.7	**Multiplier Relay**			
6.7.1	Type		Low Burden and Manually Operable	
6.7.2	Purpose		Signal Multiplication	
6.7.3	Base		With Locking Mechanism	
6.7.4	Indication		Yes	
6.7.5	Manufacturer's Name		Phoenix Contact/ABB/Siemens/Schneider/ /Equivalent	
6.7.6	Country of Origin		Germany/France/Spain/EU/Equivalent	
6.7.7	Operating Time	ms	≤ 15	
6.7.8	Spare Contact	%	≥ 10	
6.7.9	Voltage Rating	V	As per design requirement	
6.8	**Test Block**			
6.8.1	Purpose		Secondary Testing	
6.8.2	Manufacturer's Name		GE/Siemens/Schneider/Arteche/Equivalent	
6.8.3	Country of Origin		France/Germany/Spain/EU/Equivalent	
6.8.4	Contact		14	
6.9	**Heater**			
6.9.1	Manufacturer's Name		Rittal/Civaux/Stego/ Equivalent	
6.9.2	Country of Origin		Germany/Spain/EU/Equivalent	
6.9.3	Voltage & Power Rating		250V AC, 50W	

Guaranteed Technical Particulars (GTP) of Protection, Control & Metering Cubicle

SN	Description	Unit	Requirement	Guaranteed Data
6.10	**Thermostat & Hygrostat**			
6.10.1	Manufacturer's Name		Rittal/Rose/Civaux/ Equivalent	
6.10.2	Country of Origin		Germany/Spain/EU/Equivalent	
6.10.3	Voltage Rating		240V AC	
6.10.4	Activation Mechanism		Temperature and Humidity	
6.10.5	Temperature Setting Range	°C	15-45	
6.10.6	Humidity Setting Range	%	70-95	
6.11	**Power Socket**			
6.11.1	Type		3 pin UK	
6.11.2	Manufacturer's Name		Rittal/Civaux/Stego/ Equivalent	
6.11.3	Country of Origin		Germany/Spain/EU/Equivalent	
6.11.4	Voltage & Current Rating		240V AC, 10A	
6.12	**Panel Lamp**			
6.12.1	Manufacturer's Name		ABB/Siemens/Schneider/Equivalent	
6.12.2	Country of Origin		EU/Equivalent	
6.12.3	Voltage & Power Rating		240V AC, 5W LED	
6.12.4	Activation Mechanism		with limit switch	
6.13	**Panel Duct**			
6.13.1	Manufacturer's Name		ABB/Siemens/Schneider/Legrand/ Equivalent	
6.13.2	Country of Origin		EU/Equivalent	
6.13.3	Material		PVC	
6.14	**Ferrule**			
6.14.1	Materials		Rubber or PVC type	
6.14.2	Marking		Cross Ferrule	
6.14.3	Print		Two line print with permanent ink	
6.15	**Earthing Bus**			
6.15.1	Earthing Bus Material		Copper	
6.15.2	Earthing Bus Size	mm	25 × 6	
6.16	**Louver**			
6.16.1	Type		With Filter	
6.16.2	Manufacturer's Name		Reputed Manufacturer	
6.16.3	Country of Origin		Germany/EU/Equivalent	
6.16.4	Voltage Rating	V	230V AC, 50/60Hz	
6.17	**Louver Fan**			
6.17.1	Manufacturer's Name		Reputed Manufacturer	
6.17.2	Country of Origin		Germany/EU/Equivalent	
6.17.3	Voltage Rating	V	230V AC, 50/60Hz	
6.17.4	Power	W	10~30	
6.17.5	Noise	dB	≤ 50	
6.18	**Wire Termination**			
6.18.1	Type		Solderless crimping type tinned copper lugs	
7	**Main Protection Relay**		Selected as per PSLD, GTP and Approved Vendor List	

Annexure 2

The Contractor may propose cubicle from local manufacturer other than OEM of Relay, SAS, DFDR & Energy (Tarrif) meter fulfilling with below mentioned criteria:

a) Manufacturer (assembler) shall have valid ISO 9001 certification.
b) Manufacturer (assembler) shall have at least 10 years of Panel manufacturing experience for Control, Protection & Metering.
c) Manufacturer (assembler) shall have at least 30nos of complete Control/Protection Panels (132kV and above) incorporating protective relays from one or more of the following OEMs: Hitachi/ABB (Switzerland/Sweden), Schneider/Areva/Alstom/GE (France/UK/US), Siemens (Germany), NR Electric (China) and SEL (USA/UK/Canada) within the last 10 years.
d) A valid Authorization Letter from the Relay manufacturers permitting the assembler to supply fully assembled Control, Protection, and SAS Panels using the relays mentioned in above clause (c) along with Employer-approved scheme drawings.
e) Evidence from end users confirming satisfactory operation of at least 10 complete Control/Protection Panels (132kV and above) for a minimum of three (3) years, either outside the bidder's country, or in the Employer's country.
f) The assembler must have test facilities to perform required tests of complete Control, Protection, and SAS Panels, DFDR & Metering Panels using calibrated test equipment meeting in the form of FAT/Routine/factory test in compliance with the Power Grid's standard practice. The assembler shall have sufficient test Engineer certified by relay manufacturer.

Note: Above criteria shall have to confirm during detail design and execution stage of the contract before manufacturing.

SECTION-6:

Auxiliary Power and Control Cables

Index of Contents

SL No.	Name of Items	Page No.
6.1	Scope	03
6.2	General Description of Installation	03
6.3	Standards	04
6.4	Cable Installation	04
6.5	Cable Construction	07
6.6	Types of Cable	08
6.7	Straight-through Joints	11
6.8	General Methods of Cable Installation	11
6.9	Cables laid Directly in the Ground	11
6.10	Cables drawn into Ducts	12
6.11	Cables installed in Concrete Trenches	13
6.12	Cables Supported on Racks, Trays, Etc.	13
6.13	Cables Installed on Structural Steelwork and Brickwork or Concrete	15
6.14	Terminations	15
6.15	Terminating and Jointing Conductors	16
6.16	Core Identification	16
6.17	Cable Identification and Schedules	17
6.18	Inspection and Testing	17

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

6.2.1 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.

6.2.2 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.

6.2.3 The Contractor shall provide an installation in accordance with the best modem practice and complete in every detail for continuous operation.

6.2.4 Cabling areas will include those which have natural ventilation. Cabling shall therefore be designed for the maximum ambient temperatures expected.

6.2.5 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.

6.2.6 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.

6.2.7 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.

6.2.8 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

6.4.1.1 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.

6.4.1.2 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.

6.4.1.3 Cables shall be derated to allow for the likely number of cables following a given route.

6.4.1.4 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

6.4.1.5 Control and instrumentation cables shall be screened/shielded to minimise interference, where necessary.

6.4.2 Installation Criteria

6.4.2.1 Specific requirements shall be as detailed in the project requirements.

6.4.2.2 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.

6.4.2.3 In general, to minimise interference, control cables and instrumentation cables shall be separated from power cables.

6.4.2.4 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.

6.4.2.5 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.

6.4.2.6 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

6.4.3.1 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.

6.4.3.2 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

6.4.4.1 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.

6.4.4.2 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

6.4.5.1 The Contractor shall be responsible for all cable sizing and routing design, procurement, installation and testing.

6.4.5.2 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

6.4.5.3 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.

6.4.5.4 Due allowance shall be made for the method of installation, depth of laying, spacing and grouping factors.

6.4.5.5 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 advantage 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.

6.4.5.6 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.

6.4.5.7 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.

6.4.5.8 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.

6.4.5.9 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.

6.4.5.10 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.

6.4.5.11 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 without extra cost.

6.5 Cable Construction

6.5.1 Over sheaths

6.5.1.1 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.

6.5.1.2 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.

6.5.1.3 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.

6.5.1.4 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.

6.5.1.5 The minimum thickness of oversheath shall not fall below the Manufacturer's stated value by more than 0.2mm plus 20 percent.

6.5.1.6 A means of identifying the Manufacturer shall be provided throughout the length of the cable.

6.5.2 Armouring

6.5.2.1 All multicore cables shall be provided with galvanised steel wire armour. Single-core cables shall have copper or aluminium wire or tape armouring.

6.5.2.2 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

6.5.4.1 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.

6.5.4.2 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.

6.5.4.3 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 shrinkable cap and the end projecting from the drum shall be adequately protected against mechanical damage 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

6.5.7.1 Cables shall be installed in continuous lengths and straight through jointing between shorter lengths will not be permitted.

6.5.7.2 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 compounds as appropriate.

6.5.7.3 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.

6.5.7.4 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.

6.5.7.5 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.

6.5.7.6 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.

6.5.7.7 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. They cables 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.

6.6.2.1.1 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.

6.6.2.1.2 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 transmitted 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.

6.6.2.1.3 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

6.6.2.2.1 Cables shall comply with the construction here above and shall have cross-linked polyethylene (XLPE) insulation.

6.6.2.2.2 All cables shall be provided with a low smoke PVC oversheath.

6.6.2.2.3 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 accepted at 1.5 mm². Note that, the 2.5 mm² copper conductors shall be used as CT secondary cable also, however, where required the Employer shall have the right to ask for 4 mm² copper conductors – The bidder shall consider the same in his bid.

6.6.2.2.4 All these cables shall have galvanised steel wire armouring.

6.6.2.2.5 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

6.6.2.3.1 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.

6.6.2.3.2 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.

6.6.2.3.3 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 Over sheaths

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 oversheath, 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)

6.6.2.5.1 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.

6.6.2.5.2 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 Megohms. 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 minimum. The Contractor shall provide calculations to show induced voltage levels under overhead line ground fault conditions.

6.6.2.5.3 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 another in 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.

6.6.2.5.4 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

6.8.1 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.

6.8.2 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.

6.8.3 All cables routed under roads and access ways usable by vehicular traffic shall be installed in ducts.

6.8.4 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.

6.8.5 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.

6.8.6 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.

6.8.7 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

6.9.1 The method of installation shall be as follows:

6.9.2 Trenches shall be excavated to the minimum depth shown in Drawing for cable trench. Covers shall be provided over cables laid in the trench.

6.9.3 Filling in of trenches shall not be commenced before inspection and approval by the Engineer of the cables and accessories in-situ.

6.9.4 The Contractor shall lay the cables direct 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.

6.9.5 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.

6.9.6 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.

6.9.7 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.

6.9.8 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 - ELECTRIC CABLE" in English.

6.9.9 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

6.10.1 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.

6.10.2 Ducts shall be of rigid PVC and shall be surrounded by concrete of minimum thickness of 150.

6.10.3 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.

6.10.4 Any ducts or pipes not used shall be sealed by plugs (detail subject to approval) supplied by the Contractor before backfilling.

6.10.5 The ducts shall be water and vermin proof sealed, after completion of cable installation.

6.11 Cables installed in Concrete Trenches

6.11.1 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.

6.11.2 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.

6.11.3 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

6.12.1.1 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.

6.12.1.2 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.

6.12.1.3 Ample allowance shall be made in the design for additional cabling for future extensions.

6.12.1.4 Racks and trays shall be secured to channel or similar inserts installed in accordance with Building and Civil works section.

6.12.1.5 All cables shall be run with a particular regard to neatness of appearance. Multiple runs shall be arranged so that cables entering or leaving the run do so in a logical manner.

6.12.1.6 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

6.12.2.1 All supporting steelwork shall be hot dip galvanised after manufacture and shall be to the approval of the Engineer.

6.12.2.2 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.

6.12.2.3 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.

6.12.2.4 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

6.12.3.1 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.

6.12.3.2 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.

6.12.3.3 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

6.12.4.1 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.

6.12.4.2 Cables shall be installed on trays, in general as follows:

- Up to 16 mm^2- double layer touching.
- 25to 70 mm^2 - single layer touching.
- Above 70 mm^2- single layer with 25mm (minimum) spacing.

6.12.4.3 All cable trays shall be perforated.

6.12.4.4 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.

6.12.4.5 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.

6.12.4.6 The cable tray system shall have minimum of 20% spare cable capacity throughout.

6.13 Cables Installed on Structural Steelwork and Brickwork or Concrete

6.13.1 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.

6.13.2 Cables shall not be routed on tiled, lagged or other special finished surfaces.

6.14 Terminations

6.14.1 General

6.14.1.1 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.

6.14.1.2 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.

6.14.1.3 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.

6.14.1.4 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.

6.14.1.5 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.

6.14.1.6 PVC shrouds shall be supplied and installed over each gland.

6.14.2 Power Cables

6.14.2.1 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 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.

6.14.2.2 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.

6.14.2.3 Single core cables shall be similarly identified by coloured tape over the cable beneath the gland.

6.15 Terminating and Jointing Conductors

6.15.1 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.

6.15.2 For stud type terminals approved crimping lugs shall be used.

6.15.3 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

6.16.1 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.

6.16.2 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.

6.16.3 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.).

6.16.4 Direct a.c. circuits shall be identified by a yellow end piece followed by an identification of the phase concerned.

6.16.5 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.

6.16.6 All markings for terminal blocks, cables, cable conductors and wiring shall be located on the corresponding fault finding drawing.

6.16.7 Characters suitably marked "TRIP" in white shall be fitted on all wires associated with trip circuits.

6.16.8 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

6.17.1 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.

6.17.2 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.

6.17.3 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.

6.17.4 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.

6.17.5 In addition, the Contractor shall provide selected copies of the above schedules in a computer print-out form at agreed intervals.

6.17.6 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.

6.17.7 Where cables enter and leave ducts or pipes, suitable identification markers shall be fitted.

6.17.8 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.

SECTION-7:

EARTHING SYSTEM & LIGHTNING PROTECTION

Index of Contents

SL No.	Name of Items	Page No.
7.1	Scope	3
7.2	References	3
7.3	General	3
7.4	Extent of Work	4
7.5	Soil Survey	4
7.6	Fault Current and Duration	5
7.7	Earth Electrode System Design	5
7.8	Design of Earthing System	7
7.9	Materials and Installation	10
7.10	Lightning Protection	12
7.11	Earthing of Fences	13
7.12	Portable Earthing Devices	15

7. Earthing System and Lightning Protection

7.1 Scope

These chapters describe the general requirements for the earthing and lightning protection and shall be read in conjunction with the project requirements and schedules.

7.2 References

7.2.1 American Standards

- ANSI/IEEE/std 80 IEEE Guide for Safety in AC Substation Grounding
- ANSI/IEEE/std 81 IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potential of a Grounding System

7.2.2 German Standards

- VDE 0140 Earthing Systems for Power Installations with Rated Voltages above 1 kV

7.2.3 British Standards

- BS EN 13601 Specification for copper for electrical purposes: high conductivity copper rectangular conductors withdrawn or rolled edges.
- BS EN 13601 Specification for copper for electrical purposes. Rod and bars
- BS EN 12449 Specification for copper and copper alloys. Tubes
- BS 2874 Specification for copper and copper alloy rods and sections (other than forging stock).
- BS 4360 Specification for weldable structural steel
- BS 6360: Specification for conductors in insulated cables and cords.
- BS 6651 Protection of Structures against Lightning
- BS 6746 Specification for PVC insulation and sheath of electric cables.
- BS 7430 Code of Practice for Earthing

7.3 General

An earthing system generally in accordance with the requirements of IEEE 80 and BS 7430 shall be designed under this Contract. 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.

Protection for all electrical equipment against lightning shall also be provided.

7.4 Extent of Work

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 HV Voltage level (400kV, 230kV & 132kV) substation. Also included is the lightning protection scheme and the provision of portable earthing devices.

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.

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.

Normally manual calculation is not acceptable. The detail design calculation output through an internationally recognized earthing design software (latest version Autogrid Pro or, Cymgrid; as dictated by the Employer at execution stage) shall have to be submitted. The design output shall include the 3D views & profile views of Touch Potential profile, Step Potential Profile, Surface Potential Profile & GPR rise, considering extended size of 5m beyond each side of the proposed mesh area. Contractor shall share Soft copy of design files of the software and seek review and approval from the Employer.

Based on the soil resistivity, fault level & other relevant parameters, the contractor shall design suitable earthing mesh with suitable size & depth of earthing conductor & earthing rod. The cost of such design & implementation shall be deemed to be included in the Contract price.

7.5 Soil Survey

The bidders are requested visit site area and measure tentative earth resistivity for bidding purpose if they require.

Not later than one month after the site has been handed over for access, the Contractor shall carry out an earth resistivity survey of the sites and report in writing to the Engineer in accordance with the approved programme. The report shall detail the methods and instruments used and the results of the surveys. Based on the results the Contractor shall include in the report his proposals for the resistivity to be used in the design of the earthing system.

The surveys shall show the variation of resistivity across the site and with the depth below the site. The Contractor shall consider if there is a need to model the resistivity in two layers and if there is any advantage in the use of deep rod electrodes.

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.

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.

The report should also state if there are any indications that the ground is corrosive to bare copper.

The report shall be approved by the Engineer before proceeding with the design of the earthing system.

7.6 Fault Current and Duration

Each site shall be provided with an earth grid of buried conductors designed for an earth fault current as specified in the section 1 (topic: system electrical parameters) of the volume 2, or 3 of this bidding document. The preliminary earthing design shall be such that the potential rise shall not exceed 5 kV. However, relevant clause of IEC standard shall be deemed to be deciding factor for such design subject to Employer's approval.

7.7 Earth Electrode System Design

7.7.1 Design Calculations

The design of the earth electrode systems shall be based on the approved earth resistivity data and the system fault currents and their duration.

The design calculations shall be to the approval of the Engineer and shall be based on the methods given in the standards listed. 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 and outside the perimeter fence
(d) Requirements for a high resistance surface layer
(e) Conductor ratings

Earthing points shall be provided such that the combined resistance of the earth grid and all other earthing points does not exceed the allowable limit dictated by the standards for the fault current and duration specified measured during the dry season.

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.

Step, touch and mesh potentials shall be within the permitted limits calculated in accordance with the standards given in IEEE 80 for the proposed surface layer.

Consideration of other fault current distribution shall be verified during detailed design and taken approval from Engineer. In case direct current is allowed to pass through mat in any mode of operation, allowance for the same shall be made in design. However, relevant clause of IEC standard shall be deemed to be deciding factor for such design subject to Employer's approval.

For Designing the Earthing Grid, software solution must be adopted. Hand calculation for substation having 132kV Voltage level & above (AIS & GIS) shall not be acceptable. The Contractor shall always consider multi-layer soil model for such calculation. Single layer soil model is generally not acceptable. Auto-Grid Pro & CYMGRD software which shall be deemed to be used by the prospective Bidders/Contractors for such Design calculation. Contractor shall share Soft copy files of the software and seek review and approval from the Employer.

7.7.2 Earth Electrode

The earth electrode shall comprise a system of bare conductors forming a mesh buried near the surface of the ground and supplemented, if required, by one or more of the following electrodes:

(a) a system of interconnected rods driven into the ground
(b) a mesh system of bare conductors buried in the ground
(c) structural metalwork in direct contact with the ground
(d) reinforcing steel in buried concrete
(e) a system of bare conductors buried near the surface of the ground outside the perimeter fence

7.7.3 Mesh System

The mesh system shall be designed to limit touch, step and mesh potentials taking into account the combined length of the mesh conductors, other buried conductors and rods but excluding any buried conductors outside the perimeter fence. Due regard shall be given to non-linear distribution of the fault current giving rise to the highest potentials at mesh comers.

The rating of the mesh conductors shall be compatible with the fault cur-rents after allowing for parallel paths of hard drawn high conductivity copper strip with a minimum conductor size of 150 mm^2.

The conductor shall be installed in trenches excavated by the Contractor to a depth of 500mm. 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.

7.7.4 Earthing Rods

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.

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 rod electrodes of 15mm diameter 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.

Individual rods may be connected directly to the mesh, provided the rod can be disconnected for testing.

The calculation of potentials in the design of the complete installation shall be made without the group of rods with the lowest estimated resistance to simulate the condition with the group disconnected for testing.

7.7.5 Other Conductors

As an alternative to rods to supplement a mesh, additional bare copper conductors with a cross-section area of not less than 150 mm^2 may be used. They shall be buried in the ground within the perimeter fence to enclose the maximum possible area compatible with the earthing of any metallic fence. Such conductors may be laid below the mesh, below foundations or in areas where there is no plant. It shall be shown by calculation that the step potentials are low in such areas.

The conductor shall be in a ring, or a part of a ring, with at least two widely separated connections to the mesh or other parts of the earthing system.

7.7.6 Reinforcing Steel

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.

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.

7.7.7 Conductors Outside Perimeter Fence

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.

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.

The minimum conductor size shall be 75 mm² copper and shall be connected to the fence or the mesh with 75 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 Design of Earthing System

7.8.1 Earthing System

An earthing system shall comprise the following components:

(a) the conductors between the earthing electrode and the main earthing bar
(b) the main earth bar
(c) the conductors between the main earth bar and the metallic frames, enclosures or supports of electrical equipment
(d) the conductors between structural metalwork and non-electrical equipment and the main earth bar

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.

The design of earth system shall take into account the corrosiveness of the soil based on the soil survey.

The design comprising all the above mentioned items shall be submitted to the Engineer for approval within four months of the award of Contract.

7.8.2 Connection of System Neutrals and Earth

The system neutral points within a substation shall have duplicate connections to the closest earthing point.

The Transformer Neutrals, in addition to connection with mesh, shall be directly buried into earth upto 15 meters as minimum. The connection shall be in delta format. In addition to transformer neutrals, the contractor shall consider direct earthing of all LA neutrals, Lightning mast neutrals to ground through earthing rod (15 meter minimum).

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 of cross sectional area not less than 150 mm² from each test link to the earth grid. The duplicate connection may be in the form of a ring.

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.

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.

7.8.3 Main Earthing Bar

The main earthing bar shall be in the form of a ring or rings of bare conductors surrounding, or within, an area in which items to be earthed are located. Where two or more rings are installed, they shall be interconnected by at least two conductors which shall be widely separated.

The main earthing bar, or parts thereof, may also form part of the earth electrode system, providing this is bare conductor.

Each main earthing bar shall be connected by at least two widely separated conductors to the earth electrode system.

The minimum conductor size for the main earth and interconnections between earthing bars and the earth electrode system shall not be less than 150 mm².

7.8.4 Electrical Equipment and Structure Connections to Earth

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.

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.

Surge arresters installed for the protection of transformers and reactors shall be connected by low reactance paths both to the transformer tanks and to the earthing system.

Capacitor voltage transformers used in connection with line traps shall be connected by direct low reactance paths to a single earth rod for each arrester, in addition to the earth grid.

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 75 mm².

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.

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.

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.

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.

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 Connections to Non-Electrical Structural Metalwork and Equipment

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.

Individual components of metallic structures of plant shall be bonded to adjacent components to form an electrically continuous metallic path to the bonding conductor.

Small electrically isolated metallic components mounted on non-conducting building fabric need not be bonded to the main earth bar.

7.9 Materials and Installation

7.9.1 Earthing Conductors

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.

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.

Bare strip conductors only shall be used for earth electrodes or voltage control meshes.
Conductors buried in the ground shall normally be laid at a depth of 500 mm 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.

All conductors not buried in the ground shall be straightened immediately prior to installation and supported clear of the adjacent surface.

7.9.2 Earthing Rods

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.

The earth rods shall be of hard-drawn high conductivity copper with a diameter of not less than 15 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.

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 0.25 mm. The overall diameter shall be not less than 12 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.

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.

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.

The steel for copper-clad 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.

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.

7.9.3 Fittings

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.

Conductors shall be connected to earth rods by a bolted clamp to facilitate removal of the conductor for testing the rod.

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.

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.

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.

Sheathed conductor support fittings may be of silicon aluminium, glass-filled nylon or other tough non-hygroscopic material for indoor installations.

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.

7.9.4 Joints

Permanent joints shall be made by exothermic welding below ground, or crimping for above ground connections.

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.

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.

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.

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.

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.

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.

7.10 Lightning Protection

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.

The lightning protection scheme shall be designed by the Contractor using the latest version of the electro geometric model (EGM) or Rolling sphere method. The substation including building, primary plant and connected infrastructure must be protected against lightning according to IEEE 998 based on the rolling sphere method with effective shielding determined based on the calculated maximum Stroke Current and Strike Distance. 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 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.

The Contractor may propose a lightning mast and/or shield wire system, however shielding by shield wires is preferred by the Employer. Overhead shield wires shall not make use of "X" patterns & shall not lead to a fault, if broken. Conductor sag shall be considered when designing the overhead shielding system; however, conductor swing need not be considered. The Contractor must provide a formal as built CAD drawing showing the lightning protection coverage plan.

The overhead earthwire shall be suitable for extension to protect the substation equipment to be installed in future stages of development.

7.11 Earthing of Fences

7.11.1 Method

Metallic fences shall be separately earthed unless they come within 1.8m of any equipment or structure above the surface of the ground and which is connected to the main earthing system. If the separation of 1.8m cannot be obtained, the fence shall be bonded to the main earthing system.

7.11.2 Separately Earthed Fences

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.

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.

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 100 m.

7.11.3 Bonded Fences

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 1.8 m of any electrical equipment. 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 100 m.

7.11.4 Bonding of Fence Components

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.

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.

Metallic components on masonry, brick, concrete or similar boundary wall shall be treated in the same manner as metallic fences.

Wire fence components coated for anti-corrosion protection shall be earthed in accordance with this Clause.

7.11.5 Gates

The fixed metallic components on both sides of the gate shall be directly bonded together by a copper conductor installed under the surface of the access way. Flexible conductors shall be installed to bond the moving parts of the gates to the metallic fixed parts. An earth rod or a bond to the main earthing system shall be installed at each gate.

7.11.6 Potential Control Outside Fences

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.

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.

If the boundary fence is metallic and is not within 1.8 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.

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.

7.11.7 Conductors

All conductors used for earthing and bonding the fences and components and for outer rings shall have a cross-sectional area of not less than 70 mm²

Connections shall be made of copper strip of 30mm x 5mm. 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.

Earth wires shall be held in clamps with free pin type joints between clamps and supports.

Connections shall be provided for the terminations of the earth wires of the overhead lines, including bimetal connectors where necessary.

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.

7.12 Portable Earthing Devices

Portable earthing devices for use with outdoor 400 kV and 230 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.

The preferred types of portable earthing devices are Raguar Stalskog and Karl Pfisterer. However, device having origin at USA, Canada, Europe, Japan, Korea is also acceptable.

SECTION-8:

Batteries, Chargers and DC Switchgear

Index of Contents

SL No.	Name of Items	Page No.
8.1	Scope	03
8.2	References	03
8.3	Design Requirements	03
8.4	Batteries	04
8.5	Control and Charging Equipment	06
8.6	Service Manual and Spare Card	10
8.7	Distribution Switchboards	10
8.8	Insulation Monitoring System	11
8.9	Labelling	13
8.1	Special Tools	13
8.11	Inspection and Testing	13

8. Batteries, Chargers and DC Switchgear

8.1 Scope

These clauses describe the General Technical Requirements for Batteries, Chargers and DC switchgear 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 60146-1-1	Semiconductor converters; Basic requirements
IEC 60146-1-3	Semiconductor converters; Transformers and reactors.
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

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

8.3.1.1 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.

8.3.1.2 The voltage measured at the main distribution switch shall not vary by more than ±5 percent of the nominal voltage under all charging conditions when operating in accordance with the

requirements of this Section. 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.

8.3.1.3 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.

8.3.1.4 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.

8.4 Batteries

8.4.1 Type of Battery

8.4.1.1 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.

8.4.1.2 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.

8.4.1.3 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.

8.4.1.4 A complete set of test and maintenance accessories, suitably boxed, shall be provided for each battery.

8.4.1.5 A syringe hydrometer and a durable instruction card shall be included in each set.

8.4.1.6 Cells shall be numbered consecutively and terminal cells marked to indicate polarity.

8.4.1.7 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 rates

8.4.1.8 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.

8.4.3.1 Continuous Load

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.

8.4.3.2 Momentary Load

At the end of five (5) hours the battery shall have sufficient capacity to complete the operations listed below, at the end of which duty the system voltage shall not have dropped below 95 per cent of the nominal voltage with the standing loads, specified above, connected.

1. Two closing operations on all circuit breakers (including future) supplied by the battery.
2. 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.
3. Charging of DC motor wound circuit breaker closing springs (where applicable) to enable the closing operations to be carried out.
4. 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.
5. 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.

8.4.3.3 While sizing the battery, following additional aspect shall be considered:

1. The DC system voltage variation shall be considered ±5% at distribution board. The final voltage at load end shall be ±10% at 110V DC.
2. A margin of 25% 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%.
3. 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.
4. 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

8.4.4.1 The batteries shall be housed in a ventilated battery room. The charging equipment and distribution switchboards shall be housed in a separate room.

8.4.4.2 Battery rooms shall be dimensioned and the ventilation system designed to cater for the installation of 48V communications batteries. Suitable outgoing feeders shall also be provided on the station AC distribution boards to supply these future DC systems.

8.4.4.3 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.

8.4.4.4 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

8.4.5.1 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.

8.4.5.2 Alternatively, batteries may be mounted in a similar manner on treated hardwood stands.

8.4.5.3 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.

8.4.5.4 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.

8.4.5.5 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.

8.4.5.6 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.

8.4.5.7 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.

8.4.5.8 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

8.5.1.1 Each battery charging equipment shall comply with the requirements of BS 4417 (IEC 60146:), shall be of the Thyristor-controlled, 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 equipment shall be naturally ventilated. Forced cooling shall not be acceptable.

8.5.1.2 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.

8.5.1.3 Where their ratings permit, chargers shall preferably be designed for operation from a single-phase AC auxiliary supply with a nominal voltage of 230 V. Otherwise a three phase 400V supply may be utilised. 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%

8.5.1.4 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.

8.5.1.5 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.

8.5.1.6 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.

8.5.1.7 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.

8.5.1.8 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.

8.5.1.9 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.

8.5.1.10 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.

8.5.1.11 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.

8.5.1.12 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.

8.5.1.13 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.

8.5.1.14 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.

8.5.1.15 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.

8.5.1.16 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.

8.5.1.17 The boost charging equipment shall be capable of recharging the battery within six hours following a one hour discharge period.

8.5.1.18 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.

8.5.1.19 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.

8.5.1.20 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.

8.5.1.21 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.

8.5.1.22 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.

8.5.1.23 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.

8.5.1.24 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.

8.5.1.25 The charger shall also be fitted with a device to de-energise the charger in the event of a DC output float over voltage.

8.5.1.26 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.

8.5.1.27 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.

8.5.1.28 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.

8.5.1.29 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.

8.5.1.30 Each charger shall be equipped with a switch-fuse for the incoming AC supply and an off load isolator for the DC output.

8.5.1.31 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

8.6.1.1 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.

8.6.1.2 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

8.7.1.1 The switchboard shall comply with the requirements of BS 5468 (IEC.60439)

8.7.1.2 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.

8.7.1.3 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.

8.7.1.4 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.

8.7.1.5 A double pole switch or contactor shall be provided for the purpose of sectionalising the busbar.

8.7.1.6 A battery earth fault detecting relay, which will centre tap the system via a high resistance, shall be incorporated in the distribution panel.

8.7.1.7 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.

8.7.1.8 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.

8.7.1.9 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.

8.7.1.10 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.

8.7.1.11 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.

8.7.1.12 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.

8.8.2 Standard

IEC 61557-8
IEC 60364-4-41, IEC 62557-8: 1998-05

8.8.3 Principle:

8.8.3.1 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.

8.8.3.2 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.

8.8.3.3 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.

8.8.3.4 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.

8.8.4 Construction

8.8.4.1 Complete Insulation Monitoring for DC system shall be provided. Latest Technology shall be used for insulation Monitoring. The system can be standalone and integrated. Superimposition of measuring DC voltage & “AMP” measurement method

8.8.4.2 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.

8.8.4.3 The system shall be capable of communicating with the Station SAS for signalling of DC fault.

8.8.4.4 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 for

Control Circuit

Microprocessor based Control circuit shall be provided.

Fault Locator

The Device shall indicate the location of fault in the DC feeder.

HMI

Built-in HMI with high-class button or touch screen based shall be provided.

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.

Fuse

Most insulation monitoring devices are connected to the system to be monitored via two connecting wires.

8.8.4.5 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.

8.8.4.6 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 16 of this specification.

SECTION-9:

LV AC Distribution Switchgear

Index of Contents

SL No.	Name of Items	Page No.
9.1	Scope	03
9.2	References	03
9.3	Switchboard Design	03
9.4	Circuit Breakers	05
9.5	Switch Fuses	05
9.6	Oil Filtration Socket Outlet and Plug	06
9.7	Inspection and Testing	06

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	
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 - Circuitbreakers 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 -Electro mechanical contractors and motor starters.

9.3 Switchboard Design

9.3.1 General

9.3.1.1 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:

9.3.1.2 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 400/230 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.

9.3.1.3 The equipment shall be of the single busbar type with circuit equipment housed in separate compartments.

9.3.1.4 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.

9.3.1.5 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

9.3.2.1 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.

9.3.2.2 The allowable tolerance level for busbar design is ±5% at 415 V and allowable tolerance level at load terminal is ±10% at 415 V.

9.3.3 Busbars

9.3.3.1 Busbars shall be capable of carrying the full rated current continuously without exceeding the maximum temperature specified in IEC 60439 under site ambient conditions.

9.3.3.2 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

9.3.4.1 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.

9.3.4.2 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

9.3.5.1 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

9.4.1.1 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.

9.4.1.2 Where circuit breakers incorporate thermal overload protection and short-circuit protection, their settings shall be subject to agreement with the Engineer.

9.4.1.3 Tripping arrangements shall be such as to ensure simultaneous opening of all phases. Arc extinction shall be by de-ionising arc chutes.

9.4.1.4 Circuit breakers on the incoming circuits shall have facilities for locking in the "off" position.

9.4.1.5 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

9.5.1.1 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.

9.5.1.2 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.

9.5.1.3 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.

9.5.1.4 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 15 of this specification.

SECTION 10

NATIONAL LOAD DESPATCH CENTRE (NLDC) CONTROL FACILITIES

TABLE OF CLAUSES

10.1 SCOPE 10/2
10.2 REQUIRMENTS 10/5
10.2.1 Indications: Digital Input (Double Point) 10/5
10.2.2 Load Flows, System Voltage and frequency 10/5
10.2.3. Alarms: Digital Input (Single Point): 10/5
10.2.4 Controls-Digital Output (Double point) 10/5
10.2.5 Network parameters 10/6
10.3 INTERFACES 10/6

SECTION 10

NATIONAL LOAD DESPATCH CENTRE (NLDC) CONTROL FACILITIES

10.1 SCOPE

In Order to provide the tele-control & te-metering facilities required at the existing National Load Dispatch Centre (NLDC) at Rampura, 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 plants, in new and existing substations, which are in the scope of the work, under this Contract.

The NLDC is located in Dhaka (Rampura & Siddhirganj) and connected through a fiber optic network to communication equipment and Remote Terminal Unit (RTU)/Industrial Gateway of SAS system located at different power station/ substation.

The SCADA system of NLDC is based on GE Vernova e-terra platform.

The industrial gateway will be implemented at each grid substation for remote monitoring & control from the National Dispatch Centre. It will provide all necessary control and monitoring facilities for all voltage level lines, transformers and auxiliaries, capacitor banks, Reactors, Loadshed feeders.

All plant supplied under this contract shall be equipped with potential-free auxiliary contacts for indications and alarms, CT and VT circuits shall be fitted, where required.

Supply & installation of necessary equipment such as IED/relay, transducers, DI, DO card etc. for integrating new bay through existing RTU /Gateway at far end substation is supplier scope of work.

All HV breakers, motorized disconnectors, tap changers, Loadshed feeders etc. shall be controlled from NLDC through the gateway /RTU of the substation automation system using IEC 60870-5-104 protocol. Cabling between the substation automation gateway and the communication equipment shall be included in this contract.

Necessary modification in the software and hardware at NLDC master station is also to be done under this contract to accommodate all the new system extended under this contract.

In order to provide the telecontrol facilities required at the National Load Dispatch Centre (NLDC) the contractor shall supply & install 02(two) numbers of industrial gateway at new grid substation for integrating to NLDC SCADA system.

Data communication from switch to Gateway & switch to SAS server will independent.

The 02(two) gateways will be configured as master- hot standby mode.

All required electrical quantities (digital and analog) shall be transmitted to NLDC through the Industrial Gateway of the substation automation system (SAS).

The communication protocol to be used for data exchange between the NLDC and the substation shall be ***IEC 60870-5-104***.

The gateway shall be capable of reporting to both main master station at Rampura (through VLAN network) & the Standby Master Station at Siddhirganj (through routed network) simultaneously. It will be configured according to the signal list, communication parameter, IP address, station address etc. provided by PGCB.

Analog data measurement scaling shall be done at RTU or Relay (Preferable at relay). Analog data should be floating point. Analog data should be deadband with 0 %. Frequency dead band should be 0%. Digital data should be time stamp at field.

GPS is required at substation, so that RTU/Gateway can get exact time.

For securing SCADA system, hardware firewall device is required between RTU/Gateway and communication device at field, so any type of cyber intrusion or malware can be prohibited.

Necessary SCADA interfacing equipments such as Transducers, Digital input/output card, Cabling etc. is required for far end substation related to the substation.

Integration work

Integrating RTU/ Gateway with NLDC following work shall be done at Master Station Rampura, Dhaka and Backup station at Biddut Bhaban Dhaka. Scope of work includes
Pre database work:
a) Collection of network data for EMS application
b) Modeling, database creation, verification and update should be done at both NLDC
c) Modification and update of database for far end substation related to the new substation
d) The following should be done at Master station at Rampura and Backup station at Siddhirganj

1. SCADA Database Modelling
2. Substation Display
3. Network database Modelling
4. Generation Database Modelling
5. DTS Database Modelling
6. Alarm database Modelling
7. Validation

- Cross validation of all databases and create update copy of those databases.
- On-lining of databases in DTS (Simulator) server

- Checking and modifying (if require) topology of Substations, Devices, Network etc.

8. RTU/ Gateway configuration

Configuring the RTU / Gateway according to attach signal list , mapping address, data communication parameter, Source IP, Destination IP etc.

9. Local Test

The following test will be carried out at site using e-terracontrol software

- Verification of all Analog Measurement and checking of Limit, Deadband , Polling Time
- Verification of Digital signals Status (OPEN, CLOSE, BETWEEN, INVALID)
- Verification of ALARMS, EVENTS etc.
- Verification of Control and Interlock

10. Database Update

The following activities will be carried out in Master NLDC and Backup NLDC after successful site test.

- On-lining of all databases in Running Servers
- IP/VLAN Configuration on Polling servers and switch
- Compilation & On-lining of all the displays on WEB servers

11. End to End Test

The following activities will be carried out in Master NLDC and Backup NLDC

- Verification of all Analog Measurement,
- Verification of Digital signals and Controls
- Verification of displays including Single line, Pop up, alarms etc.
- Verification of communication line for Redundancy
- Verification of continuous and complete integration of the RTU/Gateway.

12. Tuning of Power System Application

- Tuning will be do required for all available Network and generation applications in SCADA/EMS server and DTS(Dispatcher Training Simulator)

Notes:

- Integrating RTU/Gateway with NLDC should be in the scope of work.
- Data communication path creation for both Main & Backup station is scope of Integration
- Collection of Network data required for modeling network database is in contractor's scope of work
- Contractor will conduct necessary work for both at NLDC & Substation (if required)
- Training is essential to realize the full potential of the Gateway/RTU.it is most efficient way to learn about the important features and operational procedures of the system.

10.2 REQUIRMENTS

10.2.1 Indications: Digital Input (Double Point)

The following indications shall be provided

-Circuit Breaker, Isolator & Earth Switch Open/ Close for line, transformer, bus coupler

-Circuit Breaker for Reactor/Capacitor bank & 33kv loadshed feeder

10.2.2 Load Flows, System Voltage and frequency

Electrical quantities shall be provided to enable the following measurements

- Voltage (kV), Frequency (Hz) for Busbar
- Megawatt(MW), MegaVar (MVAR), Amperes(AMP), Voltage (kV) for line
- MW, MVAR, Amperes, kV at both sides, Tap Position Indication (TPI) for Transformer
- Megavar, Amp & KV for Reactor/Capacitor bank

10.2.3. Alarms: Digital Input (Single Point):

- Remote/ Local Switch for all Circuit Breakers.
- Bay Fault (DC Fail for Transformer Panel).
- Breaker Fault (OR gate Spring Charge, SF6 Low).
- Protection Class-1 (Distance, Differential).
- Protection Class-2 (Over current, Earth fault).
- Protection Class-3 (bus bar).
- Transformer Alarm (Buchholz Alarm, Oil Level Low).
- Transformer Trip (Buchholz Trip, PRD Trip)
- Transformer Temperature Alarm (Oil Temp Alarm, Winding Temperature).
- Transformer Temperature Trip (Oil Temp trip, Winding Temperature trip).
- Tap Changer Alarm.
- Tap changer trip.
- Tap changer high limit.
- Tap changer low limit.
- Auto reclose operated
- DC fail
- AC fail
- Auto Reclose Block/OFF, Voltage Status, Ready Signal for Loadshed feeder

10.2.4 Controls-Digital Output (Double point)

The following facilities shall be controlled from the NLDC

-Circuit Breaker and Motorized Isolator Open/ Close for Line, Transformer bay & bus coupler,
-Circuit Breaker Open/ Close for 33kV load shed feeder
-Tap Changer Raise/ Lower for Transformer

10.2.5 Network parameters

Line length, Line Conductor type, Short Circuit data for Zero sequence (%R, %X, % of full charging Susceptance) etc.

10.3 INTERFACES

This contract includes Industrial grade Gateway to the NLDC. The Gateway shall have adequate capacity to cater to the future extensions of substation. The cabling between the Gateway and the communication equipment shall be provided under this contract.

In case of Windows operating system based gateway, there should be USB port, VGA & HDMI Porty, HDD/flash memory with one spare, TFT monitor with mouse and key board etc. Hard disk should be 50% free and CPU loading maximum of 30% at any condition. If gateway is firmware based then 02(two) nos. of control card is required. Gateways also have 08 nos LAN port & Dual supply for both Firewall & Gateway. There should be GPS facilities for time synchronization. Also cyber security has to be ensured at field SCADA interface level. Supported Protocol shall be IEC 60870-5-104, 61850 & MODBus etc.

Operating System, all necessary software and system back up & restoration software (Acronis true image or Ghost or similar software) should be licensed and supplied in CD.

SECTION 11

BUILDINGS AND CIVIL ENGINEERING WORKS (FOR OUTDOOR GIS AND AIS)

TABLE OF CLAUSES

11.1 GENERAL 11/4

11.1.1 SCOPE OF WORK 11/4
11.1.2 BIDDER TO SATISFY HIMSELF AS TO ALL CONDITIONS 11/5
11.1.3 WAY LEAVES, LAND PURCHASE AND PLANNING PERMISSION 11/6
11.1.4 SITE SURVEY DRAWINGS 11/6
11.1.5 EARTH WORKS 11/7
11.1.7 PROGRAMME 11/7
11.1.8 MONTHLY PROGRESS CERTIFICATES/PROGRESS REPORTS 11/8
11.1.9 TEMPORARY FACILITIES 11/8
11.1.10 SITE SUPERVISION 11/8
11.1.11 DESIGNS AND DRAWINGS 11/9

11.2 REFERENCES 11/9

11.2.1 GENERAL 11/9
11.2.2 DESIGN AND CONSTRUCTION STANDARDS 11/9

11.3 DESIGN 11/11

11.3.1 ARCHITECTURAL AND STRUCTURAL REQUIREMENTS OF BUILDINGS 11/11
11.3.2 GROUND CONDITIONS, FOUNDATIONS AND SITE INVESTIGATION 11/14
11.3.3 DRAINAGE 11/20
11.3.4 SURFACING 11/21
11.3.5 ROADS 11/22
11.3.6 WATER SUPPLY 11/23
11.3.7 PLUMBING AND SANITARY FITTINGS 11/23
11.3.8 BUILDING FLOORS 11/24
11.3.9 CABLE BASEMENT 11/25
11.3.10 BATTERY ROOM FLOORS 11/25
11.3.11 CONTROL ROOM FLOORS 11/25
11.3.12 SITE CLEARANCE, OBSTRUCTIONS AND ADJACENT STRUCTURES 11/25
11.3.13 GUARD HOUSES, BOUNDARY WALLS, FENCES AND ENTRANCE GATES 11/26
11.3.14 WINDOWS 11/26
11.3.15 DOORS 11/27
11.3.16 BRICKWORK 11/28
11.3.17 EXPANSION JOINTS, JOINT FILLERS AND SEALANTS 11/28
11.3.18 CABLE TRENCHES IN SWITCHYARDS 11/28
11.3.19 CABLE TRENCHES IN LOCAL CONTROL BUILDING/SPR 11/29
11.3.20 RAINWATER PIPES 11/30
11.3.21 SWITCHYARD FOUNDATIONS 11/30
11.3.22 TRANSFORMER BASES 11/31
11.3.23 BLAST WALLS 11/32
11.3.24 PAINTS AND PAINTING 11/32
11.3.25 FURNITURE 11/33
11.3.26 CONCRETE 11/33

11.3.28 EXTERNAL RENDER 11/35
11.3.29 GOALPOSTS 11/36
11.3.30 MODIFICATION WORKS 11/36
11.3.31 STAIRS 11/36

11.4 CONCRETE WORKMANSHIP 11/37

11.4.1 GENERAL 11/37
11.4.2 AGGREGATES 11/37
11.4.3 SAMPLING 11/38
11.4.4 GRADING 11/38
11.4.5 CEMENT 11/38
11.4.6 WATER 11/38
11.4.7 REINFORCING 11/38
11.4.8 STORAGE 11/39
11.4.9 DESIGN MIX 11/39
11.4.10 MIXING AND PLACING OF CONCRETE 11/40
11.4.11 TESTING OF CONCRETE 11/42
11.4.12 FORMWORK 11/43
11.4.13 REINFORCING STEEL 11/43
11.4.14 CONSOLIDATION OF CONCRETE 11/44
11.4.15 CURING OF CONCRETE 11/44
11.4.16 HOT WEATHER CONCRETING 11/44

11.5 WORKMANSHIP OF ALL OTHER MATERIALS 11/45

11.6 LAND DEVELOPMENT WORK: 11/45

11.7 FIRE EXTINGUISHER: 11/47

SECTION 11

BUILDINGS AND CIVIL ENGINEERING WORKS (FOR OUTDOOR GIS & AIS)

11.1 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.

11.1.1 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 site slope protection, cutting or filling up to the level specified in 11.1.4 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, Power Grid 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 Bidder:

(a) Guardhouse, sentry post, car port, stair railing, open store yard, 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, stair railing, open store yard 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 11.3.3 of the document.

11.1.2 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.

11.1.3 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.

11.1.4 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 900mm above the FGL.

11.1.5 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.

11.1.6.1 Engineer's and Employer's Accommodation

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.

11.1.6.2 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.

11.1.7 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 starts 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.

11.1.8 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.

11.1.9 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.

11.1.10 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.

11.1.11 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.

11.2 REFERENCES

11.2.1 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 11.2.2 below.

11.2.2 Design and Construction Standards

BS12A Ordinary Portland cement

BDS EN 197-1	Portland Composite 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 1Code 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

11.3 DESIGN

11.3.1 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, all elevations and 3D view of buildings shall be agreed before other detail plans are prepared.

All buildings (control room building and switchyard panel room (SPR) building etc.) shall be designed by a reinforced concrete frame following code provisions of BNBC 2020. All anticipated loads required for structural design shall be determined in accordance with the code provisions. Buildings, structures and components thereof, shall be designed and constructed to support all loads, including dead loads, without exceeding the allowable stresses or specified strengths (under applicable factored loads) for the materials of construction in the structural members and connections.

Structural framing systems and components shall be designed with adequate stiffness to have deflections, vibration, or any other deformations within the serviceability limit of building or structure.

However, in special cases where the design of a structure or its components cannot be covered by the provisions of BNBC, other relevant internationally accepted codes referred in BNBC may be used.

Forces imposed by unusual vibrations and impacts resulting from the operation of installed machinery and equipment shall be determined separately and treated as additional live loads. Live loads due to vibration or impact shall be determined by dynamic analysis of the supporting member or structure including foundations, or from the recommended values supplied by the manufacture of the particular equipment or machinery. A guideline can be taken from BNBC 2020 to estimate the effects for this kind of loading. Any established method (time history analysis etc.) for the dynamic analysis and design (for machine loading) might be adopted to ensure durability of the structure (foundation, frame and slab).

Seismic detailing shall be applied for reinforced concrete structures subjected to earthquake loadings according to seismic design categories following code provisions of BNBC 2020.

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/m2 live

load.

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 in-situ concrete slab designed for 2.5 kN/m2 live load. For other buildings shall be designed as per latest BNBC.

The roof shall be waterproofed with application of two non-toxic components acrylic polymer modified cementations coating of minimum 1.5mm thickness for water proofing of roof which consists of powder and liquid acrylic emulsion; under a protective cover of patent stone/tiles. For waterproofing system minimum roof slope 1:150 shall be maintained.

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 100m2 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 waterproofed 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. Facing bricks/sand stone/fair face concrete or combination of them may be used at exterior wall surface in order to render aesthetic view of the control building. An architectural feature shall be provided by panels of open decorative block work 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 approved facing bricks/sand stone. External walls of other buildings shall be minimum 230mm first class brickwork plus one layer of approved facing bricks/sand stone 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 3.6 meter and the minimum height of first floor control room shall be 4.5 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.

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.

Battery rooms shall be supplied with sink and drainer & exhaust fans (if no air conditioning).

Air conditioning units shall be provided in rooms. Air conditioned rooms shall have a false ceiling such that the overall thermal transmittance of the roof shall be below 0.45 Watts/m2˚C. The false ceiling shall be made from non-combustible materials, and shall be easily removable to provide easy access to small power cables.

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.

11.3.2 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 11.1.4. 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 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, switchyard panel room building and gantry structures, outdoor GIS/GIB foundation shall be provided with piles. Others buildings foundation shall be provided with shallow or pile foundation as per soil condition. Based on the site and soil conditions, auto-transformers and blast wall may be designed with mat foundation. Ground improvement need to be ensured by the contractor based on the underlying soil conditions. 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. Stability of surrounding and underlying soil must be ensured by the contractor. For footing supported boundary wall slope stability must be checked and necessary earth reinforcement techniques shall be adopted as appropriate.

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 11.1** 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, SPR building and one of auto-transformers at each site shall be compression load tested to 100% of design load 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. Integrity tests shall be performed on drilled shaft concrete piled foundations selected by Employer for checking the uniformity, continuity and length of such piles using the acoustic pulse echo method shall be undertaken by a specialist subcontractor appointed by the Contractor. Details of practical experience of the subcontractor along with details of the test equipment, procedure of testing, presentation of test data/results shall be submitted along with tender. The integrity test shall be done at least one time for one pile selected by the Engineer. The actual method of performing the tests and the interpreting the results shall be subject to the Engineer's approval.

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. If the filling height of the substation area exceeds 4m, then foundations of outdoor equipment must be provided with pile foundation.

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 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 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 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 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.

11.3.3 Drainage

The entire surface within boundary walls shall be of uniform sloping site, sloping at 1 in 150 minimum slopes 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 11.3.18.

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, 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 bituminous 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 provide adequate slope to achieve the self-cleansing velocity.

If a town's water supply is unreliable, the roof rain water shall be collected in an underground tank of standard Employer's design.

11.3.4 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.

11.3.5 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.

11.3.6 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 one deep tube well for control building and another for ansar barrack/guard house 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 an 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 from the roof 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.

11.3.7 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 minimum 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.

11.3.8 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 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 verandas) except for cable basement and battery room shall have mirror polished homogeneous floor tiles topping. The ground floor/cable basement floor shall be furnished with non-skid floor tiles. All external steps where public access is given to buildings shall have granite toppings.

Verandas 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.

11.3.9 Cable Basement

Ground floor of the control room building shall be used as cable floor.

11.3.10 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.

11.3.11 Control Room Floors

No raised floor except for panel installation shall be used.

11.3.12 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.

11.3.13 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.

11.3.14 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. For areas where wind speed exceed 250km/h, minimum 6mm thick glass tempered glass need to be used.

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.

11.3.15 Doors

Internal doors and door frames shall be anodised aluminium with minimum 10mm thick tempered glass. Main Entrance/Exit doors and door frames shall be steel or anodised aluminium with minimum 10mm thick tempered glass.

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.

11.3.16 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/sand stone shall be approved quality and size. Facing bricks/sand stone 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/sand stone 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/sand stone.

11.3.17 Expansion Joints, Joint Fillers and Sealants

Not used.

11.3.18 Cable 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 bituminous 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 soak well placed at the side of trench; the volume of each soak well 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.

11.3.19 Cable 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 bituminous 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.

11.3.20 Rainwater Pipes

Down pipes shall be 100mm minimum diameter placed on the outside of walls but enclosed in a brick buttress of facing bricks/sand stone. 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.

11.3.21 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.

11.3.22 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 bituminous 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.

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 bituminous paint. Skids shall receive 3 coats of bituminous paint before being cast in.

Adjacent road (perpendicular to rail) shall be extended up to transformer bases. Width of extension shall be same as width of transformer. Transformer shall be anchored in such a manner so that it can prevent the movement of transformer for 0.2G ground acceleration.

11.3.23 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. IEC guidelines shall be followed for safe distance or fire protection of other structures near to the transformer. 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.

11.3.24 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 control buildings, boundary walls, blast walls and guard posts shall be painted with a fungicide, Snowcem primer and two coats of Snowcem. All exposed facing bricks/sand stone 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 bituminous paint.

All non-galvanized 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, baseplates and holding down bolts and concrete plinths shall receive two coats of bituminous 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 bituminous paint.

11.3.25 Furniture

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.

11.3.26 Concrete

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/m3	170kg/m3
Maximum Water Cement ratio	0.55	-
Coarse Aggregate type	Well graded crushed stone chips	Jhama brick chips
Maximum Coarse aggregate size	20mm	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 maximum	50mm minimum
Slump for concrete placed below water in piling	150mm minimum	-

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 0.15% of gross cross sectional area respectively.

Minimum cover to rebar 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**.

11.3.27 Concrete 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.

11.3.28 External Render

All brickwork which is not faced with facing bricks/sand stone 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.

11.3.29 Goalposts

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 12 of this Contract for the high voltage switchgear.

11.3.30 Modification Works

In bay extension/renovation works of existing substation, sometimes modification of existing structure and or foundation may be required. The contractor should asses the existing structure and or foundation for modification. Necessary modification works should be done to install new equipment. If modification of existing control building is required, it must be done without any structural damage to the existing building. The modification work must be done keeping similarity with the existing structures.

The contractor should bear full responsibility of any modification done by them. Before starting of the modification work, the modification proposal must be submitted to the employer for approval.

11.3.31 Stairs

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.

All roofs which are not accessible by stairs shall be provided with a galvanised steel fixed ladder.

11.4 CONCRETE WORKMANSHIP

11.4.1 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.

11.4.2 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 (Colorimetric test) and ASTM. C33-82.

11.4.3 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.

11.4.4 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.

11.4.5 Cement

Ordinary Portland Cement shall comply with BS 12A or Portland Composite Cement shall comply with BDS EN 197-1. 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 or BDS EN 197-1. 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.

11.4.6 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.

11.4.7 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.

11.4.8 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.

11.4.9 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.

11.4.10 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 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.

11.4.11 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 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 $\pm$ 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.

11.4.12 Formwork

All formwork shall be steel. 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. 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.

11.4.13 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.

11.4.14 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.

11.4.15 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.

11.4.16 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.

11.5 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.

11.6 Land development work:

11.6.1 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 Modified 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 Modified Proctor Test.

11.6.2 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.

11.6.3 Before land filling, The Contractor has to construct necessary dyke/embankment for protection the developed land.

11.6.4 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.

11.6.5 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.

11.6.6 The Contractor is responsible to obtain the permission/approval from the competent authority for the works as mentioned in clause no. 4 & 5 above.

11.6.7 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.

11.6.8 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.

11.6.9 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.

11.6.10 The Contractor will arrange the testing of the samples of the fill materials & compaction tests of developed areas by Laboratory approved by employer. Two samples (one at top and another at mid height of fill) should be carried out for compaction test on every 2500 square meter of field area and provided on suitable points. The cost of any or all such tests shall be borne by the Contractor.

11.6.11 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.

11.6.12 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.

11.6.13 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.

11.7 Fire Extinguisher:

11.7.1 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.

11.7.2 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, and nontoxic. 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-11.1

DETERMINATION OF DEPTH OF FIXITY, LATERAL DEFLECTIONAND MAXIMUM MOMENT OF LATERALLY LOADED PILES

11-1. DETERMINATION OF LATERAL DEFLECTION AT THE PILEHEAD AND DEPTH OF FIXITY

11.1.1 The Long flexible pile, fully or partially embedded, is treated as a cantilever fixed at some depth below the ground level (see Fig. 2).

11.1.2 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.

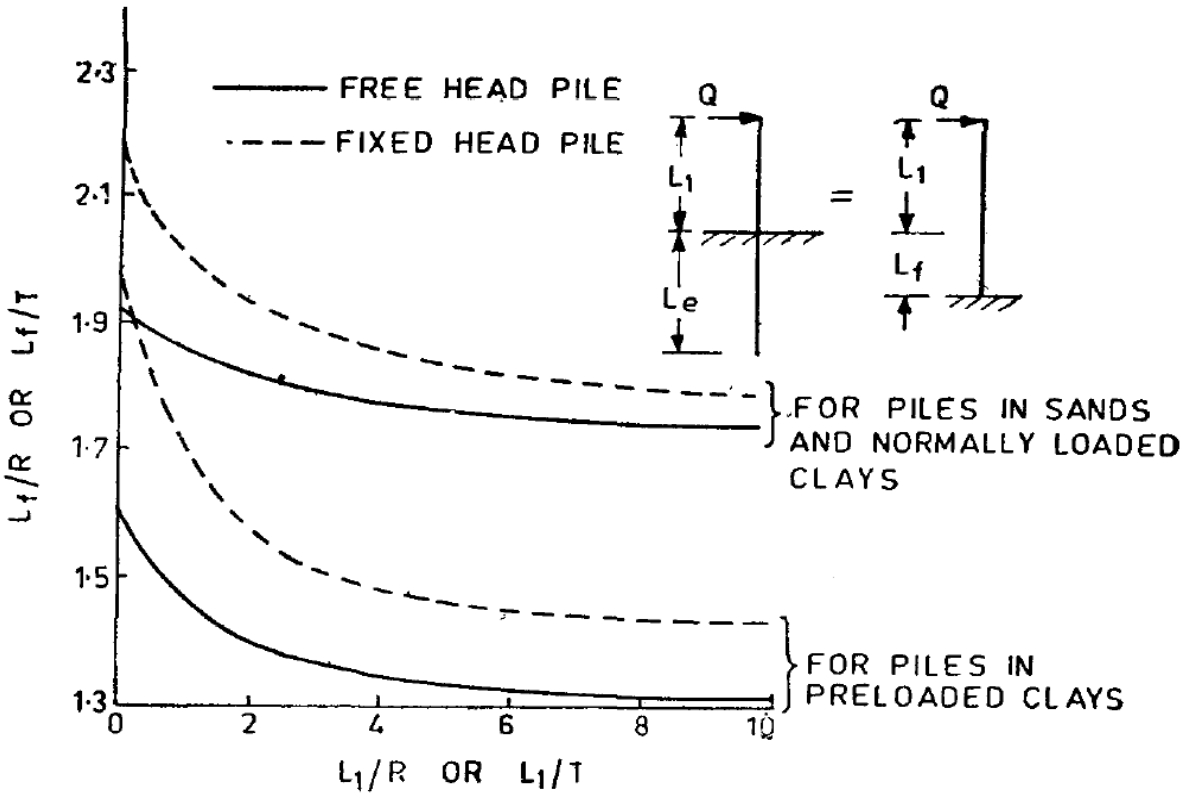


FIG. 2 DETERMINATION OF DEPTH FIXITY

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.

11.1.3 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

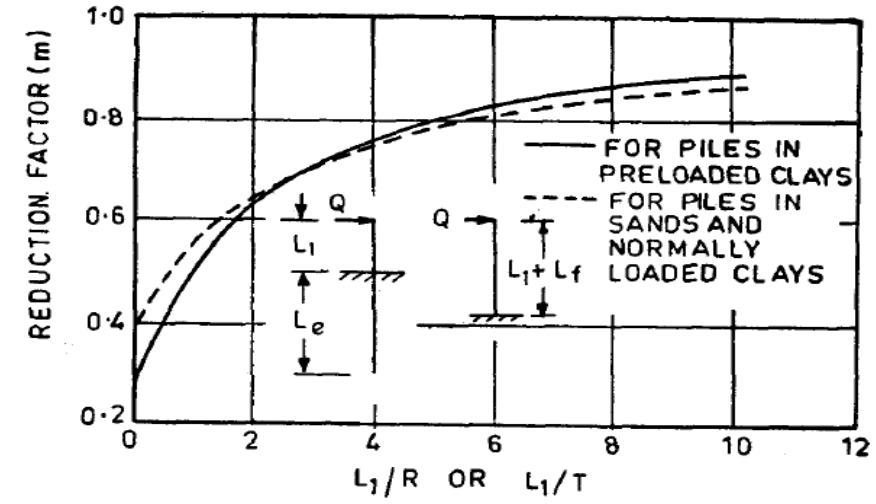
11.2. DETERMINATION OF MAXIMUM MOMENT IN THE PILE

11.2.1 The fixed end moment (MF) 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:

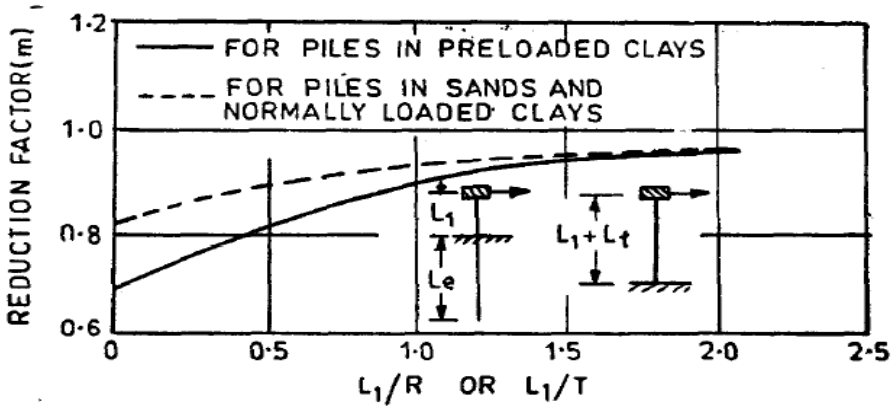
$M_f = Q(L_1$+Lf) .....for free head pile

$= \frac{Q(L_1+L_f)}{2}$ .....for fixed head pile

The actual maximum moment (M) = m (Mf)



3A FOR FREE HEAD PILE



3B FOR FIXED HEAD PILE

FIG.,3 DETERMINATION OF REDUCTION FACTORS FOR COMPUTATION OF MAXIMUM MOMENT IN PILE

11.2.2 Reinforcement of upper section of pile should be provided upto 1.25x L_f depth

SECTION 12

SUPPORTING STRUCTURES FOR OUTDOOR EQUIPMENT

TABLE OF CLAUSES

12.1 SCOPE 12/2

12.2 STRUCTURE ARRANGEMENT 12/2

12.3 DESIGN 12/2

12.3.1 GENERAL 12/2
12.3.2 ASSUMED LOADING COMBINATIONS 12/3
12.3.3 LINE TERMINATION STRUCTURES 12/4
12.3.4 PARTIAL LOAD FACTORS 12/5
12.3.5 WIND LOADING 12/5
12.3.6 EQUIPMENT AND CONDUCTOR TERMINATIONS 12/6
12.3.7 SAFETY AND ACCESS REQUIREMENTS 12/6
12.3.8 STRUCTURAL DESIGN 12/7
12.3.9 LIGHTNING MAST 12/8
12.3.10 DESIGN SUBMISSIONS 12/8

12.4 MATERIALS 12/9

12.5 WORKMANSHIP 12/9

12.6 PROTECTIVE TREATMENT 12/10

12.7 QUALITY CONTROL 12/10

12.7.1 GENERAL 12/10
12.7.2 WELDING 12/11
12.7.3 CHECK ERECTION 12/11
12.7.4 GALVANISING 12/11
12.7.5 TOLERANCES 12/12

12.8 ERECTION 12/12

SECTION 12

SUPPORTING STRUCTURES FOR OUTDOOR EQUIPMENT

12.1 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.

12.2 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 Aluminum 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.

12.3 DESIGN

12.3.1 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.

12.3.2 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 12 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;

The 'resultant spring constant' (s) of both supports in a single span of strained conductors shall be determined according to IEC guidelines for steel structures.

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 center of gravity of the equipment and structure as appropriate.

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.

12.3.3 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.

12.3.4 Partial Load Factors

The partial load factors to be applied to the loading combinations determined in accordance with Clause 12.3.2 shall be as specified in the Schedule of Technical Requirements.

12.3.5 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:

$$F_w = q_{ref} \left[\frac{H}{10}\right]^{2\alpha} C_{shp} W_A$$

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 < 4.1×10^5	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.

12.3.6 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.

12.3.7 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.

12.3.8 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
Aluminum 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 /Aluminum
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.

12.3.9 Lightning Mast

Lightning mast should be a steel structure which may be design as lattice / pole / pipe structure. Latest BNBC wind load shall be considered for design of lightning mast. Deflection should be within allowable limit of standard code and practices. Foundation should be design with the support reaction of the mast. In designing foundation bearing capacity, overturning capacity and sliding capacity must be checked.

12.3.10 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.

12.4 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.

12.5 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 aluminum structures. All members shall be stamped on before galvanizing or other protective coatings, using characters 10mm high and shall be clearly legible after galvanizing.

12.6 PROTECTIVE TREATMENT

Unless otherwise specified after fabrication, all structural steelwork, including bolts, nuts and washers shall be hot dipped galvanized 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 galvanized 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 aluminum shall be in accordance with the requirements of BS 8118.

Galvanizing thickness and aluminum protection procedure shall be as specified in the Schedule of Technical Requirements

12.7 QUALITY CONTROL

12.7.1 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/aluminum 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.

12.7.2 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.

12.7.3 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.

12.7.4 Galvanising

Tests on galvanised members and components shall be carried out at the works to ensure compliance with the requirements of BS 729.

12.7.5 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 ± 1mm

(c) On centres of holes ± 1mm

(d) On groups of holes ± 2mm

(e) On back-gauges ± 1mm

(f) On corresponding holes in opposite faces of a member ± 1mm

(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) ± 1mm

(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.**

12.8 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 12

Line	Description			
1.	Structure Arrangement [clause 12.2] High Level Low Level Primary Material		Lattice or A-Frame Lattice or Moment Steel	
2.	**Load Combination 1** [clause 12.3.2]		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 12.3.3]		**Phase**	**Earth wire**
	Conductor Designation & Type			
	132kV		Single ACSR Grosbeak	7 x 3.25 GSW
	230kV		Twin ACSR Mallard	7 x 4.0 GSW
	Number of sub-conductors (All of the above two shall be finalized during execution)		-	-
	Maximum working tension per Sub-conductor (132kV) kN (with maximum downlead span 100m)		7	4.5
	Maximum working tension per Sub-conductor (230kV) kN (with maximum downlead span 100m)		10	4.5
	Wind pressure kN/m2		1.40	1.76
	Radial ice thickness	mm	0	0
	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 12.3.4]		**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		

Line	Description		
5.	**Safety and Access Requirements** [clause 12.3.7]	**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 12.3.8]		
	Steel	0.85	
	Aluminum	-	
	Foundations	0.76	
7.	**Minimum Member Thickness** [clause 12.3.8]	**Steel**	**Aluminum**
	Main member mm	6.0	
	Other bracing members mm	5.0	
	Secondary (redundant) members mm	5.0	N/A
	Plates 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 12.6]		
	Galvanizing thickness µm	85	N/A
	Protection procedure	BS 729	No

SECTION 13

LIGHTING, SMALL POWER, HEATING AND VENTILATION

TABLE OF CLAUSES

13.1 SCOPE 4
13.2 REFERENCES 4
13.3 DEFECTS LIABILITY PERIOD 5
13.4 APPROVALS 5
13.5 LIGHTING REQUIREMENTS 5
13.6 SCHEDULE OF DESIGN REQUIREMENTS 6
13.7 CODING SYSTEMS 6
13.8 DISTRIBUTION BOARDS 7
13.9 MINIATURE CIRCUIT BREAKERS 8
13.10 CABLES 8
13.11 CABLE TERMINATIONS 8
3.12 SEALING AND DRUMMING 9
13.13 CONDUIT 9
13.14 CABLE TRUNKING 12
13.15 CABLE TRAYS 13
13.16 CABLE JOINTING 13
13.17 CONTACTORS 13
13.18 SWITCHES AND PUSHBUTTONS 13
13.19 LIGHTING FITTINGS 14
13.20 LAMPS 15
13.21 SOCKET OUTLETS AND FUSED SPUR OUTLETS 15
13.22 TIME SWITCHES 15
13.23 POLES 16
13.24 INTERIOR INSTALLATIONS 16
13.25 EXTERIOR INSTALLATION 17
13.26 EMERGENCY LIGHTING 17
13.27 TELEPHONE SYSTEM 18
13.28 SCHEDULE OF LIGHTING FITTINGS AND SOCKET OUTLETS 18
13.29 SCHEDULE OF LIGHTING REQUIREMENTS 19
13.29.1 CONTROL BUILDING 19
13.29.2 OUTDOOR AREAS 20
13.30 AIR CONDITIONING AND VENTILATION 20
13.30.1 SCOPE OF WORK 20
13.30.2 HEATING 20
13.30.3 AIR CONDITIONING 20

13.30.4 MECHANICAL VENTILATION 21
13.30.5 BASIS FOR DESIGN 21
13.30.6 AIR COOLED CONDENSING UNITS 22
13.30.7 REFRIGERATION SYSTEMS 23
13.30.8 CONSOLE AIR CONDITIONING UNITS 24
13.30.9 DUCTWORK 24
13.30.10 CONDENSATE DRAINS 24
13.30.11 EXTRACT VENTILATION UNITS 24
13.30.12 AIR FILTERS 25
13.30.13 GRILLES AND LOUVRES 25
13.30.14 CONTROL EQUIPMENT 26
13.30.15 ELECTRICAL CONNECTIONS 26
13.30.16 MANUFACTURERS 26
13.30.17 STANDARDS 26
13.30.18 APPROVAL 27
13.30.19 MAINTENANCE 27

13.31 EARTHING AND BONDING 27

13.32 TESTING AND COMMISSIONING 27

13.33 IP CAMERA SURVEILLANCE SYSTEM 27

13.33.1 SCOPE OF WORK 27
13.33.2 AREAS TO BE MONITORED 27
13.33.3 BASIS FOR DESIGN 28
13.33.4 ELECTRICAL CONNECTIONS 28
13.33.5 MANUFACTURERS 29
13.33.6 ADDITIONAL INFORMATION TO BE INCLUDED 29
13.33.7 APPROVAL 29
13.33.8 MAINTENANCE 29

13.34 ROOFTOP SPV POWER PLANT 29

13.34.1 SCOPE OF WORK 29
13.34.2 TECHNICAL SPECIFICATIONS 30
13.34.3 SOLAR PHOTOVOLTAIC MODULES: 30
13.34.4 SOLAR PV MOUNTING STRUCTURE 33

- **DETAILED SPECIFICATIONS FOR THE MOUNTING STRUCTURE 33**

13.34.6 SOLAR GRID INVERTER 34

13.34.7 GRID ISLANDING 37

13.34.8 DATA ACQUISITION SYSTEM / PLANT MONITORING 37

13.34.9 POWER CONSUMPTION: 38

13.34.10 PROTECTIONS 39

13.34.11 LIGHTNING PROTECTION 39

13.34.12 SURGE PROTECTION 39

13.34.13 EARTHING PROTECTION 39

13.34.14 CABLES 40

13.34.15 TOOLS & TACKLES AND SPARES 40

13.34.16 DANGER BOARDS AND SIGNAGES 41

13.34.17 FIRE EXTINGUISHERS 41

13.34.18 DRAWINGS & MANUALS 42

13.34.19 PLANNING AND DESIGNING 42

13.34.20 SAFETY MEASURES 42
13.34.21 DC COMBINER BOX 42
13.34.22 DC DISTRIBUTION BOX 42
13.34.23 AC DISTRIBUTION BOX 42
13.34.24 METERING 43
13.34.25 DOCUMENTATION 43
13.34.26 TEST CERTIFICATES AND REPORTS TO BE FURNISHED 43
13.34.27 GENERAL INSTRUCTIONS 43

SECTION 13

LIGHTING, SMALL POWER, HEATING AND VENTILATION

13.1 SCOPE

This section of the Specification includes for the interior and exterior lighting, small power, heating 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.

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 for electrical 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.

Institution of heating and ventilation Engineers Guide to current practice.

American Society of Heating Refrigeration and air conditioning Engineers

Recommendations

Heating and Ventilation Bidders Association of U.K. specification DW/ 121

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

13.3 DEFECTS LIABILITY PERIOD

The Bidder 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 Bidder 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 Bidder 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. Industrial Grade LED lighting shall be used for road (approach road and internal road) and security lighting. Switchyard floodlighting shall use 500W LED lamps unless otherwise specified. 10% spare of each type of lighting shall be available.

Key to Abbreviations:

L	Local switches
S1, S2 etc.	Socket outlets or fused spur circuits
P.B	Push Button 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 Bidder 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:

1. The lighting distribution board to which the fitting or socket outlet is connected.

2. If connected to the normal supplies or to the emergency DC supplies.

3. The circuit number and phase of the distribution board to which the fitting is connected.

4. 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 Bidder 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 knockouts 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.

Switchfuse 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. Typical Catalogue & Sizing Calculation of MCB shall be submitted for approval.

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 multistrands 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 Bidder 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.

3.12 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 switchrooms, 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 BS 4568, Part 2 or equivalent, with internally tapped spouts minimum length 21 mm. threaded to the correct length at intersections, tees, draw throughs and stopends.

Conduit fittings of PVC shall be of the plain bore pattern suitable for a pushon compression type jointand 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 'loopin' system of conduit shall be used and the 'loopingin' 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 flameproof, the conduit runs entering these areas shall have a barrier box inserted in the run immediately before the conduit passes

into the flameproof area. All conduit work inside the flameproof 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 flameproof 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 proposed. 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 Bidder 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 drawin 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 Bidder 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 Bidder 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 Bidder 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, aluminiurn 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 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 Bidder 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 heldin 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, twoway 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 quickmakequickbreak fixed grid industrial types mounted in galvanised malleable iron boxes with protected dolly and arranged where necessary for multigang switching.

Switches for use in areas designated for flush installation shall be microbreak types fixed to white plastic cover plates and mounted in galvanised steel flush type boxes.

Switchboxes 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, doublepole 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 nonhygroscopic material, be nonswelling 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 Bidder proposes to purchase shall be submitted to the Engineer for approval before issuing any suborders.

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 lamp holders, 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 builtin 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 antivibrators 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 lampholders. 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 MM2 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 for tungsten lamps up to 150 watts shall be brass or porcelain BC type and for higher ratings shall be ES or GES type according to size. Fittings for housing tungsten lamps exceeding 150 watts rating are to be provided with an approved method of dissipating heat from the lamp cap and terminal housing.

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 LAMPS

The Contract includes the supply and erection of all lamps and tubes necessary to complete the installation.

Fluorescent lamps shall be manufactured and tested in accordance with BS1853, IEC 60081 or equivalent, shall be bipin types and shall have colour rendering values of X = 0.335 and Y= 0.342 (i.e., Colour 2) on the CIE chromaticity scale.

Tungsten lamps shall be manufactured and tested in accordance with BS 161 or equivalent and shall be bayonet cap for lamps up to and including 100 watts. Lamps rated for 150 watts and higher shall have edison screw caps. Low wattage lamps used in exit signs and emergency lighting units may be small or miniature edison screw.

Discharge lamps shall be manufactured and tested in accordance with BS 3677 or equivalent. Mercury vapour lamps shall be fluorescent types having a 10% red ratio colour correction, whenever used.

13.21 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.

13.22 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 twentyfour 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.

13.23 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 cutout, 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 Bidder shall ensure each pole is provided with foundations suitable for the ground conditions occurring at each Site.

13.24 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 Clauses 13.13 & 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 crosssection 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.

13.25 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 Bidder 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 cutout located at the base of each support. Wiring between the cutout 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 supporting structure.

13.26 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.

13.27 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 Bidder.

13.28 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 prewired 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 lampholders 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 dusttight, weatherproof and vapour resistant fitting, having a grey polyester fibre glass reinforced chassis containing the control gear and having lampholders 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 lampholders for two fluorescent lamps.

TYPE E1 Shall indicate a selfcontained, selfsustained (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 connection from the local lighting circuit.

TYPE E2 Shall indicate a selfcontained, selfsustained (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 selfcontained, selfsustained (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 Industrial Grade LED lamp. The fittings to be complete with wall mounting bracket.

TYPE H2 Shall indicate a semi cutoff 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 lampholder 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.

TYPES4 Shall indicate a 15 amp 3 phase 4 wire switched socket outlet with plug flush mounted.

13.29 SCHEDULE OF LIGHTING REQUIREMENTS

13.29.1 Control Building

Location		Average Service Illuminance (Lux)	Glare Index
(a)	Control /Relay /Operator Room	250	25
(b)	Behind panels	100	
(c)	In charge Office	400	20
(d)	Battery Room	200	
(e)	Toilet	100	
(f)	Corridors, Stairs	80	20

The height of working plane should be 0.6-0.9 meter.

13.29.2 Outdoor Areas

(a)	Switchyard Floodlighting	20
(b)	Transformer Compounds	120
(c)	Roadway Lighting	20
(d)	Perimeter Wall Security	10
(e)	Control Building Exterior	15

13.30 AIR CONDITIONING AND VENTILATION

13.30.1 Scope of Work

This Section of the works covers the design, supply, delivery, installation, commissioning and setting to work of the heating and ventilating systems for the control building.

All heating and ventilating systems shall be fully automatic in operation and shall be capable of maintaining internal conditions within the bands of temperature and humidity specified hereafter. The substations are normally manned and allowance shall be made for at least four persons on site in the design.

13.30.2 Heating

Electrical heating shall be provided for each room of the building. Except for the battery room, the heating shall comprise of 1500mm long tubular heaters with a load of 60 watts/foot (300mm) which shall be mounted in double tier banks. Electric heaters shall be fitted with bright plate safety guards affording full portection to the heating tubes. The Bidder shall assess the thermal performance of the building and ensure that the sizes of units are adequate to maintain internal temperatures of 5° C when the external temperature is -3°C, measured 1200mm above finished floor level out of an air stream.

The heaters in each room shall be controlled by contactors which have thermostats connected into the coil circuit. Thermostats shall be located in each room and have a maximum cut-off temperature of 17° C.

Each heater bank shall be equipped with a local isolator. The lower tubular heater shall be mounted at 500mm above finished floor level.

13.30.3 Air Conditioning

The following areas shall be air conditioned.

Operation Room

Switchyard Control/Relay room

Communication/SCADA/PLC room

Office/record room

Air conditioning shall be provided in the form of Air Cooled Split System 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 split 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.

The air-conditioning system shall be 100% redundant, rugged, reliable, maintenance free, industrial type and designed for long life. Necessary temperature transducer (along with all accessories) shall be provided in the panel room to monitor the temperature inside the panel room and output of transducer shall be integrated to SAS.

The air-conditioning system shall be designed for continuous or 24/7 operation.

13.30.4 Mechanical Ventilation

Supply and extract ventilation shall be provided to serve the following areas:

Switchgear room

Battery Rooms

Toilets (Extract only)

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 louvred discharges to atmosphere. Individual extract fans shall be provided for Battery room and toilets.

Extract fans for battery room shall be explosion proof, corrosion resistant throughout, with a 4 mm PVC lining.

13.30.5 Basis for Design

(a) External Design Conditions

The external conditions for the calculation of duties for the mechnaical services shall be with mean monthly, maximum and minimum values as below:

Maximum ambient shade temperature		42 ^{o}C
Minimum ambient shade temperature		4 ^{o}C
Maximum daily average temperature		35 ^{o}C
Maximum annual temperature		25 ^{o}C
Relative humidity	- maximum	100%
- minimum	80%	

Solar radiation 100mW/sq.m

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 ^{o}C DB

40 to 70% R.H.

The following air change rates/hour shall be provided in mechanically ventilated area:

Switchgear Rooms	10
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 or 24/7 operation with n-1 contingency i.e. failure of one device shall not reduce the required/designed Cooling & ventilation. Plant shall be arranged to facilitate maintenance and future replacement of equipment. Such provision shall be made available that, the Air Conditioning Device shall be remotely monitored & controlled.

The Bidder 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 electrical equipment and lighting, personnel, infiltration and any other sources. The Bidder shall be responsible for determining the heat transfer coefficients for all materials used in building construction. The full Air Conditioning Design shall be submitted to the Employer for review and approval. In the event of any change in materials. design or method of building construction, the Bidder 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 and taken approval from the Employer.

13.30.6 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 non galvanised 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 be contained in a fully weatherproof enclosure with internal division between the power connections and equipment and the control connections and equipment.

13.30.7 Refrigeration Systems

(A) 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 pipework shall be flexible closed cell l foam phenolic rubber type with a temperature range of -40°C to +105°C and having a thermal conductivity of 0.0375 w/m °C at 2l °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:-

i) Suction Lines

Location	Insulation thickness for O.D. Pipe Sizes Range	
	6-10mm	12-22mm
Exposed to weather	13mm	19mm
In air conditioned spaces	9mm	19mm
In non-air conditioned spaces	9mm	9mm

ii) Liquid Lines

Exposed to weather and in non-air conditioned spaces	9mm	9mm

(b) 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.

13.30.8 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 aluminum 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.

13.30.9 Ductwork

All sheet metal ducting shall be manufactured and installed in accordance with the Institution of Heating arid Ventilation Engineers Guide to Current Practice Section B 16, the American Society of Heating, Refrigeration and Air Conditioning Engineers, or the Heating and Ventilating Bidders 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.

13.30.10 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.

13.30.11 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 designed 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.

13.30.12 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.

13.30.13 Grilles and Louvres

Grilles shall be of aluminum 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 aluminum 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 centers 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.

13.30.14 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 Bidder 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 $\pm$ 1oCover the range of 0 ^{o}C to 30 ^{o}C. The sensor resistance shall be compatible with the measuring bridge of the matching control box.

13.30.15 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.

13.30.16 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 minimurn. Local service facilities shall be available for the equipment proposed.

The Bidder shall provide, with his submission, illustrated technical literature covering all plant and equipment offered.

13.30.17 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 with 25% design margin..

13.30.18 Approval

The Bidder 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 Bidder of his contractual responsibilities.

13.30.19 Maintenance

The Bidder shall be responsible for the maintenance of all installations covered by this section of the Specifications for the period stated elsewhere in the Specification.

13.31 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.

13.32 TESTING AND COMMISSIONING

The Bidder shall be required to prove that the installed system meets the design requirements and Specification to the satisfaction of the Engineer.

13.33 IP CAMERA SURVEILLANCE SYSTEM

13.33.1 Scope of Work

This Section of the works covers the design, supply, delivery, installation, commissioning and setting to work of the IP camera surveillance system of the complete substation.

13.33.2 Areas to be monitored

In most cases, areas shall be monitored with more than one (1) camera for redundancy. Complete substation including the following areas shall be monitored:

Sl. No.	Installations / areas to be monitored	Camera type
1.	Main gate & other entrances	Bullet & Dome
2.	Complete 360° view of the outermost perimeter of the substation	Bullet
3.	Complete 360° view of AIS & GIS area but focusing on transformers	Bullet
4.	Entrances of office/buildings/other civil instillations	Dome
5.	Indoor stores	Dome
6.	Outdoor stores	Bullet
7.	Indoor type capacitor banks	Dome
8.	Inside of GIS halls, control rooms & sub control rooms	Dome

9.	Equipment rooms for third party vendors (i.e.: Fibre at home, BTCL, UGC, etc.)	Dome
10.	Multi junction roads	Bullet

13.33.3 Basis for Design

This Section of the works covers the design, supply, delivery, installation, commissioning and setting to work of the IP camera surveillance system of the complete substation.

All the cameras shall be viewable (through NVR) to authorized users from outside of the local network using smartphone application. The surveillance live view shall be streamed from the local network via NVR manufacturers secure servers to smartphone app developed by said manufacturer. Having dedicated public IP or port forwarding on routers in the local network shall not be necessary in this regard. Provision shall be kept for viewing cameras (through NVR) centrally from PGCB head office and necessary IP address shall be collected from communication circle office of PGCB.

Cameras shall be mounted using metal shield casing. Surge protective devices shall be installed for protection from direct/indirect lightning, transient over voltage, switching over voltage etc. Ethernet surge protectors shall be installed for rj45 connections from each camera before connecting to access switch. MDB, SDB, racks etc. shall be connected to substation grounding. Ethernet surge arresters shall be grounded via earthing plates of surveillance cabinets. Poles & surveillance cabinets shall be connected to mesh of the substation using earthing rods / cables. The power distribution network of the surveillance system shall not be used for any other purpose other than the surveillance system.

This rj45 connectors or power connectors from cameras at each location shall be housed in a small, easily accessible waterproof box so as to protect the connectors from water splash / rain. Optical fiber cables, ethernet cables, shall be carried through uPVC pipes. Cable wiring, clipping, dressing, earthing & identification shall be done using good quality kits. All equipment (poles, switches, cameras) & connections (rj45, fibers cores / SFP, power cables) shall have proper numbering / marking for easy identification and troubleshooting.

At least Two (2) SFP connections from each access switch shall established, one of them will be connected to main core switch and the other to a backup core switch. For cameras located at the main control building & high gantry structures, at least two (2) runs of CAT6 cables shall be laid for each camera, one (1) of them shall be in use and the other shall be kept as spare with its RJ45 connectors (at both ends) equipped with protective caps. For one or more cameras installed on a pole / structure, at least one (1) CAT6 cable shall be provided which shall be kept as spare with its RJ45 connectors (at both ends) equipped with protective caps.

The equipment in the surveillance network should be EMC compatible and shall work in EHV environment.

13.33.4 Electrical Connections

As appropriate.

13.33.5 Manufacturers

Wherever possible equipment 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.

13.33.6 Additional information to be included

The contractor shall provide catalogues, brochures with detailed specification for the supplied items.

During execution stage: the contractor shall submit diagram & layout of the surveillance network including fiber, cat6, power cables. Bandwidth calculation at all points on the network shall also be submitted to prove that bottleneck / traffic congestion does not occur at any point. Load calculation of the entire system shall be submitted to prove that UPS capacity is sufficient to provide backup of the full surveillance system for at least 30 minutes. If UPS capacity is not sufficient, higher capacity UPS shall be provided at no additional cost. The contractor shall submit detail detailed diagrams of civil works, poles, camera mountings.

13.33.7 Approval

The Contractor shall submit to the Engineer for approval of the supplied items.

13.33.8 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 bid document.

13.34 Rooftop SPV Power Plant

13.34.1 SCOPE OF WORK

(a) Scope of work covers Design, Supply, Installation, Commissioning and five years comprehensive warranty Maintenance and Operation of SPV Rooftop Plant under Net Metering as per the technical specification given as following.

(b) Wiring up to Distribution Board from the SPV Rooftop system will be in the scope of the Contractor including the cables for every solar power plant installed.

(c) Performance testing of the complete system.

(d) The contractor will collect firm work order from the Client. The technical details of module, PCU, junction boxes, transformer (if required), structure, data collection system, meter, cables, etc. and its test report and Qualifications & Certificates, testing and commissioning report of plant, Net Metering Work Completion & Synchronization reports, installed system photographs, bill of material and As-built drawings has to be submitted to Client.

13.34.2 TECHNICAL SPECIFICATIONS

The proposed projects shall be commissioned as per the technical specifications given below.

The Solar Rooftop Photo Voltaic (SPV) power plant consists of SPV array, Module Mounting Structure, Power Conditioning Unit (PCU) consisting of Maximum Power Point Tracker (MPT), Inverter, and Controls & Protections, interconnect cables, Junction boxes, Distribution boxes and switches. PV Array is mounted on a suitable structure. SPV system should be designed with necessary features. Components and parts used in the SPV power plants including the PV modules, metallic structures, cables, junction box, switches, PCUs etc., should conform to the IEC or international specifications, wherever such specifications are available and applicable. Solar PV rooftop system shall consist of following major equipment/components. And Contractor shall submit a relative type test certificate (specially capacity test) about (a) & (b) and Factory test certificate about others of (c)~(g) as per IEC or IEEE.

(a) Solar PV modules consisting of required number of Crystalline PV cells.

(b) Grid interactive Power Conditioning Unit with Remote Monitoring System

(c) Mounting structures

(d) SPV P/P monitoring & control system

(e) Junction Boxes.

(f) Earthling and lightening protections.

(g) IR/UV protected PVC Cables, pipes and accessories

13.34.3 SOLAR PHOTOVOLTAIC MODULES:

Solar PV modules should be of the crystalline silicon type. Detailed specifications of the solar PV modules are given below.

Type	**Monocrystalline Silicon**
Minimum rated Power (P_{max})	Not less than 400W per a single PV module at STC (Standard Test Condition)
Efficiency	>= 19%

Warranty	At least 98% of nominal power during first year. Thereafter max 0.54% degradation per year. At least 93% of nominal power upto 10 years and at least 85% of nomina power upto 25 years.

Type	**Monocrystalline Silicon**
Module frame	Non-corrosive and electricaly compatible with the mounting structure material
Termination box	Thermo-plastic, IP 67, UV resistant
Operating Temperature	-40 ~ +85°C
Maximum System Voltage	1,000 V
Maximum Reverse Current	20 A
Mechanical Test Load	5,400 / 2,400 Pa (Push / Pull)
Fire Rating	C / Type 2 (based on ANSI / UL 1703)
Qualifications & Certificates	IEC 61215:2016, IEC 61730:2016
Salt Mist Corrosion Testing	As per IEC 61701:2012
Weight	Not more than 23kg ± 2% (including frame)

The bidder shall carefully design & accommodate requisite numbers of the modules to achieve the rated power in his project proposal submitted to the Client.

The rated output power of any supplied module shall have tolerance of +/- 3%.

The peak-power point voltage and the peak-power point current of any supplied module and/or any module string (series connected modules) shall not vary by more than 2 (two) per cent from the respective arithmetic means for all modules and/or for all module strings.

Each PV module used in solar power project must have a RF identification tag (RFID), which must contain the following information. The RFID can be inside or outside the module laminate, but must be able to withstand harsh environmental conditions.

a. Name of the manufacturer of PV Module
b. Name of the Manufacturer of Solar cells
c. Month and year of the manufacture (separately for solar cells and module)
d. Country of origin (separately for solar cells and module)

e. I-V curve for the module

f. Peak Wattage, Im, Vm and FF for the module

g. Unique Serial No and Model No of the module

h. Date and year of obtaining IEC PV module qualification certificate

i. Name of the test lab issuing IEC certificate

j. Other relevant information on traceability of solar cells and module as per ISO9000 series.

13.34.4 Solar PV Mounting Structure

The PV modules shall be mounted on fixed metallic structures having adequate strength and as per requirement of site to withstand the load of the modules and high wind velocities. The mounting structure steel shall be as per the Chapter 11 (Supporting Structures for Outdoor Equipment) of the Volume 2 of the current Bidding document.

❑ **Detailed specifications for the mounting structure**

Wind velocity withstanding capacity	150 km / hour The designs have been certified by a recognized Lab/Institution/certified engineers in this regard and submit wind loading calculation sheet to users if they desire so. Suitable fastening arrangement such as grouting and calming should be provided to secure the installation against the specific wind speed
Structure material	Pre-galvanized sheet steel with a minimum galvanization thickness of 80 microns and the structural patterns shall be made before galvanizing
Bolts, nuts, panel mounting clamps, fasteners (with spring washers)	Stainless steel SS 304
Mounting arrangement for metal sheet roofs	Mounting directly on the sheet metal, ensuring stability and wind withstanding capacity or penetrating the sheet metal and fixing to the sub-structure, ensuring that the roof remains water proof and ensuring stability and wind withstanding capacity.
Mounting arrangement for elevated structures	The elevated structure has to be securely anchored to the supporting surface. Concrete foundations of appropriate weight and depth for elevated structures mounted directly on the ground; Bolted with anchor bolts of appropriate strength for elevated structures mounted on RCC surfaces.

Mounting arrangement for ground installations	With removable concrete ballast made of pre-fabricated PCC (1:2:4), M15; assuring enough ground clearance to prevent damage of the module through water, animals and other environmental factors.
Mounting arrangement for RCC-flat roofs	With removable concrete ballast made of pre-fabricated PCC (1:2:4), M15. The structures shall be designed for simple
Installation	mechanical on-site installation. There shall be no requirement of welding or complex machinery at the installation site.
Minimum distance	Between foundation and module: 0.5m Between roof edge and mounting structure: 0.5m
Access for panel cleaning and maintenance	All solar panels must be accessible from the top for cleaning and from the bottom for access to the module- junction box.
Panel tilt angle	North – south orientation with a fixed tilt angle of 20-30 degrees (depending on location), south facing. However to accommodate more capacity the angle inclination may be reduced until the plant meets the specified performance ratio requirements.

Regarding civil structures the Contractor need to take care of the load bearing capacity of the roof and need arrange suitable structures based on the quality of roof.

13.34.5 Solar Array Fuse

The cables from the array strings to the solar grid inverters shall be provided with DC fuse protection. Fuses shall have a voltage rating and current rating as required. The fuse shall have DIN rail mountable fuse holders and shall be housed in thermoplastic IP 65 enclosures with transparent covers.

13.34.6 Solar Grid Inverter

As SPV array produce direct current electricity, it is necessary to convert this direct current into alternating current and adjust the voltage levels to match the grid voltage. Conversion shall be achieved using an electronic Inverter and the associated control and protection devices. All these components of the system are termed the “Power Conditioning Unit (PCU)”. In addition, the PCU shall also house MPPT (Maximum Power Point Tracker). Inverter output should be

compatible with the grid frequency. Typical technical features of the inverter shall be as follows:

1	Total output power (AC)	To match solar PV plant capacity while achieving optimum system efficiency
2	Input DC voltage range	As required for the solar grid inverter DC input
3	Maximum power point (MPPT)	Shall be incorporated
4	Switching devices	IGBT/MOSFET
5	Control	Microprocessor /DSP

6	Nominal AC output voltage and frequency	415V, 3P4W Phase, 50Hz
7	Output frequency	50 Hz (Operating range: 47.5 – 52.5 Hz)
8	Grid Frequency Synchronization range	+ 3 Hz or more
9	Power factor of the inverter	> Built-in Protection 0.98 at nominal power
10	Total harmonic distortion	Less than 3%
11	Built-in Protection	AC high / low voltage; AC high /low frequency
12	Anti-islanding protection	As per VDE 0126-1-1 / IEC 60255.5/ IEC 60255.27 / IEC 62116
13	Operating ambient temperature range	+4 ^{o}C to +45 ^{o}C
14	Humidity	0 ~ 95% Rh
15	Inverter efficiency	>=95%
16	Inverter weighted efficiency	>=94%
17	Protection degree	IP 65 for outdoor mounting, IP 54 for indoor mounting
18	Communication interface	RS 485 / RS 232 / RJ45
19	Safety compliance	IEC 62109-1, IEC 62109-2
20	Environmental Testing	IEC 60068-2 (1, 2, 14, 30)
21	Efficiency Measurement Procedure	IEC 61683
22	Cooling	Convection

23	PCU house installed on the Roof	Requirement of the PCU house 1. Foundation : Reinforced concrete 2. External wall & roof : Sandwich panel 3. Post : Miscellaneous steel 4. Others : Four side walls shall be equipped with an adjustable louver to cool the heat generated by the inverter
24	Display type	LCD for data display. LCD /LED for status display
25	Display parameters to include	Output power (W), cumulative energy (Wh), DC voltage (V), DC current (A), AC voltage (V), AC frequency (Hz), AC current (A), cumulative hours of operation (h).

The combined wattage of al inverters should not be less than rated capacity of power plant under STC.

PCU/inverter shall be capable of complete automatic operation including wake-up, synchronization & shutdown. The output of power factor of PCU inverter is suitable for all voltage ranges or sink of reactive power, inverter should have internal protection arrangement against any sustainable fault in feeder line and against the lightning on feeder. Built-in meter and data logger to monitor plant performance shall be provided.

The PCU/ inverters should be tested from the approved test centres of IEC accredited testing-calibration laboratories.

13.34.7 GRID ISLANDING

In the event of a power failure on the electric grid, it is required that any independent power-producing inverters attached to the grid turn off in a short period of time. This prevents the DC-to-AC inverters from continuing to feed power into small sections of the grid, known as "islands." Powered islands present a risk to workers who may expect the area to be unpowered, and they may also damage grid-tied equipment. The Rooftop PV system shall be equipped with islanding protection. In addition to disconnection from the grid (due to islanding protection) disconnection due to under and over voltage conditions shall also be provided.

A manual disconnect 4pole isolation switch beside automatic disconnection to grid would have to be provided at utility end to isolate the grid connection by the utility personnel to carry out any maintenance. This switch shall be locked by the utility personnel

The AC output of the solar grid inverter shall be connected to the building's electrical system after the Net meter and main switch on the load side. The solar grid inverter output shall be connected to a dedicated module in the Main Distribution Board (MDB) of the building. It shall not be connected to a nearby load.

13.34.8 DATA ACQUISITION SYSTEM / PLANT MONITORING

Data Logging Provision for plant control and monitoring, time and date stamped system data logs for analysis with the high quality, suitable PC, Metering and Instrumentation for display of systems parameters and status indication to be provided. Solar Irradiance: An integrating Pyranometer / Solar cell based irradiation sensor (along with calibration certificate) provided, with the sensor mounted in the plane of the array. Readout integrated with data logging system. Temperature: Temperature probes for recording the Solar panel temperature and/or ambient temperature to be provided complete with readouts integrated with the data logging system. The following parameters are accessible via the operating interface display in real time separately for solar power plant:

a. AC Voltage.
b. AC Output current.
c. Output PowerPower factor.

d. DC Input Voltage.
e. DC Input Current.
f. Time Active.
g. Time disabled.
h. Time Idle.
i. Power produced

Protective function limits (Viz-AC Over voltage, AC Under voltage, over frequency, Under frequency ground fault, PV starting voltage, PV stopping voltage.

All major parameters available on the digital bus and logging facility for energy auditing through the internal microprocessor and read on the digital front panel at any time) and logging facility (the current values, previous values for up to a month and the average values) should be made available for energy auditing through the internal microprocessor and should be read on the digital front panel. PV array energy production: Digital Energy Meters to log the actual value of AC/ DC voltage, Current & Energy generated by the PV system provided. Energy meter along with CT/PT should be of 0.5 accuracy class. Computerized DC String/Array monitoring and AC output monitoring shall be provided as part of the inverter and/or string/array combiner box or separately. String and array DC Voltage, Current and Power, Inverter AC output voltage and current (All 3 phases and lines), AC power (Active, Reactive and Apparent), Power Factor and AC energy (All 3 phases and cumulative) and frequency shall be monitored. Computerized AC energy monitoring shall be in addition to the digital AC energy meter. The data shall be recorded in a common work sheet chronologically date wise. The data file shall be MS Excel compatible. The data shall be represented in both tabular and graphical form. All instantaneous data shall be shown on the computer screen. Software shall be provided for USB download and analysis of DC and AC parametric data for individual plant. Provision for Internet monitoring and download of data shall be also incorporated.

Remote Server and Software for centralized Internet monitoring system shall be also provided for download and analysis of cumulative data of all the plants and the data of the solar radiation and temperature monitoring system. Ambient and Solar PV module back surface temperature shall be also monitored on continuous basis. Simultaneous monitoring of DC and AC electrical voltage, current, power, energy and other data of the plant for correlation with solar and environment data shall be provided. Remote Monitoring and data acquisition through Remote Monitoring System software at the owner with latest software & hardware configuration and service connectivity for online, real time data monitoring & control complete to be supplied and operation & maintenance control to be ensured by the supplier.

13.34.9 POWER CONSUMPTION:

Regarding the generated power consumption, priority need to give for internal consumption.

13.34.10 PROTECTIONS

The system should be provided with all necessary protections like earthing, Lightning, and grid islanding as follows:

13.34.11 LIGHTNING PROTECTION

The SPV power plants shall be provided with lightning & overvoltage protection. The main aim in this protection shall be to reduce the over voltage to a tolerable value before it reaches the PV or other sub system components. The source of over voltage can be lightning, atmosphere disturbances etc. The entire space occupying the SPV array shall be suitably protected against Lightning by deploying required number of Lightning Arrestors. Lightning protection should be provided as per IEC 62305 /IS 2309 standard. The protection against induced high-voltages shall be provided by the use of metal oxide varistors (MOVs) and suitable earthing such that induced transients find an alternate route to earth.

13.34.12 SURGE PROTECTION

Surge protection shall be provided on both the DC and the AC side of the solar system. The DC surge protection devices (SPDs) shall be installed in the DC distribution box adjacent to the solar grid inverter.

The AC SPDs shall be installed in the AC distribution box adjacent to the solar grid inverter. The SPDs earthing terminal shall be connected to earth through the above mentioned dedicated earthing system. The SPDs shall be of type 2 as per IEC 60364-5-53.

13.34.13 EARTHING PROTECTION

(a) Each array structure of the PV yard should be grounded/ earthed properly as per Chapter 7 (Earthing system and lightning protection) of the Volume 2 of the current Bidding document. In addition, the lighting arrester/masts should also be earthed inside the array

field. Earth Resistance shall be tested in presence of the Client and Consultant. PCU, ACDB and DCDB should also be earthed properly.

(b) Earth resistance shall not be more than 5 ohms. It shall be ensured that all the earthing points are bonded together to make them at the same potential.

13.34.14 CABLES

Cables of appropriate size to be used in the system shall have the following characteristics:

a. Shall meet IEC 60227/IS 694, IEC 60502/IS1554 standards Temp. Range: – 10oC to +80oC. Voltage rating 600/1000V

b. For the DC cabling, Solar cables with multi stranded copper conductors XLPE or XLPO insulated and sheathed with the voltage rating of 1000 V DC or higher UV stabilised single core flexible copper cables shall be used. Multi-core cables shall not be used.

c. For the AC cabling, PVC or XLPE insulated and PVC sheathed single or multi-core flexible copper cables shall be used. Outdoor AC cables shall have a UV-stabilised outer sheath

d. The total voltage drop on the cable segments from the solar PV modules to the solar grid inverter shall not exceed 1.0%.

The total voltage drop on the cable segments from the solar grid inverter to the building distribution board shall not exceed 2.0%

e. The DC cables from the SPV module array shall run through a UV-stabilised PVC conduit pipe of adequate diameter with a minimum wall thickness of 1.5mm or through a High Density Poly Ethylene (HDPE) conduit. The conduits shall not run across the path way of the terrace. Flexible corrugated PVC conduits shall not be used.

f. Cables and wires used for the interconnection of solar PV modules shall be provided with solar PV connectors (MC4) and couplers.

g. All cables and conduit pipes shall be clamped to the rooftop, walls and ceilings with thermo-plastic clamps at intervals not exceeding 50 cm. The minimum DC cable size shall be 4.0 mm2 copper. The minimum AC cable size shall be 4.0 mm2 copper for up to 10kWp and 16.0mm2 for above 10kWp / required standard size. In three phase systems, the size of the neutral wire shall be equal to the size of the phase wires. The following colour coding shall be used for cable wires:

13.34.15 TOOLS & TACKLES AND SPARES

After completion of installation & commissioning of the power plant, necessary tools & tackles are to be provided free of cost by the bidder for maintenance purpose.

13.34.16 DANGER BOARDS AND SIGNAGES

Danger boards should be provided as and where necessary as per related Act and rules as amended up to date. Three signage shall be provided one each at control room, solar array area and main entry from administrative block. Text of the signage may be finalized in consultation with Client.

13.34.17 FIRE EXTINGUISHERS

The firefighting system for the proposed power plant for fire protection shall be consisting of: Portable fire extinguishers in the control room for fire caused by electrical short circuits Sand buckets in the control room. The installation of Fire Extinguishers should confirm to the regulations and standards of Bangladesh. The fire extinguishers shall be provided in the control room housing PCUs as well as on the Roof or site where the PV arrays have been installed.

13.34.18 DRAWINGS & MANUALS

Two sets of Engineering, electrical drawings and Installation and O&M manuals are to be supplied.

13.34.19 PLANNING AND DESIGNING

The bidder should carry out Shadow Analysis at the site and accordingly design strings & arrays layout considering optimal usage of space, material and labor.

13.34.20 SAFETY MEASURES

The bidder shall take entire responsibility for electrical safety of the installation(s) including connectivity with the grid and follow all the safety rules & regulations applicable as per related Act and Rules.

13.34.21 DC COMBINER BOX

A DC Combiner Box shall be used to combine the DC cables of the solar module arrays with DC fuse protection for the outgoing DC cable(s) to the DC Distribution Box.

13.34.22 DC DISTRIBUTION BOX

A DC distribution box shall be mounted close to the solar grid inverter. The DC distribution box shall be of the thermo-plastic IP65 DIN-rail mounting type and shall comprise the following components and cable terminations:

i. Incoming positive and negative DC cables from the DC Combiner Box;

ii. DC circuit breaker, 2 pole (the cables from the DC Combiner Box will be connected to this circuit breaker on the incoming side);

iii. DC surge protection device (SPD), class 2 as per IEC 60364-5-53;

iv. Outgoing positive and negative DC cables to the solar grid inverter.

As an alternative to the DC circuit breaker a DC isolator may be used inside the DC Distribution Box or in a separate external thermoplastic IP 65 enclosure adjacent to the DC Distribution Box. If a DC isolator is used instead of a DC circuit breaker, a DC fuse shall be installed inside the DC Distribution Box to protect the DC cable that runs from the DC Distribution Box to the Solar Grid Inverter.

13.34.23 AC DISTRIBUTION BOX

An AC distribution box shall be mounted close to the solar grid inverter. The AC distribution box shall be of the thermo plastic IP65 DIN rail mounting type and shall comprise the

following components and cable terminations:

a. Incoming 3-core / 5-core (single-phase/three-phase) cable from the solar grid inverter

b. AC circuit breaker, 2-pole / 4-pole AC surge protection device (SPD), class 2 as per IEC 60364-5-53

13.34.24 METERING

The existing service connection meter needs to be replaced with a bidirectional (import kWh and export kWh) service connection meter for the purpose of net-metering for eligible categories. Installation of the net meter will be carried out by the authorized body.

13.34.25 DOCUMENTATION

The Installer shall supply the following documentation:

a. System description with working principles.

b. System design document including drawings.

c. All the test and commissioning, performance test result etc.

d. Warranty of Qualifications and Certificates

e. Solar PV array lay-out.

f. Routing diagram of cables and wires.

g. Data sheets, drawings and user manuals of the all equipment and system.

h. A system operation and maintenance manual including As-built drawings.

i. Name, address, mobile number and email address of the service centre to be contacted in case of failure or complaint.

j. Warranty cards.

k. Maintenance registers.

13.34.26 TEST CERTIFICATES AND REPORTS TO BE FURNISHED

Test Certificates / Reports from the accredited laboratory for relevant IEC standard for quoted components shall be furnished. Type Test Certificates / reports shall be provided for the solar modules and solar grid inverters. (self-certification by the manufacturer of the said inverter is acceptable.)

13.34.27 GENERAL INSTRUCTIONS

(a) Water and power supply for the construction shall be the responsibility of the Contractor/Bidder

(b) Security, safety, watch, and ward of al materials at sites shall be the responsibility of the Contractor/Bidder

(c) Expenses for any other works, supply of material, and providing services required for the successful commissioning and operation of the plant, but not specifically mentioned in this document.

(d) Safety management to be strictly complied with by the Contractor/Bidder throughout implementation activity.

(e) First-aid medical facilities at the Site during construction to be provided by the Contractor/ Bidder(s)

(f) All local labor, employment, and other issues shall be handled independently by the Contractor/ Bidder(s)

(g) The entire responsibility and risk relating towards the workforce working at the Site, and compliance of different statutory regulations like Workman Compensation Act, Employees' State Insurance Corporation (ESIC), Factory Act, Contract Labour Regulation, and Abolition Act, Shop and Establishment Act, and other Statutory regulatory bodies shall solely lie with the Contractor/ Bidder(s).

(h) The Contractor/ Bidder(s) shall also be solely responsible for payment of wages, provident fund, bonus, retrenchment compensation leave, etc. applicable as per various statutory regulations to their entire workforce,

(i) Location and area for inverter and another interconnection equipment should be located in suitable and secure place and this should be approved by the Client.

(j) Installation diagram and wiring from array to proposed location of inverter and interconnection should be clearly presented by the Contractor before work starts on the site.

(k) Any installations on the roof should be planned and executed in such a way that water proofing will not be disturbed and harmed. In case any area water proofing is affected it will be the Contractor's responsibility to correct it and put it right.

SECTION 14

FIBRE OPTIC MULTIPLEXER EQUIPMENT FOR COMMUNICATION AND PROTECTION

Contents

14.1 SUMMARY OF STANDARDS 14/4

14.1.1 PDH INTERFACES 14/4

14.1.2 ARCHITECTURE OF OPTICAL SDH INTERFACES 14/5

14.1.3 SYNCHRONISATION AND TIMING OF OPTICAL SDH INTERFACES 14/6

14.1.4 ARCHITECTURE OF MPLS-TP INTERFACES 14/7

14.2 ABBREVIATIONS 14/7

14.3 GENERAL REQUIREMENTS 14/8

14.4 GENERAL CONDITIONS 14/9

14.4.1 Channel Capacity: Digital Cross Connection 14/10
14.4.2 Redundant Centralised Functions 14/10
14.4.3 Power Supply 14/10
14.4.4 ITU Compliance 14/10
14.4.5 Electromagnetic Compatibility and Safety Regulations 14/10
14.4.6 Ambient Conditions 14/11
14.4.7 Mechanical Construction 14/11
14.4.8 Network Management System 14/11
14.4.9 1+1 Path Protection 14/11
14.4.10 1+1 Section Protection 14/12
14.4.11 Network Topology 14/12
14.4.12 Synchronisation 14/12
14.4.13 Alarms 14/12
14.4.14 Test Loops 14/13
14.4.15 Maintenance Facilities 14/13

14.5 REQUIREMENTS FOR TRANSPORT LEVEL 14/13

14.5.1 SDH Aggregate Units 14/13
14.5.2 MPLS-TP Aggregate Units 14/14

14.6 Tributary Units 14/14

14.6.1 Analogue Subscriber Interface 14/15
14.6.2 Exchange Interface 14/15

14.6.3 64 kbit/s Co-directional Interface 14/16
14.6.4 Ethernet Interface 14/16
14.6.5 Alarm Interface 14/16
14.6.6 Teleprotection Interface 14/17
14.6.7 Optical Protection Relays Interface 14/18
14.6.8 Binary Contact Interface 14/18
14.6.9 2Mbit/s G.703 / G.704 Interface 14/19

14.7 Telephone System **14/19**

14.8 Communications DC Power Supply Equipment **14/20**
14.8.1 General 14/20
14.8.2 Configuration 14/20
14.8.3 Charger 14/21
14.8.4 Battery 14/23
14.8.5 D.C. Distribution and Instrumentation 14/25
14.8.6 Housing 14/26

SECTION 14

FIBRE OPTIC MULTIPLEXER AND POWER LINE CARRIER EQUIPMENT FOR COMMUNICATION AND PROTECTION

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 & BNLDC) in Rampura and Siddirganj, including engineering, configuration, testing, installation, commissioning and training.

The scope of work is to connect the Substation Automation System to the existing communication system 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 Fiber Optic Multiplexer Equipment and Line/Current Differential Protection of the 400 kV, 230 kV & 132 kV 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 network, including the telecommunication network management system. The fibre optic multiplexers presently used in PGCB’s network are:

- Hitachi FOX 515/615, and

- GE MSE 5001, MSE 5010
- Huawei OSN 1800V, E6616

The Manufacturer of Telecommunication system – Fibre optic multiplexer equipment for communication and protection shall be: Hitachi Energy (Switzerland)(Former ABB), , GE (Former Alstom/Areva), HUAWEI (China).

Any other Manufacturer of Telecommunication system shall have to fulfil the Qualification Criteria required in sub-clause 2.6. of Section 3 of Volume 1 of Tender documents

14.1 Summary of Standards

The Equipment shall comply with the latest ITU-T recommendations for the Plesiochronuous, synchronous hierarchies & multiprotocol label switching-transport -profile.

The equipment shall be KEMA type tested.

14.1.1 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

14.1.2 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) network protection architectures
ITU-T G.957	Optical interfaces for equipment and systems relating to the synchronous digital hierarchy
ITU-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 7 bit coded character set for information interchange

14.1.3 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.	Transmission and Multiplexing (TM); Generic requirements for synchronisation networks; Part 1: Definitions and

1	terminology for synchronisation networks.
EN 300 462-4-1 V1.1.1	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)

14.1.4 Architecture of MPLS-TP Interfaces

The architecture of MPLS-TP interfaces shall conform to the following recommendations

ITU

ITU-T G.8112/Y.1371	MPLS-TP Interface
ITU-T G.8113:	Operations, administration and maintenance mechanisms for MPLS-TP in packet transport networks.

14.2 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
MPLS-TP	Multiprotocol Label Switching- Transport Profile
VF	Voice Frequency

14.3 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 interfaces. On aggregate level 2Mbit/s and 8Mbit/s electrical interfaces complying with ITU-T recommendations G.703 / G.704, G.8112/Y.1371 shall be available. In addition, optical STM-1/STM-4/STM-16 and/or Ethernet 1GE/10GE aggregate interfaces 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 supported.

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
- 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

The equipment may provide 1GE/10 GE Ethernet interface

The equipment shall be equipped with a ringing generator for analogue subscriber interfaces.

14.4 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 Kbit/s), second order multiplexing (8448 Kbit/s/s) and

STM-1/STM-4 or STM-16 & 1Gbps/10 Gbps 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.

14.4.1 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.

14.4.2 Redundant Centralised Functions

The equipment shall be equipped with redundant circuits for all centralised functions.

14.4.3 Power Supply

The multiplex equipment shall operate at 48VDC +/- 15%. Redundant power-supply shall be supported.

14.4.4 ITU Compliance

The Equipment shall comply to the latest ITU-T recommendations for the plesiochronuous, synchronous hierarchies & multiprotocol label switching-transport - profile such as:

G.702-704, G.706, G.711-714, G.732, G.735-737, G.742, G.826, G.823, G.8112/Y.1371, Q-552

14.4.5 Electromagnetic Compatibility and Safety Regulations

The equipment shall comply with the EN50022, EN50082, IEC 801-2, IEC 801-6 and shall be conformant with CE.

14.4.6 Ambient Conditions

Storage and transport: -40... +70˚C; 98% (no condensation)

Operation: -5... +45˚C, humidity of max. 95% (no condensation)

14.4.7 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.

14.4.8 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/SDH/MPLS-TP equipment.

14.4.9 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.

14.4.10 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.

14.4.11 Network Topology

It shall be possible to build point to point, linear, ring, T, and meshed networks.

14.4.12 Synchronisation

The equipment shall be synchronisable with an external centralised clock, with connected 2.048 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.

14.4.13 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.

14.4.14 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.

14.4.15 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.

14.5 Requirements for Transport Level

14.5.1 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

14.5.2 MPLS-TP Aggregate Units

The interface shall be designed for use on single mode fibre at 1310nm and 1550nm

The following main functions may be also supported:

- MPLS forwarding
- Pseudo-wire (PWE3)
- Bi-directional LSPs
- Static Provisioning

The following maintenance functions shall be supported:

- Continuity Check (CC)
- Connectivity Verification (CV)
- Loopback (LB)
- Remote Defect Indication (RDI)
- Loss Management (LM)
- Delay Measurement (DM)

The following MPLS-TP interfaces shall be available:

- 1/10 Gbps
- The number of optical ports shall be as per field requirement

14.6 Tributary Units

14.6.1 Analogue Subscriber Interface

An interface with at least 10 subscribers as well as high-density analogue subscriber card with 60 subscribers 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

14.6.2 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

14.6.3 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.

14.6.4 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.

14.6.5 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.

14.6.6 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.

14.6.7 Optical Protection Relays Interface

This interface shall have an optical port to connect protection relays for teleprotection to the multiplexer. It shall operate on 1300nm use MCMI line coding and be suitable for teleprotection relays. Optical Interface of Fiber Optic Multiplexer must comply with IEEE C37.94 protocol for differential protection.

14.6.8 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.

14.6.9 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.

14.7 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.

14.8 Communications DC Power Supply Equipment

14.8.1 General

14.8.1.1 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.

14.8.1.2 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.

14.8.2 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.

14.8.3 Charger

14.8.3.1 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.

Internal cooling shall be by natural ventilation. Forced cooling is not acceptable.

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.

14.8.3.2 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.

14.8.3.3 Boost Charging

Both Auto &Manual boost charging shall be provided. A boost timer shall be included to prevent overcharging.

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.

14.8.3.4 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 rnV 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.

14.8.3.5 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.

14.8.3.6 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.

14.8.4 Battery

14.8.4.1 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:

- Manufacturer's reference number and code
- year and month of manufacture
- voltage and nominal capacity at C5 rate
- cell number.
- Cell Class-L

14.8.4.2 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.

14.8.4.3 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.

14.8.4.4 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.

14.8.4.5 Capacity

The battery capacities shall be 250 ampere hours at C5 rate.

14.8.5 D.C. Distribution and Instrumentation

14.8.5.1 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.

14.8.5.2 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.

14.8.6 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.

SECTION 15

QUALITY ASSURANCE, INSPECTION, TESTING, COMMISSIONING AND WARRANTY

TABLE OF CLAUSES

15.1 SCOPE OF SECTION 15/3

15.2 SUBCONTRACTS 15/3

15.3 GUARANTEES 15/4

15.4 QUALITY AUDIT 15/5

15.5 MEASURING AND TESTING EQUIPMENT 15/5

15.6 INSPECTION PLAN AND PROCEDURE 15/5

15.7 TEST CERTIFICATES 15/6

15.8 MATERIAL TESTS 15/6

15.9 GENERAL REQUIREMENTS FOR TESTS AT MANUFACTURERS' WORKS 15/6

15.9.1 TESTING OF PLANT 15/6
15.9.2 REJECTION OF PLANT 15/7

15.10 SPECIFIC REQUIREMENTS FOR TESTS AT MANUFACTURER'S FACTORIES 15/7

15.10.1 PRESSURE VESSELS 15/7
15.10.2 DELETED 15/7
15.10.3 RELAYS 15/7
15.10.4 INSTRUMENT TRANSFORMERS 15/8
15.10.5 ELECTRICAL INSTRUMENTS AND METERS 15/8
15.10.6 AC SWITCHBOARDS 15/8
15.10.7 CONTACTORS 15/8
15.10.8 PVC CABLE 15/8
15.10.9 SWITCHGEAR (OTHER THAN GIS) 15/8
15.10.10 DISCONNECTORS AND EARTH SWITCHES 15/8
15.10.11 DELETED 15/8
15.10.12 CURRENT AND VOLTAGE TRANSFORMERS 15/8
15.10.13 STRUCTURES OF ELECTRICAL EQUIPMENT 15/9
15.10.14 SURGE ARRESTERS 15/9
15.10.15 BATTERIES AND BATTERY CHARGERS 15/9
15.10.16 CONTROL PANELS 15/9
15.10.17 BUSBARS (OTHER THAN GIS) 15/10
15.10.18 INSTRUMENTS 15/10
15.10.19 NEUTRAL EARTHING RESISTOR 15/10
15.10.20 POWER TRANSFORMERS 15/10

15.10.20.1 MAIN TRANSFORMERS 15/10
15.10.20.2 VOLTAGE CONTROL EQUIPMENT 15/12
15.10.20.3 MAGNETIC CIRCUIT 15/12
15.10.21 OUTDOOR BUSHING ASSEMBLIES WITH PORCELAIN INSULATORS 15/12
15.10.22 TANKS 15/12
15.10.23 COOLING PLANT 15/13
15.10.24 GAS AND OIL ACTUATED RELAYS 15/13
15.10.25 GALVANIZING 15/13
15.10.26 EARTHING TRANSFORMERS 15/13
15.10.27 FIBRE OPTIC MULTIPLEXER EQUIPMENT 15/13
15.10.28 DELETED 15/13
15.10.29 TELEPHONE EQUIPMENT 15/14
15.10.30 TELEPROTECTION EQUIPMENT 15/14
15.10.31 TRANSDUCERS 15/14
15.11 DISMANTLING PRIOR TO SHIPMENT 15/14
15.12 INSPECTION AND TESTING DURING SITE ERECTION 15/14
15.12.1 GENERAL 15/14
15.12.2 MECHANICAL EQUIPMENT 15/15
15.12.3 ELECTRICAL EQUIPMENT 15/16
15.13 STAFFING 15/22
15.14 TAKING OVER 15/23
15.15 DEFECTS AFTER TAKING OVER 15/23
15.16 FINAL ACCEPTANCE CERTIFICATE 15/23

SECTION 15

QUALITY ASSURANCE, INSPECTION, TESTING, COMMISSIONING AND WARRANTY

15.1 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.

Within 40 days of the Letter of Acceptance for the Contract the Bidder shall submit a quality assurance programme and a work quality programme for the Engineer's approval. It shall be submitted on the Engineer's standard form, a sample of which is included at the end of this Section.

The Bidder shall have an approved Quality Management System complying with BS5750 Part 1 or CEN 209001, which shall cover all activities being undertaken during the design, procurement, manufacturing, inspection, testing, packaging, shipping, storage, installation and erection and commissioning of the Works.

After the award of Contract, the Engineer shall have the right to carry out a review of the quality assurance procedures operated by the Bidder. The Engineer's review may consider quality assurance in relation to the design and manufacture of plant items, but may equally investigate the Bidder'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 Bidder shall give all necessary help and assistance to the Engineer in carrying out such a quality assurance review. The Bidder shall consider and discuss the results of the review and make any reasonable improvements in his procedures.

Before any plant is packed or despatched from the Main or Sub Bidders' 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 Bidder and his SubBidders 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.

15.2 SUBCONTRACTS

Within two months of acceptance of the Bid and in order to facilitate the inspection of

bought out materials and plant, the Bidder shall submit to the Engineer for approval three copies of all suborders placed by him as soon as they are issued. One copy of any drawing or schedule referred to in the suborder shall be submitted simultaneously unless agreed otherwise with the Engineer. Any reference to price may be deleted from the copies so submitted.

The suborders 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 despatched to Site direct from the SubBidder's factory.

Suborders are to include a statement advising the SubBidder that the items being ordered will be subject to inspection and test by the Engineer and Employer.

The Bidder shall advise his SubBidders of all the pertinent clauses in the Specification when ordering bought out plant, equipment or materials.

Every suborder or subcontract shall contain the following information:

(a) Main Bidder's name and suborder or subcontract number.

(b) Quantities and description of work.

(c) Delivery requirements.

(d) Delivery consignment instructions.

(e) Details of Employer and/or main Bidder's applicable drawing or schedule numbers.

(f) Name of the Engineer.

(g) 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 Bidder.

(h) A reference, particularised in the accompanying Specification, covering the following information:

Employer's name Project title

Contract No.

Engineer's reference number

SubBidders shall comply with all the applicable requirements of this Specification and the onus is upon the Bidder to ensure that SubBidders comply with these requirements.

For the purposes of this clause, interworks orders shall be treated as suborders.

15.3 GUARANTEES

The Bidder 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 Bidder 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.

15.4 QUALITY AUDIT

The Quality Programme established by the Bidder 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.

15.5 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 internationally recognised 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.

15.6 INSPECTION PLAN AND PROCEDURE

The Inspection Plan, as submitted by the Bidder to the Engineer for approval, shall cover the following:

(a) Relevant British Standards or equivalent International Standard. For each of the following stages of the work, the acceptance criteria shall be stated.

(b) The stages of inspection which shall include but not be limited to the following:

i) Tests to review or approve certification of material;

ii) Review and approval of manufacturing procedures;

iii) Witnessing tests or review and approval of certification of operator's qualification to carry out the work required;

iv) Visual and dimensional examination of components;

v) Pressure tests on casings and vessels;

vi) Nondestructive examination of materials in progress;

vii) Functional tests on subassemblies, performance tests, type tests on complete units;

viii) 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 despatch from the works.

15.7 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.

15.8 MATERIAL TESTS

The Bidder 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 Bidder.

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 Bidder's or SubBidder's designers and metallurgists will be consulted before any material is to be so rejected.

If the Engineer is furnished with certified particulars of tests which have been carried out for the Bidder by the suppliers of material, he may, at his own discretion, dispense with the previously mentioned tests.

15.9 GENERAL REQUIREMENTS FOR TESTS AT MANUFACTURERS' WORKS

15.9.1 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 which are considered necessary by the Engineer shall be carried out by the Bidder and the whole cost of the repeated tests borne by the Bidder. This also applies to tests carried out at the SubBidders' 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 Bidder and the whole cost of the repeated tests shall be borne by the Bidder. This also applies to tests carried out at SubBidders' 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 Bidder.

Specific details of tests to be carried out at the manufacturers' works are defined elsewhere in this Specification.

15.9.2 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 Bidder 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 Bidder, at his own expense, to the entire satisfaction of the Employer.

15.10 SPECIFIC REQUIREMENTS FOR TESTS AT MANUFACTURER'S FACTORIES

15.10.1 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 nondestructive 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 is completed. This shall be done whatever the programme of nondestructive testing before heat treatment.

(c) Hydrostatic test shall be conducted in accordance with BS 5500.

15.10.2 Deleted

15.10.3 Relays

All relays and associated equipment shall be routine tested to prove the quality and accuracy. Routine tests shall be in accordance with relevant IEC Recommendations and BS 142:1966, 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.

(a) Accuracy of calibrated pickup and dropoff levels over the effective range of settings

(b) Insulation tests

(c) Accuracy of timing elements

(d) Correct operation of flag (or other) indicators

(e) Mechanical requirements, integrity/safety of drawout units, check of contact pressure and alignment.

15.10.4 Instrument Transformers

Current transformers for differential protection shall be routine tested as sets.

(a) Short time current test

(b) Temperature rise tests

(c) Impulse voltage test

All instrument transformers shall be routine tested as per clause 15.10.12.

15.10.5 Electrical Instruments and Meters

One instrument and meter of each type and rating shall be subjected to the tests as specified in IEC 60051.

15.10.6 AC Switchboards

Routine tests shall include general inspection and electrical operation tests.

15.10.7 Contactors

One contactor of each type and rating shall be subjected to type tests as specified in IEC 60292 1.

15.10.8 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.

15.10.9 Switchgear (Other than GIS)

Routine tests in accordance with IEC 60056 shall be carried out on all circuit breakers.

15.10.10 Disconnectors and Earth Switches

Routine tests to IEC 60271-102 for switch disconnection.

15.10.11 Deleted

15.10.12 Current and Voltage Transformers

Routine tests to IEC 60044-1 and IEC 60044-5.

15.10.13 Structures of Electrical Equipment

Sample tests on the assembly and galvanising 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.

15.10.14 Surge Arresters

Routine tests to the specified standards shall be carried out.

The following routine tests shall be carried out on all arrester units in accordance with IEC 600994.

(a) measurement of reference voltage

(b) residual voltage test

(c) partial discharge test

(d) housing leakage test

(e) current distribution test for multicolumn arrester.

The following acceptance tests shall be carried out on one complete arrester of each voltage rating and/or type being supplied, all in accordance with IEC 600994.

(a) measurement of power frequency voltage at reference current

(b) lightning impulse residual voltage at nominal discharge current

(c) partial discharge current

(d) accelerated ageing test followed by an operating duty test details are to be agreed with the Engineer.

15.10.15 Batteries and Battery Chargers

Battery -The Bidder shall demonstrate that the battery will perform the duties specified.

Battery Charger - Routine tests according to IEC 60146 (BS 4417)

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 amperehour 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 five 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, integrity of the changeover system without break or voltage variations during loading of the standby or test charger shall be demonstrated.

15.10.16 Control Panels

Routine operation tests and insulation resistance tests shall be carried out.

15.10.17 Busbars (other than GIS)

Routine tests including millivolt drop tests shall be carried out in accordance with the specified standard.

15.10.18 Instruments

Calibration tests shall be witnessed on all important pressure gauges and other instruments as required by the Engineer.

15.10.19 Neutral Earthing Resistor

Routine leakage and over voltage tests.

Bushing insulator wet flashover tests (internal and external).

15.10.20 Power Transformers

Inspection and testing during manufacture 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 Bidder and the whole costs of the repeated tests borne by the Bidder. This also applies to tests carried out at the SubBidders' 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 despatched to Site until the Employer has given his approval in writing.

15.10.20.1 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.

i) Measurement of winding resistance on all tap positions and phases.

ii) Ratio, polarity and phase relationship.

iii) Impedance voltage.

iv) Load loss at normal, maximum and minimum taps.

v) No load loss and no load current at normal voltage Un and at +5% Un and at +10% Un.

vi) Magnetising current at nominal voltage Un and at 5% Un and +5% Un and at +10% Un.

vii) Insulation resistance.

viii) Dielectric Withstand Tests:

- On uniformly insulated windings with highest voltage Um = 36kV, tests shall comprise:

(a) induced over voltage withstand.

(b) short duration power frequency voltage withstand.

(c) full wave lightning impulse withstand for line terminals.

(d) lightning impulse chopped wave at 115% of the full wave level.

- On nonuniformly insulated windings with highest voltage Um 145 W, tests shall comprise:

(a) induced over voltage withstand combined with partial discharge.

(b) short duration power frequency voltage withstand.

(c) full wave lightning impulse withstand for line terminals.

(d) lightning impulse chopped wave at 115% of the full wave level.

- On nonuniformly insulated windings with highest voltage Um = 245kV, tests shall be carried out according to a combination of methods 1 and 2 and comprise:

(a) short duration power frequency voltage withstand.

(b) induced line to earth overvoltage withstand test at 460kV (method one routine test).

(c) full wave lightning impulse withstand for line terminals.

(d) lightning impulse chopped wave, at 115% of the full wave level.

(e) induced power frequency overvoltage withstand test with partial discharge measurement.

This shall be performed in symmetrical threephase connection on completion of all the above tests. The time sequences and test levels shall be:

U2 (1.5Um/1.732 with Q = 500pC) 5 minutes duration

U1 (Um) 5 seconds duration

U2 30 minutes duration

ix) Insulation Resistance

Type Tests

i) Temperature rise test:

The test shall be in accordance with IEC 60076-2, and shall be carried out on one transformer of each size and type. Temperaturerise tests shall be conducted on the tapping corresponding to the maximum losses.

ii) Noise level tests:

A noise level test to IEC 60076 shall be carried out on one transformer of each type specified under items 1 and 2 in accordance with IEC 60551**.**

Special Tests

i) Measurement of Zero Phase Sequence Impedance:

The test shall be in accordance with IEC 600761 Clause 8.7 and shall be carried out on one transformer of each type.

15.10.20.2 Voltage Control Equipment

Routine Tests

Each finished tap changer shall be subjected to the routine tests specified in IEC 60214 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.

15.10.20.3 Magnetic Circuit

Routine Tests

Each core completely assembled shall be tested for one minute at 2,000V AC 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 steelwork to prove that the core is earthed through the removable link, at one point only.

15.10.21 Outdoor Bushing Assemblies with Porcelain Insulators

Hollow insulators tested in accordance with IEC 60233

Complete bushings tested in accordance with IEC 60137

Routine Tests

To include:

i) Oil leakage test

ii) 50Hz dry withstand test

iii) Power factor/voltage test

iv) Partial discharge test on all bushings of which the major insulation is either oil impregnated paper or resin impregnated paper.

15.10.22 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 to

69kN/m^2 or the normal pressure plus 34kN/m^2 whichever is the greater, for 24 hours

during which time no leakage or oil ingress into normally oil free spaces shall occur.

15.10.23 Cooling Plant

Routine Tests

(a) Coolers: Pressure test to be as specified above.

(b) Motors and Control Gear: To the requirements as specified.

15.10.24 Gas and Oil Actuated Relays

Routine Tests

(a) Oil Leakage:

When subject to an internal oil pressure of 207kN/m^2 for fifteen minutes.

(b) Gas Collection

(c) Oil Surge

(d) Performance test under service conditions

(e) Voltage: 2kV for one minute between electrical circuits and casing.

15.10.25 Galvanizing

Routine Tests

To the requirements of BS 443 or BS 729 whichever is applicable,

15.10.26 Earthing Transformers

Routine Tests

(1) Measurement of Winding Resistance

(2) Ratio, polarity and phase relationships

(3) Measurement of impedance voltage

(4) Measurement of loss

(5) Short duration power frequency voltagewithstand test

(6) Induced overvoltage withstand test

(7) Insulation resistance of each winding

Special Tests

(1) Measurement of zerophase sequence impedance

15.10.27 Fibre Optic Multiplexer Equipment

Works tests shall be in accordance with the IEC standard

15.10.28 Deleted

15.10.29 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.

15.10.30 Teleprotection Equipment

Back to back tests shall be carried out to determine the satisfactory operation of the teleprotection equipment.

These tests shall be via fibre 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.

15.10.31 Transducers

Transducers shall be tested in accordance with IEC 606881.

15.11 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 plant shall be despatched to site until the Engineer has given approval in writing.

15.12 INSPECTION AND TESTING DURING SITE ERECTION

15.12.1 General

The Bidder 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 Bidder 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 Bidder shall provide, at his own cost, all labour, materials, stores, and apparatus as may be requisite 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 Bidder in accordance with the General Conditions of Contract. The Bidder shall provide all necessary test equipment to carry out the site tests, but where 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 Bidder 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 Bidder shall provide experienced test personnel and testing shall be carried out during normal working hours as far as is practicable. Tests which involve existing apparatus and outages may be carried out outside normal working hours. The Bidder shall give sufficient notice to allow for the necessary outage arrangements to be made in conformity with the testing programme.

The Bidder 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 alternative arrangements should this be necessary.

The Bidder shall record the results of the tests clearly, on an approved form and with 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 Bidder to the Engineer as soon as possible after 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 Bidder's test equipment shall be of satisfactory quality and condition and, where necessary, shall be appropriately calibrated by an approved authority at the Bidder'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.

15.12.2 Mechanical Equipment

The extent of testing during erection shall include, but not be limited to, the following:

(a) Checking the accuracy and alignment of 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 Bidder.

(b) Checking the alignment of rotating equipment to the manufacturer's requirements.

(c) Nondestructive testing of site welds as required by the relevant standard and as detailed in this specification.

(d) Hydrostatic testing of pipework systems at a pressure of 1.5 times the design pressure but not less that 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.

(e) Site fabricated tanks and vessels shall be subjected to hydrostatic tests in accordance with the relevant standards.

(f) 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 nondrainable sections shall be injected with an oxygenabsorbent chemical and elements plugged.

(g) Pressure vessels and other parts, including pipework, that are 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 Bidder and with the agreement of the Engineer, an 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 Bidder 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.

(h) Calibration checks on all instrumentation.

(i) 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.

(k) Other tests as specified which have not been previously conducted.

15.12.3 Electrical Equipment

15.12.3.1 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, labelling, 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 which 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:

(a) Routine high voltage tests to the appropriate IEC Standard. Where no relevant standard exists, tests shall be agreed with the Engineer.

(b) Insulation resistance tests on all electrical equipment.

(c) Continuity and conductivity resistance tests.

(d) Test operation of alarm and tripping devices from local and remote location.

(e) Rotational tests on all motors.

(f) Polarity tests on CTs and VTs.

(g) Oil tests.

(h) Grounding system and electrode tests.

(i) Ratio, Vector Grouping and magnetising current tests on each transformer.

0) Calibration of winding and oil temperature devices.

(k) Vector group and phasing tests on VT circuits.

(1) Magnetisation current/voltage tests and winding resistance tests on all current transformers.

(m) Primary and secondary injection tests on relays, protection devices and equipment.

15.12.3.2 Circuit Breakers

Circuitbreakers shall be given a visual inspection.

In the case of gas type circuitbreakers 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 multiinterrupter circuitbreakers 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 circuitbreakers, except those which are below 66kV and which are neither assembled at Site nor have mechanically ganged pole operation.

Local air components associated with 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.

15.12.3.3 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.

15.12.3.4 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 is fully accommodated by flexible connections.

Conductivity tests shall be carried out on all connections and joints which are made on site, without exception.

15.12.3.5 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 possible corrosion attack on the earthing system.

Test probes at approximately 300 and 600 metres 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:

(a) of each earth rod after driving

(b) of the earth grid after completion and backfilling of the trenches

(c) of each group of earth rods or earth point after completion of the connection from the test link terminal

(d) 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 Bidder may also be called upon to provide assistance in the measurement of earth resistance after earth connections to the system have been completed.

15.12.3.6 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 phaseshifting 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 severity of current inrush when energised 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 labelled 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:

i) establish that the equipment has not suffered damage during transit.

ii) establish that the correct equipment has been supplied and installed.

iii) confirm that the various items of equipment have been correctly interconnected.

iv) confirm performance of schemes designed on the bases of calculation e.g. differential protection.

v) 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 Bidder and the methods employed for a particular installation are to be agreed with the Engineer.

Tests are to be carried out as follows

i) 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.

ii) Overall primary injection to prove correct interconnection between current transformer groups and associated relays.

iii) 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 required by the Engineer.

All tripping, control, alarm and interlocking circuits shall be functionally tested to prove satisfactory and foolproof 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 microfarad.

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 circuitbreaker (or other device) both open and closed.

15.12.3.7 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.

15.12.3.8 Power Cables

Each completed circuit shall be tested for continuity and insulation resistance.

15.12.3.9 Current Transformers

A magnetisation curve shall be obtained for each current transformer in order to:

(a) Detect damage in transit or installation

(b) Prove that the correct cores have been wired out to the relevant terminals

(c) 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 transformers 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.

15.12.3.10 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 transformers 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.

15.12.3.11 Control and Instrumentation Equipment

The following general tests shall be performed on control and instrumentation equipment at site:

(a) High voltage testing of all circuits, as specified in the relevant IEC or approved standard.

(b) Insulation resistance testing of all circuits.

(c) Functional tests of all tripping, control, alarm and interlocking circuits.

(d) The testing of all equipment in accordance with the manufacturer's instructions or as advised by the Engineer.

15.12.3.12 Transformers and Ancillary Equipment

The following tests shall be performed.

i) Insulation resistance tests on bushings.

ii) Insulation resistance test at 500V between core and core clamping structure.

iii) Voltage withstand tests on insulating oil to BS 148.

iv) Ratio.

v) Phase relationship.

vi) Magnetisation characteristics of current transformers of winding temperature devices.

vii) Calibration of winding temperature devices.

viii) Tap Selector and Diverter Switch alignment.

ix) Calibration of automatic voltage control equipment.

x) Proving tests as necessary on control schemes.

xi) Measurement of winding resistance on all taps and phases.

Where applicable the above tests shall also be carried out on Earthing Transformers.

15.12.3.13 FOX, Teleprotection and Communication

Tests shall be exhaustive and shall demonstrate that the overall performance satisfies every requirement specified.

The tests to be carried out shall be:

(a) Physical inspection unit testing and demonstration of diagnostic aids as appropriate of al equipment in stand alone mode.

(b) System testing of 48V power supply equipment.

(c) System testing of FOX equipment for speech and teleprotection.

(d) System testing of telephone equipment.

(e) System testing of teleprotection equipment to plant.

15.13 STAFFING

During precommissioning the Bidder 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 Bidder's supervisors.

The Bidder 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 Bidder shall provide suitably qualified and experienced operating staff, who shall instruct the Employer's staff in the correct operating procedures.

The Bidder shall provide a team of suitably qualified and experienced engineers and technicians to precommission and commission the overall plant. The Bidder 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 Bidder shall ensure that his staff and any SubBidder's or seconded staff, observe all prescribed safety rules and permit systems.

15.14 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 Bidder 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 Bidder 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.

15.15 DEFECTS AFTER TAKING OVER

In accordance with the General Conditions of Contract, the Bidder 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 Bidder 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 Bidder's representative for the purpose of such inspection.

The Bidder 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.

15.16 FINAL ACCEPTANCE CERTIFICATE

Application for the Final Certificate may be made to the Engineer after the Bidder 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 TakingOver 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 Bidder has carried out replacements or renewals to the Works, the Bidder's obligations shall continue, but the right of the Bidder to apply

for a Final Certificate other than for the replacements or renewals shall not be affected by that fact.

SECTION 15
APPENDIX A

REF. N0.	ITEM OR COMPONENT	PROC-ESS	DESCRIPTION OF OPERATION	DOCUMENT-ATION	SPECIFICATIONS/STANDARDS	PROG	ACTION BY		
						DATE			
							BIDDER	EPL	THIRD PARTY
Quality Assurance &			Project Title: Job No. Client: Contract No: Bidder Contract No:			Legend XI Hold Point X2 Witness Point X3 Record Review QAS QA Surveillance		Note Certification Requirements Note Any Other Requirements	

Inspection Dept.	Author: Date	Checked by:			Approved by:	
						QUALITY PLAN
	Rev.No/Date	1	2	3	4	Number: Sheet
	Revision					

SECTION 15
APPENDIX B

NOTIFICATION OF WORKS INSPECTION

To facilitate the handling of inspection notifications, the following procedure shall be observed.

At the commencement of all contracts, discussions shall be held with the Main Bidder's nominated representative and the Engineer to establish guidelines for the handling of inspection notifications and test documentation.

The Main Bidder shall prepare a notification form which shall include, but not necessarily be limited to, the following:

1 . INSPECTION NOTIFICATION NUMBER

2. PROJECT TITLE

3. MANUFACTURER AND FULL ADDRESS

4. WHERE TEST/INSPECTION WILL BE CARRIED OUT
(IF DIFFERENT FROM 3 ABOVE)

5 ORDER/SUB ORDER NUMBER

6 CONTACT NAME

7 FAX/TELEPHONE NUMBER

8 DETAILS OF EQUIPMENT TO BE TESTED/INSPECTED AND WHETHER EQUIPMENT IS COMPLETE

9 SCHEDULE OF TESTS

10 MANUFACTURER'S APPROVED DRAWING NUMBER AND CORRESPONDING MEP NUMBER

11 DATE OF INSPECTION

The Main Bidder shall be responsible for recording all inspection notifications in numerical order and shall submit copies of the appropriate record at monthly intervals to the Inspection Department.

SECTION-16

Conductors, Clamps, Connectors

Index of Contents

SECTION-16 1

CONDUCTORS, CLAMPS, CONNECTORS 1

19. SUBSTATION CLAMPS-CONNECTORS & CONDUCTORS 3

19.1 Scope **3**

19.2 References **3**

19.2.1 American Standards **3**

19.3 Definitions **4**

19.5 Service Condition **6**

19.6 Types of Connections & Devices **6**

19.7 Technical Requirements **11**

19.8 Quality Assurance **15**

19.9 Notification of Changes **16**

19.10 Tests **16**

19.11 Identification Marking **22**

19.12 Inspection of Samples **23**

19.13 Packaging **23**

19.14 Off-loading and Storage Procedure **23**

19.15 Installation **24**

19.16 Inspections **24**

19.17 Documentation to be Submitted **25**

19.18 Substation Handover **26**

19.19 Appendices **26**

19.20 Busbars, Conductors and Connections **27**

19.20.1 Tubular Bus Conductors **27**

19.20.2 Flexible Bus-Bars and Earthwire 28

19.21 Spacers 29

16 Substation Clamps-Connectors & Conductors

19.1 Scope

19.1.1 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.

19.1.2 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.

19.1.3 Complete system generally shall be designed in accordance with the requirements of this specification.

19.1.4 After finishing the work, Full set of Design & Drawing documentation shall be provided as reference.

19.2 References

19.2.1 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.

19.2.2 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.

19.2.3 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.

19.3 Definitions

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 connected conductors.
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 in place
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 earth fault (3I0)
IACS	International Annealed Copper Standard
EHV	Voltage level 230kV & above
HV	Voltage level greater than 36kV , less than 230kV , including 132kV

19.4 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.

19.5 Service Condition

19.5.1 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: -.

i. Altitude: up to 1,000 m AMSL
ii. Ambient air temperatures

a) minimum : -10 °C
b) maximum : 45 °C
c) daily average : 35 °C
d) yearly average : 25 °C

iii. Maximum solar radiation: 1 100 Watts /m^2
iv. Minimum Wind speed: 0.44 m/s

The humidity is high and the atmosphere is not salt-laden.

19.6 Types of Connections & Devices

19.6.1 Bolted Connection

19.6.1.1 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.

19.6.1.2 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.

19.6.1.3 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.

19.6.1.4 Nuts shall comply with the requirements of ~~SANS 1700~~. Nuts shall be made of tensile steel . Nuts shall be resistant to corrosion.

19.6.1.5 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.

19.6.1.6 After the bolts have been tightened, the gap between the saddle and the clamp body shall be not less than 2 mm.

19.6.1.7 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/mm^2.

19.6.2 Compression Connections

19.6.2.1 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.

19.6.2.2 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.

19.6.2.3 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 refer 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.

19.6.2.4 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.

19.6.2.5 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
5.				
6.				
7.				

19.6.2.6 If line boring, or drilling techniques are used in the manufacture of the sleeves, the tolerance on the wall thickness shall not exceed 5%.

19.6.2.7 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.

19.6.2.8 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.

19.6.2.9 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.

19.6.2.10 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.

19.6.2.11 Each set of tools shall be supplied with a manual, describing the method of operation and detailing maintenance requirements.

19.6.2.12 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

19.6.3 Welding

19.6.3.1 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.

19.6.3.2 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.

19.6.3.3 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.

19.6.4 Electrical Joint Compound

19.6.4.1 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.

19.6.4.2 The compound shall not attack the aluminium material.

19.6.4.3 The compound shall not cause corona.

19.6.4.4 The drop point of the compound shall be >90 °C.

19.6.4.5 The flash point of the compound shall be ≥140 °C.

19.6.4.6 The oil separation of the compound shall be ≤ 1% at 100°C for 4 hours.

19.6.5 Spacers

19.6.5.1 Spacers shall be designed to meet all the requirements of IEC 61854.

19.6.5.2 Bundle spacer is to be used for 'Quadruple' & twin ACSR/TACSR/ACCC conductor

19.6.5.3 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.

19.6.5.4 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.

19.6.5.5 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.

19.6.5.6 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.

19.6.5.7 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.

19.6.5.8 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.

19.6.5.9 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.

19.6.5.10 The spacers shall conform to ANSI standard. Only Type tested spacers shall be offered.

19.6.6 Equipotential Ring For 230kV & 400kV Equipment:

19.6.6.1 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.

19.6.6.2 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.

19.6.6.3 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.

19.6.6.4 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.

19.6.6.5 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.

19.6.6.6 Provisions shall be made in order:

a) To prevent ingress and accumulation of moisture and impurities inside the ring.

b) To fasten the ring to the associated equipment, in such a way as to prevent loosening under any circumstances.

c) To avoid vibrations or resonance effects during operation.

19.6.6.7 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.

19.6.6.8 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.

19.6.6.9 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.

19.6.6.10 The design and arrangement of the equipotential rings shall be subject to the approval of PGCB.

19.6.7 Fittings for tube conductor

19.6.7.1 Clamp connectors shall be provided for Aluminium tube conductors.

19.7 Technical Requirements

19.7.1 Materials

19.7.1.1 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.

19.7.1.2 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.

19.7.1.3 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.

19.7.1.4 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".

19.7.1.5 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.

19.7.1.6 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.

19.7.1.7 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.

19.7.1.8 Wherever connector will bridge Aluminum & Copper for bimetallic clamps, pure copper with tin coated liner having minimum thickness of 2 mm. shall be used.

19.7.1.9 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.

19.7.1.10 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.

19.7.1.11 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.

19.7.1.12 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.

19.7.1.13 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.

19.7.1.14 Other steel parts may be made of non-stainless steel but shall be hot-dipped galvanised in accordance with SS-EN ISO 1461

19.7.2 Machining

19.7.2.1 The contact areas of all clamps used for current-carrying purposes are to be machined to create true cylindrical surfaces.

19.7.2.2 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.

19.7.2.3 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.

19.7.2.4 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.

19.7.2.5 If line boring, or drilling techniques are used in the manufacture of the sleeves, the tolerance on the wall thickness shall not exceed ±5%.

19.7.2.6 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 .

19.7.3 Design Requirement

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.
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. 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%.
4. Sharp Corners and edges shall be rounded off.
5. The connector shall be mechanically strong so that it can withstand loads imposed during erection, normal service, electro-mechanical force due to temperature variation and short circuit condition.
6. The current density considered for Aluminium & copper shall not be greater than 0.75 & 1.75 A / sq. mm respectively, unless otherwise agreed.
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.
8. Permanent deformations, cracks or failures shall not occur in connectors for bundled stranded 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.
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.

19.7.4 Electrical Requirement

19.7.4.1 Current Rating

19.7.4.1.1 The rated normal current of each clamp shall be in accordance with the value stated in the relevant table of this specification.

19.7.4.1.2 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.

19.7.4.1.3 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.

19.7.4.2 Corona Characteristics

19.7.4.2.1 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.

19.7.4.2.2 The offered connector for phase conductor shall be free from visible corona at a test voltage, phase – earth of:

Test voltage = $= \frac{U_m}{\sqrt{3}} \times 1.1$

Where Um is 36kV, 145kV, 245 kV and 420 kV respectively.

19.7.4.2.3 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.

19.7.4.2.4 Corona Inception & Extinction voltage shall be provided.

19.7.4.2.5 These characteristics shall be proven by test.

19.7.4.3 Resistance

19.7.4.3.1 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.

19.7.4.3.2 Test result clearly identify this requirement is fulfilled.

19.7.4.4 Short-Circuit Current

19.7.4.4.1 Two types of SC current are defined: symmetrical & Asymmetrical.

19.7.4.4.2 The connector shall withstand a short-circuit current that of same as the connected conductors without any deformation.

19.7.4.4.3 For rating of symmetrical short circuit current at different voltage levels, please refer to section 01 of the specification.

19.7.4.4.4 A minimum of 2.69 times the symmetrical short circuit current shall be applied to get the Asymmetrical short circuit current.

19.7.5 Mechanical Requirement

19.7.5.1 Tightening torques
Tightening torques for screws and nuts shall be at least 45 Nm for M10 and at least 75 Nm for M12.

19.7.5.2 Threaded holes
Threaded holes shall have at least the same strength as A2-80 nuts in accordance with SS-EN-ISO 3506-2.

19.7.5.3 Washers
Washers shall have a hardness of HV min 200 at tests in accordance to SS-EN-ISO 6507-1.

19.7.5.3.1 Contact force
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 in accordance to ~~Clause 7.1.~~

19.7.5.3.2 The connectors shall provide the contact forces specified in Tables 1 to 8. Contact forces are defined in Figures 12 to 14.

19.7.5.4 Deformation

Permanent deformation shall not occur in current carrying parts or keepers at a torque of 110% of the torque given in Clause 7.1.

19.7.5.5 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 centreline 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 centre line of the tube to the outer-most part of the connector.

This dimension has been specified to permit the connection of tubes to different types 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 the longitudinal 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 dimension relates 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 accordance with the previous, max 500 N. The prescribed force applies when the vertical force between 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 length of the tube which can arise as a result of temperature changes between the minimum temperature encountered during the night and the maximum temperature encountered during the day, without giving rise to fatigue failure in the connectors.

Flexible connectors shall impose the least possible tensile, torsion and bending forces on terminals under both normal operating conditions and short-circuit conditions.

Flexible connectors shall not fail through fatigue, nor shall abnormal wear of tubes and connectors occur during operation. Tubes shall be so supported that it is not possible for 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.

19.8 Quality Assurance

19.8.1 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.

19.8.2 Registration to ISO 9001 is desired.

19.8.3 Connectors shall be class A in accordance with IEC 61238-1.

19.8.4 All offered items shall be type tested in STL member laboratory.

19.8.5 The alloy shall be as per specification or better quality.

19.8.6 Manufacturing technology shall be recognized and acceptable .Special technology by manufacturer is preferred.

19.8.7 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.

19.8.8 For compression, manufacturer recommended tools & die size shall be used.

19.8.9 The same personnel, components and tools used to carry out the installation shall be involved in the sample exercise.

19.8.10 PGCB shall be provided with an opportunity to witness the preparation of the samples.

19.8.11 The samples shall be sent to an independent facility for mechanical (pull) testing according to section 7 of IEC 61238-1.

19.8.12 The Contractor shall outline their quality procedure to ensure the correct selection and use of crimping dies and tools.

19.9 Notification of Changes

19.9.1 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.

19.10 Tests

19.10.1 Type Test Clamps

19.10.1.1 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.

19.10.1.2 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.

19.10.1.3 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.

19.10.1.4 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.

19.10.1.5 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.

19.10.1.6 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.

19.10.1.7 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.

19.10.1.8 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.

19.10.1.9 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.

19.10.1.10 Following type test shall be applied for all types of clamp-connector

1.11.1.10.1 **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.

1.11.1.10.2 **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.

1.11.1.10.3 **Corona and RIV Test**

19.10.1.10.1 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.

19.10.1.10.2 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.

1.11.1.10.4 **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.

1.11.1.10.5 **Bolt Tightening Torque Test**

The bolt tightening torque test shall be performed according to the test procedure and requirements of ANSI/NEMA CC1.

1.11.1.10.6 **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.

1.11.1.10.7 **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.

19.10.2 Type Tests Acceptance Criteria (Clamps)

19.10.2.1 Heat (Current)-Cycle Test

19.10.2.1.1 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.

19.10.2.1.2 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 %.

19.10.2.2 Temperature Rise Test

i. 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.

ii. 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.

19.10.2.3 Corona and RIV Test

i. 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.

19.10.2.4 Short-Circuit Withstand Test

i. 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.

ii. 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.

19.10.2.5 Bolt Tightening Torque Test

i. There shall be no evidence of mechanical damage to all the clamp components and the conductor after the test.

19.10.2.6 Slip/Pull-out Strength Test

i. 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.

19.10.2.7 Cantilever Strength of Bus Supports Test

i. There shall be no evidence of mechanical damage to all the clamp components and the conductor after the test.

19.10.3 Type Tests --Spacers

19.10.3.1 Corona and RIV Test

ii. Corona tests shall be done according to the test procedure and requirements of ANSI/NEMA CC1 or IEC 61284.

iii. RIV tests shall be performed according to the test procedure and requirements of CISPR 16-1 and CISPR 18-2 or NEMA 107.

19.10.3.2 Clamp Slip Test

iv. **Longitudinal Slip Test**
Longitudinal slip tests shall be done according to the relevant procedure of IEC 61854.

v. **Torsional Slip Test**
Torsional slip tests shall be done according to the relevant procedure of IEC 61854.

19.10.3.3 Breakaway Bolt Test: Breakaway bolt tests shall be done according to the relevant procedure of IEC 61854.

19.10.3.4 Clamp Bolt Tightening Test: Clamp bolt tightening tests shall be done according to the relevant procedure of IEC 61854.

19.10.3.5 Simulated Short-Circuit Current Test: Simulated short-circuit current tests shall be done according to the relevant procedure of IEC 61854.

19.10.3.6 Compression and Tension Test: Compression and tension tests shall be done according to the relevant procedure of IEC 61854.

19.10.4 Type Test Acceptance Criteria --Spacers

19.10.4.1 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.

19.10.4.2 Clamp Slip Test

a) **Longitudinal Slip Test**
No slippage shall occur at or below the minimum specified value.

b) **Torsional Slip Test**
No slippage shall occur at or below the minimum specified value.

19.10.4.3 Breakaway Bolt Test: The bolt shall not be damaged or broken at the end of the test.

19.10.4.4 Clamp Bolt Tightening Test: The bolt shall not be broken or damaged. The threads shall not suffer any damage.

19.10.4.5 Simulated Short-Circuit Current Test: There shall be no damage that will result in the spacer not maintaining the bundle design spacing.

19.10.4.6 Compression and Tension Test: There shall be no damage that will result in the spacer not maintaining the bundle design spacing after the test.

19.10.5 Sample Tests -- Clamps

19.10.5.1 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

19.10.6 Sample Tests - Spacers

19.10.6.1 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

19.10.7 Routine Tests --Clamps

19.10.7.1 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.

19.10.7.2 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.

19.10.7.3 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.

19.10.7.4 Visual Examination

vi. 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.

vii. For corona-free clamps, visual inspection shall include comparison of the surface finish of sampled clamps with those clamps that passed corona tests.

19.10.8 Routine Tests -Spacers

19.10.8.1 The following routine tests shall be conducted according to the relevant procedures of IEC 61854.

a) Visual examination
b) Verification of dimensions, material and mass

19.10.9 Type Test Certificates and Reports

19.10.9.1 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.

19.10.9.2 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.

19.10.9.3 Type test reports shall contain, as a minimum, the following information:

i. Name and address of test facility.
ii. Contact details of test facility.
iii. Details and validity of accreditation of test facility.
iv. Date of test.
v. Type of clamp tested.

vi. Description of the test equipment used, including test equipment serial number and last date of calibration.
vii. Description of test set-up, including photographs of the set-up.
viii. Description of test procedure.
ix. Test results.
x. Analysis of test results.
xi. A statement that the clamp conforms, or does not conform, to the requirements of this specification.
xii. Description of the condition of the clamp after testing (include picture of the clamp).
xiii. Names and titles of personnel who conducted the test.

19.10.10 TESTS AT MANUFACTURER'S WORKS AND TEST CERTIFICATES :

19.10.10.1 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.

19.10.10.2 Acceptance Test for Clamps & Connectors:

(a) Tensile test
(b) Resistance test
(c) Dimensional check
(d) Galvanizing test, where applicable.

19.10.10.3 Routine Test for Clamps & Connectors:

i. 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.

ii. 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.

iii. 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.

iv. 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.

19.11 Identification Marking

1.1.1 Clamps shall be clearly and indelibly marked with the following minimum information:

a) Manufacturer's identification.

b) PGCB clamp code number.

c) Nominal size or range of sizes of conductors with which the clamp is intended to be used.

19.12 Inspection of Samples

1.1.2 A list of samples of clamps to be submitted during tendering shall be included in the tender enquiry documents.

19.13 Packaging

1.1.3 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.

1.1.4 To facilitate inspection and handling, the sealed clamps shall be supplied in strong durable containers.
Wooden crates shall be treated.

1.1.5 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.

1.1.6 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.

19.14 Off-loading and Storage Procedure

1.1.7 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.

1.1.8 The supplier shall contact the relevant personnel for delivery of clamp consignment at least one (1) week
before delivery.

1.1.9 At the time of off-loading at an PGCB facility, the supplier shall ensure that clamps are off-loaded properly
and safely.

19.15 Installation

19.15.1 General

19.15.1.1 The Installation shall be in accordance with the approved installation instruction of vendors.

19.15.1.2 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.

19.15.1.3 Earthing Current carrying parts, conductor groove and conductor, shall be treated in the following way at installation:

a) Current carrying surfaces shall be brushed thoroughly with a steel brush.

b) Contact paste shall be applied on the current carrying surfaces.

c) The current carrying surfaces shall be brushed with a steel brush into the contact Paste

d) Additional contact past shall be applied

19.15.1.4 Locally made Connector having type tested is preferred so that after sales technical support is properly achieved.

19.15.2 Galvanic Action

19.15.2.1 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.

19.15.2.2 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.

19.15.2.3 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.

19.15.2.4 All connectors in contact with galvanised steel shall be tinned. Where possible, connections shall be made to vertical faces only.

19.16 Inspections

19.16.1 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:
a) Frequency of inspections
b) Scope of inspection
c) Parameters to be inspected
d) Inspection tools
e) Inspection procedure
f) Remedial actions

19.17 Documentation to be Submitted

19.17.1 Design-Document Approval

19.17.1.1 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.

19.17.1.2 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.

19.17.1.3 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

19.17.1.4 Set of Electromagnetic Field & Expected Corona simulation for 400kV & above voltage level.

19.17.1.5 Inspection & Test Plan and Manufacturing Quality Plan

19.17.1.6 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.

19.17.1.7 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.

19.17.1.8 Manual(s) for handling, storage and inspections

19.17.2 Before test

19.17.2.1 List of tests to be performed

19.17.2.2 Procedures of test with circuit or test arrangement diagram

19.17.2.3 Sampling Plan

19.17.2.4 Descriptions of tools to be used

19.17.2.5 Sample Test & Report Format including acceptance criteria.

19.17.3 After Installation

i. Photographic of installation & testing (if any) QA records.
ii. Test results of Ductor tests and joints.

19.18 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.

19.19 Appendices

APPENDIX A: LIST OF TYPICAL CONDUCTORS USED IN PGCB SUBSTATIONS

Table -A1: Flexible conductor

SL	Conductor	Overall Diameter, mm	Nominal Al area, mm^2	No. of Al/St	Weight (Approx.), kg/km
	ACSR				
1.	Moose	31.77	500	54/7	~2000
2.	Martin	36.17	685	54/19	~2588
3.	Mallard	28.96	403	30/19	~1840
4.	Finch	32.85	565	54/19	2134
5.	Grosbeak	25.15	321.8	26/7	1300
	TACSR				
6.	TACSR 410	28.5	414	26/7	1673
7.	TACSR 610	34.2	612	54/7	2325
8.	TACSR 680	35.10	684	45/7	2260
9.	TACSR 810	38.40	814	45/7	2699

Table -A2: Rigid conductor

SL	Rigid Conductor
1.	Al tube 5''
2.	Al tube 4.5''
3.	Al tube 4''

4.	Al tube 3''

Note; Above list indicate typical conductors only. The list does not necessarily mean that, other conductor cannot be used / proposed for new station; also, the list does not rule-out the possibility that, other non-standard or customised connection is present in the system; actually, as per requirement, other customised connection is also existent. However, the list gives an overview of the substation conductor system & may serve as an initial guide for new construction.

Appendix B– Indicative Drawings

Not Applicable. Detailed Drawing shall be provided by Vendors/Contractors/Suppliers

19.20 Busbars, Conductors and Connections

Busbars and electrical connections in outdoor substations shall be in accordance with BS 215, 159 and 2898 and relevant IEC standards in respect of current rating and material analysis.

Overhead conductors carried by the switchyard structures shall be erected with such sags and tensions that when the conductors are subjected to the load combinations in Section 11, the factor of safety will not be less than 3.5. The switchyard structures shall be designed considering the sag limit at minimum ambient temperature (50 degree C) in still air not exceeding one(1) percent of the horizontal span length. Conductor sag chart and clearance data shall be subject to approval of Engineer.

Materials used for busbars and connections shall be stressed to not more than two-fifths of their elastic limit. Provision shall be made for expansion and contraction with variation in conductor temperature and busbars shall be arranged so they may be readily extended in length with a minimum of disturbance to existing equipment.

Tubular bus conductor shall be used for 400kV, 230kV and 132kV busbar and supported by station post insulator, as required by project scope.

19.20.1 Tubular Bus Conductors

General

Aluminium used shall be of grade 63401 WP conforming to relevant IEC/BS Standard.

Constructional Features

a) For outside diameter (OD) & thickness of the tube there shall be no minus tolerance. The other requirements shall be as per IEC 114.

b) Corona bells shall be provided wherever the bus extends beyond the clamps and on free ends for sealing the ends of the tubular conductor against rain and moisture and to reduce the electrostatic discharge loss at the end points. There shall be small drain hole at the end of each corona bell.

c) No jointing/welding of Al tube is allowed at site & Factory. Cutting length of al tube shall be

such that, they lie in the HPI and they are joined by thermal expansion joint at the PI.

d) Tube bending shall be done at factory to avoid any bending during operational period.

Parameters

The size and other parameters of tubular bus conductors suitable for the busbar specification stated in Appendix A1 in Volume 3 of 3 of the bid document shall be determined by the Bidder.

Tests

The tests shall be conducted on tubular bus conductors as per relevant IEC Standard. Also the wall thickness and ovality of the tube shall be measured by ultrasonic method. In addition to the above tests, 0.2% proof test on both parent metal and aluminium to be after welding shall be conducted.

19.20.2 Flexible Bus-Bars and Earthwire

General

The conductors shall conform to relevant IEC/BS Standard. The number and diameters of the individual wires forming the finished conductor shall be subject to approval of Engineer.

Constructional Features

Workmanship

All the aluminium strands shall be smooth, uniform and free from all imperfections, such as spills and splits, die marks, scratches, abrasions and kinks after drawing and also after stranding. The finished conductor shall have a smooth surface without any surface cuts, abrasions, scuff marks and shall be free from dirt, grit etc.

Joints in Wires

No joints shall be permitted in the individual wires in the outermost layer of the finished conductor. However, joints in the inner layers of the conductor shall be allowed but these joints shall be made by cold pressure butt-welding and shall be such that no two such joints are within 15 metres of each other in the complete stranded conductor.

Materials

The aluminium strands shall be hard drawn from electrolytic aluminium rods having purity not less than 99.5% and a copper content not exceeds 0.04%.

Parameters

The size, rating, number of conductors per phase and the configuration, etc. shall be determined by the Bidder.

Tests

The following type, acceptance and routine tests and tests during manufacture shall be carried out on the conductor in addition to the tests specified in relevant applicable standards.

Type Test

DC Resistance Test on Stranded Conductor On a conductor sample of minimum 5 m length two contact clamps shall be fixed with a predetermined bolt torque. The resistance shall be measured by Kelvin double bridge by placing the clamps initially zero meter and subsequently one meter apart. The test shall be repeated at least five times and the average value recorded. The value obtained shall be corrected to the value at 20 degree C as per relevant IEC Standard.

Acceptance Test

i) Visual and Dimensions check on Drums

ii) Visual Check for Joints, Scratches etc.

iii) Dimensional check on Aluminium Strands

iv) Check for lay-ratios of various Layers The following tests shall be conducted once on sample/samples of conductor.

- Breaking load test on aluminium strands

- Wrap load test on aluminium strands

- DC resistance tests on aluminium strands

All the above tests shall be carried out on aluminium strands after stranding only.

Routine Tests

i) Check to ensure that the joints are as per specification.

ii) Check that there are no cuts, fins, etc. on the strands.

iii) Check that drums are as per specification.

iv) All acceptance tests as mentioned above are to be carried out on each coil

Tests During Manufacture

Chemical Analysis of Aluminium used for making aluminium strands Samples taken from the aluminium ingots/coils/ strands shall be chemically/spectrographically analyzed. The same shall be in conformity to the specified requirements.

Packing

The conductor shall be supplied in strong wooden drums constructed to protect the conductor against all damage and displacement during transit, storage and subsequent handling and stringing operations in the field. The drums shall generally conform relevant IEC/Standard. Only one length of conductor shall be wound on each drum.

19.21 Spacers

General

The spacers shall conform to relevant IEC/ BS Standard.

Constructional Features

No magnetic material should be used in the fabrication of the spacers except for the GI bolts and nuts. Spacer design shall be made to take care of fixing and removing during installation and maintenance. The design of spacer shall be such that the conductor does not come in contact with any sharp edge.

Tests

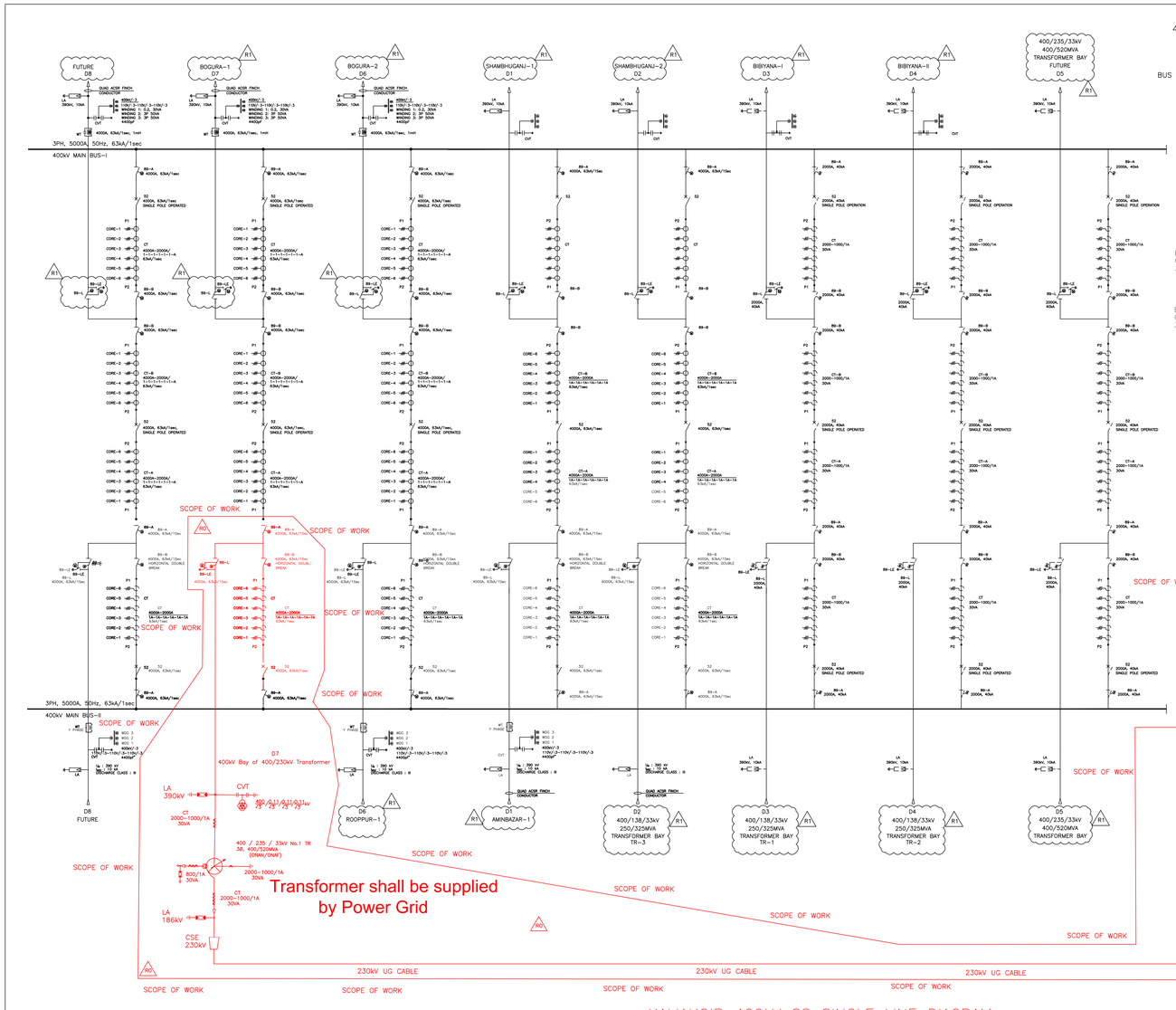
The spacers shall be subjected to the type tests, acceptance tests and routine tests in accordance with relevant IEC/BS Standard.

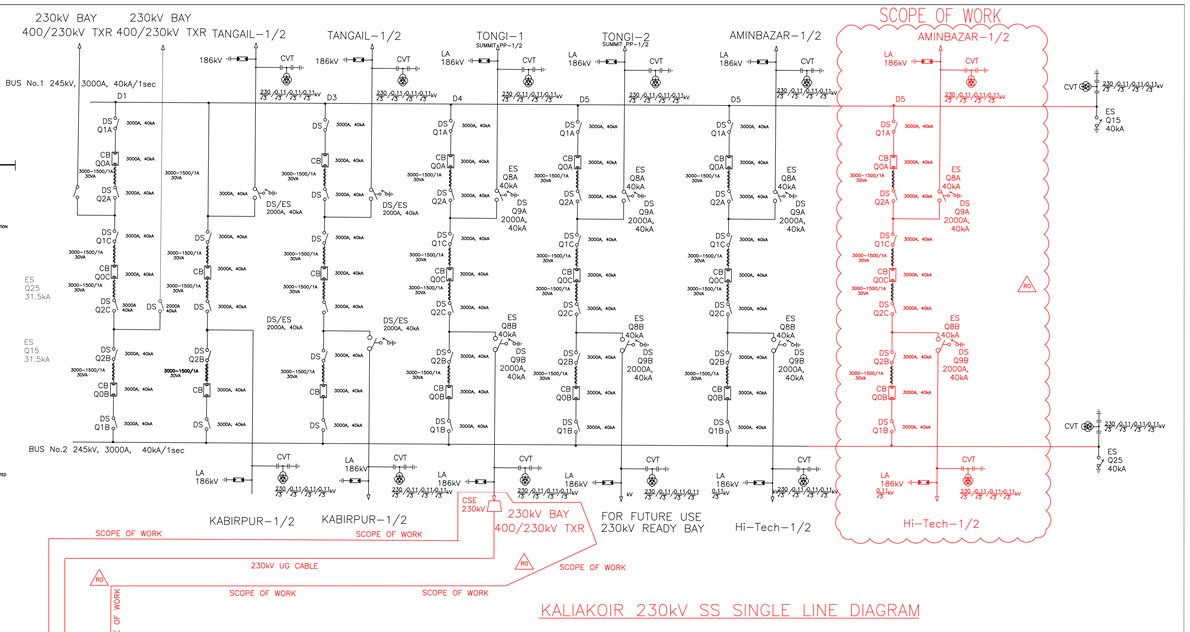
Section 17
Drawings

The drawings provided in this section are solely for the purpose of bid information and bid preparation. They present the typical details of the project facilities and plant requirements for the following.

List of Bid Drawings

SL No.	Drawing Title
1.	SLD for 400kV & 230kV Bay Extension
2.	Layout for 400kV & 230kV Bay Extension
3.	Gas SLD, MRE
4.	110V, 48V LVDC and LVAC
5.	Substation Automation System Architecture
6.	Guard house
7.	Switchyard Surface Level
8.	Car Port with Solar
9.	Fence
10.	Boundary Wall
11.	Gate
12.	Approach Road
13.	Typical Road Sections
14.	Sentry Post
15.	Septic Tank
16.	Soak Well
17.	Slope Protection
18.	Walk Way
19.	Ansar Barrack
20.	Stair Railing
21.	Property Line Marking
22.	Open Storeyard
23.	PFI Plant
24.	IP Camera





SCOPE OF WORK

- PRESENT SCOPE OF WORK
- EXISTING
- FUTURE PGCB SCOPE
- REVISION CLOUD
- R1 REVISION NUMBER

SITE SPECIFICATION

LOCATION	KALIAKOIR
NEAREST TOWN	KALIAKOIR
COUNTRY	BANGLADESH
ALTITUDE	LESS THAN 1000M
MAXIMUM AMBIENT TEMPERATURE	40° C
EQUIPMENT DESIGN TEMPERATURE	40° C
MINIMUM AMBIENT TEMPERATURE	4° C
MAXIMUM RELATIVE HUMIDITY	100% RH
AVERAGE RELATIVE HUMIDITY	80% RH
SEISMIC CONDITIONS	0.1g
CORROSION TREATMENT	70 micron ZINC LAYER

SYSTEM PARAMETERS

SYSTEM PARAMETER	400 kV SYSTEM
No. OF PHASES	3 PHASE
FREQUENCY	50 Hz
SYSTEM GROUNDING	SOLIDLY GROUNDED
MINIMUM OPERATING VOLTAGE OF SYSTEM	420 kV
FULL WAVE LIGHTNING IMPULSE WITHSTAND VOLTAGE (1.2/50 μS)	1425 kVp
SWITCHING IMPULSE WITHSTAND VOLTAGE (250/2500μS)	1050 kVp
ONE MINUTE POWER FREQUENCY DRY AND WET WITHSTAND VOLTAGE (RMS)	520 kV
RATED SHORT CIRCUIT CURRENT AND ITS DURATION	63 kA, 1 Sec
CREEPAGE DISTANCE	25 MM / KV
MINIMUM CLEARANCE BETWEEN LIVE METAL	4000 mm
MINIMUM CLEARANCE BETWEEN LIVE METAL PARTS AND EARTH	3500 mm
SAFETY CLEARANCE/SECTION CLEARANCE	6400mm
BAY WIDTH	26 mm

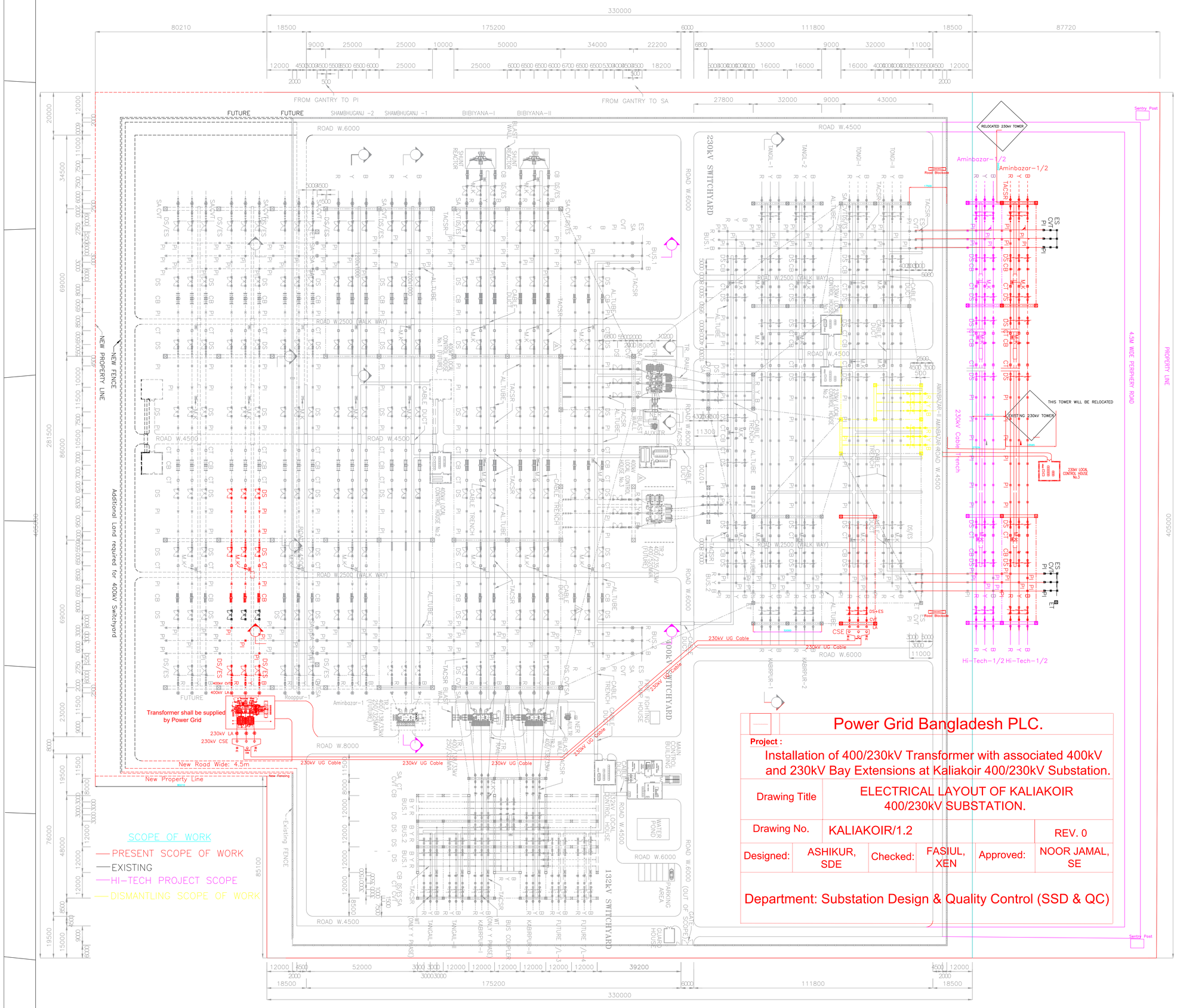
Power Grid Bangladesh PLC.

Project :

Installation of 400/230kV Transformer with associated 400kV and 230kV Bay Extensions at Kaliakoir 400/230kV Substation.

Drawing Title	SINGLE LINE DIAGRAM (SLD) OF KALIAKOIR 400/230kV SUBSTATION.				
Drawing No.	KALIAKOIR/1.1				REV. 0
Designed:	ASHIKUR	Checked:	FASIUL	Approved:	SAHRIAR

Department: Substation Design & Quality Control (SSD & QC)



Power Grid Bangladesh PLC.

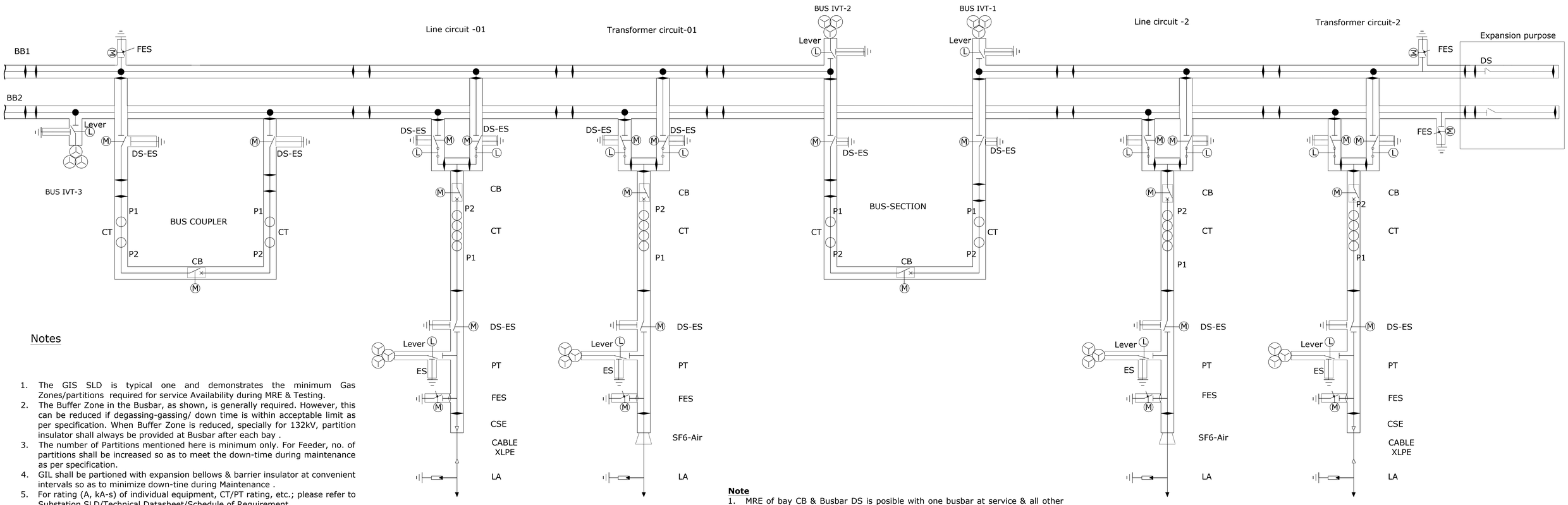
Project :
Installation of 400/230kV Transformer with associated 400kV and 230kV Bay Extensions at Kaliakoir 400/230kV Substation.

Drawing Title	ELECTRICAL LAYOUT OF KALIAKOIR 400/230kV SUBSTATION.				
Drawing No.	KALIAKOIR/1.2				REV. 0
Designed:	ASHIKUR, SDE	Checked:	FASIUL, XEN	Approved:	NOOR JAMAL, SE

Department: Substation Design & Quality Control (SSD & QC)

GIS SLD for MRE & Testing Scheme (For Double Busbar)

The Drawing is tentative & is for Tender Purpose Only. Details shall be finalized during Execution.



Notes

1. The GIS SLD is typical one and demonstrates the minimum Gas Zones/partitions required for service Availability during MRE & Testing.
2. The Buffer Zone in the Busbar, as shown, is generally required. However, this can be reduced if degassing-gassing/ down time is within acceptable limit as per specification. When Buffer Zone is reduced, specially for 132kV, partition insulator shall always be provided at Busbar after each bay .
3. The number of Partitions mentioned here is minimum only. For Feeder, no. of partitions shall be increased so as to meet the down-time during maintenance as per specification.
4. GIL shall be partioned with expansion bellows & barrier insulator at convenient intervals so as to minimize down-tine during Maintenance .
5. For rating (A, kA-s) of individual equipment, CT/PT rating, etc.; please refer to Substation SLD/Technical Datasheet/Schedule of Requirement.
6. The noumber of Feeders are typical only. Actual no. of Feeders are as per substation SLD.
7. The Location/Sequence of Bus-coupler & Bus-section are typical only and shall be finalized during Detail Engineering at Execution stage prior to Employers' approval.
8. The sequence of Bays are typical only and shall be finalized during Detail Engineering at Execution stage prior to Employers' approval.
9. The Bus-section at BB1 is for shown as typical only; BS shall be per Substation SLD.
10. For 400kV, 230kV & 132kV system, ISX is required. Moreover, if required, ISX shall be provided at both end of Buses. Purpose of ISX is to facilitate HV testing of Extended Bays while ensuring service continuity of Existing Plant.
11. The Feeder termination mentioned as CSE/SF6-Air Bushing are indicative only, actual termination [SF6-Air, Direct transformer Connection etc.] are as per Substation SLD/Schedule of Requirement . When CSE is required, the Earthing of GIS & cable must be kept separate.
12. All Busbar DS are DS-ES arrangement i.e., DS Integrated with ES [Substation SLD & Scope shall prevail].
13. Bus VT & Feeder VT isolation is with externally hand Operated Lever; Earthing facility is without Motor for 132kV & with motor operation at 230kV & 400kV; Note that, in such cases, interlock shall be provided so that VT cannot be isolated unless FES is operated, i.e., Earthing is ensured both at Bus & Feeder. When VT isolation is provided, VT with reduced Insulation [phase-earth] is acceptable.

Note

1. Isolating Switch shall have view-port to see it's status.
2. All DS/DS-ES shall have view port to see its' status.
3. HV test Voltage injection facility shall be provided for Cable connected feeder.
4. HV test Voltage injection facility shall be provided for Bus-Coupler & Bus-section Bay independently.
5. VT shall be connected to test voltage part during HV test

Note

1. Gas Diagram shall be submitted with all required information like Weight of Bays with /without gas; No of compartments; no. of accessories like valve; gauge, PRD etc
2. Rated operating, Design , test & bursting pressure of gas compartment shall be indicated
3. PD sensors shall be provided & indicated
4. Each Compartment will have its own gassing-Degassing Valve; gauge;PRD; Absorption material etc.
5. Partitions shown means gas tight partition insulators
6. Setting of rated, Alarm, Lock-out, re-sting pressure shall be provided;
7. Total Copper Loss for GIS shall be calculated & provided; temperature rise at different parts shall be calculated, tested & provided;Method of Fault Identification within the GIS shall be provided

Note

1. MRE of bay CB & Busbar DS is posible with one busbar at service & all other bays are at service
2. MRE of bay Bus-Coupler / Bus-Section CB & Busbar DS is posible with one busbar at service & all other bays are at service
3. HV testing of a Bay is possible with one busbar at service & all other bays at service.
4. HV Testing of Bus-section Bay is possible with one busbar at service & all other bays at service.
4. HV Testing of Bus-coupler Bay is possible with one busbar at service & all other bays at service.
5. HV testing of Busbar DS is possible with one busbar at service & all other bays at service.

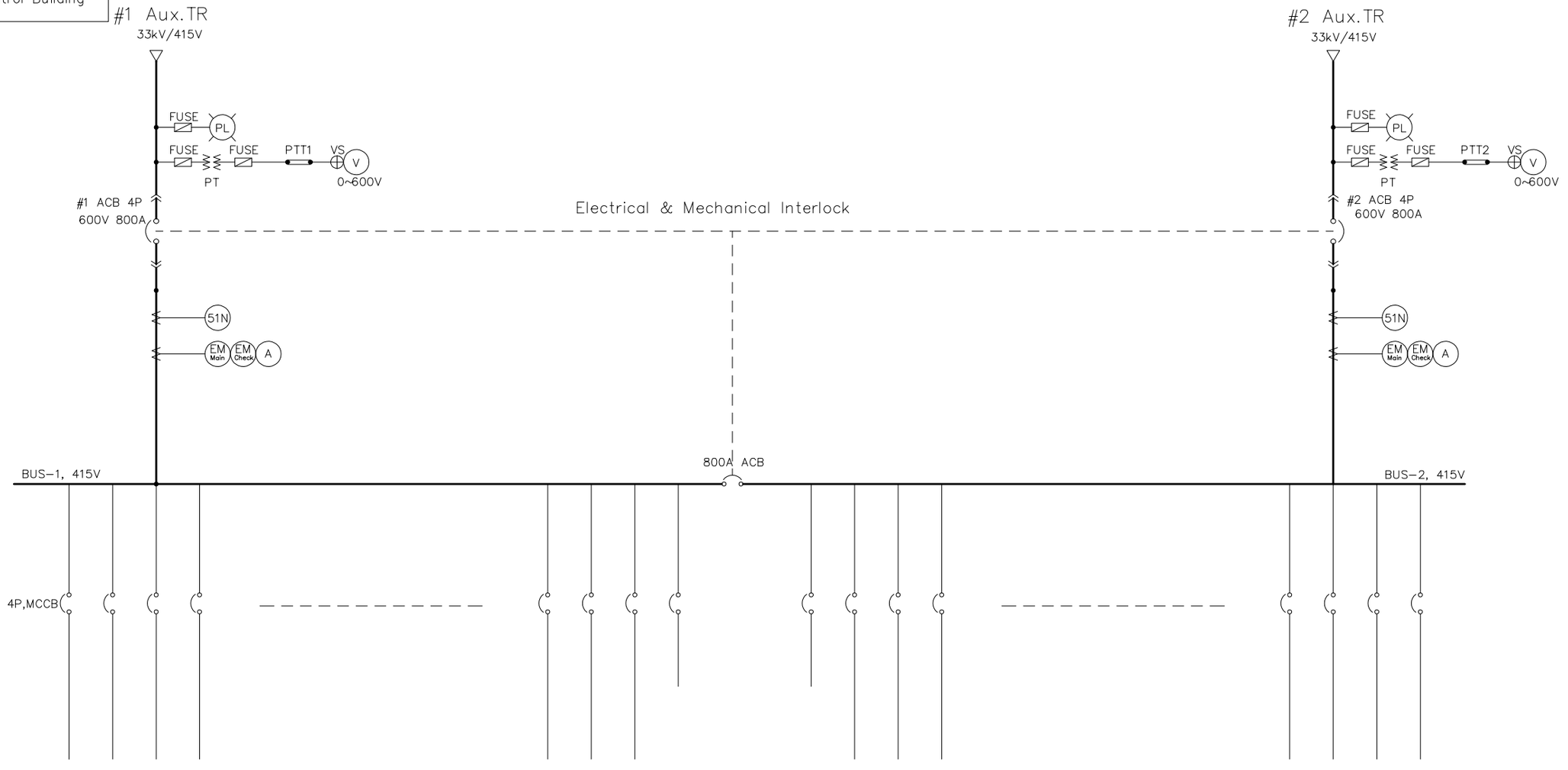
02	09.09.2021	Version -02
Rev.	Date	Revision Note

Project: Applicable for ALL GIS Project with Double Busbar Scheme[New or Extension]

Drawing Title:
GIS Gas Zone SLD- MRE and Testing

Applicable Busbar Scheme			Double Busbar Scheme
Approved			
Checked			
Designed		Date	
Drawing No.-	SSD-DGL-DWG-02-GSLD-DB-000		

Main Control Building

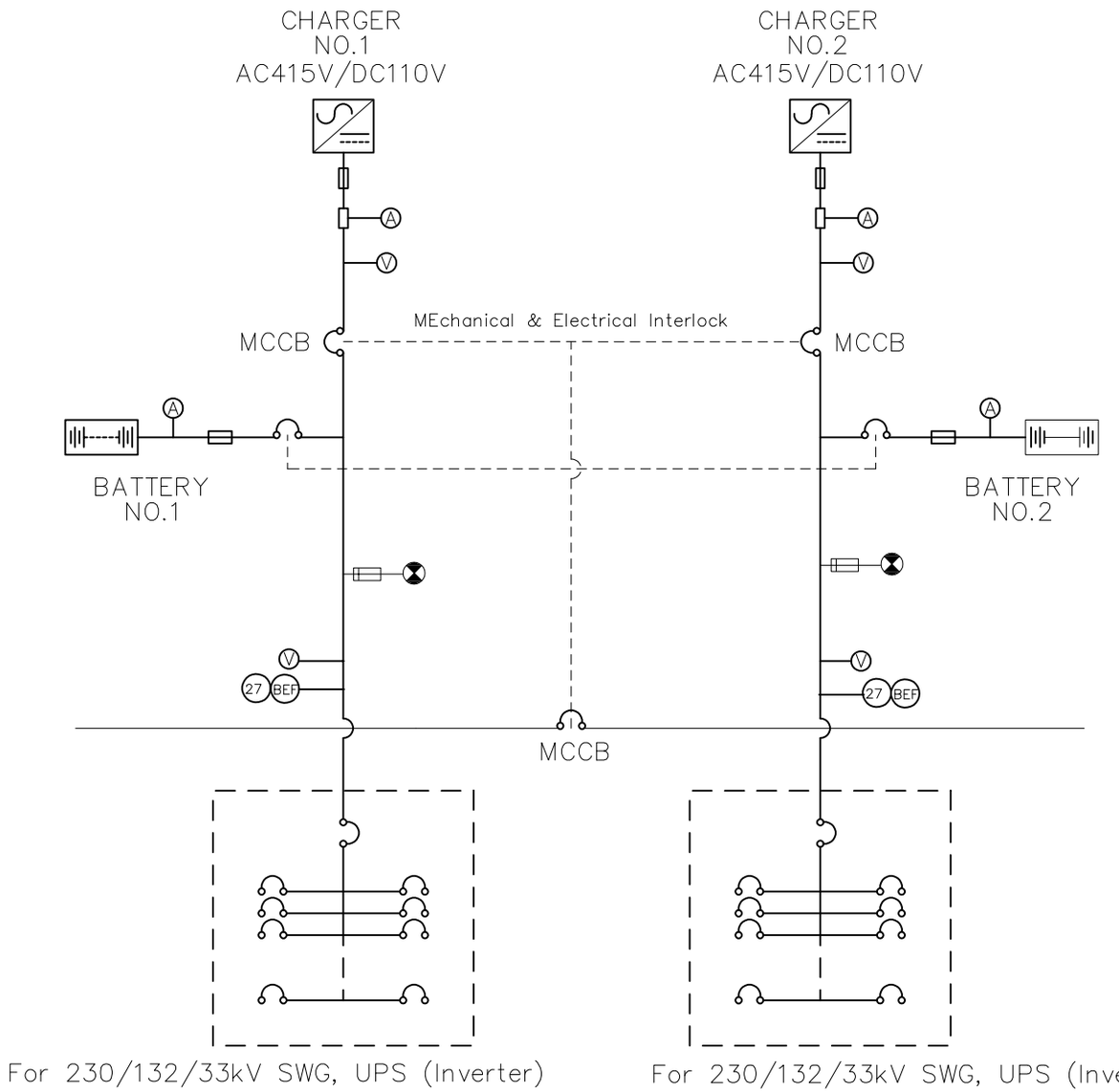


FOR TENDER PURPOSE ONLY

OWNER:-	POWER GRID COMPANY OF BANGLADESH(PGCB)
CONSULTANT:-	NOT APPLICABLE
PROJECT:	
SUBSTATION:	
TITLE:	LVAC Scheme DRAWING
DATE / PREPD. / CHKD. / SCALE / DRG.NO. / REV	

* Auto changeover facilty shall be provided for AC1, AC2 & Coupler
* Detail Rating & specification shall be finalized during execution stage as per tender requirement
* 25% overall spare MCB shall be provided for future extension in addtion to present requirement.
* Necessary status shall be integrated to SAS.

Main Control Building



* Auto changeover facilty shall be provided for AC1, AC2 & Coupler
* Detail Rating & specification shall be finalized during execution stage
* 25% overall spare MCB shall be provided for future extension in addtion to present requirement.
* Necessary status shall be integrated to SAS.

LEGEND

(27) U/V PROTECTION

(BEF) BATTERY E/F PROTECTION

DC INCOMER ON/OFF INDICATION

FOR TENDER PURPOSE ONLY

OWNER:-
POWER GRID COMPANY OF BANGLADESH(PGCB)

CONSULTANT:- NOT APPLICABLE

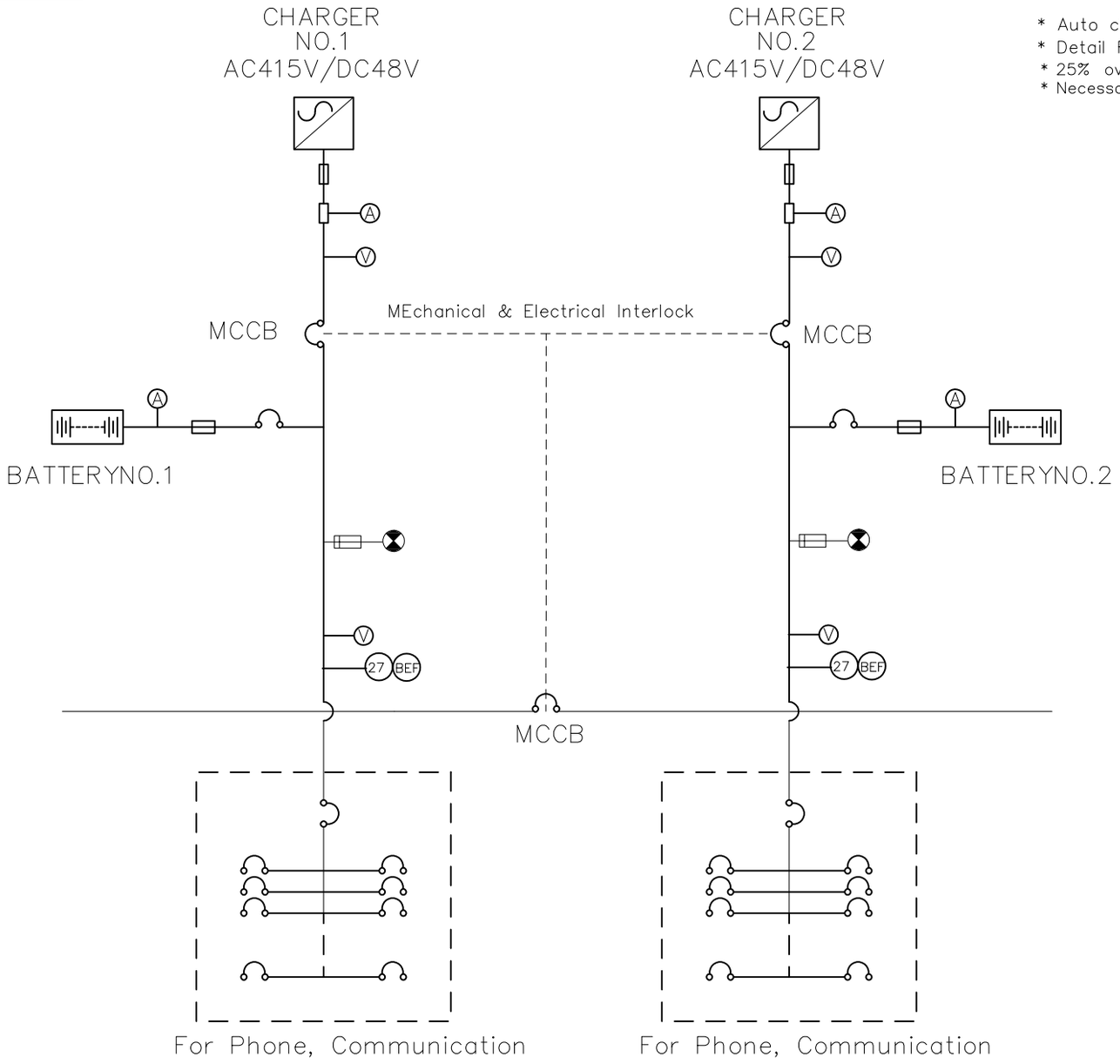
PROJECT:

SUBSTATION:

TITLE: 110V DC DISTRIBUTION SCHEME

DATE	PRPD.	CHKD.	SCALE	DRG.NO.	REV
				PGCB/110V DCDB/**	0

Main Control Building



* Auto changeover facilty shall be provided for AC1, AC2 & Coupler
* Detail Rating & specification shall be finalized during execution stage
* 25% overall spare MCB shall be provided for future extension in addtion to present requirement
* Necessary status shall be integrated to SAS.

LEGEND

27 U/V PROTECTION

BEF BATTERY E/F PROTECTION

DC INCOMER ON/OFF INDICATION

FOR TENDER PURPOSE ONLY

OWNER:-

POWER GRID COMPANY OF BANGLADESH(PGCB)

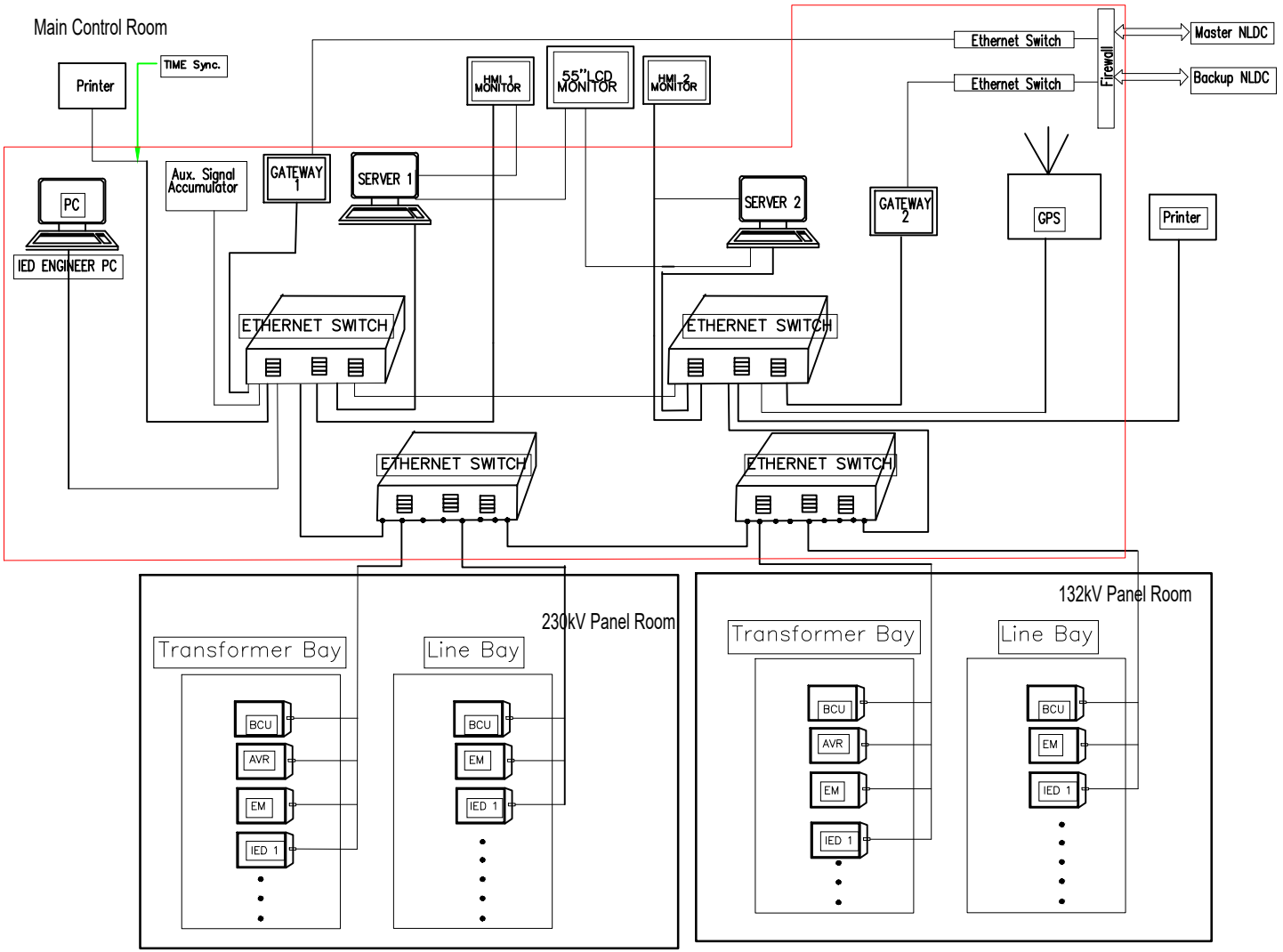
CONSULTANT:- NOT APPLICABLE

PROJECT:

SUBSTATION:

TITLE: 48V DC DISTRIBUTION SCHEME

DATE	PRPD.	CHKD.	SCALE	DRG.NO.	REV
				PGCB/48V DCDB/**	0



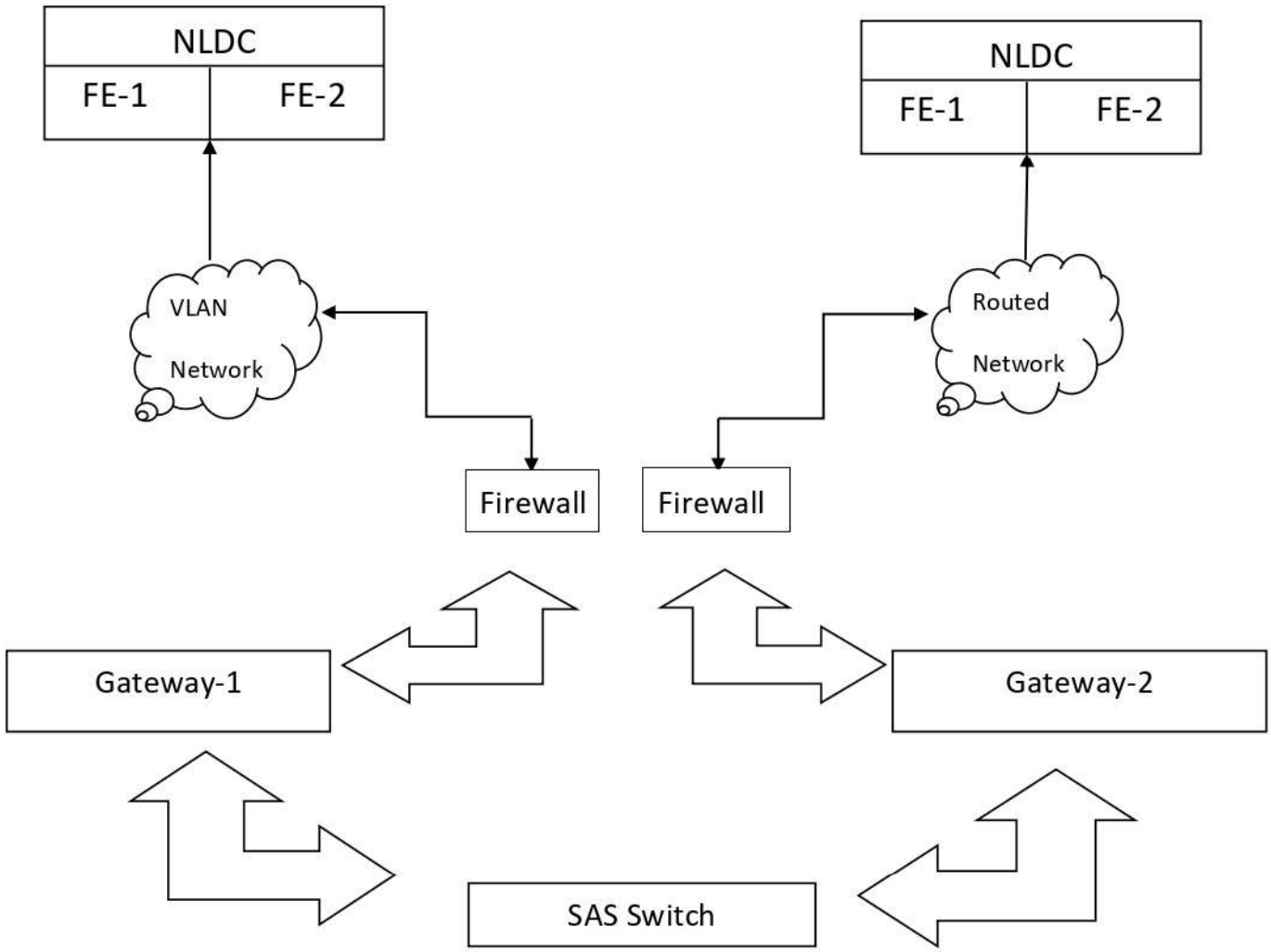
NOTE:

- For 400kV , SAS protocol shall be PRP
- SAS-1 & SAS-2 shall receive data from BCU/Relay through IEC61850 protocol
- SAS SERVER & ENGINEERING PC Shall be panel Mounted
- Gateway shall get data from SAS/BCU/Relay through IEC61850 protocol
- Gateway shall be in HOT & Standby Mode. Gateway shall be 01 no. for 132kV & 02 nos. for above
- The Tarrif Meters shall also be integrated to SAS
- At-least 01 No. Firewall shall be provided for SAS at the Data Extraction Point
- Server shall consist of CPU,monitor Keyboard etc.
- Server with HMI Scheme is also acceptable.
- No. of Ethernet Switches, IEDs shown is typical only. Actual no. shall be as per final design requirement
- PR-MCR cable connection shall be Armoured

SAS INTEGRATED WITH SCADA

	POWER GRID COMPANY OF BANGLADESH LIMITED
PROJECT: DHAKA and WESTERN ZONE GRID TRANSMISSION EXPANSION PROJECT	
TITLE: SAS ARCHITECTURE DRAWING	
Prepared by: / Checked by: / Approved by:	Sheet 1 of 1

Conceptual Drawing of SCADA Communication Architecture

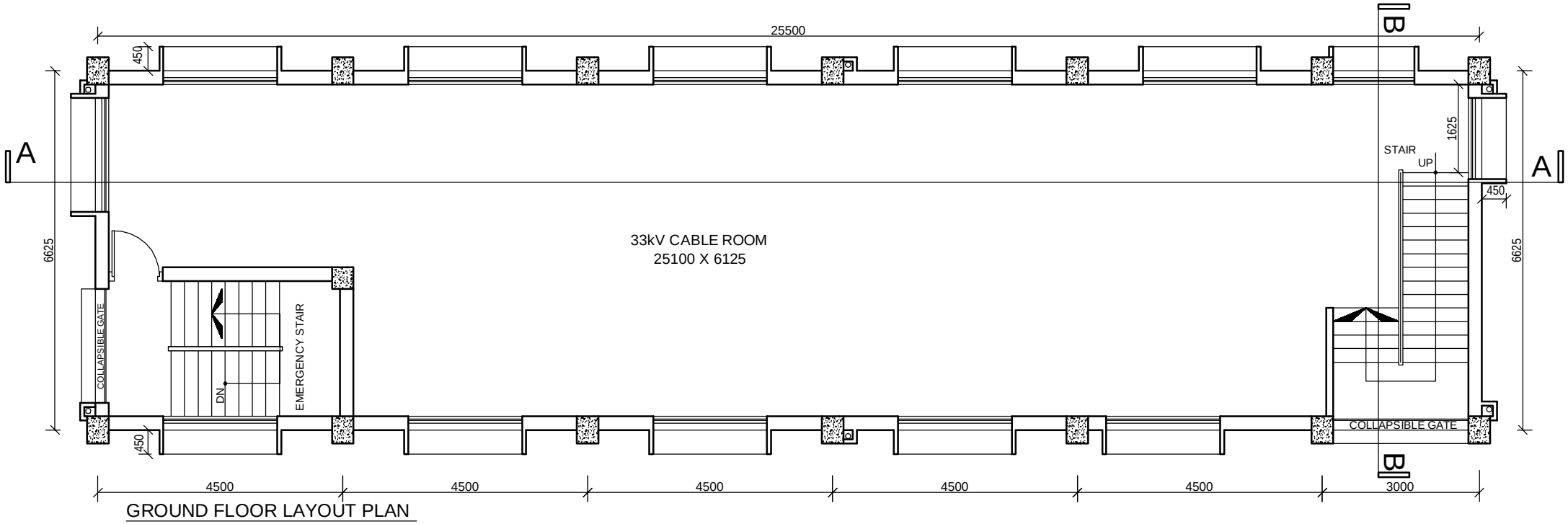


Note:

- ✓ SCADA Gateway and SAS Gateway shall be independent of each other.
- ✓ Both SCADA Gateways shall be capable of reporting to both Master & Backup station of NLDC simultaneously in HOT and STANDBY mode using IEC-104 protocol.
- ✓ Firewall shall be capable of communicationg with at least 3 different set of networks viz.
  - Substation internal network
  - NLDC Master Station
  - NLDC Backup station

OR

02 (Two) Nos of firewall may be provided to serve the purpose.



GROUND FLOOR LAYOUT PLAN

Note:

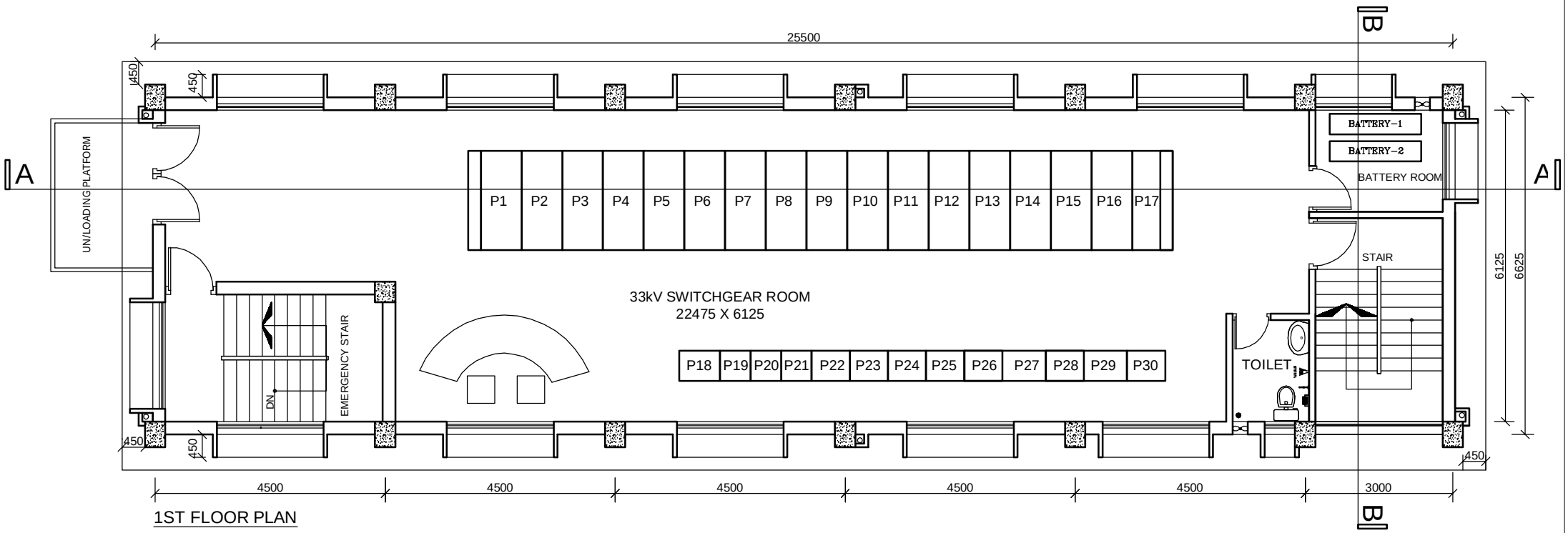
1) Floor area and height of the building provided here are minimum required size. If larger size is required due to bidder's GIS specifications, the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.

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, loading platform, cable shaft, emergency exit stair, lift core *etc.* will be finalized during detail design.

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:			
CONTRACT NO:			
Prepared		TITLE: 33 KV GIS BUILDING – GROUND FLOOR PLAN	Paper size
Checked			
Approved			Scale NTS
		DOCUMENT ID:	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, 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, loading platform, cable shaft, emergency exit stair, lift core *etc.* will be finalized during detail design.

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:			
CONTRACT NO:			
Prepared		TITLE: 33 KV GIS BUILDING – 1ST FLOOR PLAN (TENTATIVE POSITION OF PANELS)	Paper size
Checked			
Approved			Scale NTS
		DOCUMENT ID:	Page 02



FRONT ELEVATION

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, 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, loading platform, cable shaft, emergency exit stair, lift core *etc.* will be finalized during detail design.

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:			
CONTRACT NO:			
Prepared		TITLE: 33 KV GIS BUILDING – FRONT ELEVATION	Paper size
Checked			
Approved			Scale NTS
		DOCUMENT ID:	Page 03



BACK ELEVATION

Note:

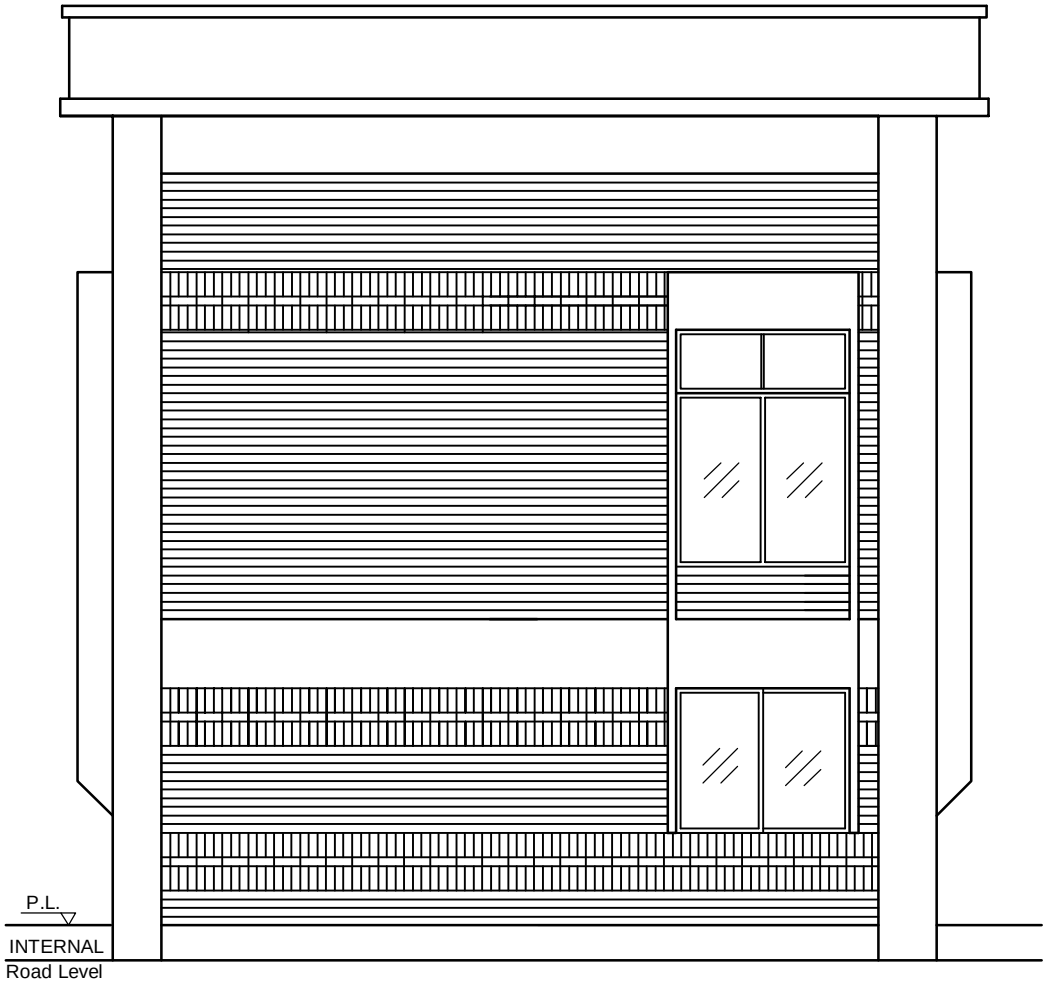
1) Floor area and height of the building provided here are minimum required size. If larger size is required due to bidder's GIS specifications, the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.

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, loading platform, cable shaft, emergency exit stair, lift core *etc.* will be finalized during detail design.

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:			
CONTRACT NO:			
Prepared		TITLE: 33 KV GIS BUILDING – BACK ELEVATION	Paper size
Checked			
Approved			Scale NTS
		DOCUMENT ID:	Page 04



LEFT ELEVATION



RIGHT ELEVATION

Tender Drawing

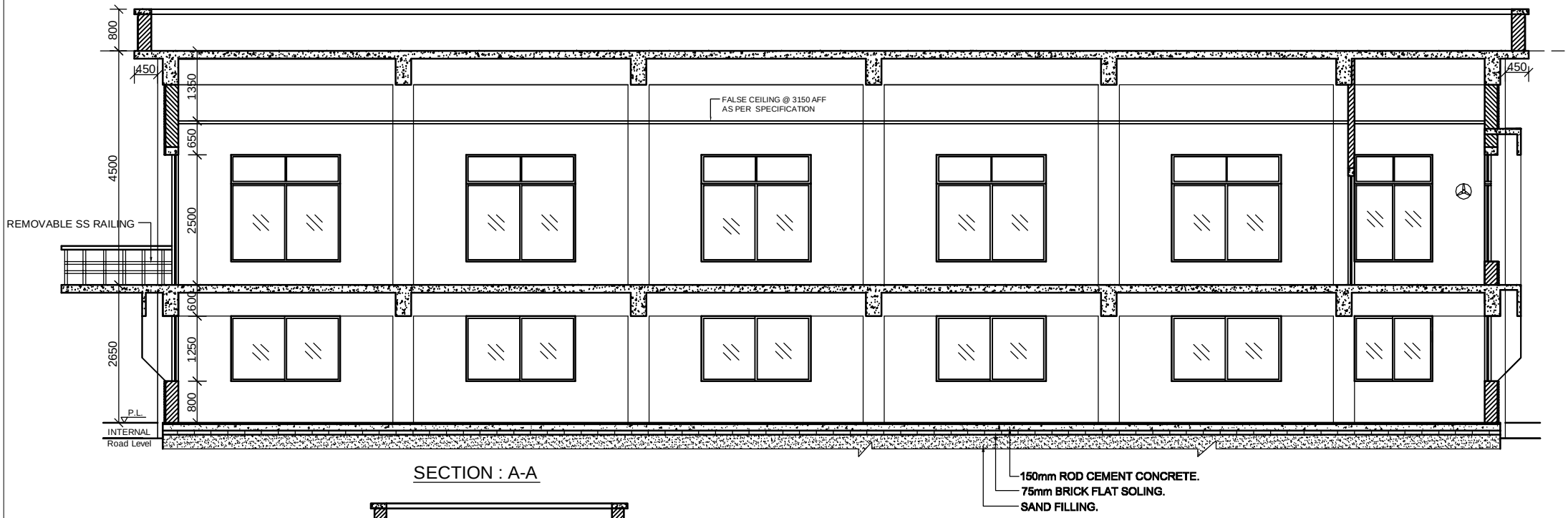
Note:

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, the bidder may increase size of the building within the quoted price. No additional payment shall be made in this regard.

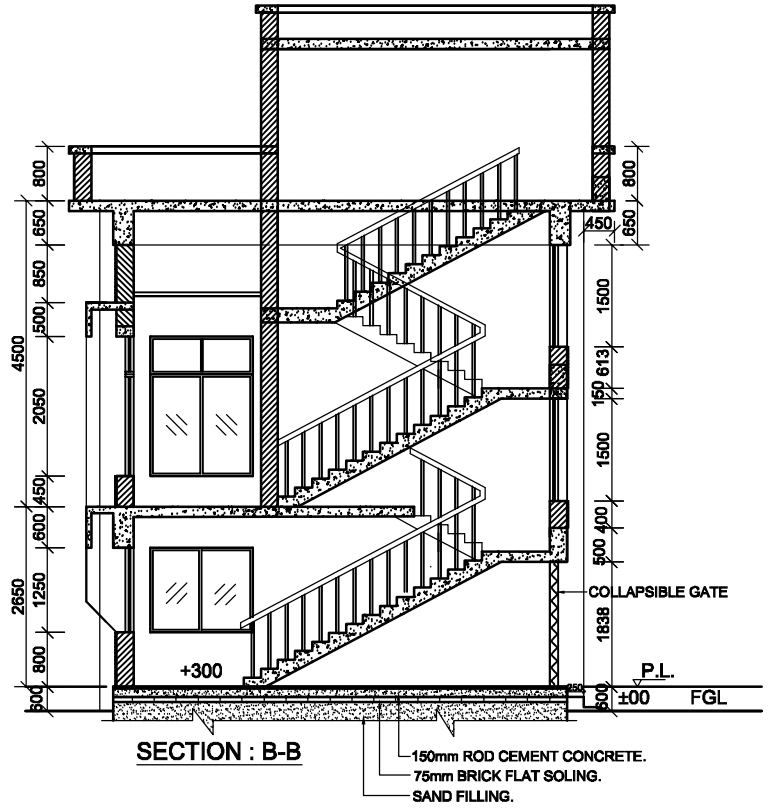
2) If transformers are positioned near the GIS building, due to fire safety reasons no window shall be provided on the transformer side of the building. But, if transformers are positioned sufficiently far from the GIS building, then windows shall be provided on the transformer side of the building.

3) Position and size of GIS equipments, cable ducts, loading platform, cable shaft, emergency exit stair, lift core *etc.* will be finalized during detail design.

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:			
CONTRACT NO:			
Prepared		TITLE: 33 KV GIS BUILDING – LEFT & RIGHT ELEVATION	Paper size
Checked			
Approved			Scale NTS
		DOCUMENT ID:	Page 05



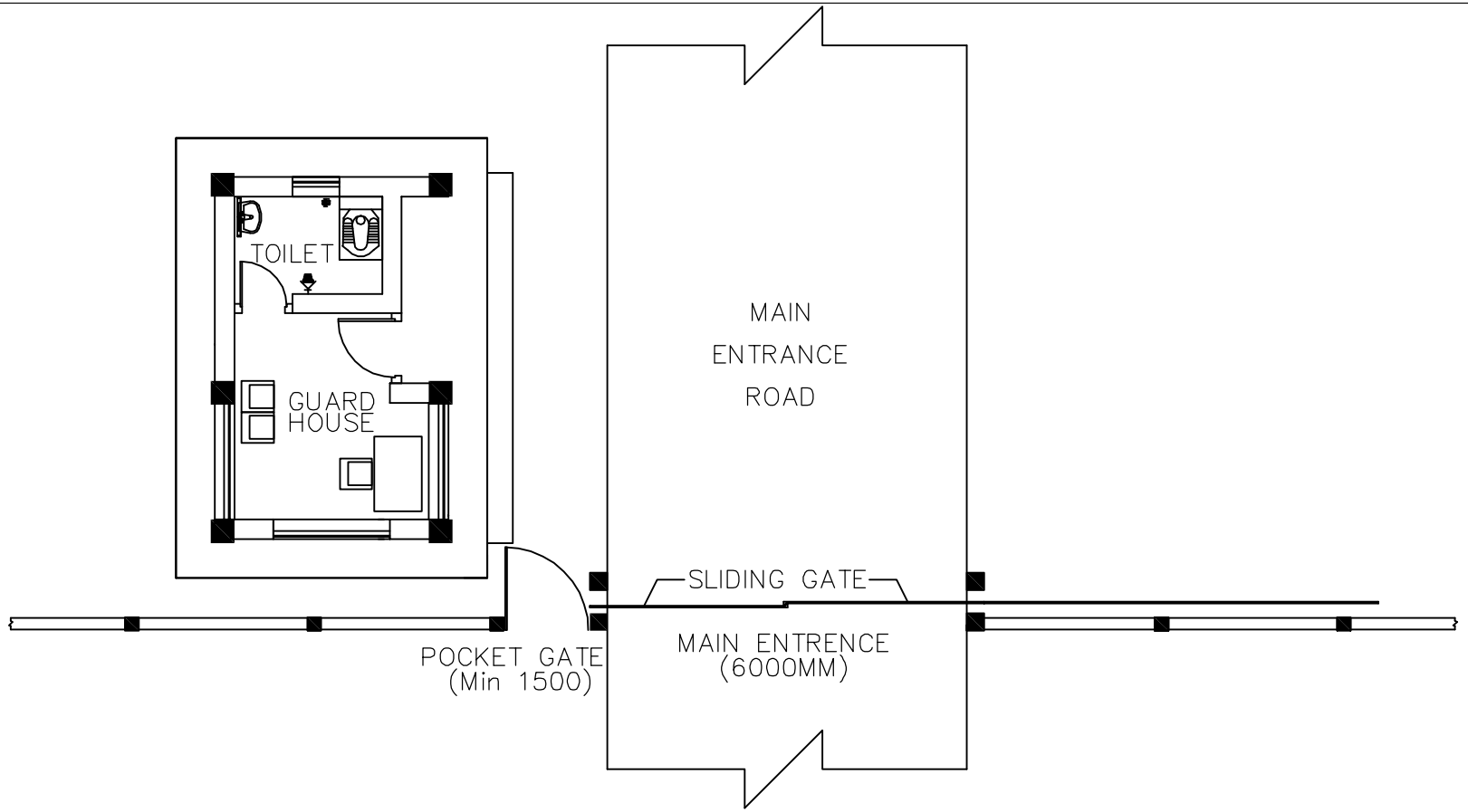
SECTION : A-A



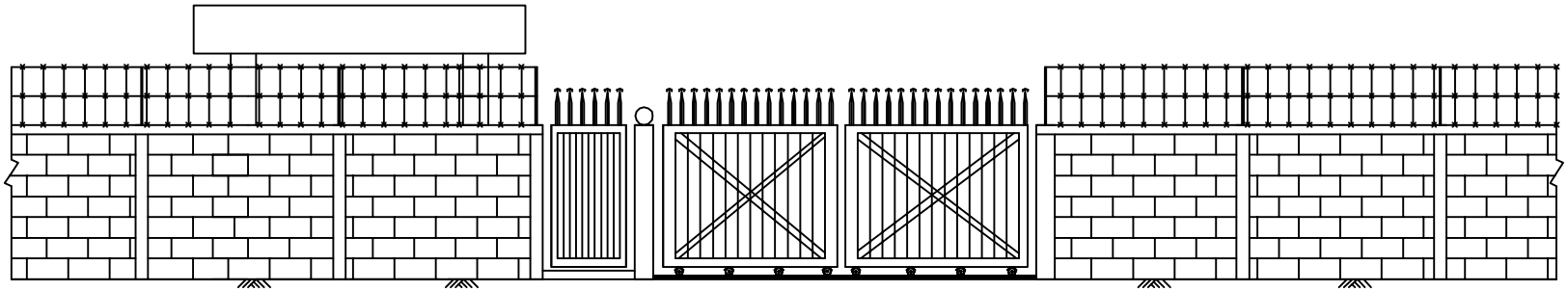
SECTION : B-B

Tender Drawing

EMPLOYER	POWER GRID COMPANY OF BANGLADESH LTD.		
PROJECT:			
CONTRACT NO:			
Prepared		TITLE: 33 KV GIS BUILDING – SECTION: A–A & B–B	Paper size
Checked			Scale NTS
Approved		DOCUMENT ID:	Page 06



PLAN VIEW



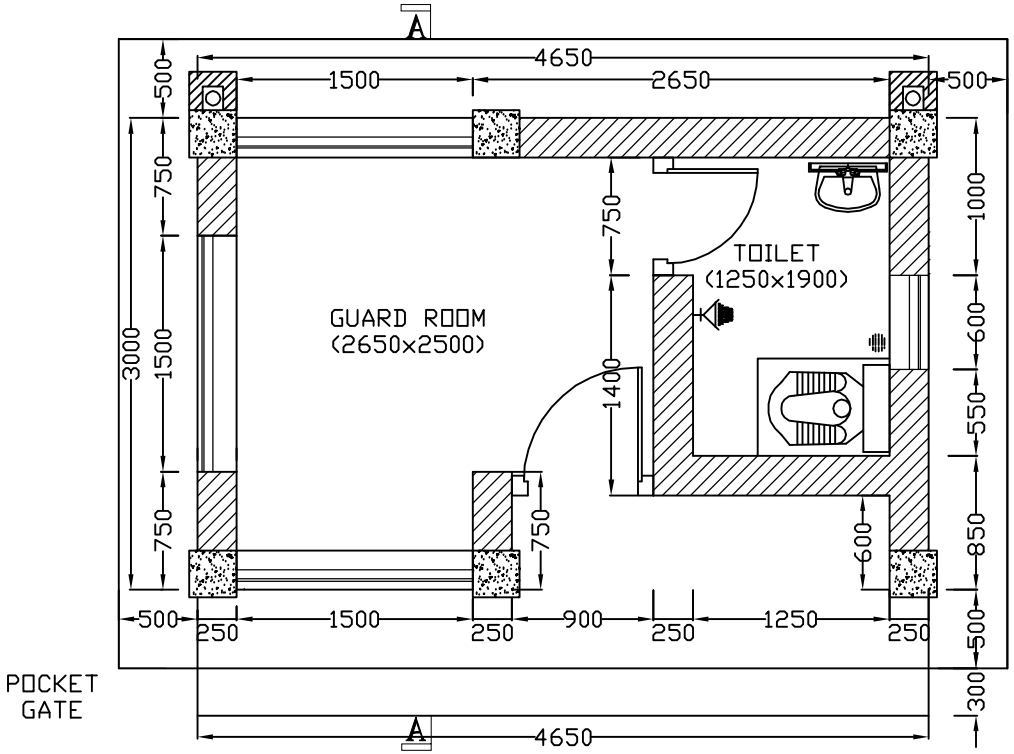
FRONT VIEW

ENTRANCE GATE

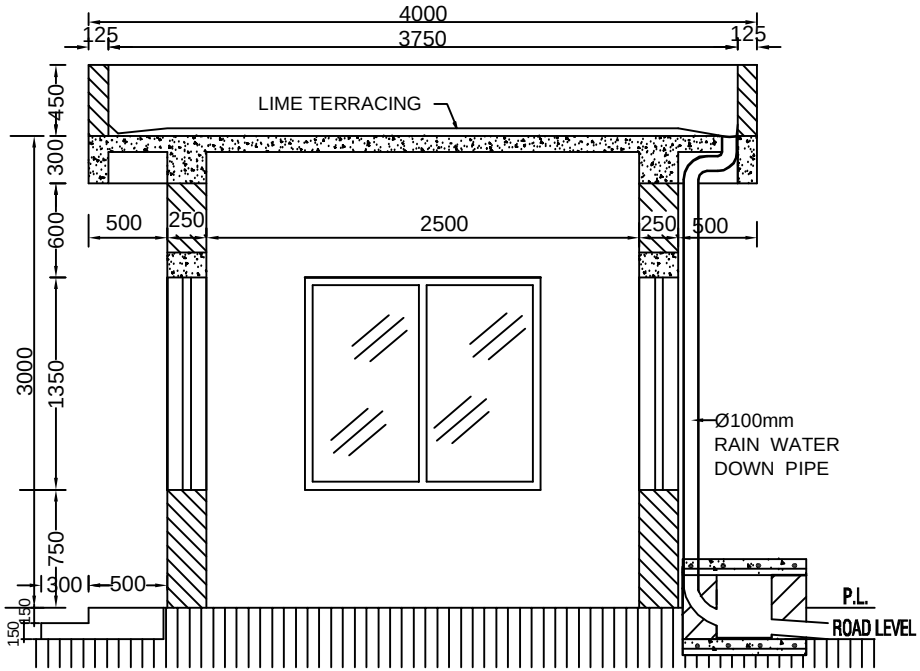
NOTE: Gate design shall be finalized during design stage.

Tender Drawing

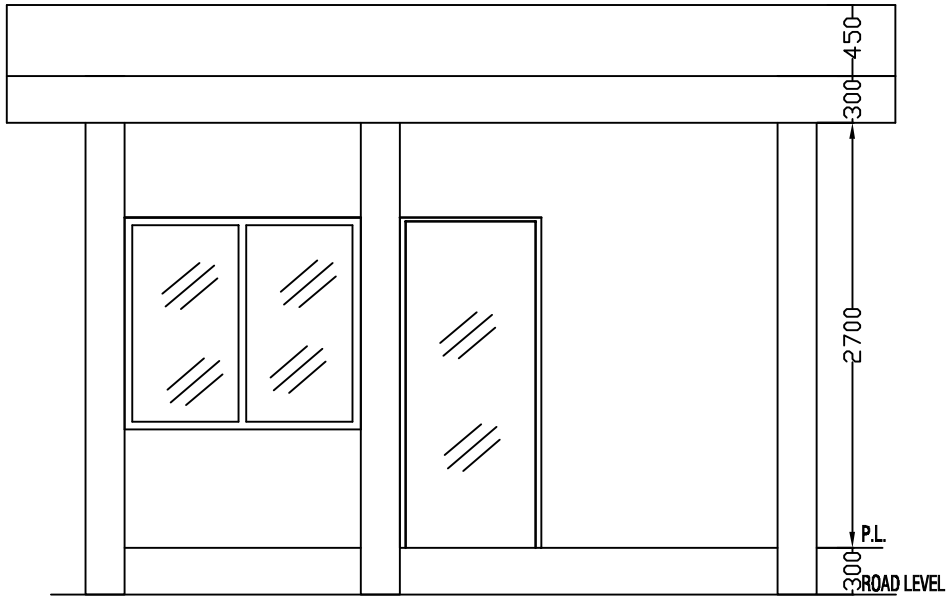
Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Main Entrance Gate
Drawing No.	
Drawn:	Checked: Approved:



PLAN OF GUARD HOUSE



SECTION : A-A



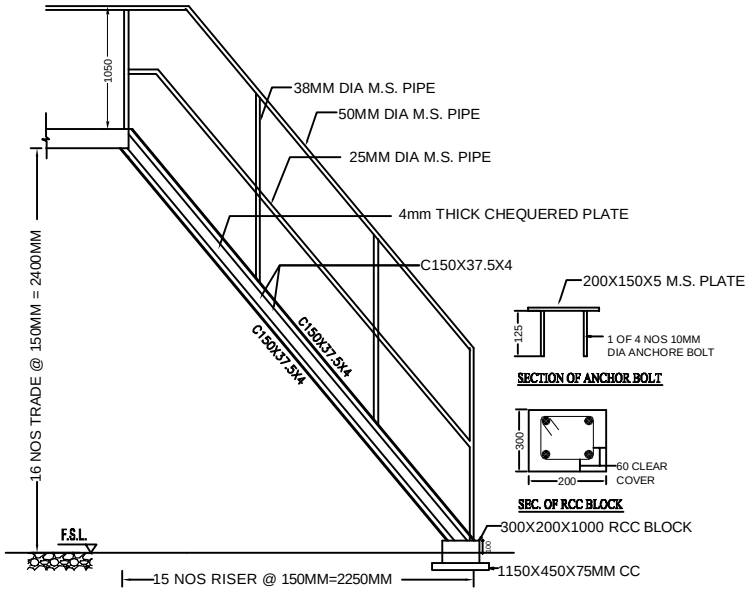
ROAD SIDE ELEVATION

NOTES:

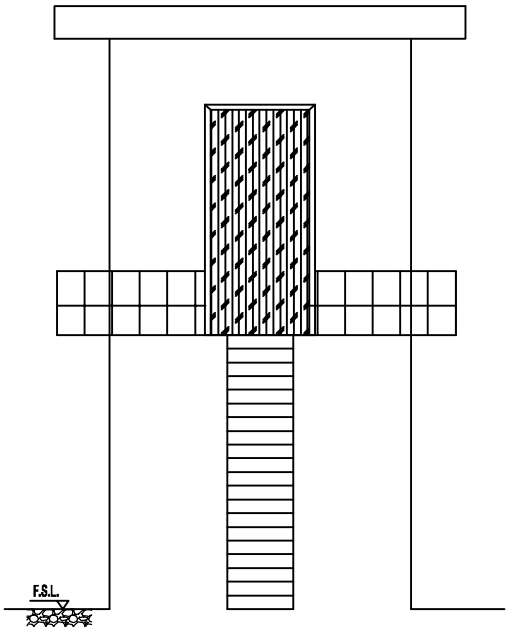
1. DETAILS OF ARCHITECTURAL, STRUCTURAL & FOUNDATION DRAWING SHALL BE SUBMITTED FOR APPROVAL.
2. WATER SUPPLY SYSTEM, TOILET & OTHER SANITARY FITTINGS SHALL BE PROVIDED.
3. ROOF SHALL BE WATER PROOFED WITH LIME TERRACING 2:2:7– LIME, SHURKI (POWDERED BRICK) & 0.75'' DOWN BRICK CHIPS.
4. RAIN WATER DOWN PIPE & BUILDING DRAINAGE SYSTEM SHALL BE TAKE INTO CONSIDER PRIOR TO SLAB CASTING.
5. POWER CONNECTION LAYOUT SHALL BE APPROVED BEFORE WORK.

Tender Drawing

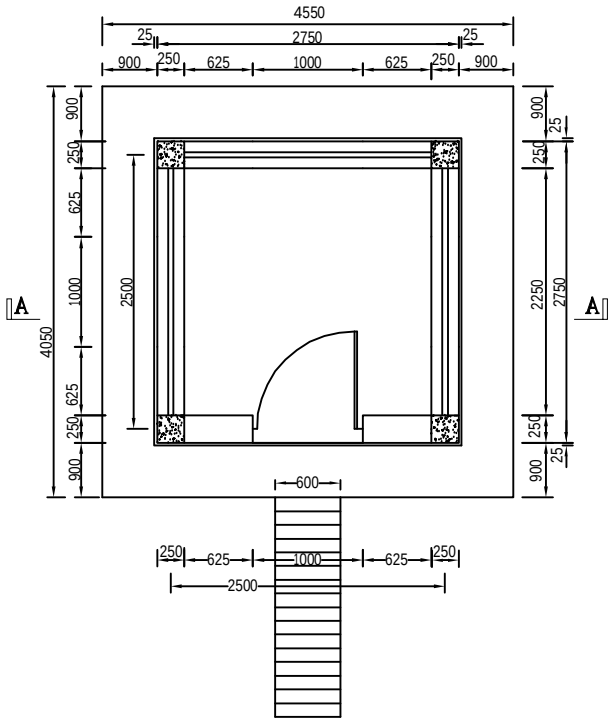
Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Gaurd House
Drawing No.	
Drawn:	Checked: / Approved:



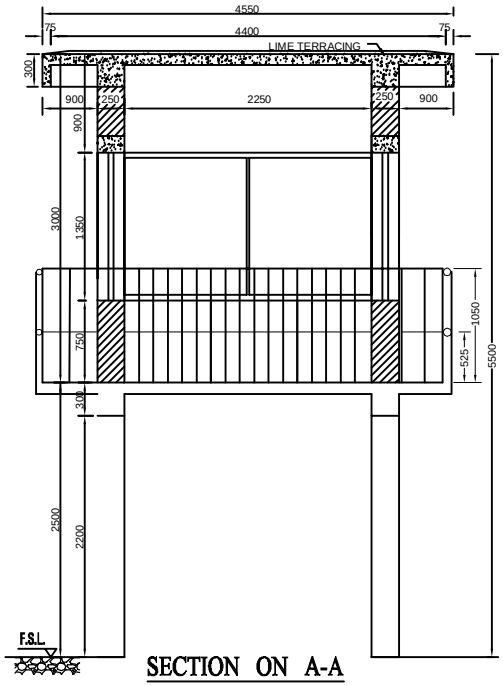
DETAILS OF STAIR



FRONT ELEVATION



PLAN OF SENTRY POST

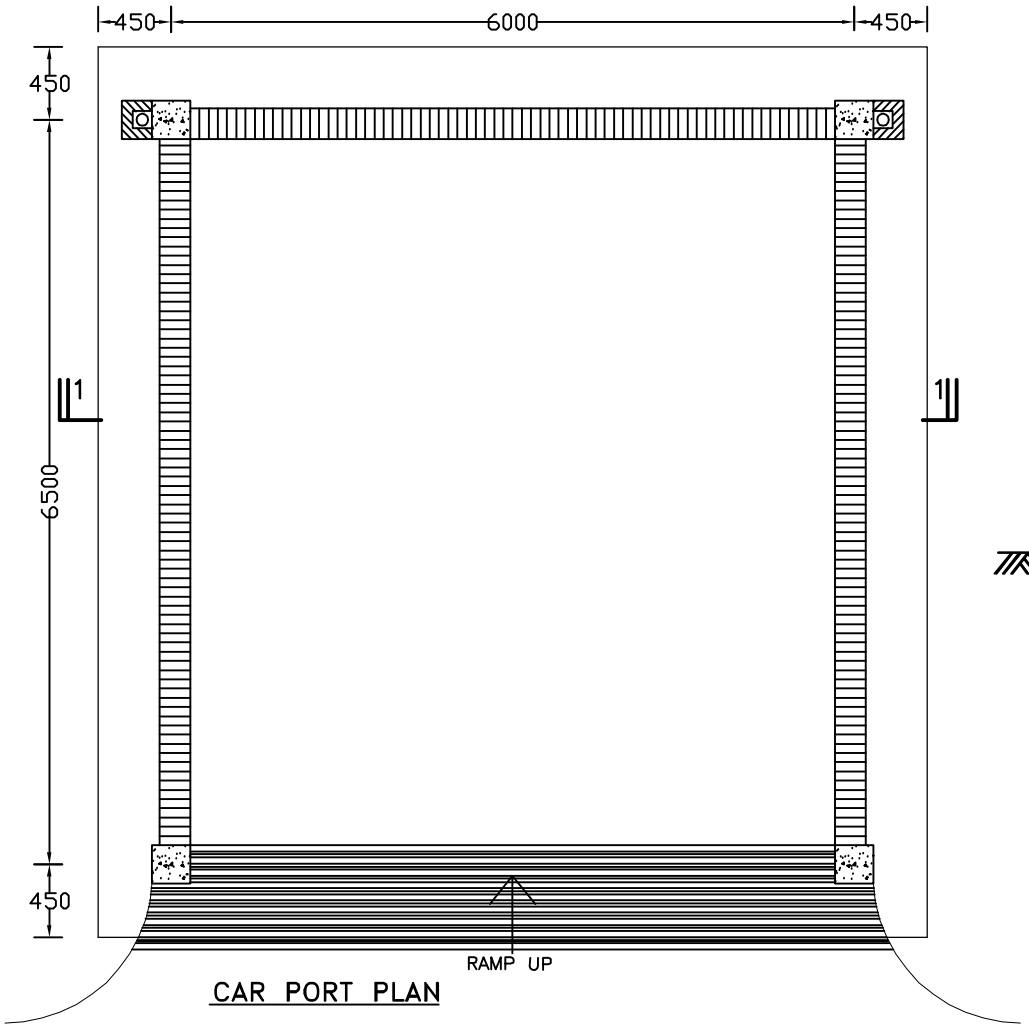


SECTION ON A-A

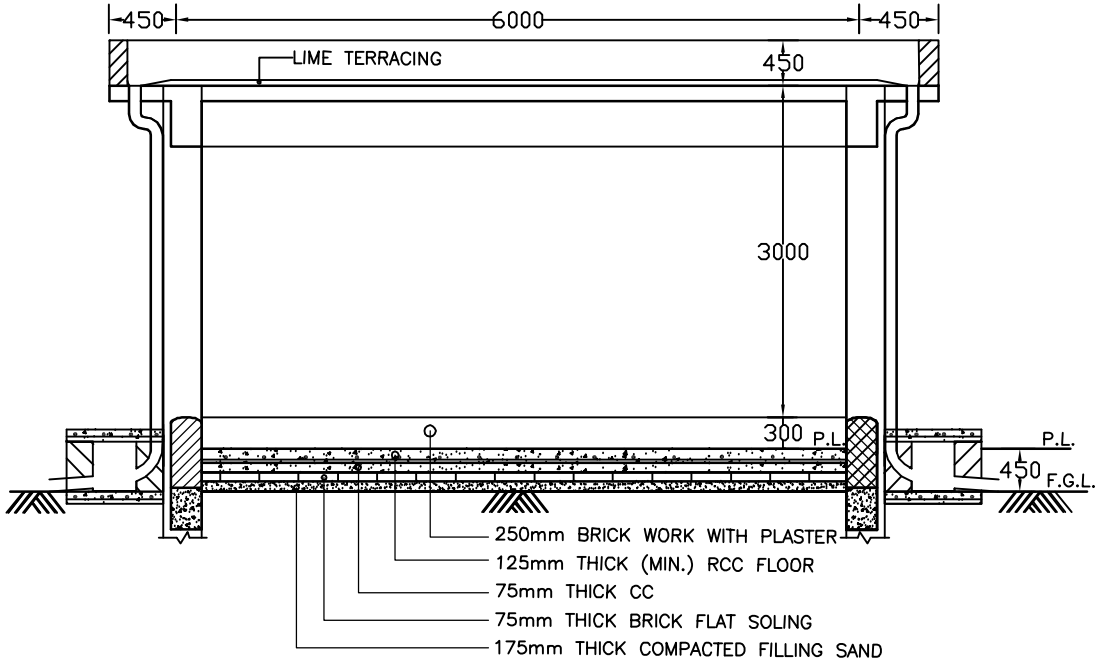
NOTES:
1. DETAILS OF ARCHITECTURAL, STRUCTURAL & FOUNDATION DRAWING & LADDER DETAILS SHALL BE SUBMITTED FOR APPROVAL.
2. ROOF SHALL BE WATER PROOFED WITH LIME TERRACING 2:2:7–LIME, SHURKI (POWDERED BRICK) & 0.75" DOWN BRICK CHIPS.
3. RAIN WATER DOWN PIPE & BUILDING DRAINAGE SYSTEM SHALL BE TAKE INTO 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	
Drawing Title	Sentry Post
Drawing No.	
Drawn:	Checked: Approved:



CAR PORT PLAN

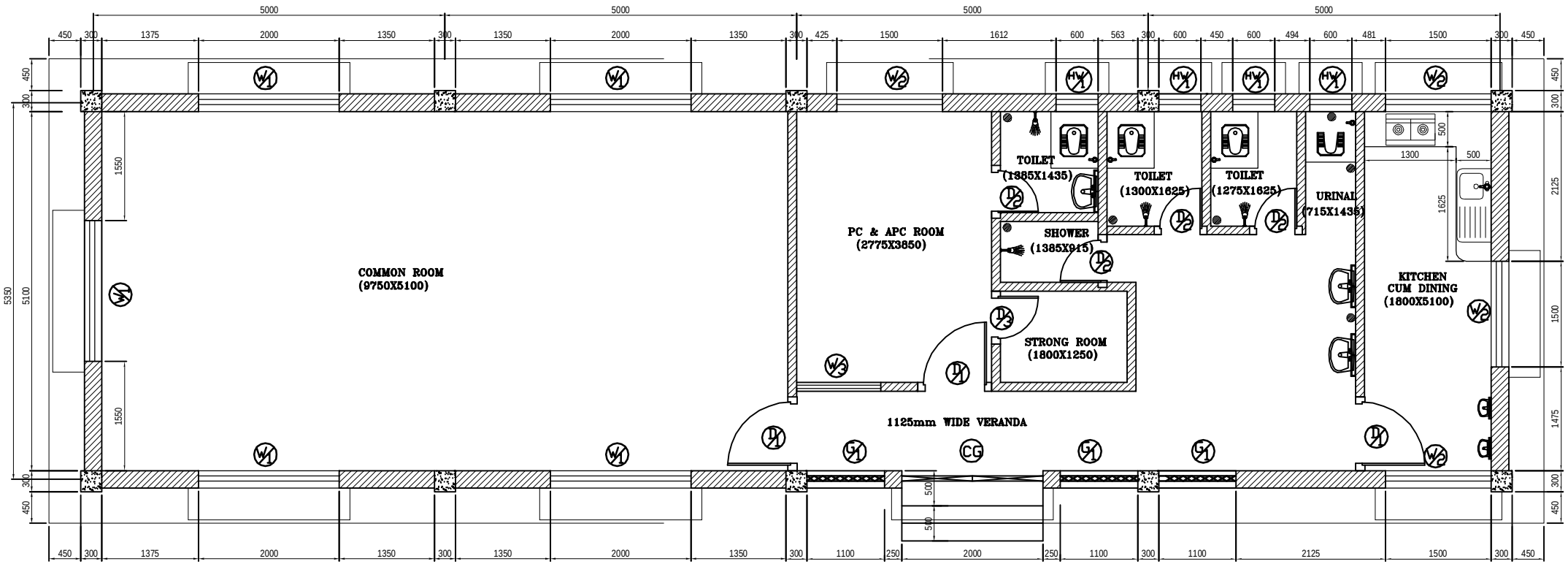


SECTION:1–1

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	
Drawing Title	Car Port (For Two Cars)
Drawing No.	
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

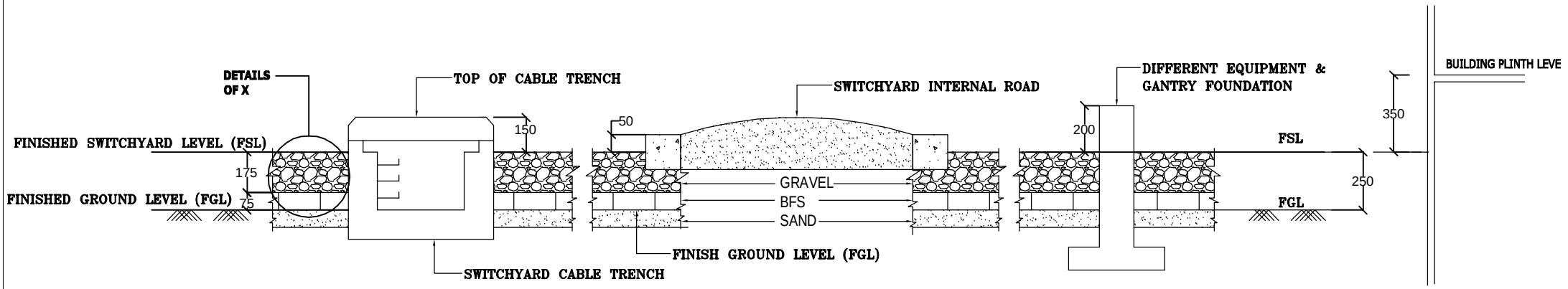
Power Grid Company of Bangladesh Limited

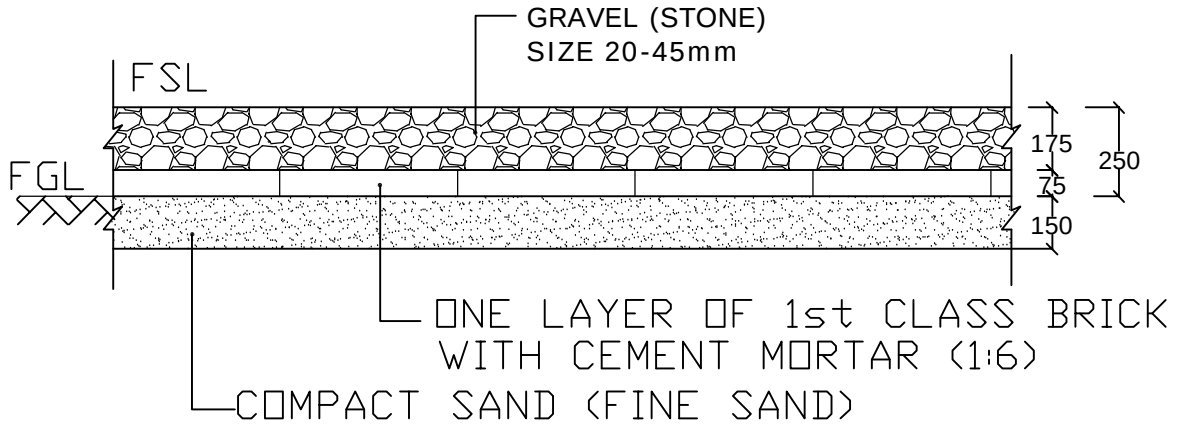
Project

Drawing Title: Ansar Barak

Drawing No.

Drawn: Checked: Approved:





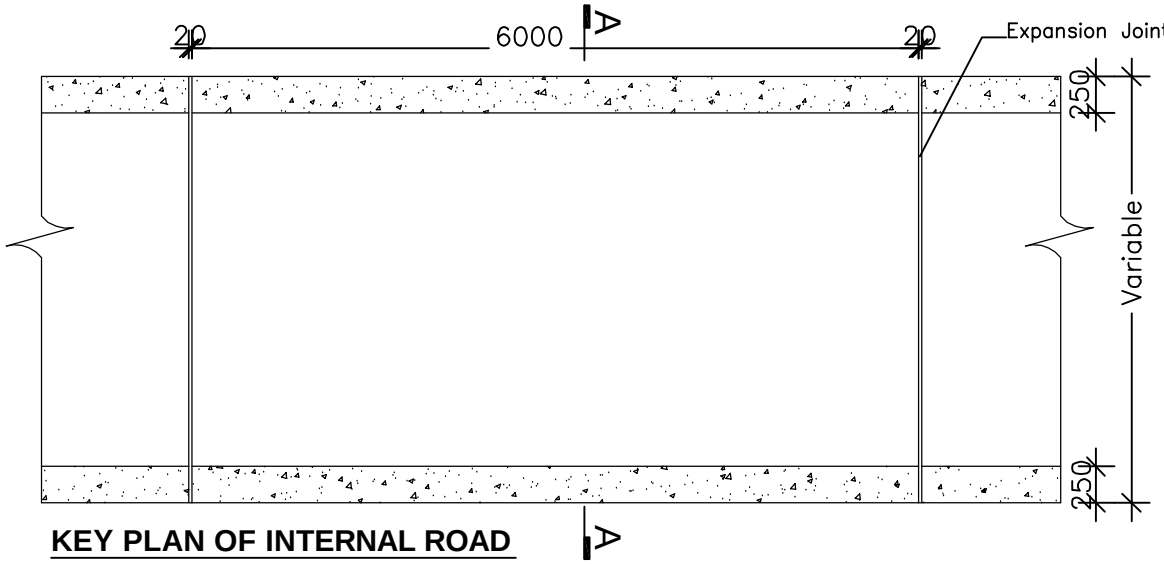
DETAIL OF X

NOTE:

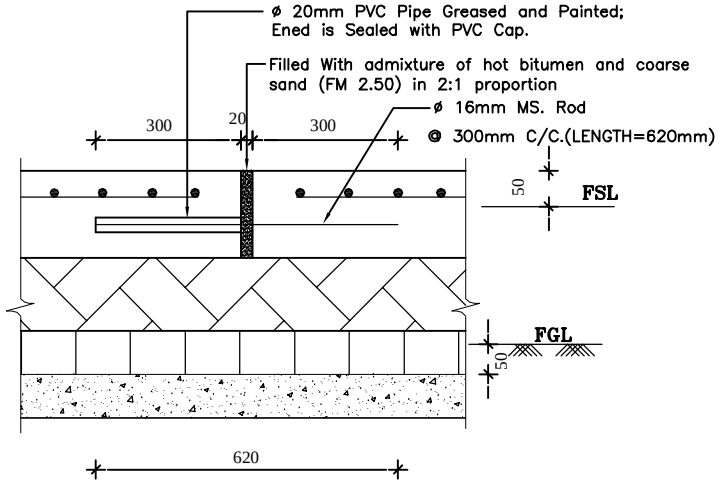
After determination of Finished Ground Level (FGL) with respect to MSL/PWD, the contractor should prepare and submit the relative RLs of all the structures for approval for each site.

Tender Drawing

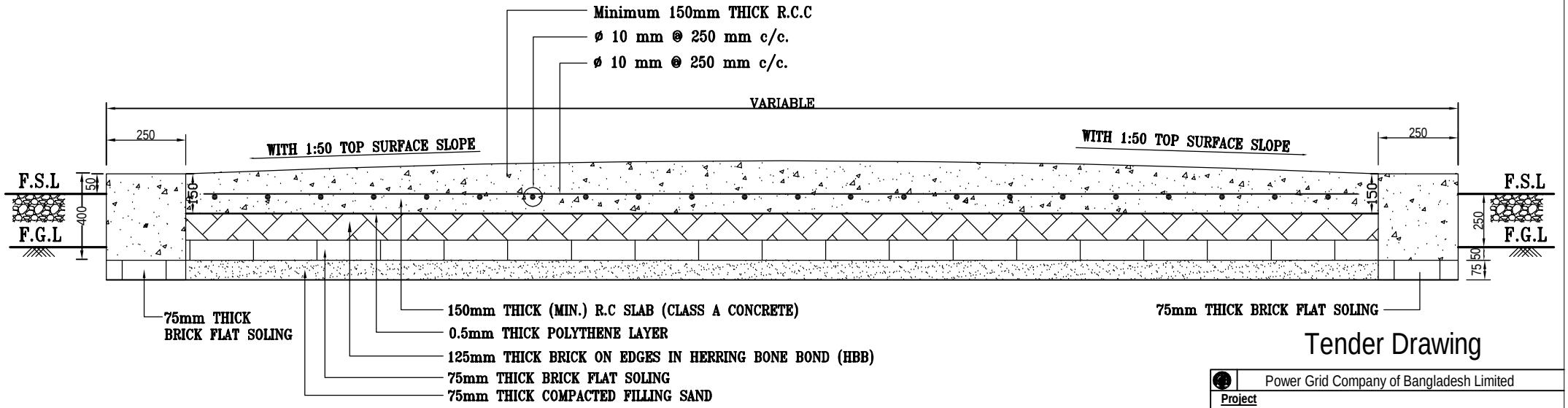
Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Switchyard Gravelling and Relative Levels of Different Structures
Drawing No.	
Drawn:	Checked: Approved:



KEY PLAN OF INTERNAL ROAD
(SCALE - NTS)



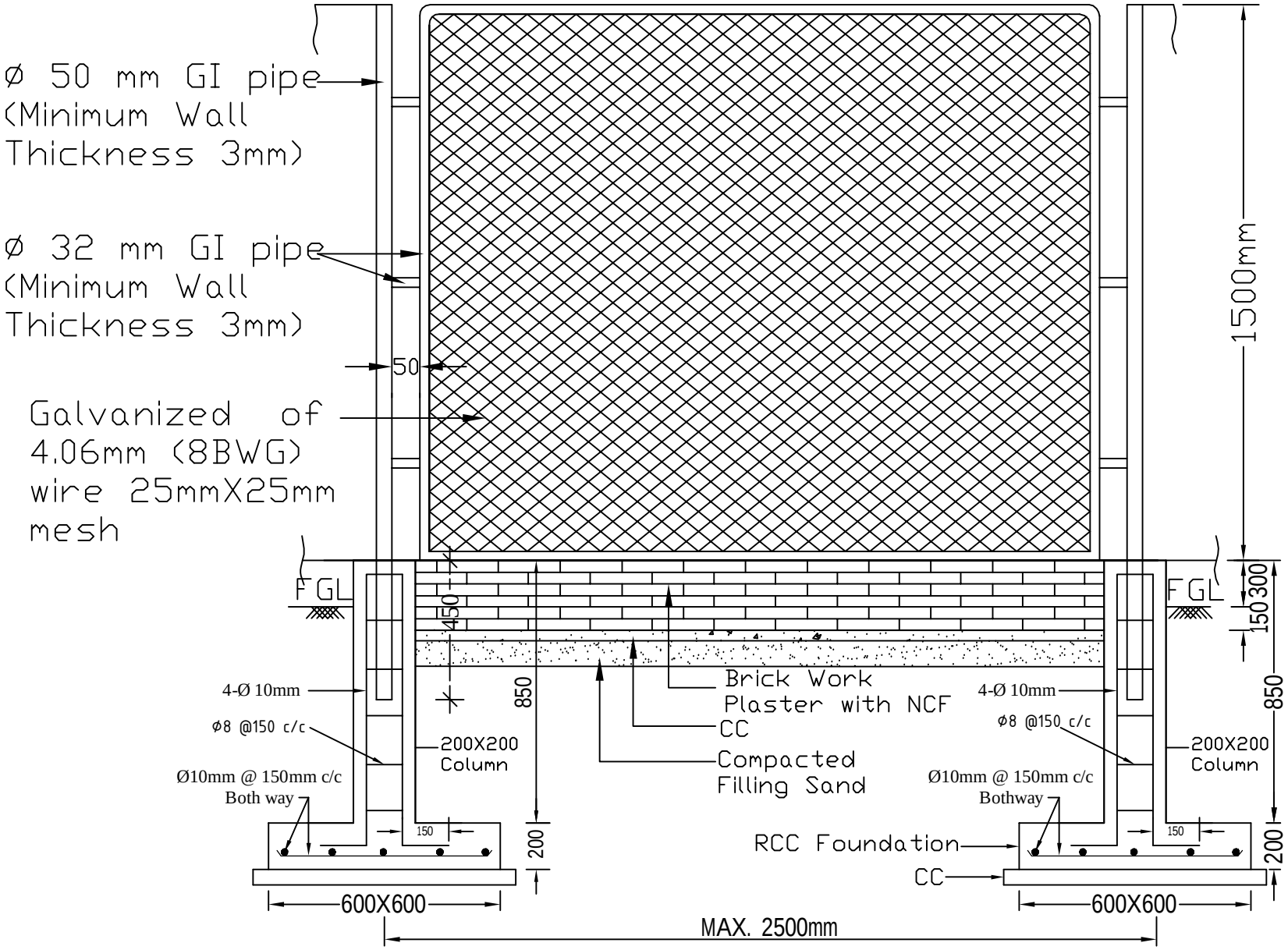
DETAIL OF EXPANSION JOINT
(SCALE - NTS)



ROAD CROSS SECTION : A-A
(SCALE - NTS)

Tender Drawing

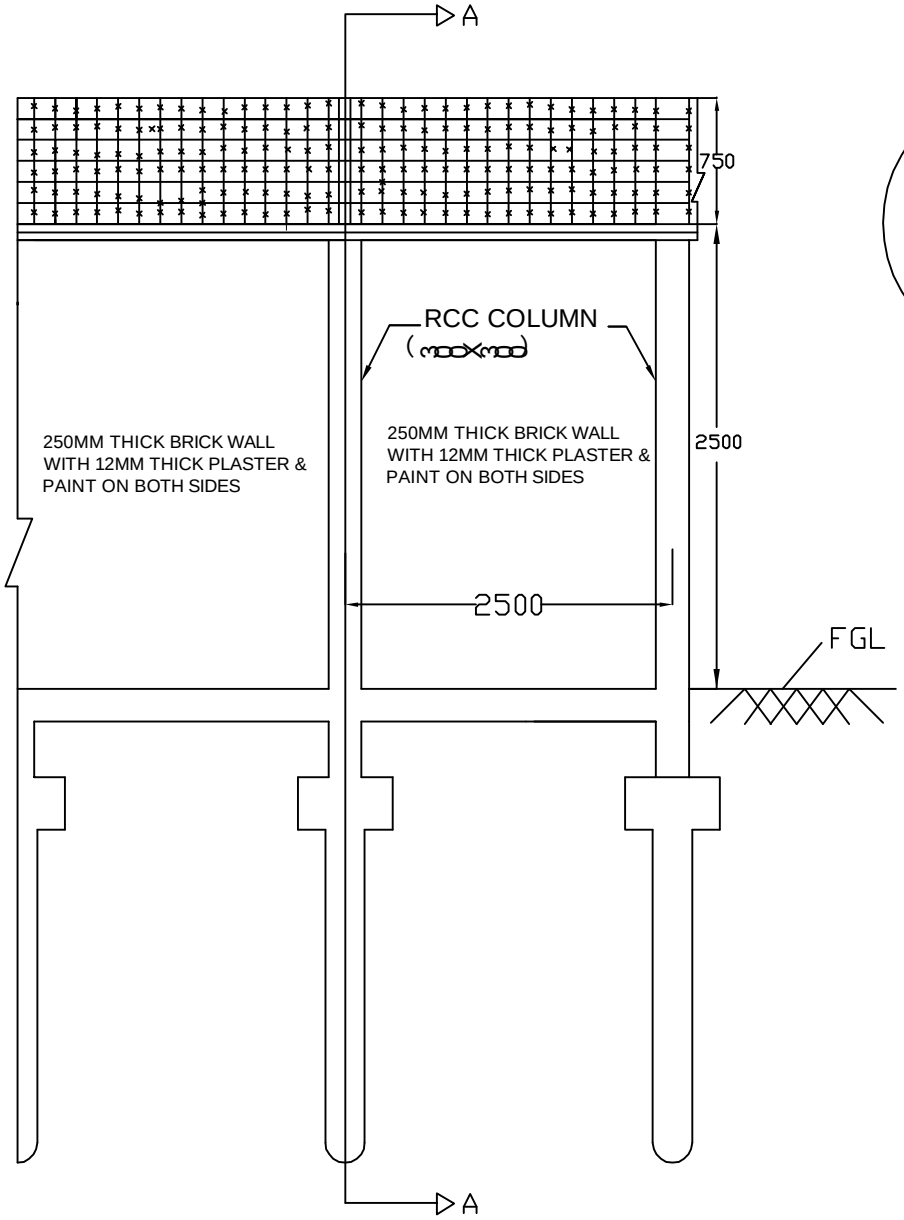
Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Typical Road sections
Drawing No.	
Drawn:	Checked: / Approved:



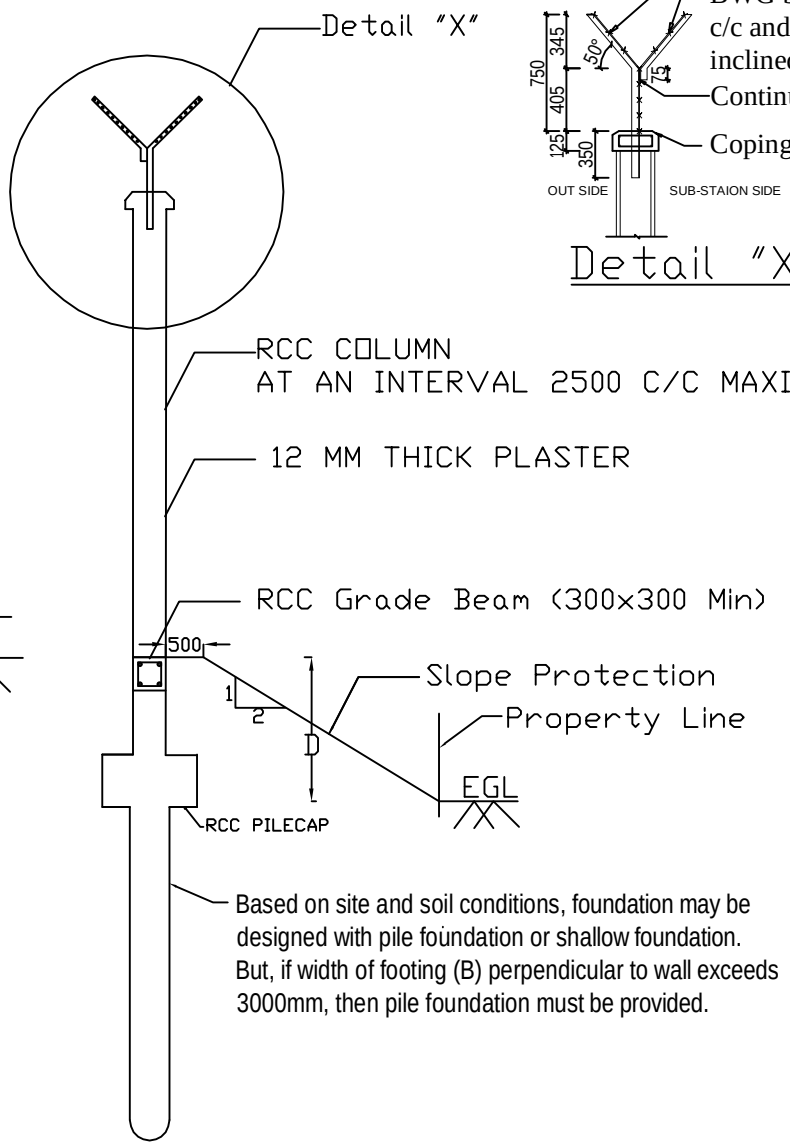
Typical Section of Chain Linked Fencing

Tender Drawing

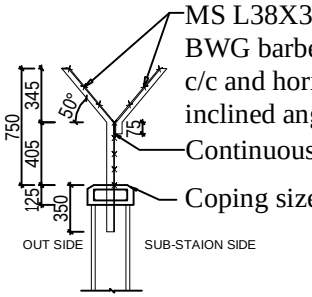
Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Typical Section of Chain linked fencing
Drawing No.	
Drawn:	Checked: Approved:



FRONT ELEVATION



SECTION:A-A



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"

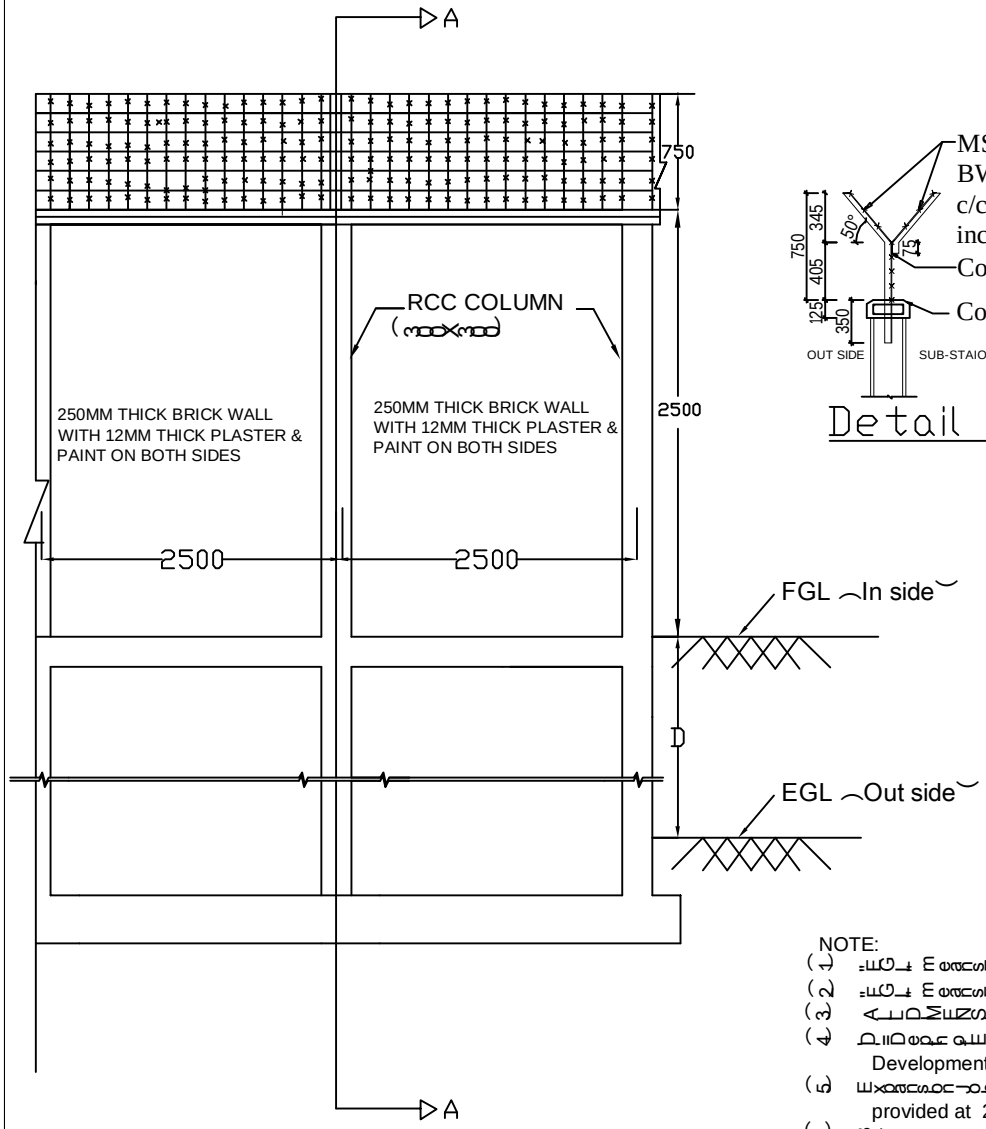
Based on site and soil conditions, foundation may be designed with pile foundation or shallow foundation. But, if width of footing (B) perpendicular to wall exceeds 3000mm, then pile foundation must be provided.

NOTE:

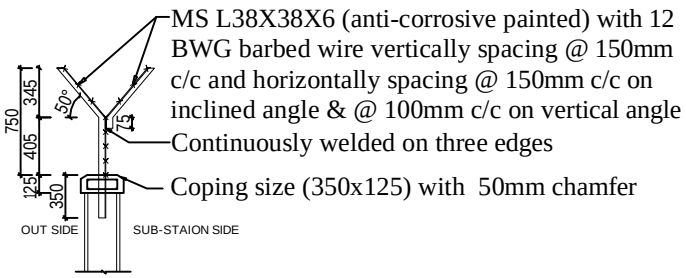
1. "EGL" means Existing Ground level
2. "FGL" means Finished Ground level
3. ALL DIMENSIONS ARE IN MM
4. 'D'=Depth of Earth Filling for Land Development
5. Expansion Joints shall have to be provided at maximum 25m Interval.

Tender Drawing

Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Boundary wall without retaining wall
Drawing No.	PGCB/ADB/400kV/GOPAL-SS/MEG
Drawn:	Checked: / Approved:



FRONT ELEVATION



Detail "X"

NOTE:

(1) [illegible]

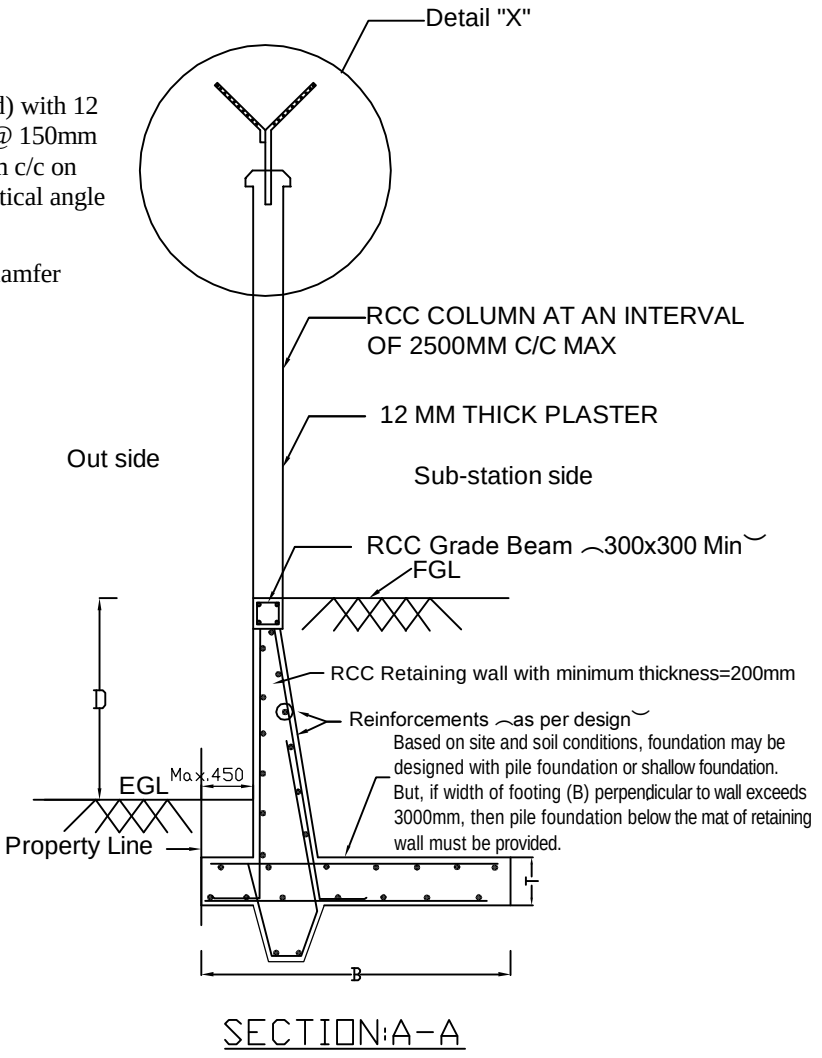
(2) [illegible]

(3) [illegible]

(4) [illegible]
Development (as per site condition)

(5) [illegible]
provided at 25m Interval.

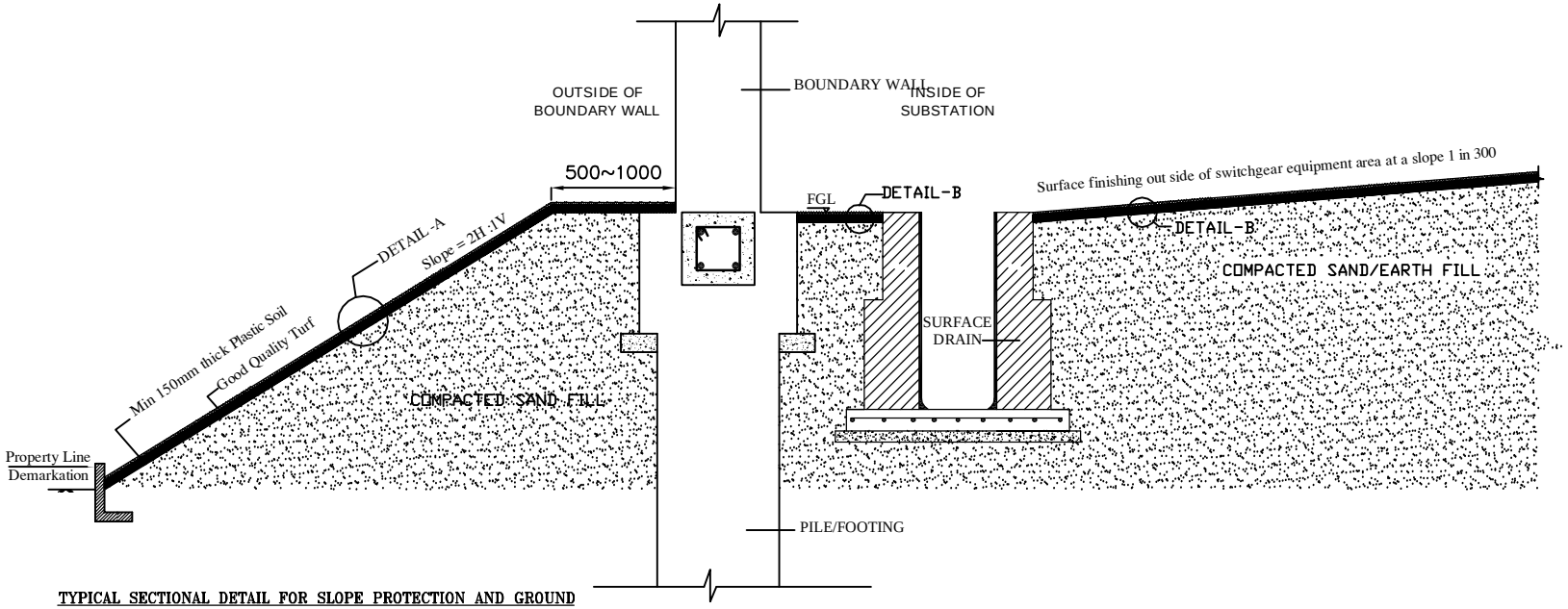
(6) [illegible]
force, lateral earth pressure, depth of filling (D) and soil bearing capacity.



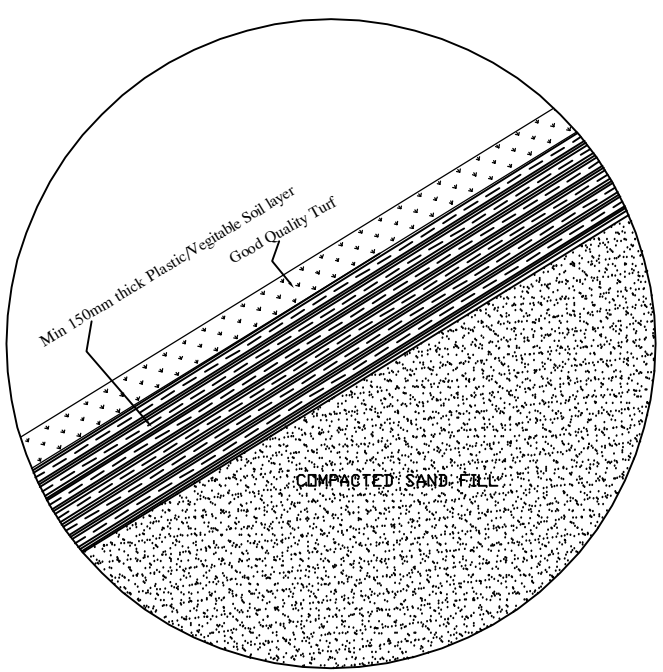
SECTION:A-A

Tender Drawing

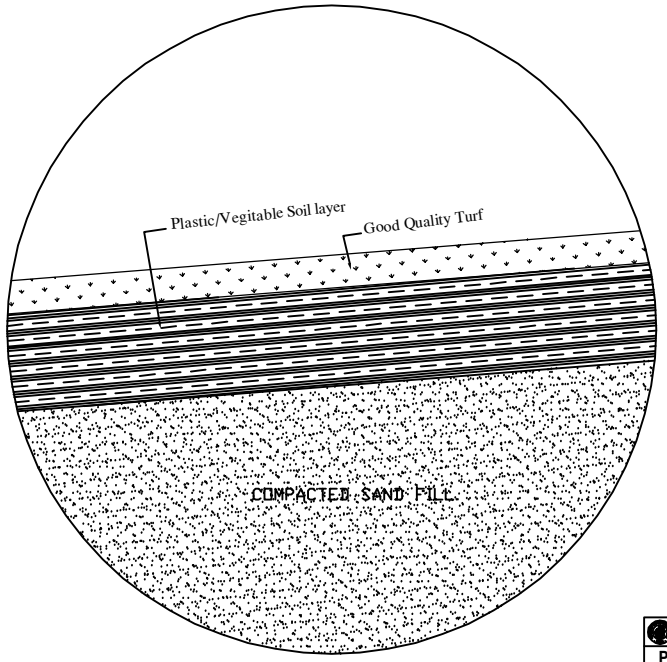
Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Boundary wall with RCC retaining wall
Drawing No.	
Drawn:	Checked: / Approved:
Department: civil Design	



TYPICAL SECTIONAL DETAIL FOR SLOPE PROTECTION AND GROUND SURFACE FINISHING AROUND THE SURFACE DRAIN



DETAIL-A



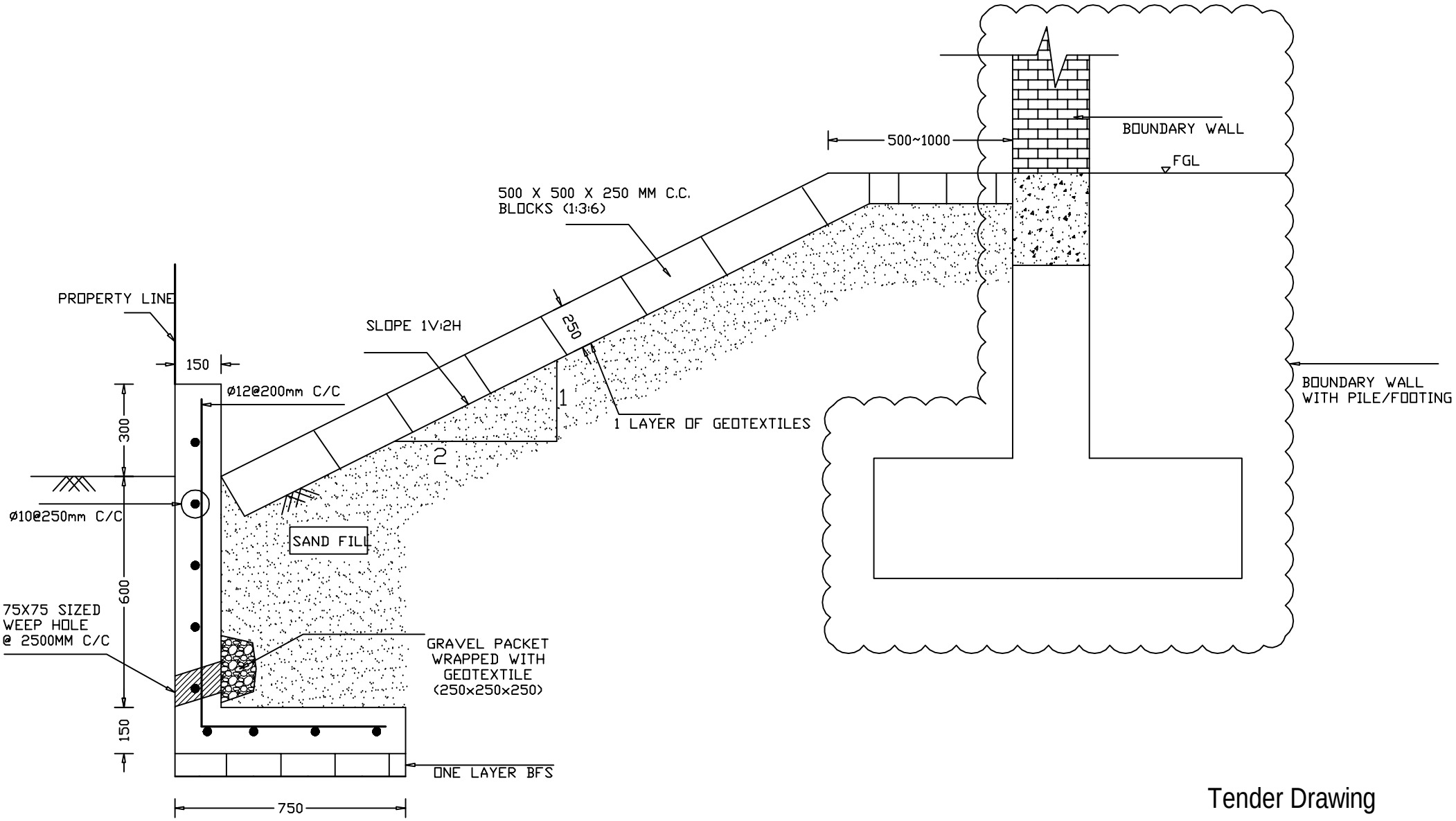
DETAIL-B

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.

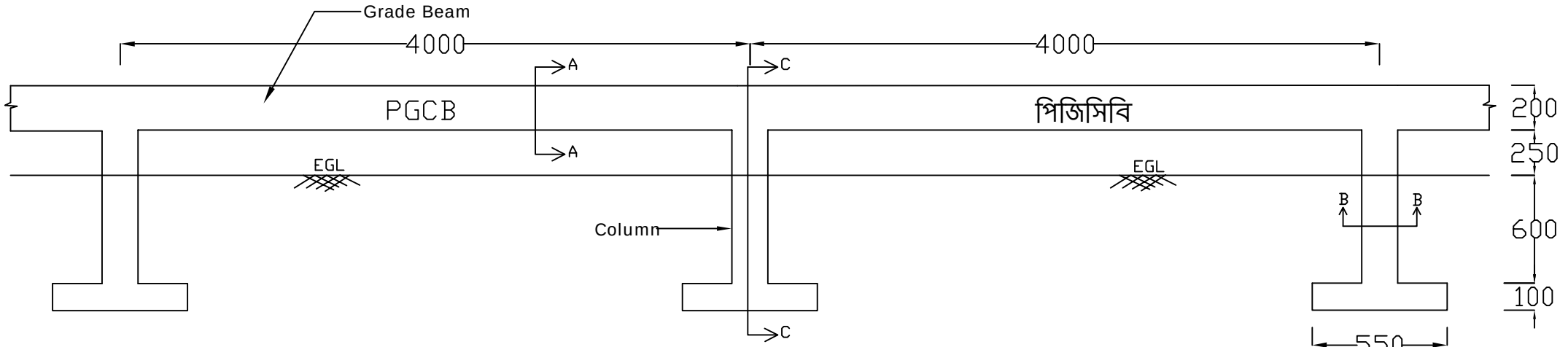
Tender Drawing

Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Slpoe (1V:2H) protection with turfing
Drawing No.	
Drawn:	Checked: Approved:

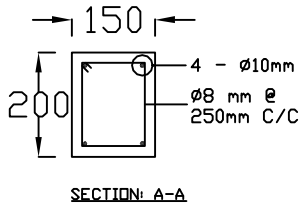


Tender Drawing

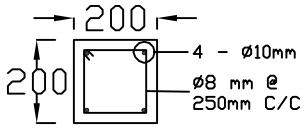
Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Slpoe (1V:2H) protection with CC blocks
Drawing No.	
Drawn:	Checked: Approved:



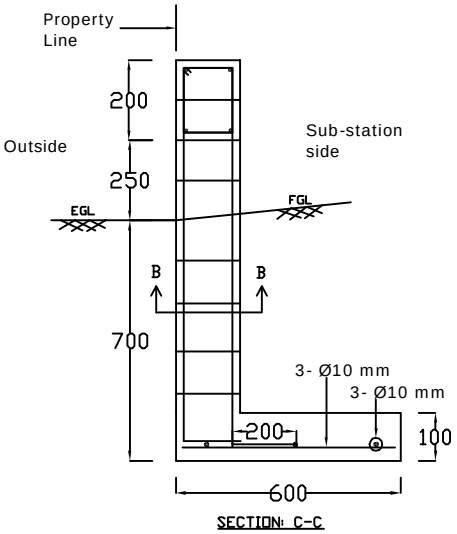
SECION ALONG PROPERTY LINE



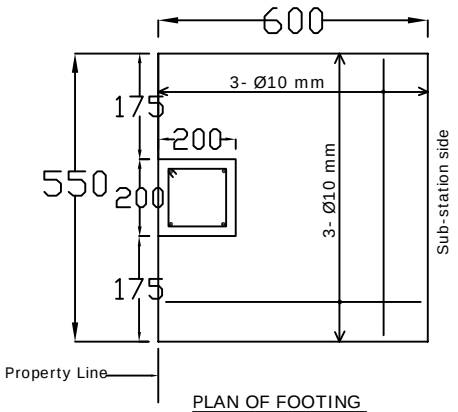
SECTION: A-A



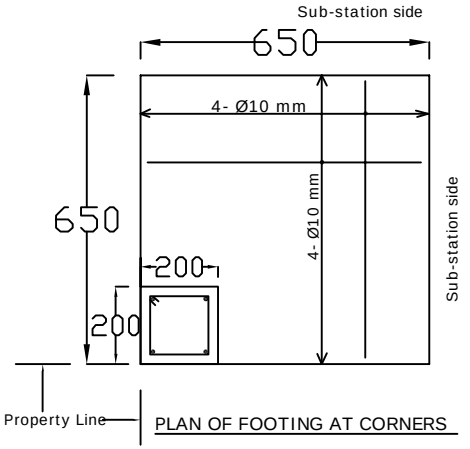
SECTION: B-B



SECTION: C-C



PLAN OF FOOTING



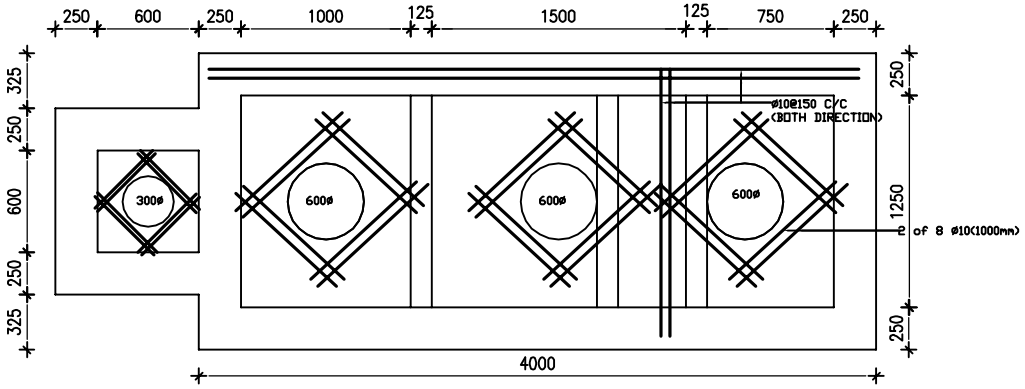
PLAN OF FOOTING AT CORNERS

General Notes:

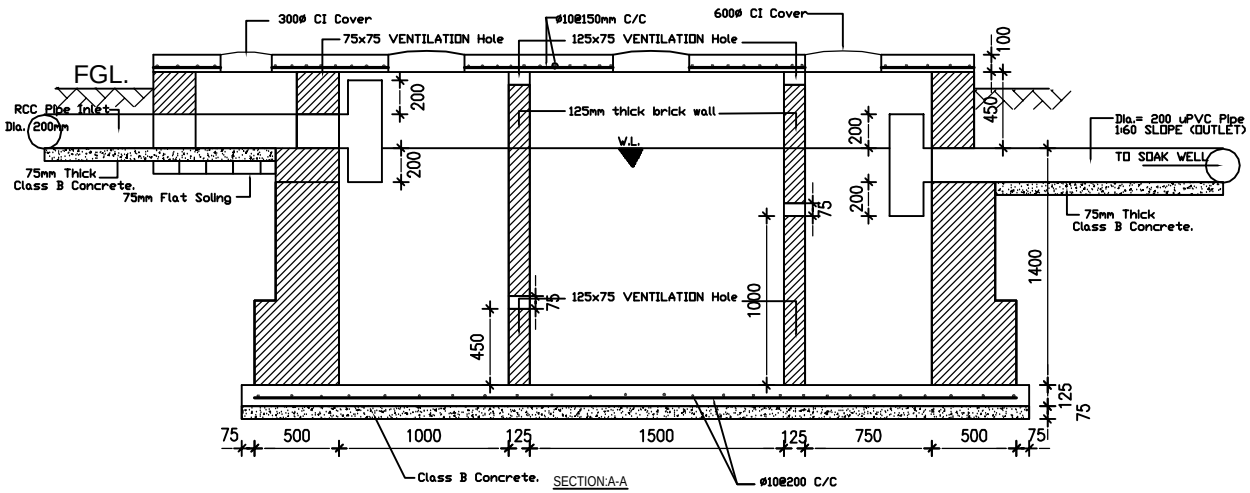
1. Grade beams, columns and footings are Class A Reinforced Cement Concrete(RCC) structures.
2. Grade of rebar shall be deformed bar of Fy 415 MPa minimum.
3. Clear cover both side and bottom: For Grade beam & column= 25mm and for Footing= 40mm.
4. Maximum centre to centre distance of columns = 4000mm.
5. All dimension are in mm where not stated.

Tender Drawing

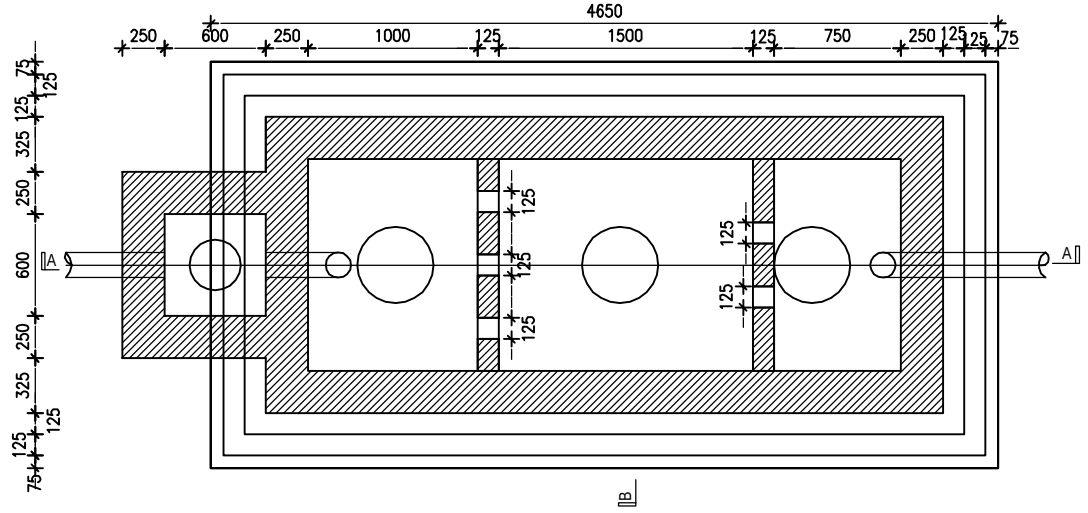
Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Property Line demarkation
Drawing No.	
Drawn:	Checked: Approved:



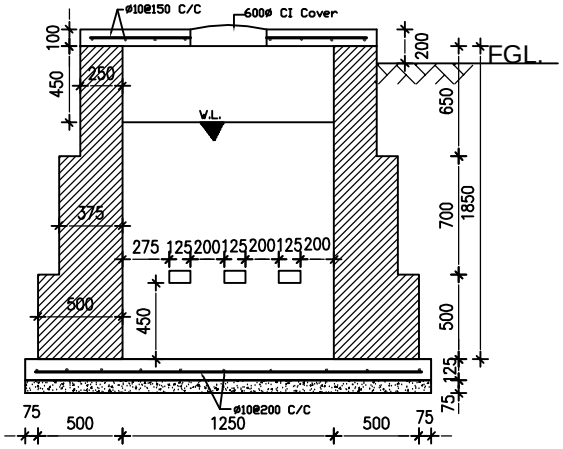
TOP SLAB REINFORCEMENT OF SEPTIC TANK



SECTION:A-A



PLAN OF SEPTIC TANK.



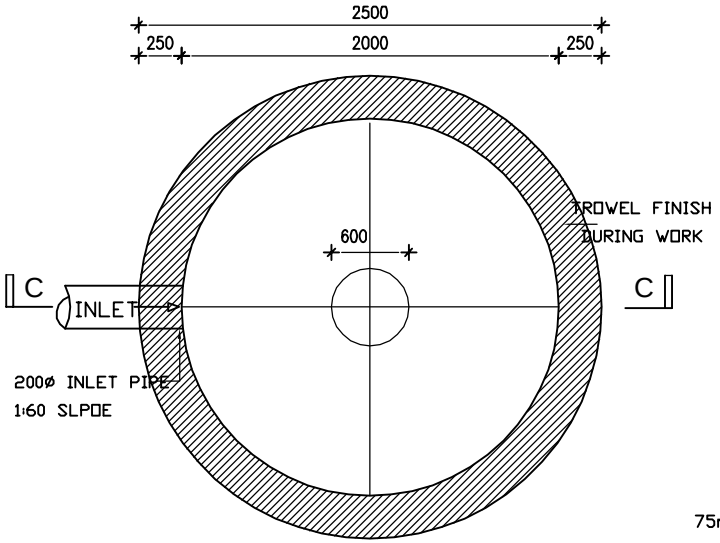
SECTION:B-B

NOTES:

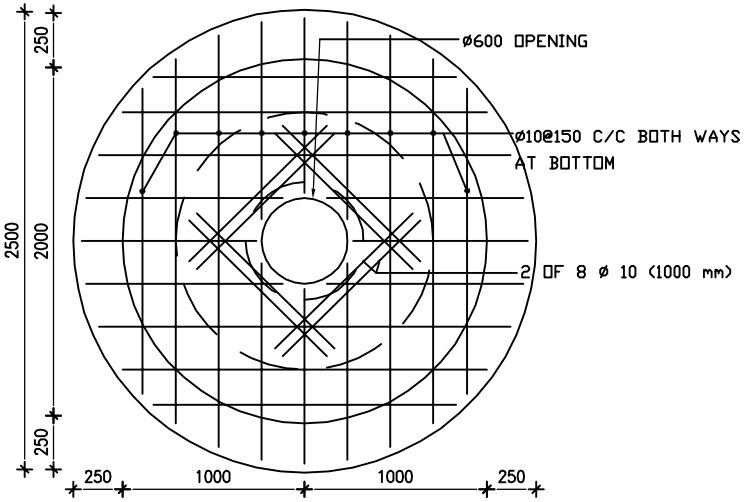
1. TYPE OF COVER FOR ALL INSPECTION HOLES IS C.I.
2. SIZE OF THE HOLE INSIDE BRICK HOLE INSIDE BRICK WALL FOR SEPTIC TANK IS 125X75 mm2.
3. R.C.C. WORK AS PER APPROVED MIX. DESIGN.
4. MINIMUM YIELD STRENGTH OF REBAR IS 415 N/ mm2.
5. MORTAR MIXING PROPORTION IS 1:4
6. PLASTER MIXING PROPORTION IS 1:3.
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

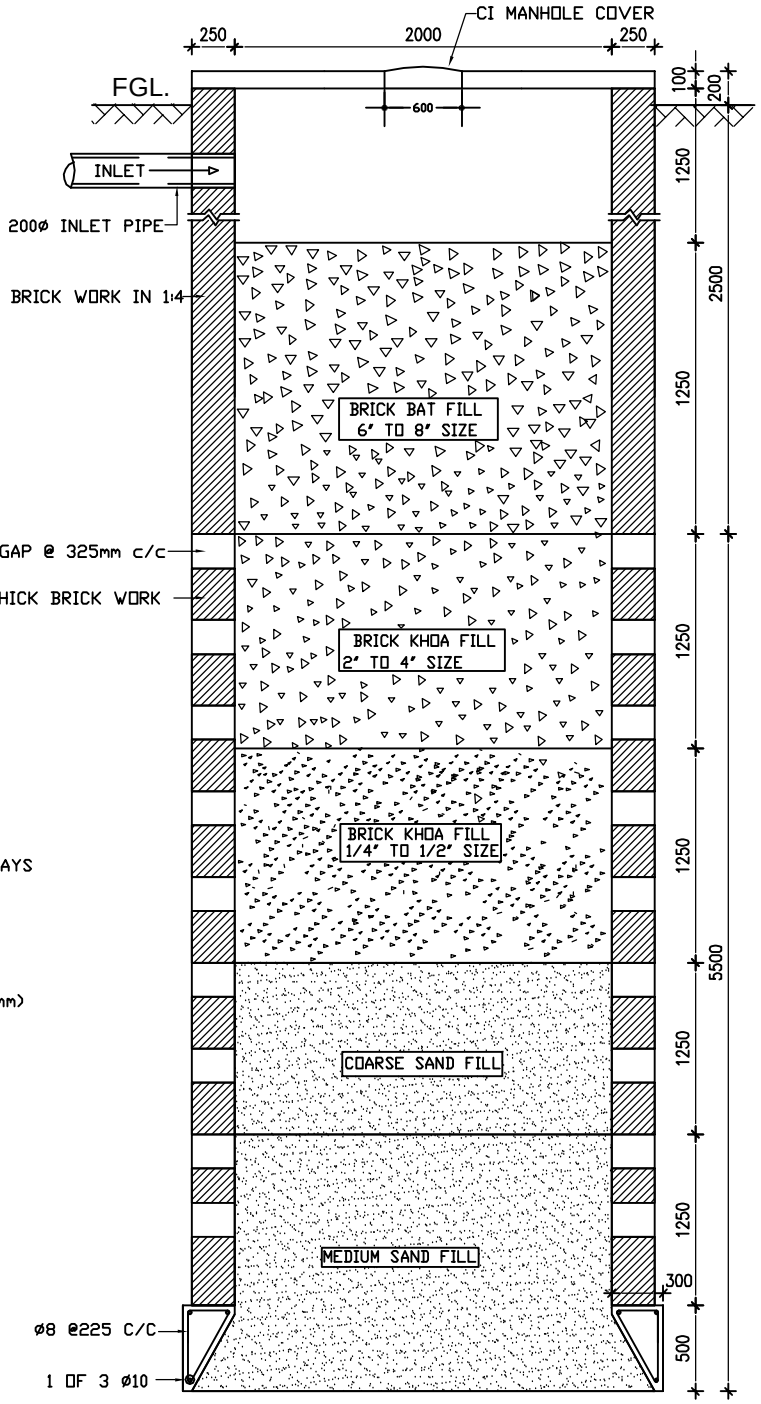
Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Septik Tank
Drawing No.	
Drawn:	Checked: Approved:



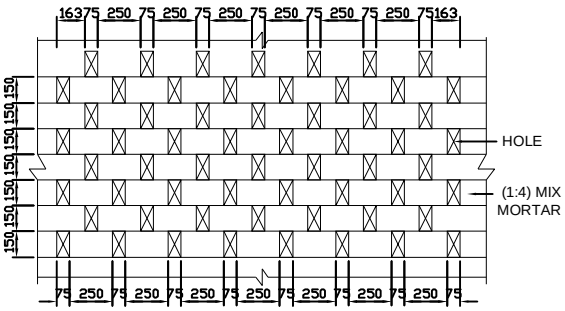
PLAN OF SOAK WELL (SW)



SLAB OF SW
REINFORCEMENT PLAN OF TOP



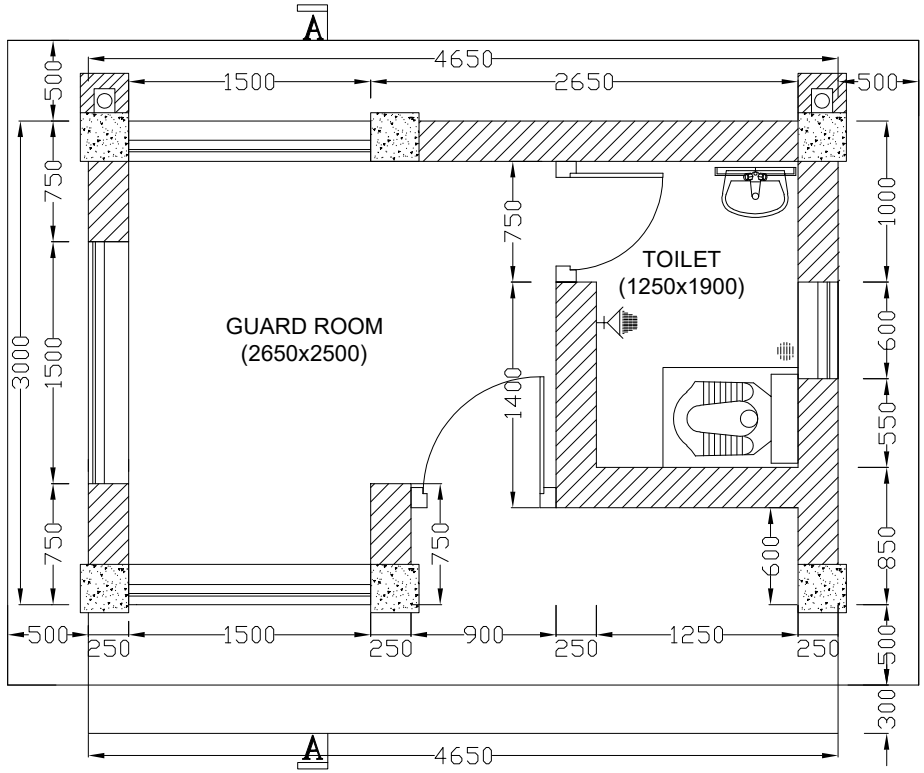
SECTION ON C - C



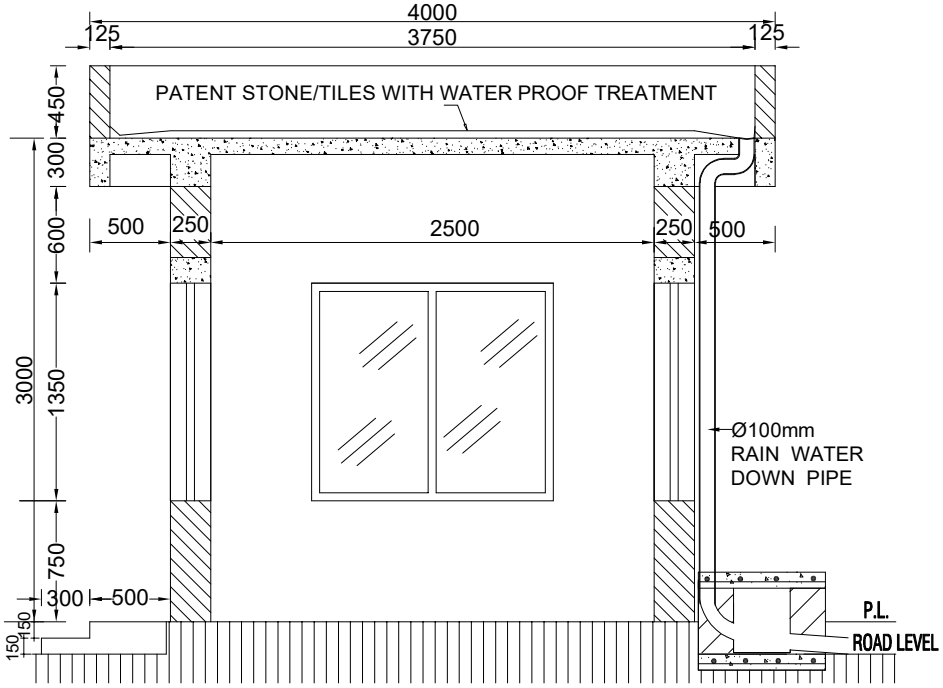
PART VIEW OF WALL WITH HOLE

Tender Drawing

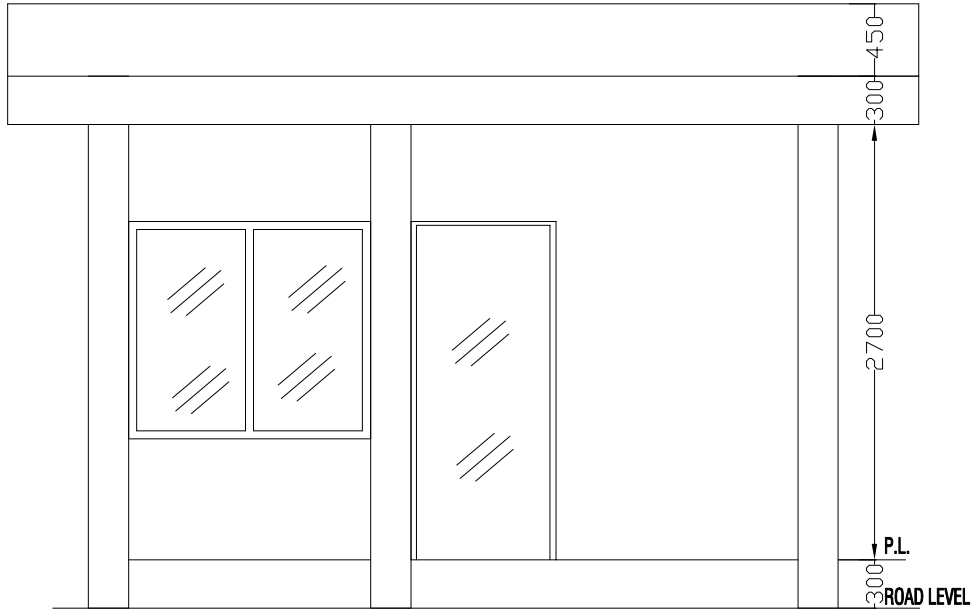
Power Grid Company of Bangladesh Limited	
Project	
Drawing Title	Soak Well for Septik Tank
Drawing No.	
Drawn:	Checked: Approved:



PLAN OF GUARD HOUSE



SECTION : A-A



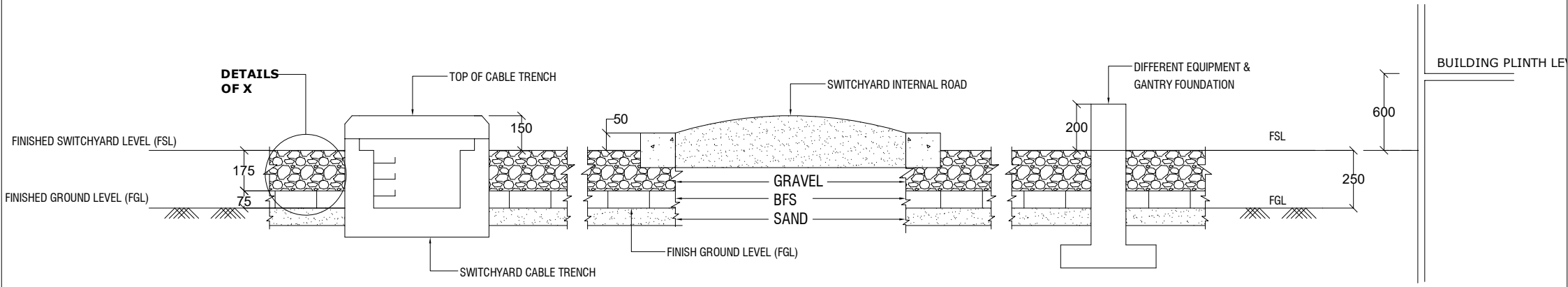
ROAD SIDE ELEVATION

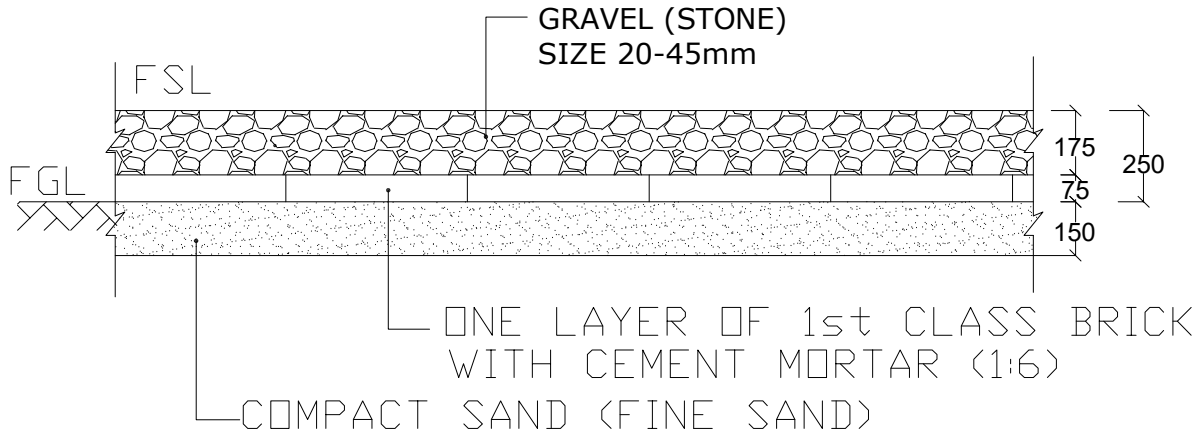
NOTES:

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 PATENT STONE/TILES.
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 Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Guard House
Drawing No.	PG/ADB/GH
Drawn:	Checked: Approved:





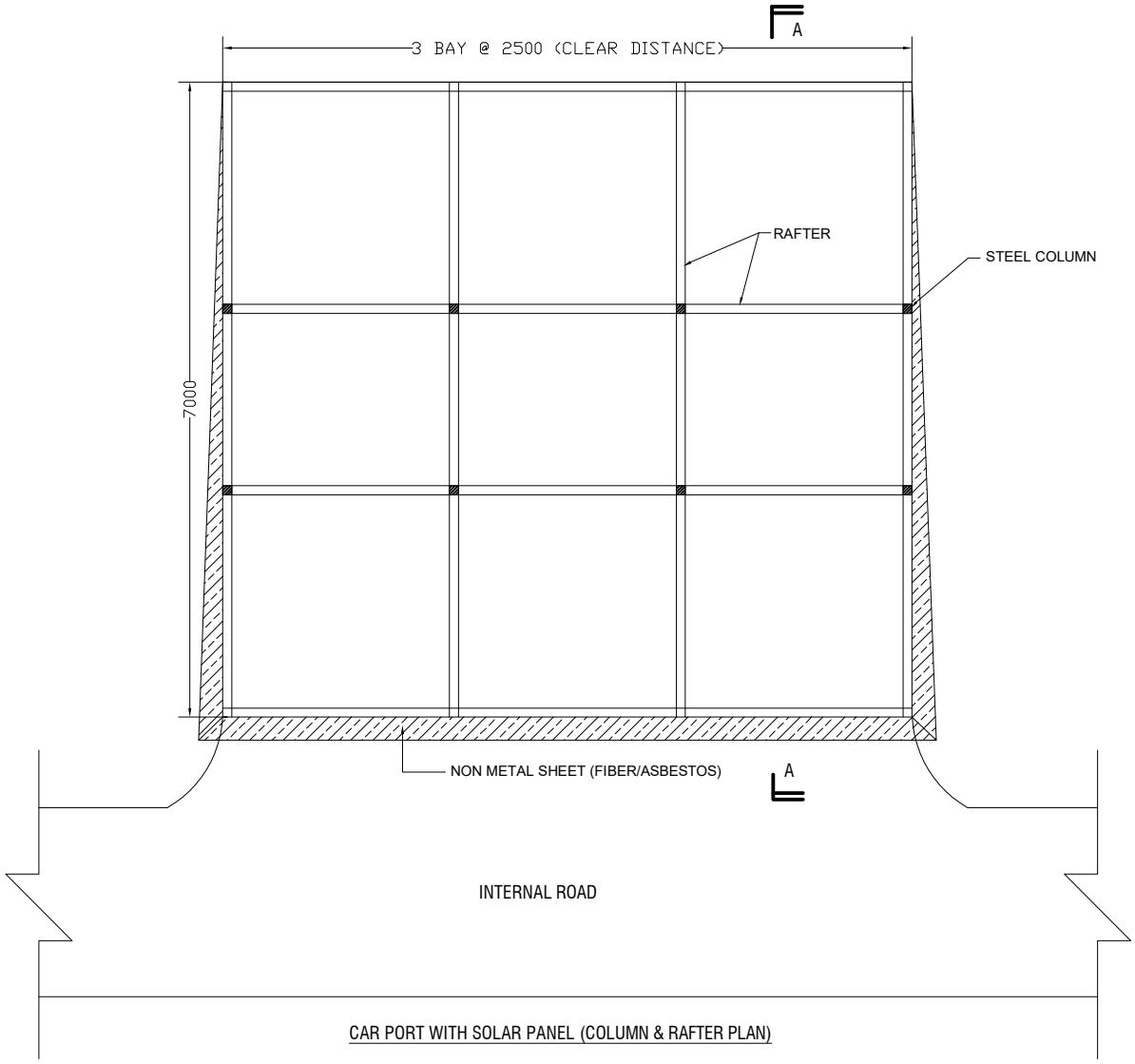
DETAIL OF X

NOTE:

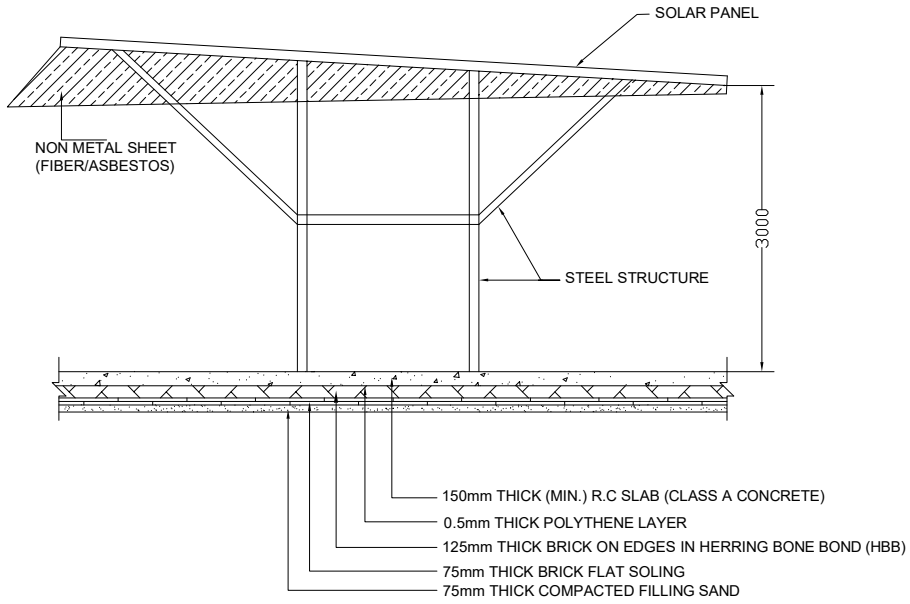
After determination of Finished Ground Level (FGL) with respect to MSL/PWD, the contractor should prepare and submit the relative RLs of all the structures for approval for each site.

Tender Drawing

Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Switchyard Surface Level
Drawing No.	PG/ADB/SSL
Drawn:	Checked: Approved:



CAR PORT WITH SOLAR PANEL (COLUMN & RAFTER PLAN)

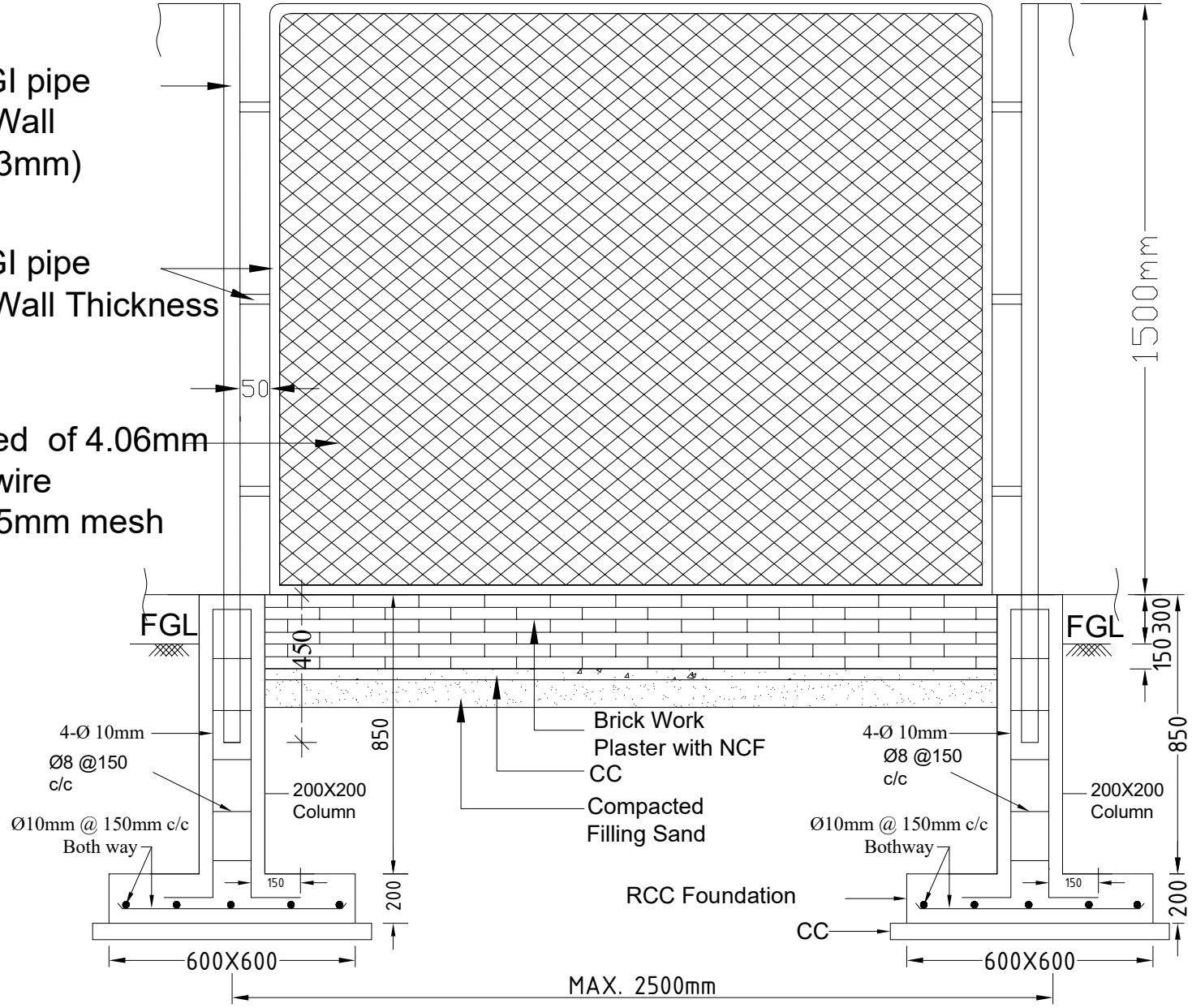


SECTION A-A

NOTES:
1. DETAILS OF ARCHITECTURAL, STRUCTURAL & FOUNDATION DRAWING SHALL BE SUBMITTED FOR APPROVAL.
2. SOLAR PANEL SHALL BE PLACED ON ROOF.
3. TILT ANGEL AND AZIMUTH ANGEL SHALL BE FINALIZED DURING DETAILED DESIGN.

Tender Drawing

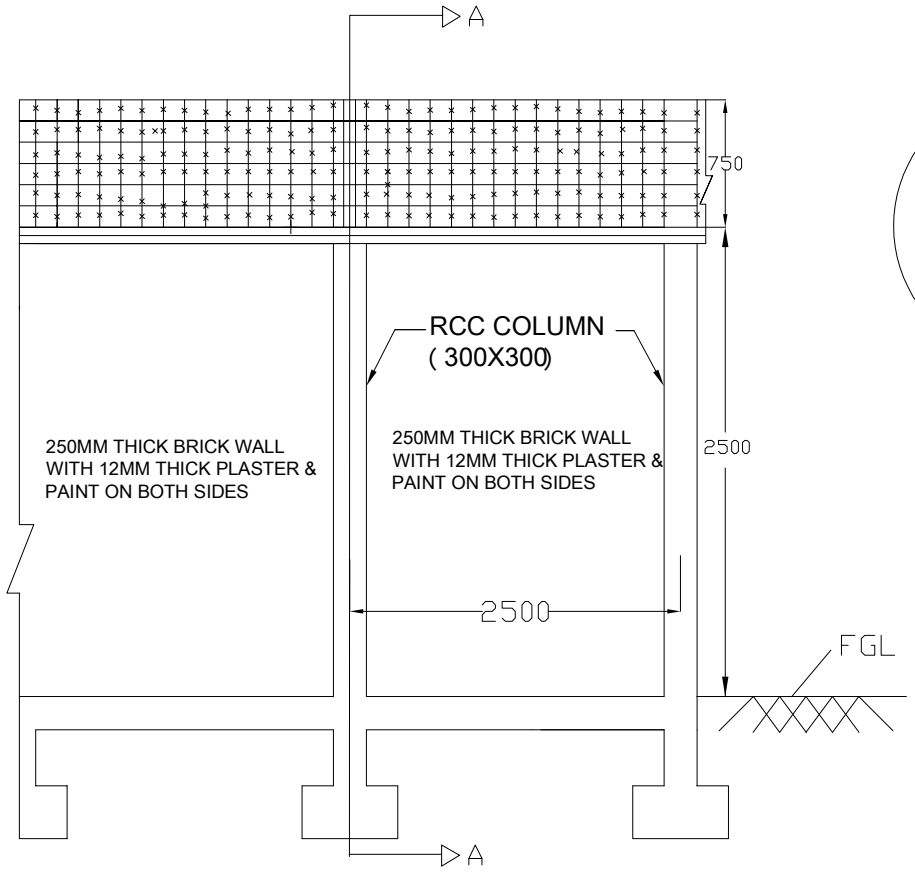
Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Car Port with Solar Panel (For Three Bays)
Drawing No.	PG/ADB/CAR
Drawn:	Checked: Approved:



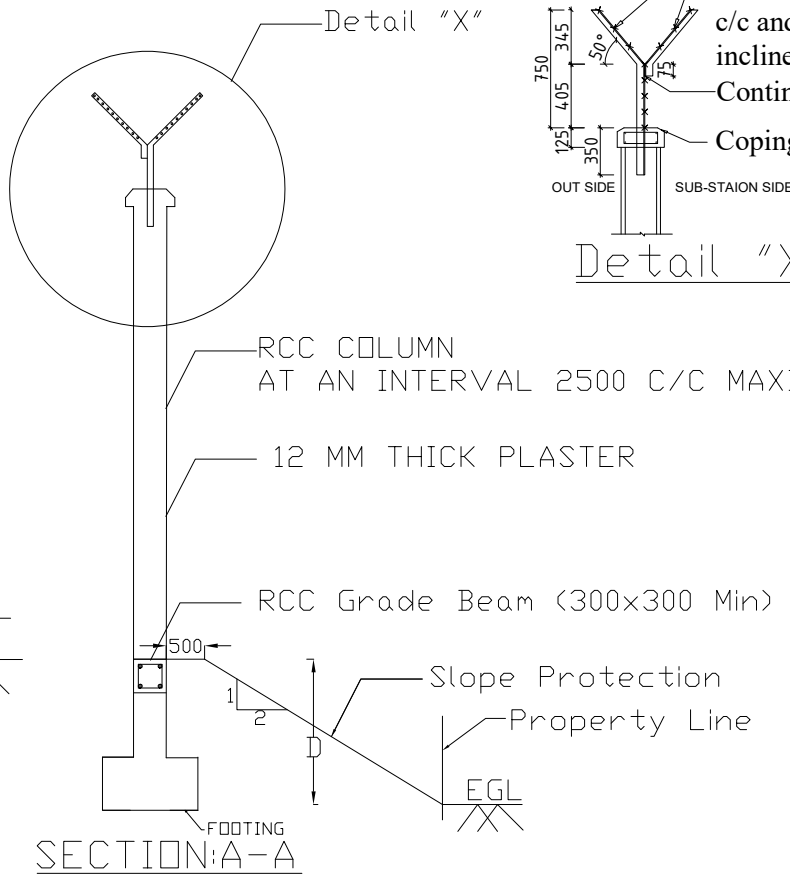
Typical Section of Chain Linked Fencing

Tender Drawing

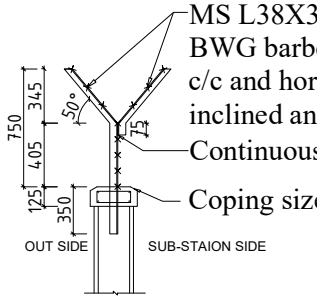
Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Typical Section of Chain linked fencing
Drawing No.	PG/ADB/Fence
Drawn:	Checked: Approved:



FRONT ELEVATION



SECTION:A-A



Detail "X"

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

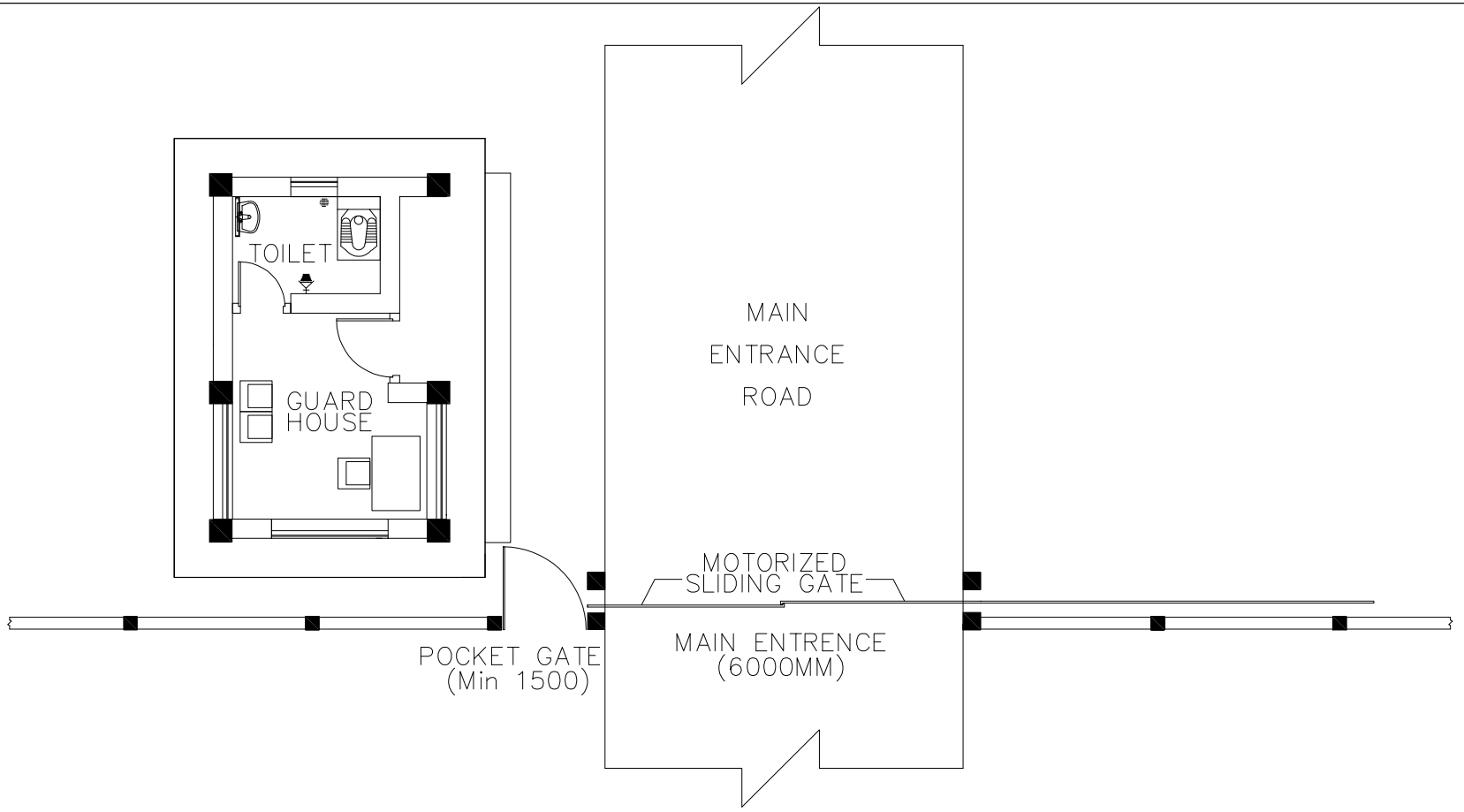
Coping size (350x125) with 50mm chamfer

NOTE:

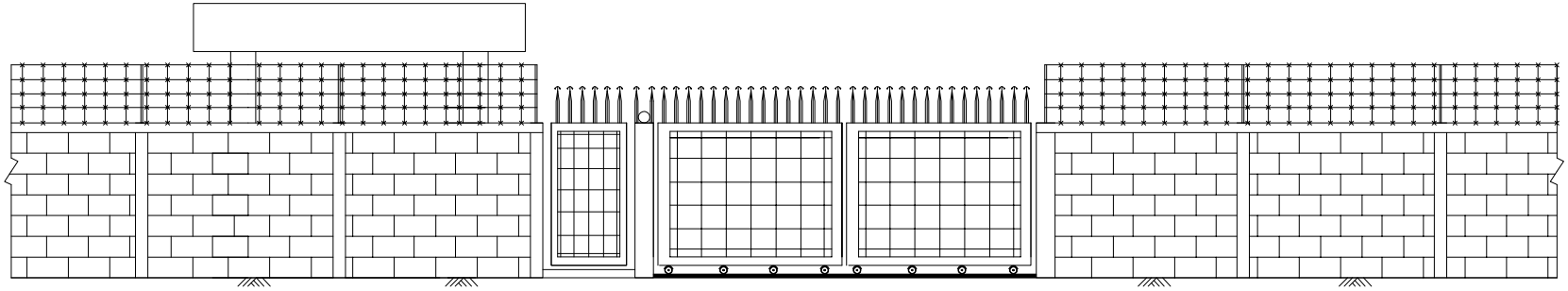
1) "EGL" means Existing Ground level
2) "FGL" means Finished Ground level
3) ALL DIMENSIONS ARE IN MM
4) 'D'=Depth of Earth Filling for Land Development
5) Expansion Joints shall have to be provided at maximum 25m Interval.

Tender Drawing

Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Boundary wall without retaining wall
Drawing No.	PG/ADB/BW
Drawn:	Checked: Approved:



PLAN VIEW



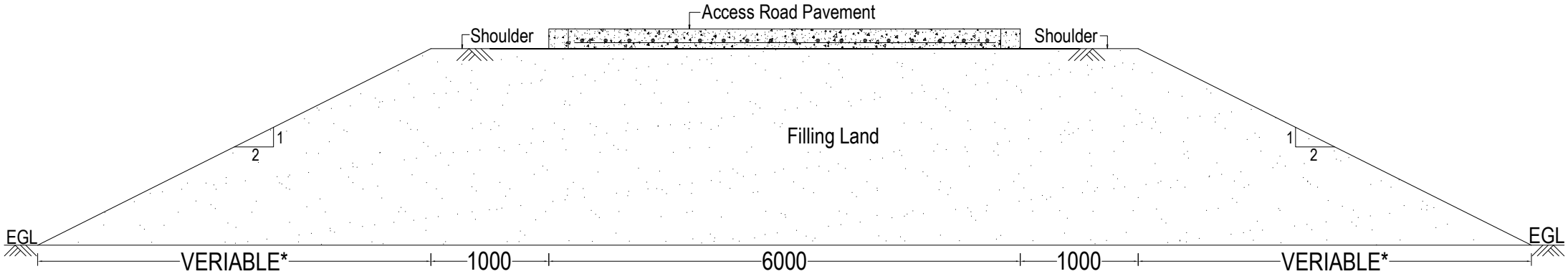
FRONT VIEW

ENTRANCE GATE

NOTE: Gate design shall be finalized during design stage.

Tender Drawing

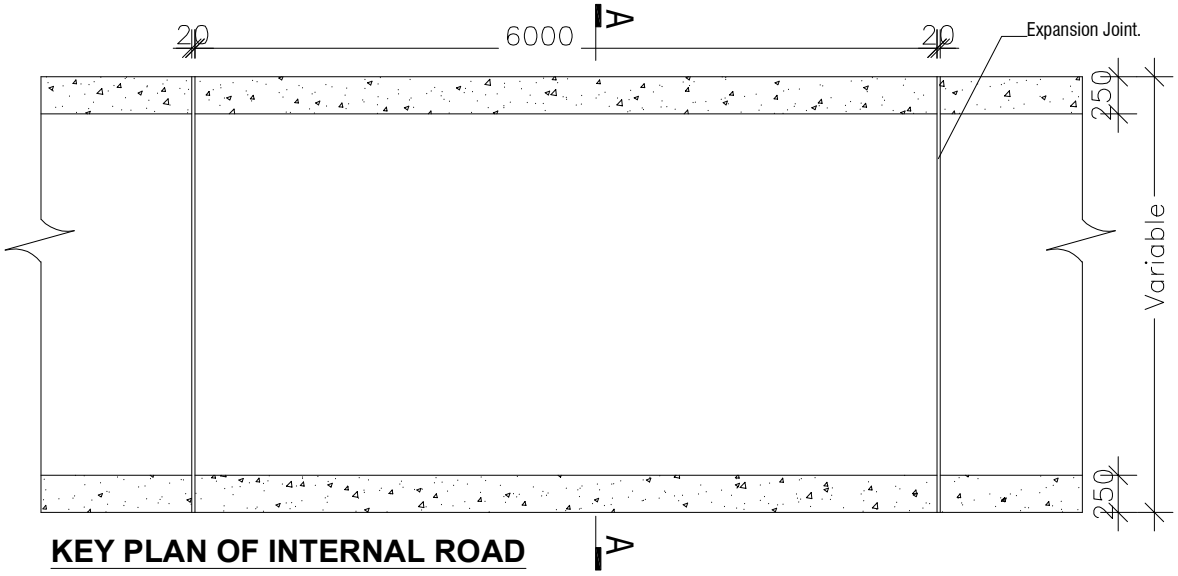
Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Main Entrance Gate
Drawing No.	PG/ADB/GATE
Drawn:	Checked: Approved:



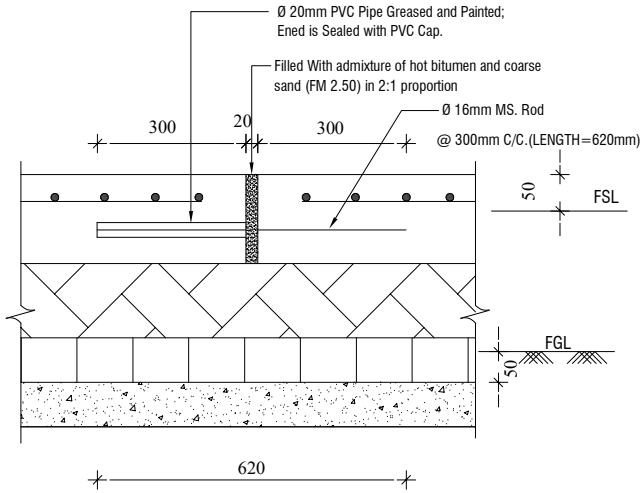
TYPICAL SCHEMATIC DIAGRAM FOR APPROACH ROAD

Tender Drawing

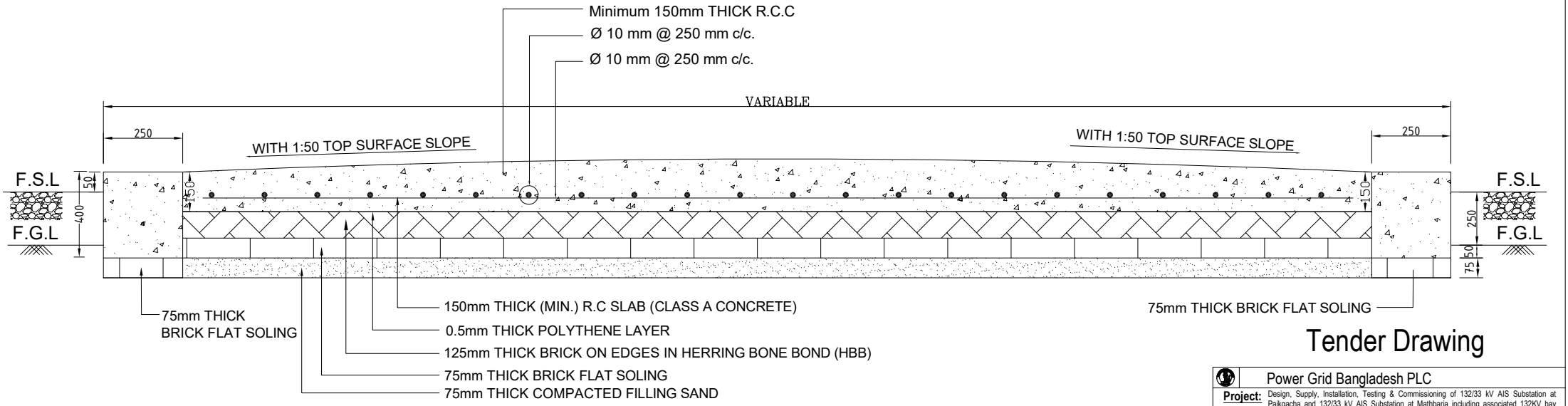
Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Approach Road
Drawing No.	PG/ADB/AR
Drawn:	Checked: Approved:



KEY PLAN OF INTERNAL ROAD
(SCALE - NTS)



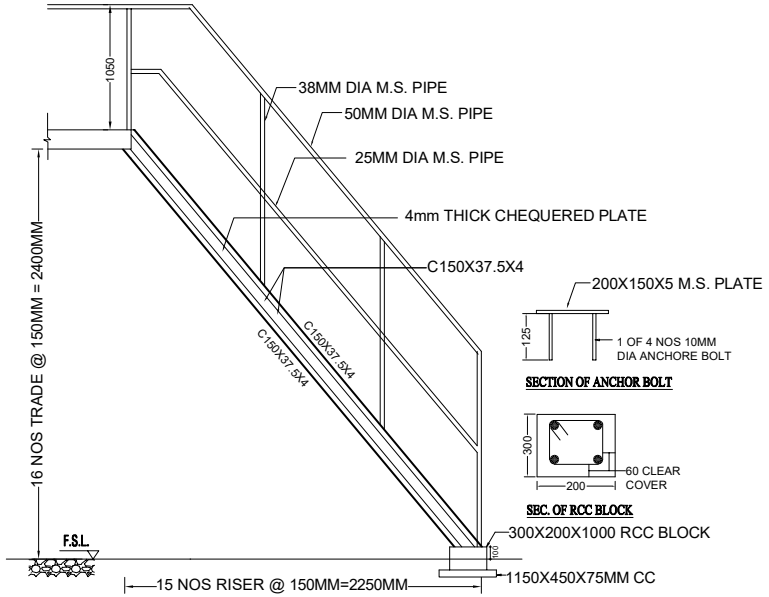
DETAIL OF EXPANSION JOINT
(SCALE - NTS)



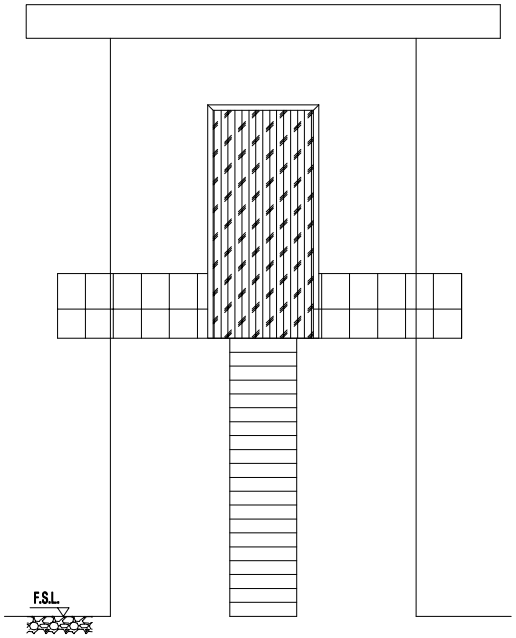
ROAD CROSS SECTION : A-A
(SCALE - NTS)

Tender Drawing

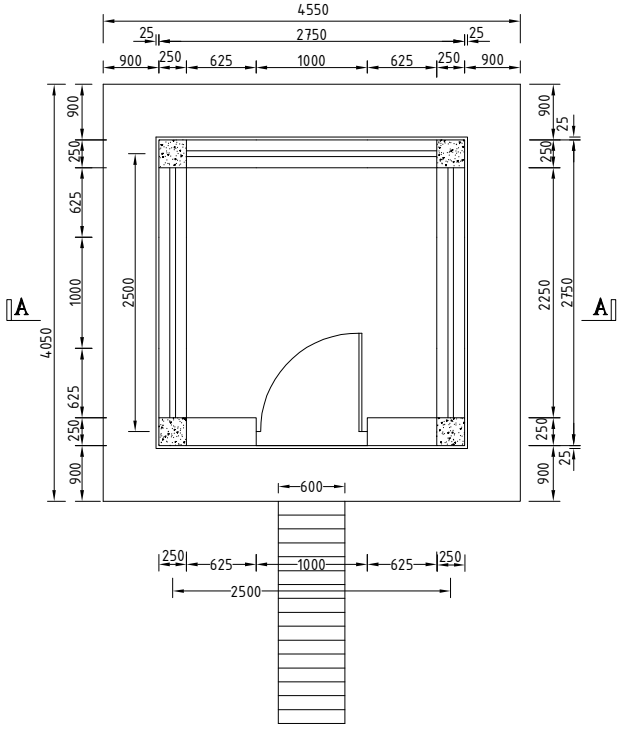
Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Typical Road sections
Drawing No.	PG/ADB/TRS
Drawn:	Checked: Approved:



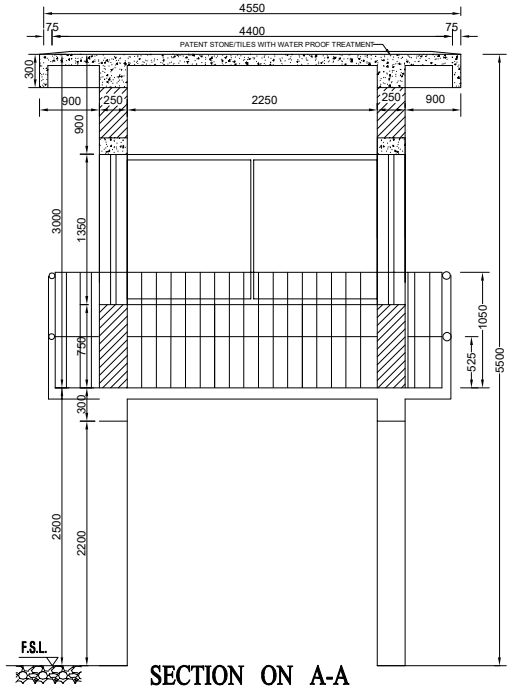
DETAILS OF STAIR



FRONT ELEVATION



PLAN OF SENTRY POST



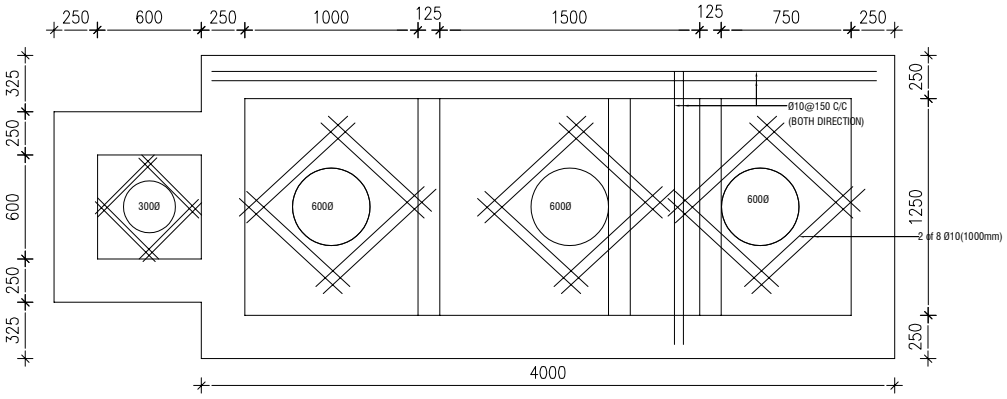
SECTION ON A-A

NOTES:

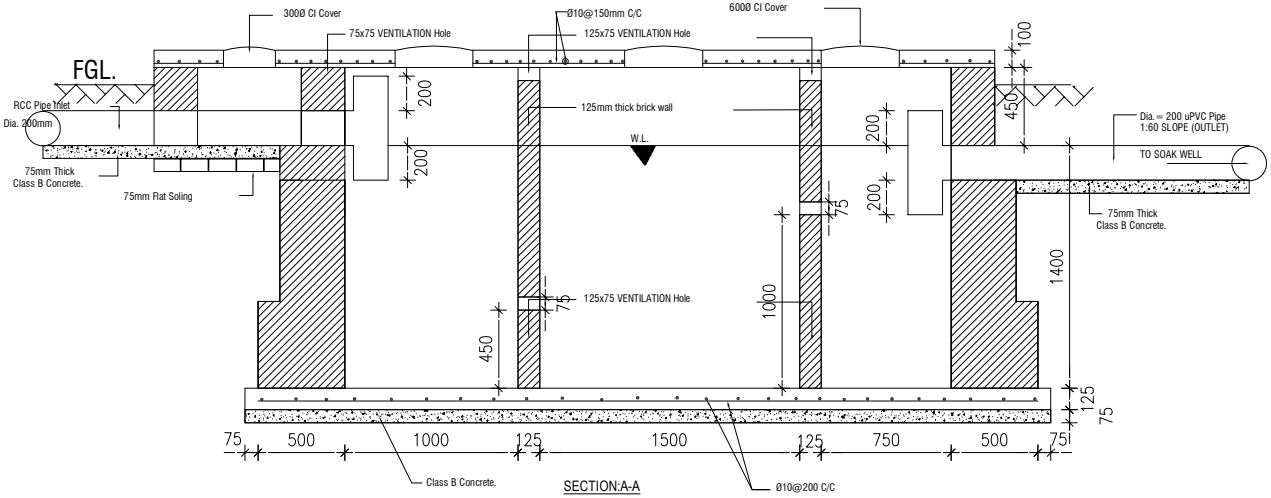
1. DETAILS OF ARCHITECTURAL, STRUCTURAL & FOUNDATION DRAWING & LADDER DETAILS SHALL BE SUBMITTED FOR APPROVAL.
2. ROOF SHALL BE WATER PROOFED WITH WITH PATENT STONE/TILES.
3. RAIN WATER DOWN PIPE & BUILDING DRAINAGE SYSTEM SHALL BE TAKE INTO CONSIDER PRIOR TO SLAB CASTING.
4. POWER CONNECTION LAYOUT SHALL BE APPROVED BEFOR WORK.
5. ALL EXPOSED STEEL SHALL BE GALVANIZED PAINT.

Tender Drawing

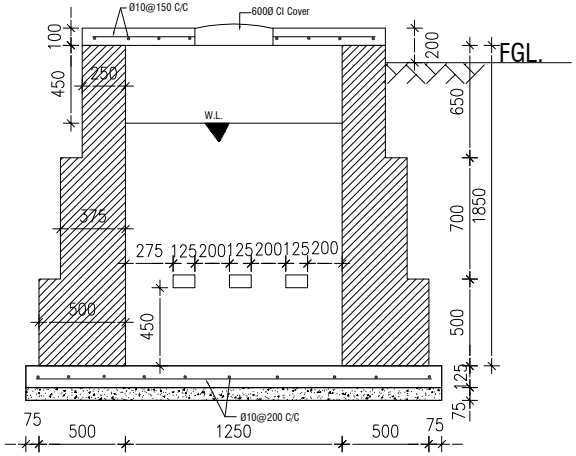
Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Sentry Post
Drawing No.	PG/ADB/SEP
Drawn:	Checked: / Approved:



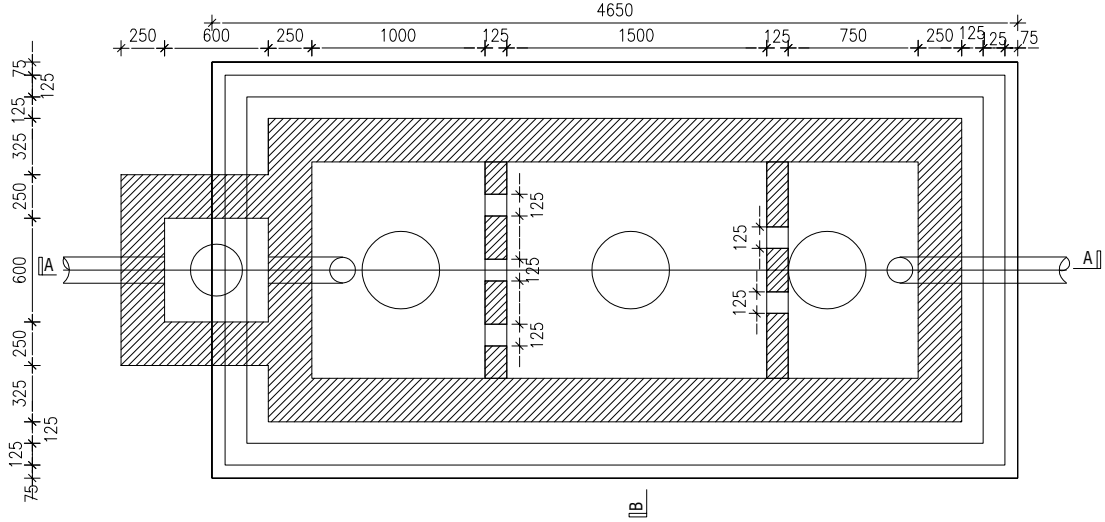
TOP SLAB REINFORCEMENT OF SEPTIC TANK



SECTION:A-A



SECTION:B-B



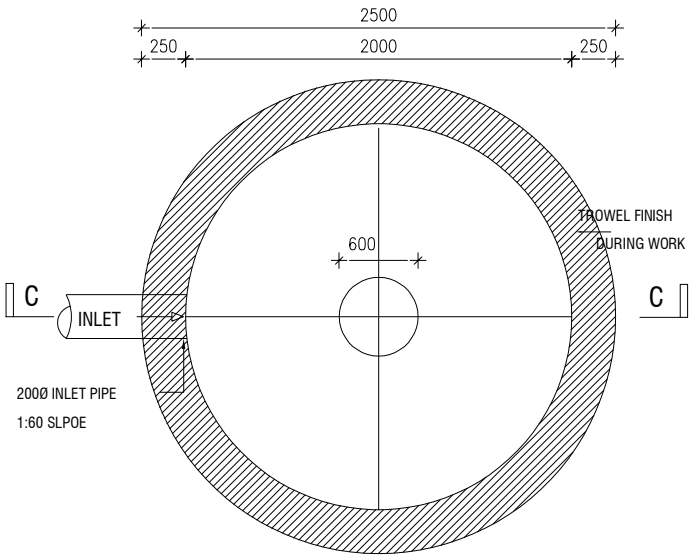
PLAN OF SEPTIC TANK.

NOTES:

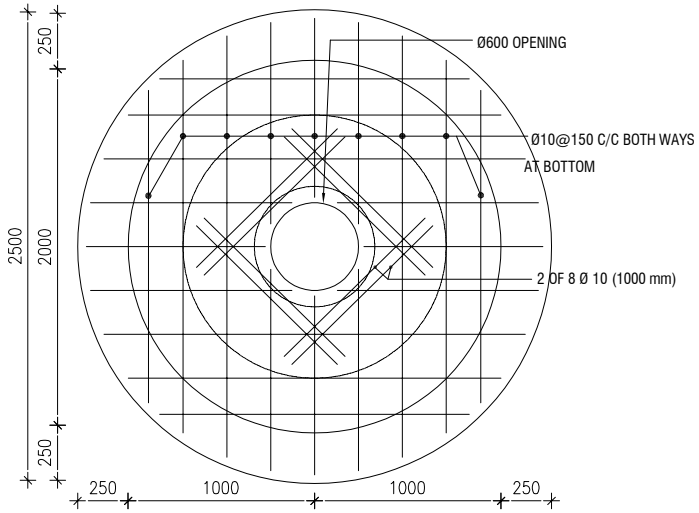
1. TYPE OF COVER FOR ALL INSPECTION HOLES IS C.I.
2. SIZE OF THE HOLE INSIDE BRICK HOLE INSIDE BRICK WALL FOR SEPTIC TANK IS 125X75 mm2.
3. R.C.C. WORK AS PER APPROVED MIX. DESIGN.
4. MINIMUM YIELD STRENGTH OF REBAR IS 415 N/ mm2.
5. MORTAR MIXING PROPORTION IS 1:4
6. PLASTER MIXING PROPORTION IS 1:3.
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

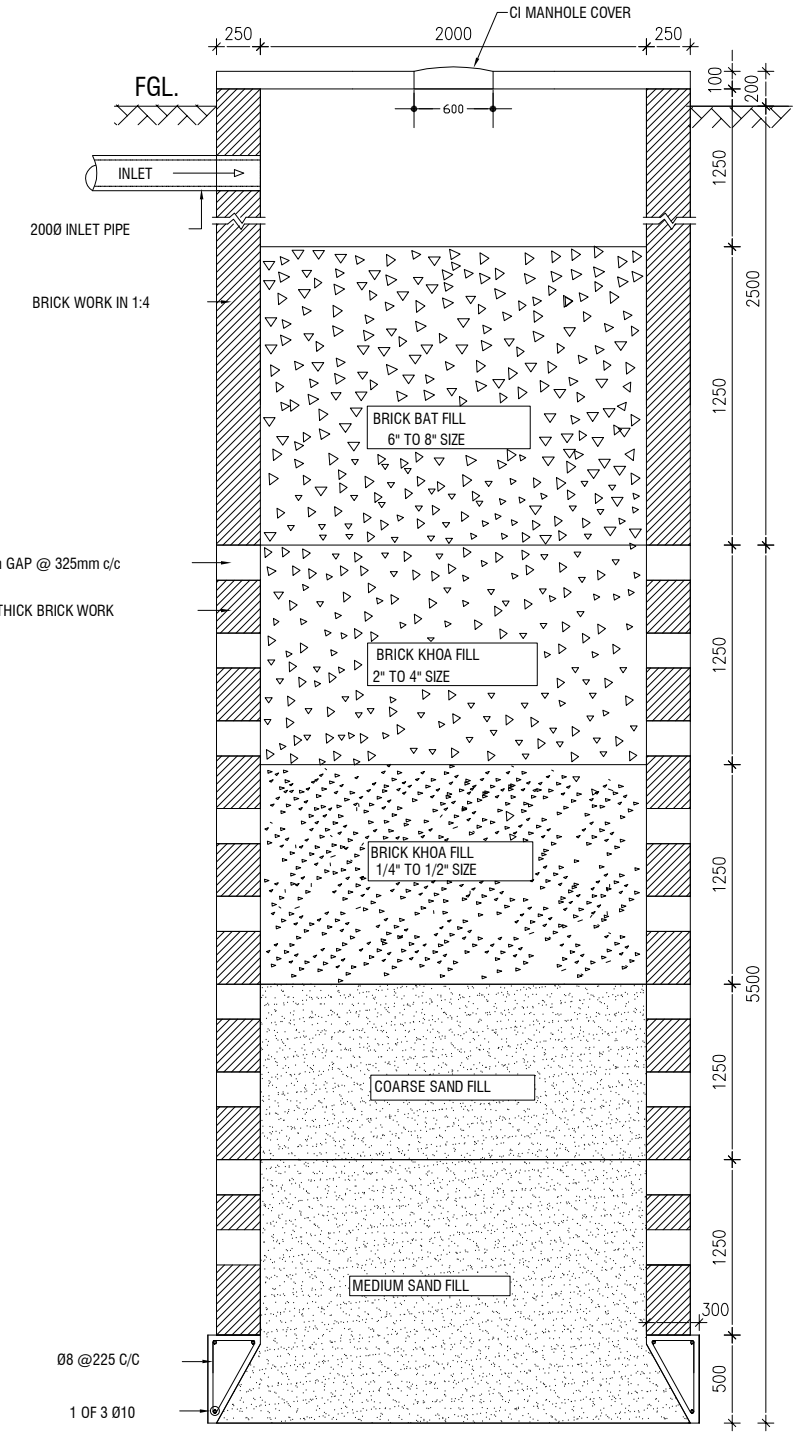
Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Septik Tank
Drawing No.	PG/ADB/ST
Drawn:	Checked: Approved:



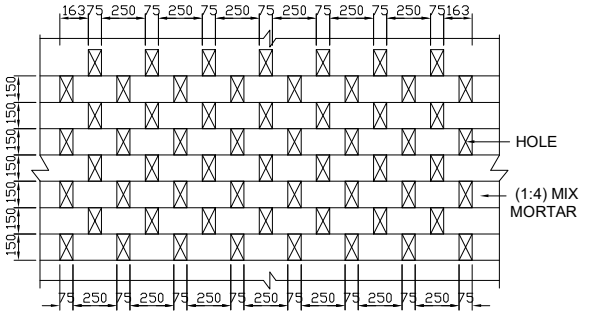
PLAN OF SOAK WELL (SW)



SLAB OF SW
REINFORCEMENT PLAN OF TOP



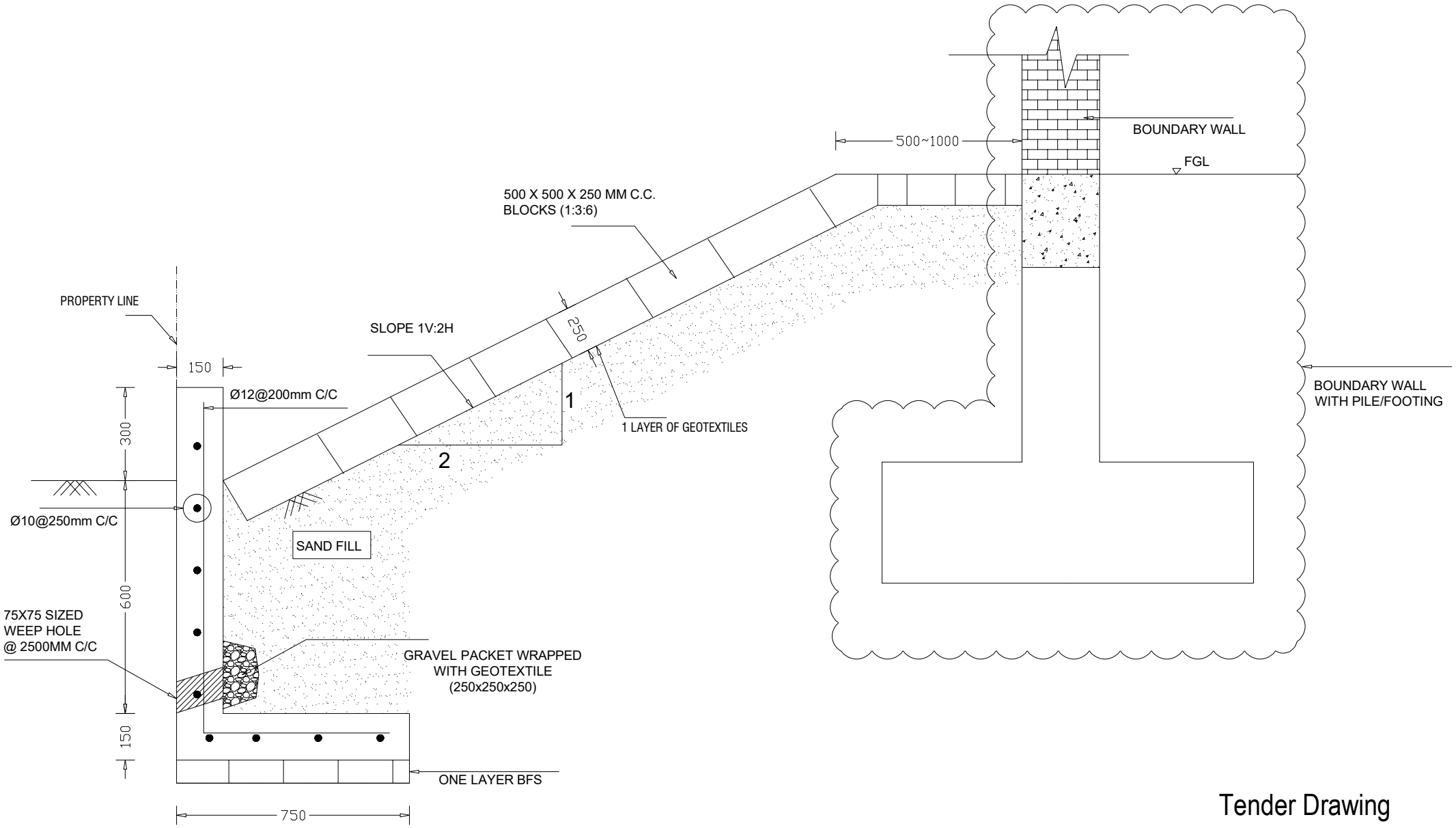
SECTION ON C - C



PART VIEW OF WALL WITH HOLE

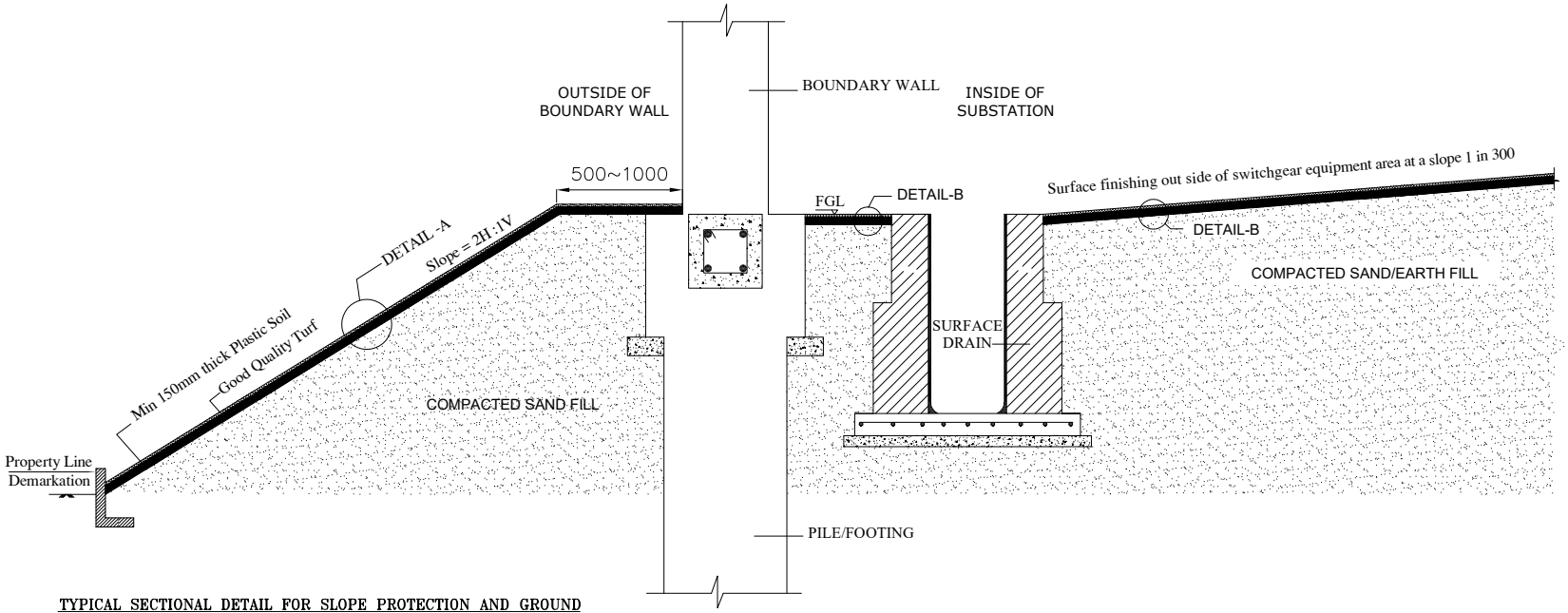
Tender Drawing

Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Soak Well for Septik Tank
Drawing No.	PG/ADB/SW
Drawn:	Checked: Approved:

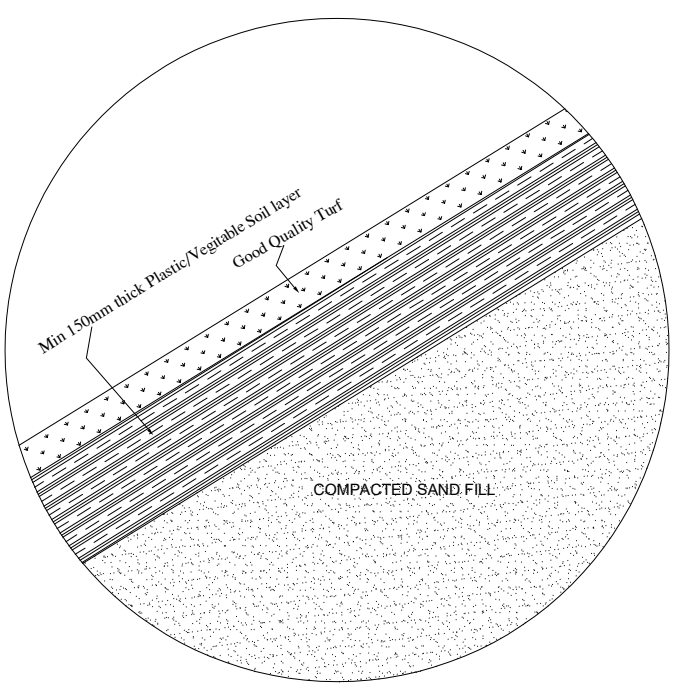


Tender Drawing

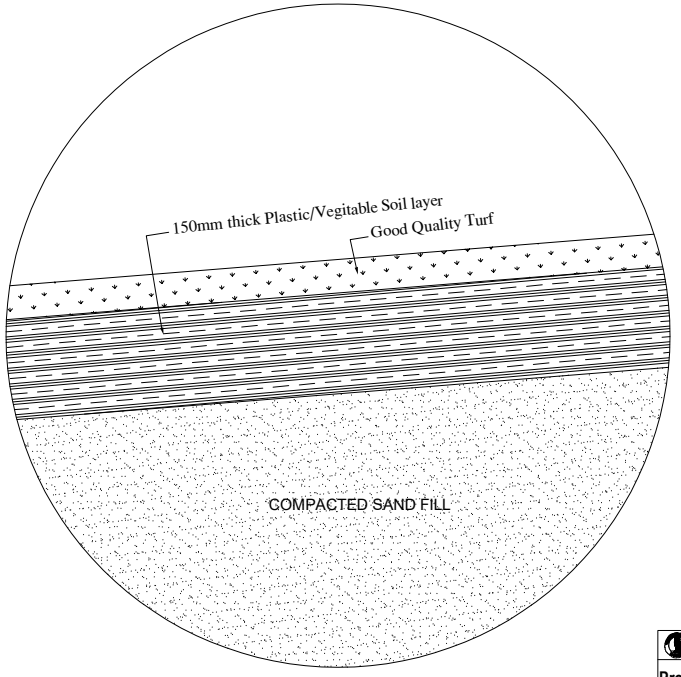
Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 230/132/33 kV AIS Substation at Madhabpur and Monohardi including two nos. 132KV bay extension at Bajitpur 132/33kV grid substation and associated 230kV and 132kV Transmission Lines on turnkey basis (Package-2)
Drawing Title	Slpoe (1V:2H) protection with CC blocks
Drawing No.	PG/ADB/SLP (1)
Drawn:	Checked: Approved:



TYPICAL SECTIONAL DETAIL FOR SLOPE PROTECTION AND GROUND SURFACE FINISHING AROUND THE SURFACE DRAIN



DETAIL-A



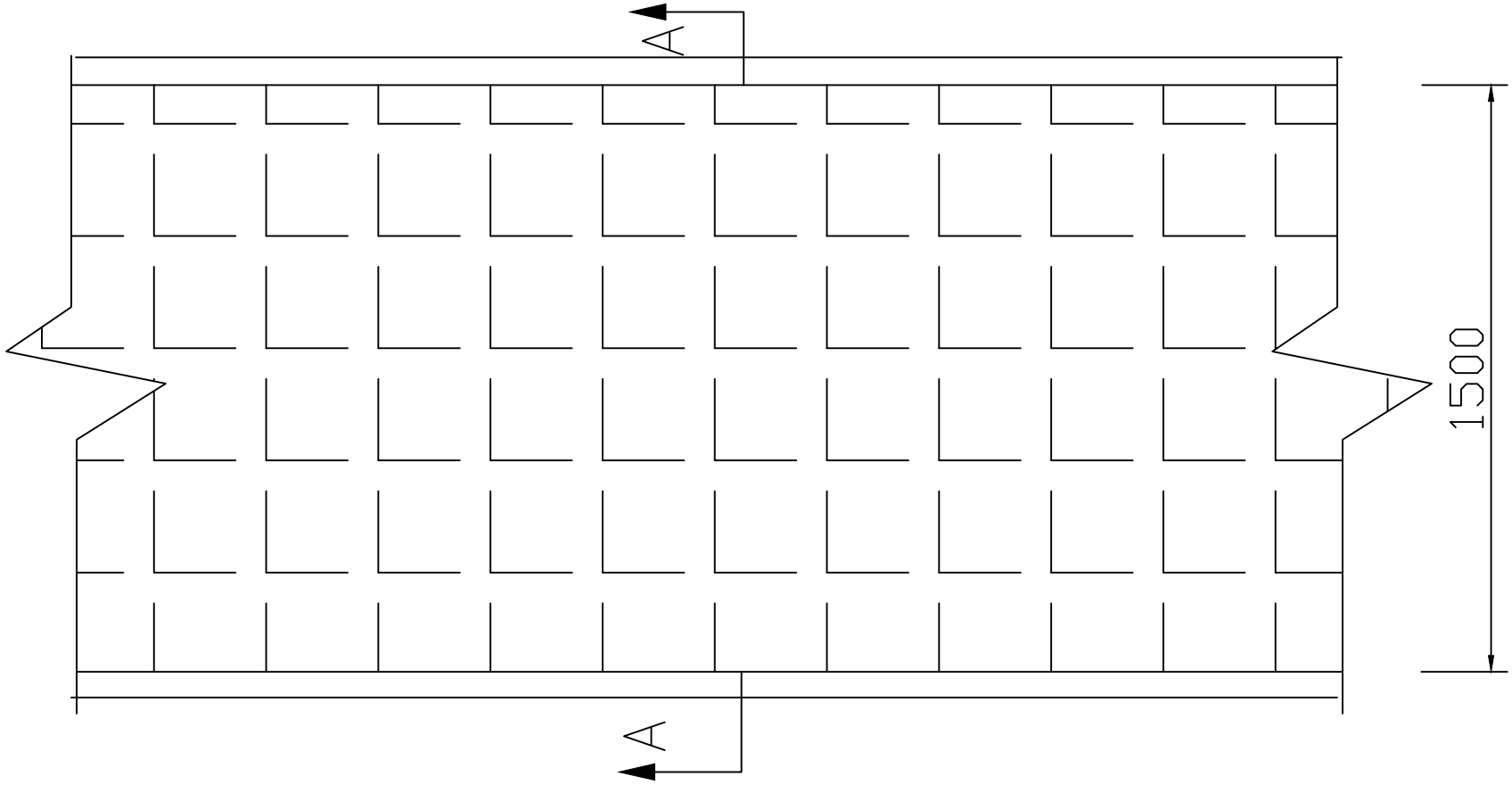
DETAIL-B

NOTE :

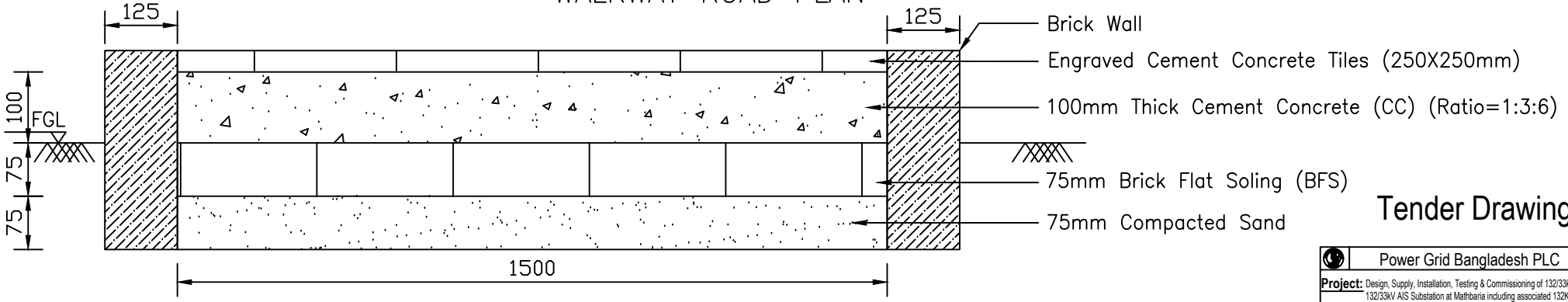
The substation plot, outside of the designated switchgear equipment areas, shall be turfed. Turf shall be of good quality, free from weeds and impurities. Samples of the turf which is proposed to use shall have to be approved by the Engineer. The turfs shall be laid to even surfaces on a bed of vegetable soil, which shall be raked and consolidated to provide a suitable bed.

Tender Drawing

Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Slpoe (1V:2H) protection with turfing
Drawing No.	PG/ADB/SLP (2)
Drawn:	Checked: Approved:



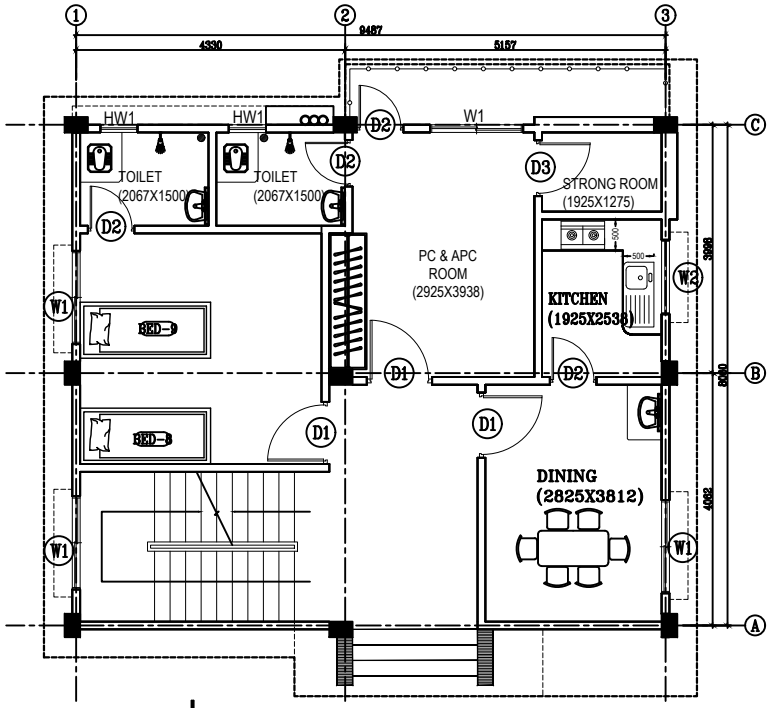
WALKWAY ROAD PLAN



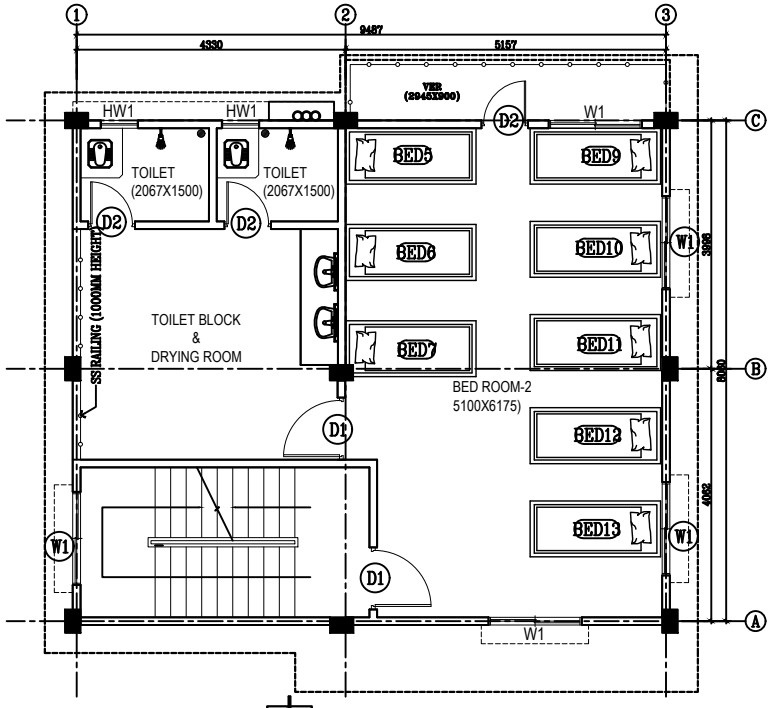
SECTION: A–A

Tender Drawing

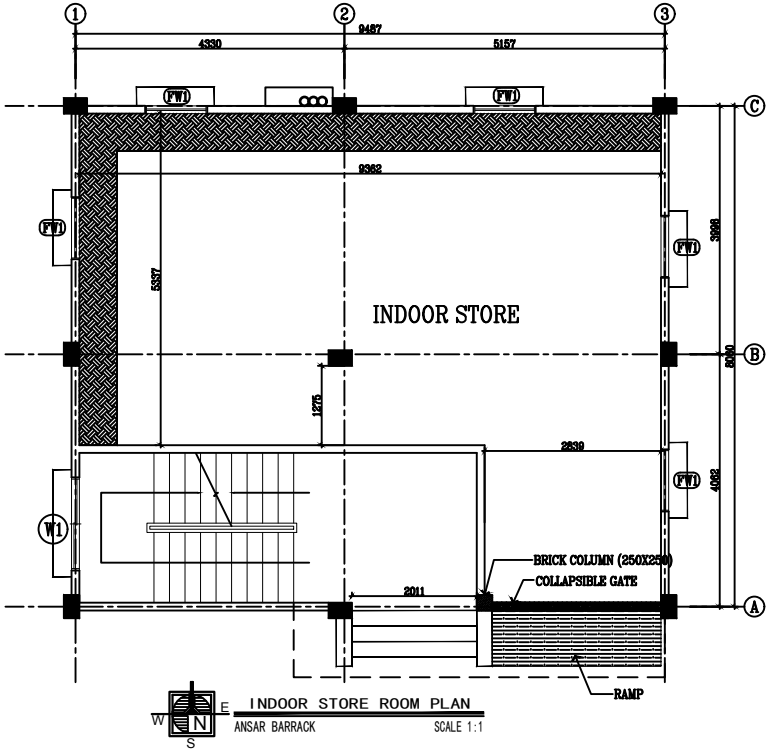
Power Grid Bangladesh PLC	
Project: Design, Supply, Installation, Testing & Commissioning of 132/33kV AIS Substation at Paikgacha and 132/33kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3).	
Drawing Title	Walk Way
Drawing No.	PG/ADB/WW
Drawn:	Checked: Approved:



GROUND FLOOR PLAN
ANSAR BARRACK SCALE 1:1



1ST FLOOR PLAN
ANSAR BARRACK SCALE 1:1



INDOOR STORE ROOM PLAN
ANSAR BARRACK SCALE 1:1

LEGEND

D = DOOR
W = WINDOW
HW = HIGH WINDOW

DOOR SCHEDULE

S.L.	NO.	SIZE		MATERIAL
		WIDTH	HEIGHT	
D /1	5	1050	2100	TIMBER
D /2	5	750	2100	PLASTIC
D /3	1	750	2100	M. STEEL
D /4	2	1050	2100	M. STEEL

WINDOW / VERANDA GRIL SCHEDULE

S.L.	NO.	SIZE		MATERIAL
		WIDTH	HEIGHT	
W /1	9	1500	1350	ALUMINIUM
W /2	1	1200	1350	ALUMINIUM
HW /1	4	600	600	ALUMINIUM
FW1	5	1000	1000	ALUMINIUM

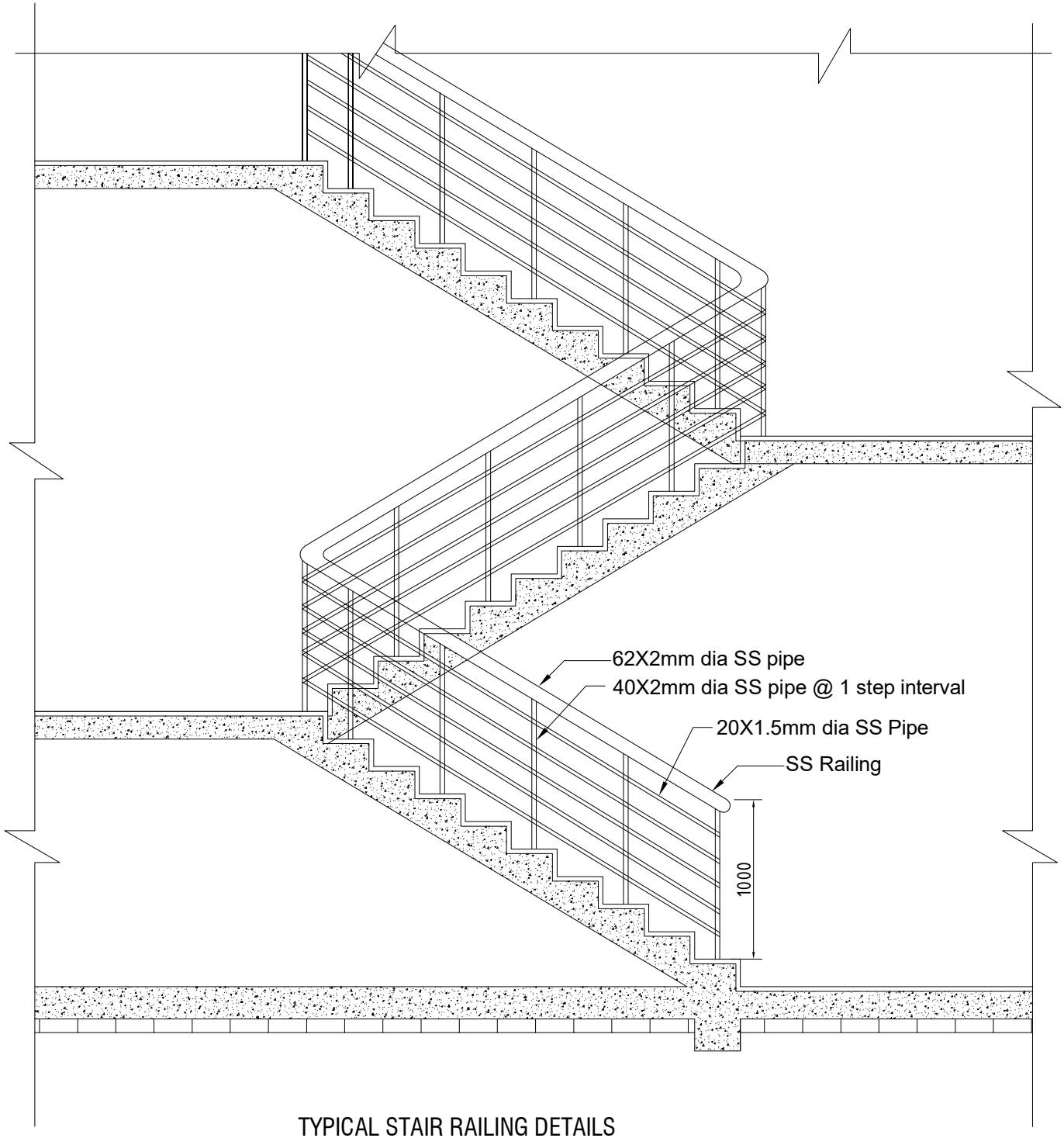
NOTES:
1. ANSAR BARRACK BUILDING SHALL BE RCC FRAME STRUCTURE AND FLOOR HEIGHT SHALL BE 3.0 METER.
2. DETAILS OF ARCHITECTURAL, STRUCTURAL & FOUNDATION DRAWING SHALL BE SUBMITTED FOR APPROVAL.
2. WATER SUPPLY SYSTEM, TOILET & OTHER SANITARY FITTINGS SHALL BE PROVIDED.
3. ROOF SHALL BE WATER PROOFED WITH PATENT STONE/TILES.
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 Bangladesh PLC

Project: Design, Supply, Installation, Testing & Commissioning of 132/33kV AIS Substation at Paikgacha and 132/33kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3).

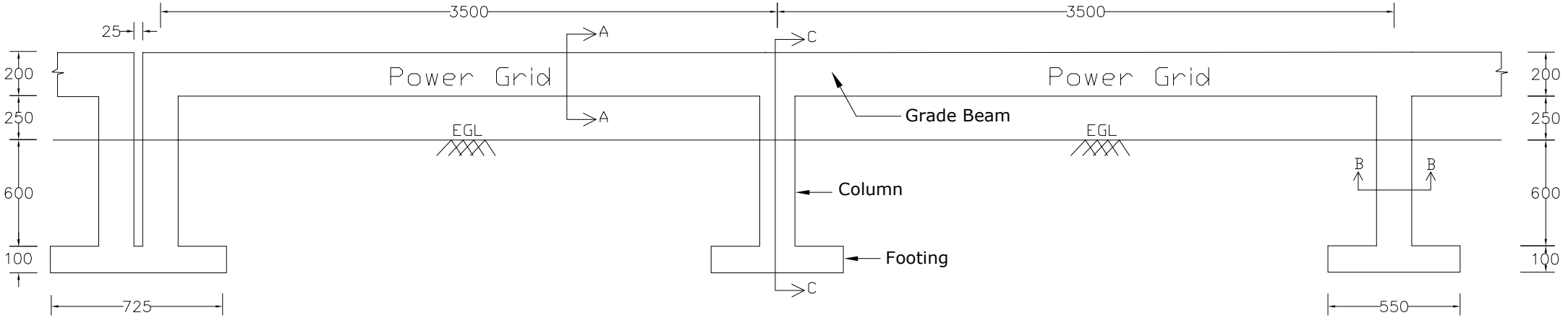
Drawing Title	Ansar Barak
Drawing No.	PG/ADB/AB
Drawn:	Checked: Approved:



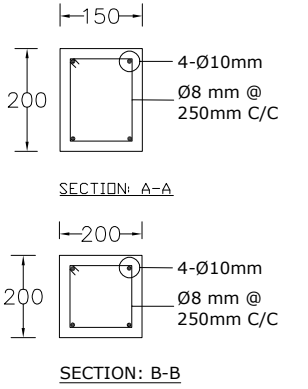
TYPICAL STAIR RAILING DETAILS

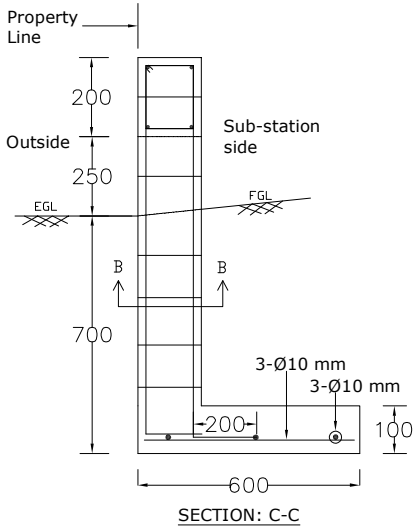
Tender Drawing

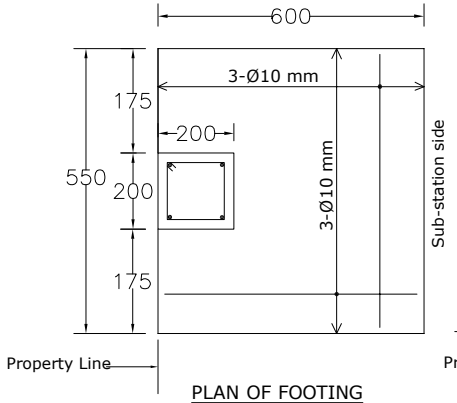
Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Typical Stair Railing
Drawing No.	PG/ADB/SR
Drawn:	Checked: / Approved:

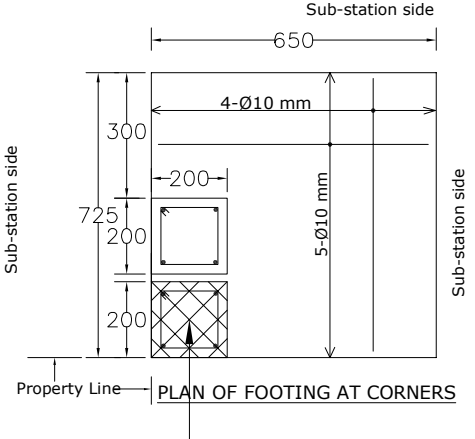


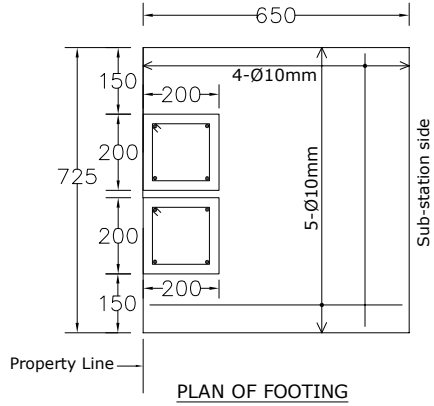
SECION ALONG PROPERTY LINE









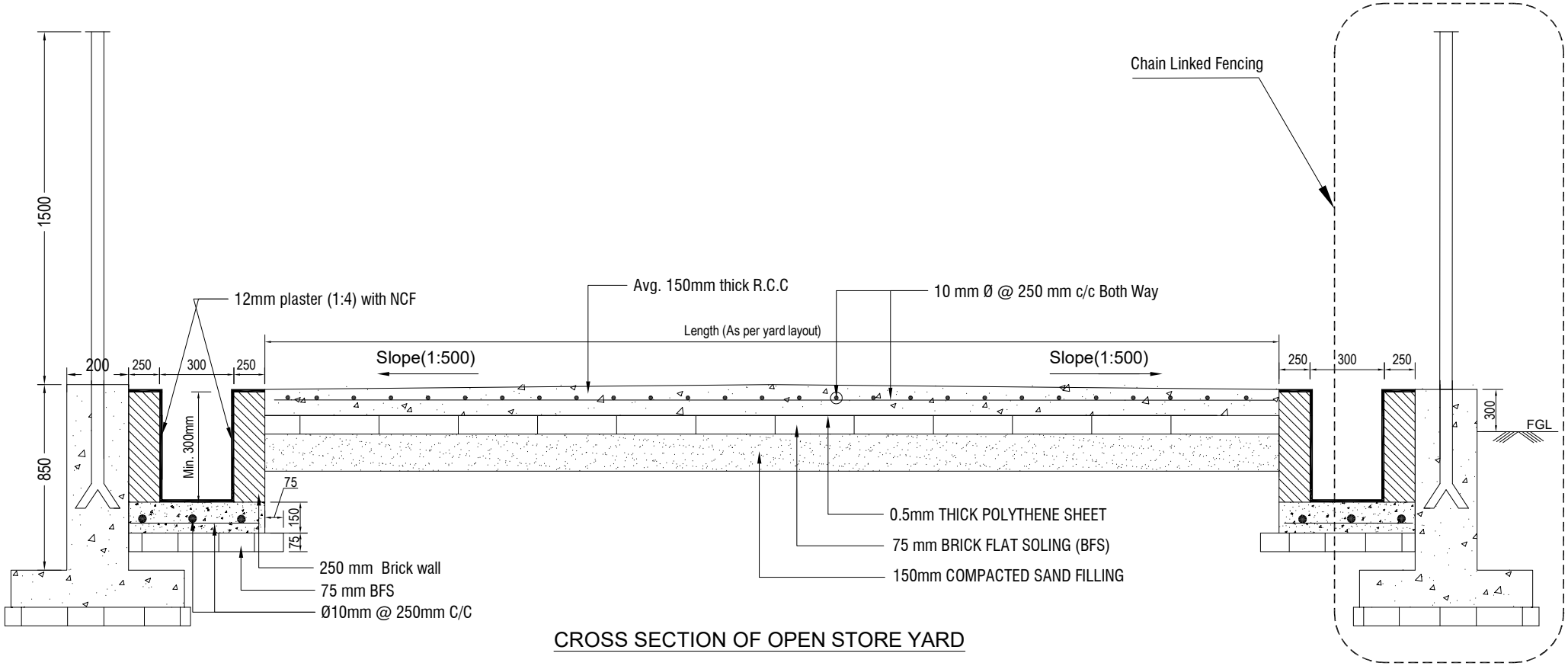


General Notes:

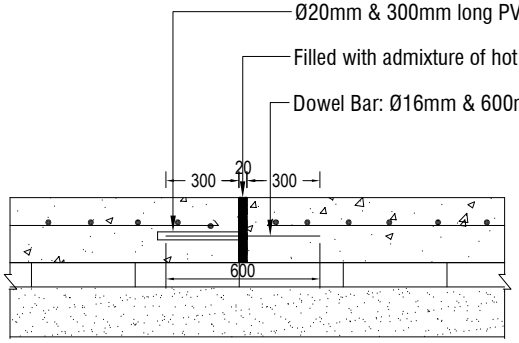
1. Grade beams, columns and footings are Class A Reinforced Cement Concrete(RCC) structures.
2. Grade of rebar shall be deformed bar of Fy 415 MPa minimum.
3. Clear cover both side and bottom: For Grade beam & column= 25mm and for Footing= 40mm.
4. Maximum centre to centre distance of columns = 3500mm.
5. 25mm expansion gap shall be provided at 35000mm interval by double column.
6. All dimension are in mm where not stated.

Tender Drawing

Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Property Line demarkation
Drawing No.	PG/ADB/PL
Drawn:	Checked: Approved:



CROSS SECTION OF OPEN STORE YARD



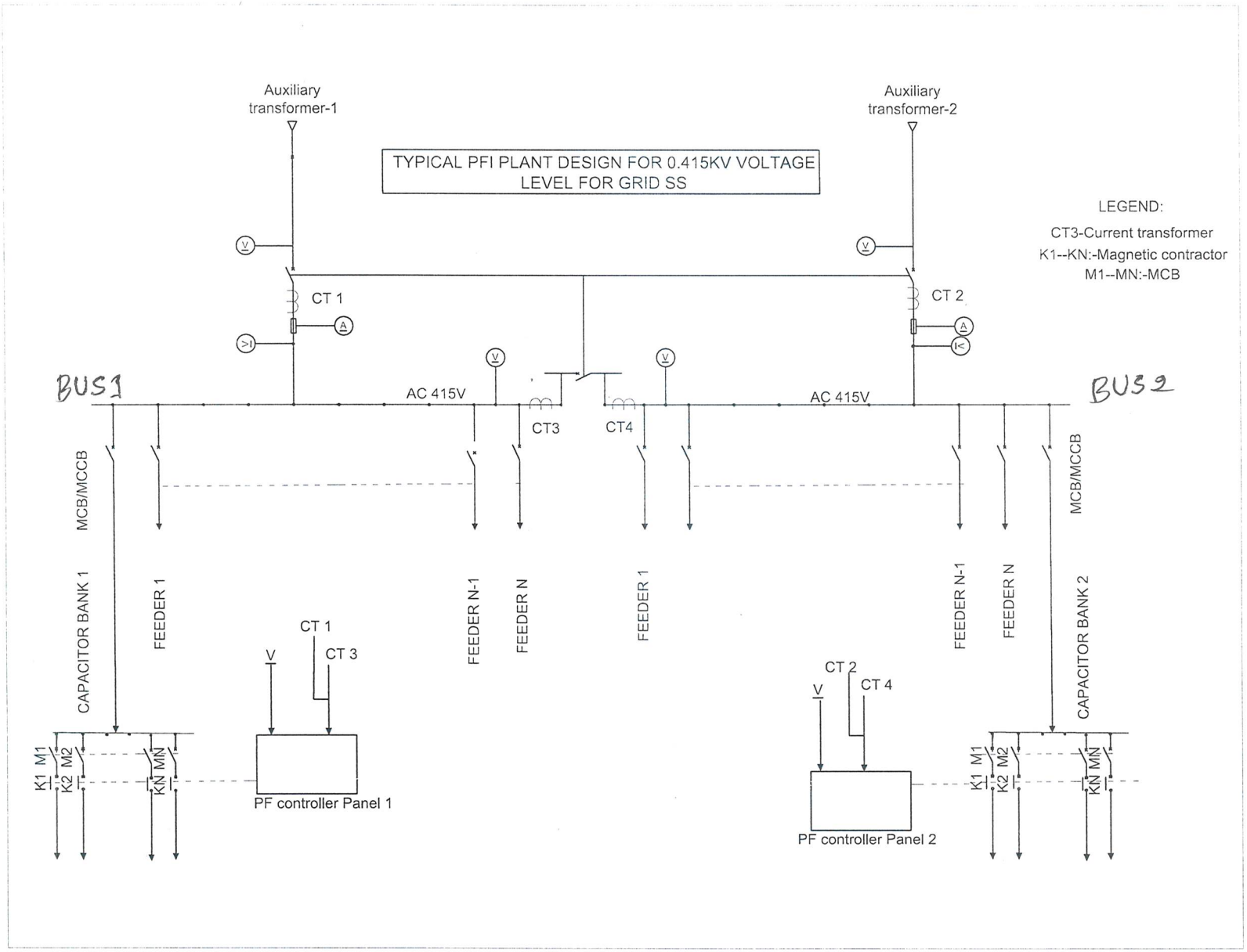
DETAILS OF EXPANSION JOINT

NOTES:

1. EXPANSION JOINTS SHALL BE PROVIDED AT EVERY 6M INTERVAL.

Tender Drawing

Power Grid Bangladesh PLC	
Project:	Design, Supply, Installation, Testing & Commissioning of 132/33 kV AIS Substation at Paikgacha and 132/33 kV AIS Substation at Mathbaria including associated 132KV bay extension at Sathkhira 132/33kV grid substation & at Bhandaria 132/33kV grid substation on turnkey basis (Package-3)
Drawing Title	Typical Section of Open Store Yard
Drawing No.	PG/ADB/OSY
Drawn:	Checked: Approved:

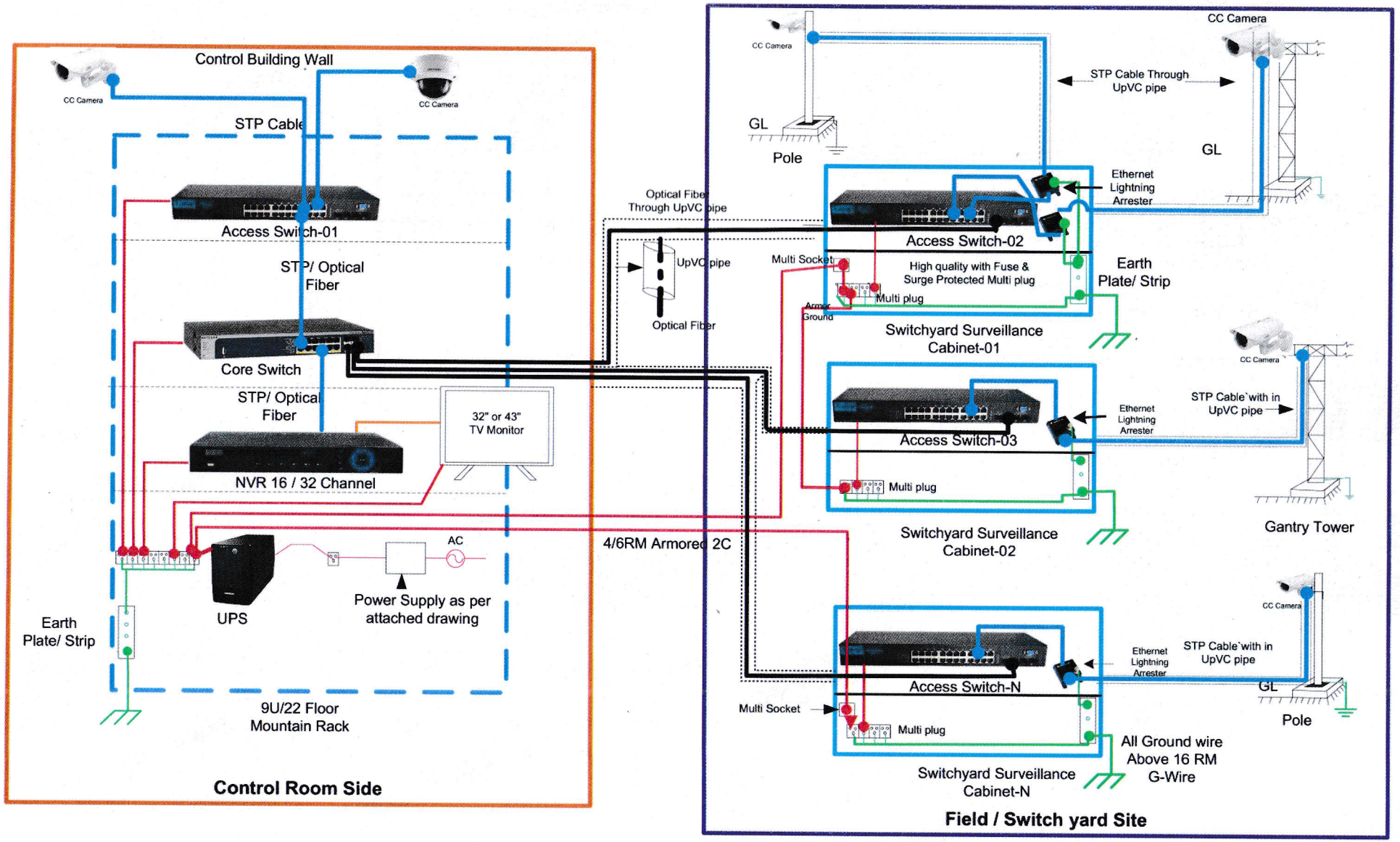


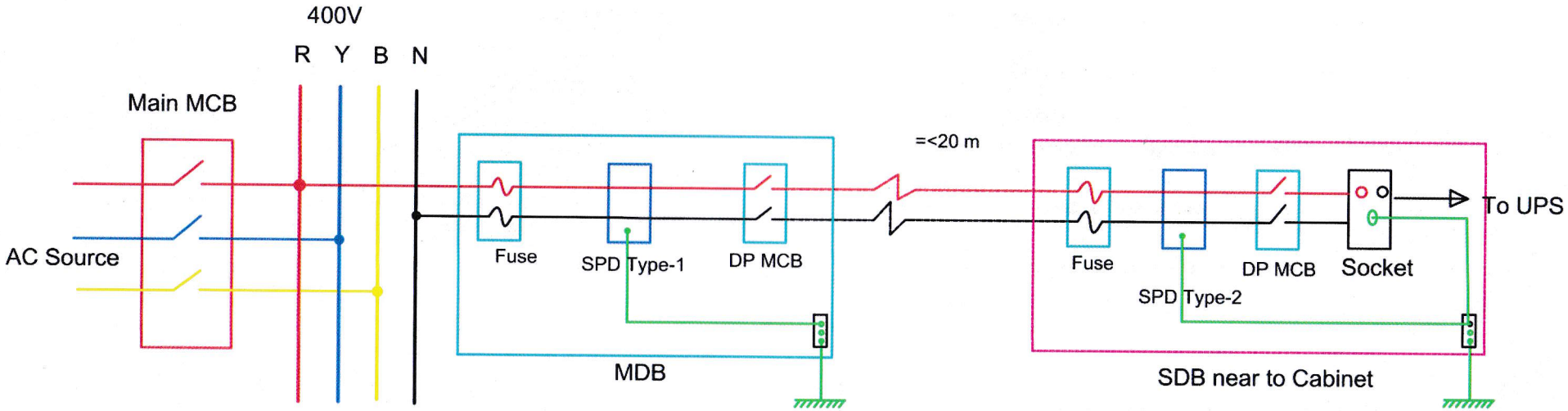
Tender Purpose Only

Drawing no: PG/ADB/PFI

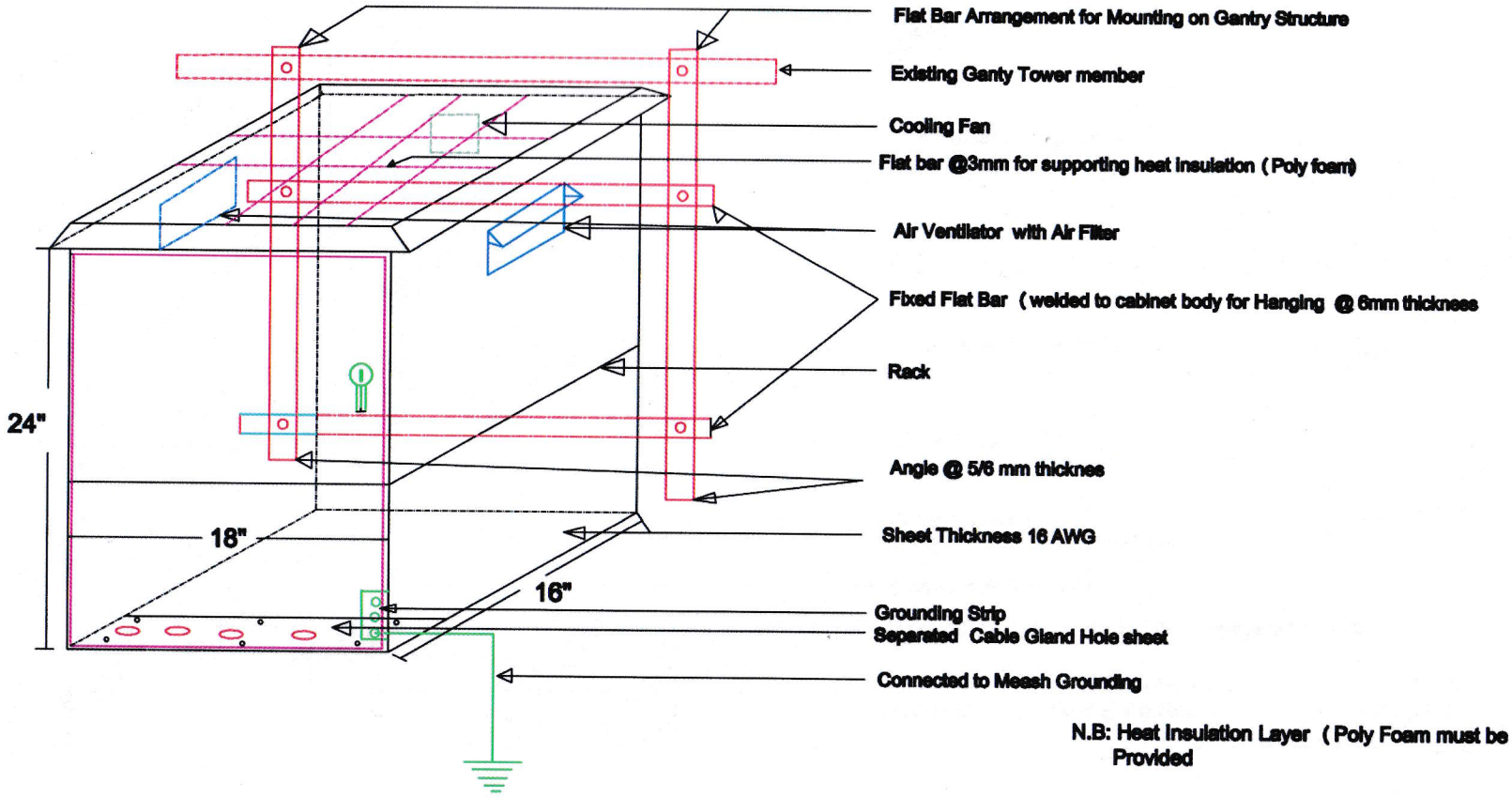
Fig: Layout of IP Camera Surveillance system in a Grid Substation

(For Tender Purpose Only)

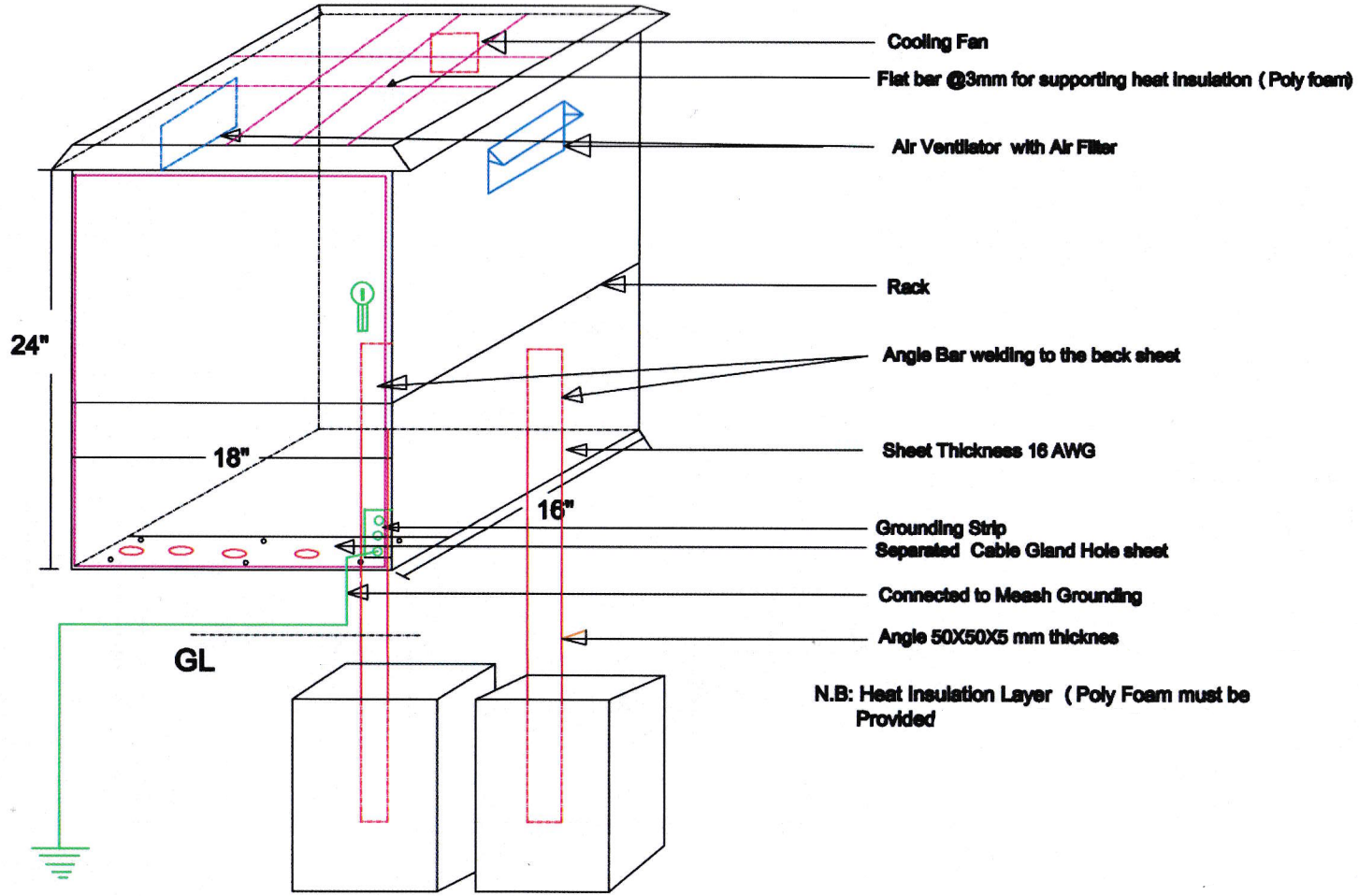




POWER GRID COMPANY OF BANGLADESH (PGCB)	TITLE : LAYOUT OF POWER SOURCE INPUT TO SERVEILLANCE SYSTEM (For Tender Purpose Only)	

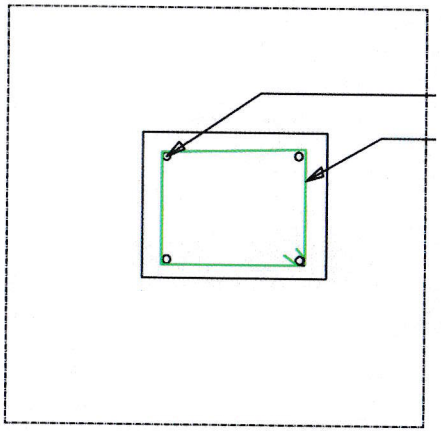


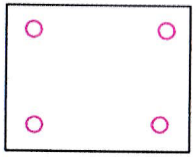
POWER GRID COMPANY OF BANGLADESH (PGCB)	TITLE : **Switchyard Serveillance Cabinet (Hanging type)** (For Tender Purpose Only)	



RCC/CC

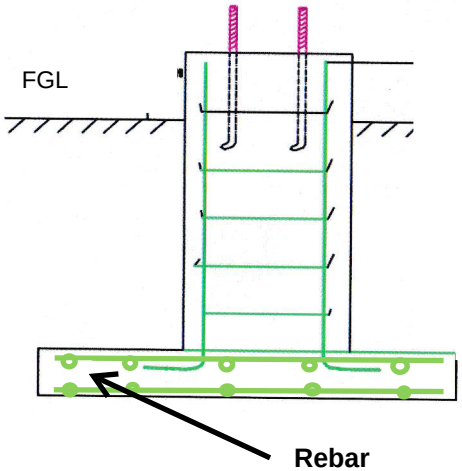
POWER GRID COMPANY OF BANGLADESH (PGCB)	TITLE : Switchyard Serveillance Cabinet (Fixed Type) (For Tender Purpose Only)	

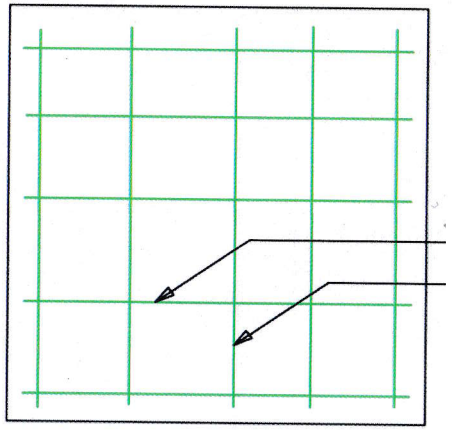




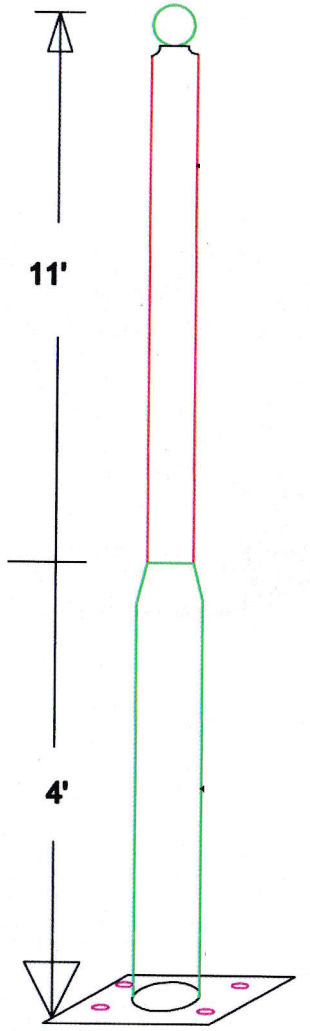
Anchor Bolt Arrangement

Anchor Bolt-





Rebar
(Top & Bottom Layer)



POWER GRID COMPANY OF BANGLADESH (PGCB)

TITLE : Foundation Details of Pole Mounted IP Camera

(For Tender Purpose Only)