POWER GRID COMPANY OF BANGLADESH LIMITED

Bidding Document
for

Design, Supply, Erection, Testing & Commissioning of capacity enhancement and Capacitor Bank installation with associated switchgear in existing grid substation (Package-2, Lot-2)

Volume 2 of 3

Issued on	**:**	**October 25, 2022**
Invitation for Bids No.	**:**	**27.21.0000.101.07.418.22.5935**
OCB No.	**:**	**PGCB/CEEGSTL/SS/Package-2/Lot-2**
Country	**:**	**Bangladesh**

Employer:

Power Grid Company of Bangladesh (PGCB)
PGCB Head office Building, Jahurul Islam city, Avenue-3
Aftabnagar, Badda, Dhaka-1212, Bangladesh

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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	520	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			

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 40 °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	40
Minimum ambient shade temperature	°C	4
Maximum daily average temperature	°C	35
Maximum annual average temperature	°C	25
Maximum wind velocity	km/h	160
Minimum wind velocity for line rating purposes	km/h	3.2
Solar radiation	W/m²	1000
Rainfall	mm/year	2500
Relative humidity, maximum	%	100
Relative humidity, average	%	80
Altitude	m	< 1000
Atmospheric pollution	-	medium
Icing		no ice or snow expected

Description	Unit	Required
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:

1. System Parameters & Design

- 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 following design, drawings & calculations of equipment listed below:

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	Signaling 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	
12	Conductor GA & GTP	
13	Fittings /Clamp-Connector GA & GTP	
14	Substation Automation System (SAS) GA & GTP	
15	Digital Fault & Disturbance Recorder (DFDR) GA & GTP	
16	Power Cable GA & GTP	
17	Control Cable GA & GTP	
18	Fire Fighting System GA & GTP	
19	Oil Treatment Plant GA & GTP	
20	Auxiliary Transformer GA & GTP	
23	Junction Box	

24	Fibre Optic Cable GA & GTP	
25	Test Equipment	
26	Fiber Optics Telecommunication System GA & GTP	
28	Gravel Layout Drawing	
29	Cable Trench Drawing :	
	1	Cable Sealing End
	2	Cable Termination Kits
	3	Cable Gland
	4	Cable Tray & Rack
30	Load Break Switch / DS with Fuse GA & GTP	
31	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, transformer pad design, cable trench, road etc. 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 [Not Applicable]

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:

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

2. Technical Specifications

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) weld able holding primer for 12 months x match protection. After fabrication is complete dress all welds, thoroughly clean to remove corrosion products, oil, grease and dirt and apply one coat (50 microns) of two pack epoxy zinc phosphate primer followed by two coats two pack epoxy micaceous iron oxide (250 microns total).	Thoroughly clean to remove oil, grease and dirt. Paint coats to be touched up where necessary. Then apply one tie coat to finish (30 microns) and one coat alkyd gloss (25 microns)
(b) Steel floors, chequer plates, galleries, stairways, treads, kick stops.	
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.	

Treatment at Factory	Treatment at Site after Completion of Erection
Not Applicable	Thoroughly clean to remove oil, grease and dirt. Then apply: 1st coat alkyd undercoat (30 microns) 2nd coat alkyd gloss (25 microns).
(e) Bitumen dipped items	
Bitumen dipped.	Thoroughly clean to remove oil, grease and dirt.Then apply: 1st coat general purpose aluminium paint (18 microns) 2nd coat alkyd undercoat (30 microns) 3rd coat alkyd gloss (25 microns).
Battery Rooms (open top batteries), Chlorination Plant Rooms, Electrolytic Cell Rooms	
(a) Steelwork	
Blast clean to 2nd quality BS 7079 (SA2.5) profile amplitude 40-75 microns	Thoroughly clean to remove oil, grease and dirt. Priming coat to be touched up where necessary. Then apply: 1st coat chlorinated rubber primer to Manufacturer's instructions 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

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

2.4.3 Schedules for Outdoor Surfaces Finishes

Treatment at Factory	Treatment at Site after Completion of Erection
General	
(a) Structural and supporting steelwork, plant items above ground, tank external surfaces. All not above 95°C (or 65°C for chlorinated rubber finishes).	
Blast-clean to BS 7079 2nd quality (SA2.5) profile amplitude 40-75 microns. Then apply within 4 hours one coat (13 microns) weld able holding primer for 6 months protection or (25 microns) weldable holding primer for 12 months protection. After the protection period, thoroughly clean to remove oil, grease and dirt and apply one coat (50 microns) of two pack epoxy zinc phosphate primer followed by two coats two pack epoxy micaceous iron oxide (250 microns total).	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)
(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

Treatment at Factory	Treatment at Site after Completion of Erection
	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 applied at Manufacturer's works	Clean and touch up as necessary
Water and Oil Storage Tanks-Internal Surfaces	
The epoxy paint formulation shall be to the approval of the Engineer. The finished coating shall be capable of being tested with a high voltages spark tester for	

Treatment at Factory	Treatment at Site after Completion of Erection
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 coat of zinc chromate primer followed by the same number and type of paint coatings specified in Clause.	

Treatment at Factory	**Treatment at Site after Completion of Erection**
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:

2.13.5 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.

2.13.6 Thorough cleaning of all pipework after erection by blowing through to atmosphere to ensure that no extraneous matter is left in the system.

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

2.13.8 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 mm² 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 mm² 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 mm² 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:

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

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.

3. HV Switchgear and Outdoor Equipment

3.1 Scope

3.1.1. These clauses describe the general technical requirements for the new 420 kV, 245 kV, 145kV and 36kV Gas Insulated Switchgear (GIS) & 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 60044, IEC 60869 Instrument transformers
- IEC 60060 High voltage test techniques
- IEC 60071 Insulation coordination
- IEC 60099 Surge arresters

- IEC 60137 Bushings for alternating voltages
- IEC 60265-1 High-voltage switches - Part 1: Switches for rated voltages above 1 kV and less than 52 kV
- IEC 60265-2 High-voltage switches. Part 2: High-voltage switches for rated voltages of 52 kV and above
- IEC 60269 Low voltage fuses
- IEC 60273 Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000V
- IEC 60282 High voltage fuses.
- IEC 60305 Insulators for overhead lines with a nominal voltage above 1000V - Ceramic or glass insulator units for ac systems - Characteristics of insulator units of the cap and pin type.
- IEC 60358 Coupling capacitors and capacitor dividers
- IEC 60364 Electrical installation of buildings
- IEC 60376 Specification of technical grade sulphur hexafluoride (SF6) for use in electrical equipment
- IEC 60383 Insulators for overhead lines with a nominal voltage above 1000V
- IEC 60815 Guide for the selection of insulators in respect of polluted conditions
- IEC 60865-1 Short-circuit currents - Calculation of effects
- IEC 61639 Direct connection between power transformers and gas insulated metal enclosed switchgear for rated voltages of 72.5 kV and above
- IEC 62155 Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than
  1000 V
- IEC 62271-1 HV switchgear and controlgear - part 1: common specifications
- IEC 62271-100 HV switchgear and controlgear - part 100: AC circuit breakers
- IEC 62271-103 Switches for rated voltage above 1 kV and less than 52 kV
- IEC 62271-104 Switches for rated voltage of 52 kV and above
- IEC 62271-102 HV switchgear and controlgear - part 102: AC disconnectors and earthing switches
- IEC 62271-200 HV switchgear and controlgear - part 200: A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV

- IEC 62271-203 HV switchgear and controlgear - part 203: Gas insulated metal-enclosed switchgear for rated voltages 52 kV and above
- IEC 62271-209 HV switchgear and controlgear - part 209: Cable connections for gas insulated metal-enclosed switchgear for rated voltages of 52 kV and above

3.2.2 British Standards

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

3.3 Design Principles

3.3.1 General Requirement

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

3.3.1.2 The GIS assembly shall consist of separate modular compartments e.g. Circuit Breaker compartment, Bus bar compartment filled with SF6 Gas and separated by gas tight partitions so

as to minimize risk to human life, allow ease of maintenance and limit the effects of gas leaks failures & internal arcs etc. These compartments shall be such that maintenance on one feeder may be performed without de-energising the adjacent feeders. These compartments shall be designed to minimize the risk of damage to adjacent sections and protection of personnel in the event of a failure occurring within the compartments. Rupture diaphragms with suitable deflectors shall be provided to prevent uncontrolled bursting pressures developing within the enclosures under worst operating conditions, thus providing controlled pressure relief in the affected compartment.

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

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

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

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

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

3.3.1.7 Service continuity requirement:

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

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

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

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

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

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

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

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

3.3.1.12 The maximum SF6 gas leakage shall not exceed 0.5% (half percent) per year for the whole equipment and for any individual gas compartment separately. The SF6 gas leakage should not exceed 0.5% per year and the leakage rate shall be guaranteed for at least 10 years. In case the leakage under the specified conditions is found to be greater than 0.5% after one year of commissioning, the manufacturer will have to supply free of cost, the total gas requirement for subsequent ten (10) years, based on actual leakage observed during the first year of operation

after commissioning.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

i. **Lateral / Vertical mounting units: These shall be inserted, as required, between sections of busbars, on transformer, shunt reactor and XLPE cable etc. Lateral mounting shall be made possible by a sliding section of enclosure and tubular conductors.**
ii. **Axial compensators: These shall be provided to accommodate changes in length of busbars due to temperature variations.**
iii. **Parallel compensators: These shall be provided to accommodate large linear expansions and angle tolerances.**
iv. **Tolerance compensators: These shall be provided for taking up manufacturing, site assembly and foundation tolerances.**
v. **Vibration compensators: These bellow compensators shall be provided for absorbing vibrations caused by the transformers and shunt reactors when connected directly to SF6 switchgear by oil- SF6 bushings.**

3.3.1.37 The electrical connections across the bellows or compensating units shall be made by means of suitable connectors. For sliding type compensators, markers/pointers shall be provided to

observe expansion or contraction during climatic conditions.

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

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

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

3.3.1.41 Grounding:

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

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

3.1.1.1.3. The enclosure of the GIS may be grounded at several points so that there shall be grounded cage around all the live parts. A minimum of two nos. of grounding connections should be provided for each of circuit breaker, bushing terminals, surge arrestors, earth switches and at each end of the bus bars. The grounding continuity between each enclosure shall be effectively interconnected either internally or externally with Copper/Aluminum bonds of

suitable size to bridge the flanges. Subassembly to subassembly bonding shall be provided to bridge the gap & safe voltage gradients between all intentionally grounded parts of the GIS assembly & between those parts and the main grounding bus of the GIS.

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

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

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

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

3.1.1.1.8. Best patterns for GIS earthing and bonding include the following:

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

3.3.1.42 UHF sensors for PD detection:

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

3.3.1.43 GIS Building & GIB layout: **[Not Applicable]**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.3.1.44 Extension of GIS

3.1.1.1.24. 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.

3.1.1.1.25. 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.

3.1.1.1.26. 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.

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

3.3.1.45 SF6 GAS

3.1.1.1.28. The SF6 gas insulated metal-clad switchgear shall be designed for use with SF6 gas complying with the recommendations of IEC 60376, 60376A & 60376B, at the time of the first charging with gas. All SF6 gas supplied as part of the contract shall comply with the requirements of IEC & should be suitable in all respects for use in the switchgear under all operating conditions. Necessary statutory clearances from concerned authorities for import of the Gas and for storage of the Gas shall be obtained.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.1.1.1.33. 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.

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

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

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

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

3.3.1.50 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.

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

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

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

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

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

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

3.3.2 Availability for Maintenance, Repair, Extensions, Testing

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

3.3.2.2 MRE 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 bus coupler bay shall be possible with one busbar at the time in normal operation and all switchgear bays in normal operation.

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

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

3.3.3 Design Review and Performance

3.3.3.1 Design Review

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

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

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

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

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

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

3.1.12.1.6.1. Dielectric Stress of Solid Insulation like Gas Barrier, support insulator etc.
3.1.12.1.6.2. Dielectric stress of SF6 Gas Volume.
3.1.12.1.6.3. Mechanical strength of enclosure, expansion joints etc.
3.1.12.1.6.4. Criteria for providing expansion joint.
3.1.12.1.6.5. Sealing system
3.1.12.1.6.6. Insulation coordination
3.1.12.1.6.7. Thermal stress and resulting increase in gas pressure during short circuit condition.
3.1.12.1.6.8. Earthing of enclosure w.r.t circulating current.
3.1.12.1.6.9. Seismic design, as per IEC 62271-207
3.1.12.1.6.10. Circuit Breaker.
3.1.12.1.6.11. Isolator and Earth switch.
3.1.12.1.6.12. Voltage transformer.
3.1.12.1.6.13. Current Transformer.
3.1.12.1.6.14. Surge Arrester.
3.1.12.1.6.15. Bushing.
3.1.12.1.6.16. Ducting.
3.1.12.1.6.17. Corrosion protection.
3.1.12.1.6.18. Electrical and physical Interfaces with substation.
3.1.12.1.6.19. Testing capabilities.
3.1.12.1.6.20. Inspection and test plan.
3.1.12.1.6.21. Transport and storage.
3.1.12.1.6.22. Maintainability.
3.1.12.1.6.23. Site Test.

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

3.1.12.1.7.1. Study report of VFTO generated for GIS installation for 400 kV and above.
3.1.12.1.7.2. Calculation for adequacy of UHF sensors to be provided in GIS Installation as per clause no 5.41.
3.1.12.1.7.3. The calculations and documents in support of the average intensity of electromagnetic field on the surface of the enclosure.
3.1.12.1.7.4. Calculations to show that there is no Ferro resonance due to capacitance of GIS for the voltage transformers.
3.1.12.1.7.5. Calculations in support of touch & step voltages in all enclosures and earthing of complete GIS installation.
3.1.12.1.7.6. Measures to mitigate transient enclosure voltage by high frequency currents.

3.1.12.1.7.7. The acceptance criteria and limits of impact (of impact recorder) in all three directions which can be withstood by the equipment during transportation and handling.

3.3.3.2 Performance

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

3.1.12.1.2. 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 by the bidder.

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

3.1.12.1.4. 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.

3.1.12.1.5. 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.

3.1.12.1.6. 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.

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

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

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

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

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

3.3.4 Current Ratings

3.1.12.2. 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.

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

3.3.5 Corona

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

3.3.6 Local, Remote and Supervisory Control

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

3.1.12.5. 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.

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

3.4 GIS Switchgear (GIS)

3.4.1 General

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

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

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

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

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

3.4.1.6 Gas Compartments

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

3.4.1.6.2 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.

3.4.1.6.3 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.

3.4.1.6.4 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.

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

3.4.1.6.6 ***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.***

3.4.1.6.7 ***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.***

3.4.1.6.8 ***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.***

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

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

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

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

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

3.1.1.1. 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 at operation pressure.

3.1.1.2. Enclosures

- The enclosures for the SF6 gas insulated switchgear shall be of Aluminum or Aluminum Alloy.
- 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.
- 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.
- 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.
- 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.
- Each enclosure shall be provided with lifting points to facilitate maintenance or repair works.

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

3.1.1.4. 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.

3.1.1.5. 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.

3.1.1.6. 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 afore-mentioned conditions over the full permitted range of movement. Where such joints may be made or adjusted on Site, full details of alignment procedure, together with any necessary alignment tools or gauges shall be described in the maintenance manual and included in the supply of special tools.

3.1.1.7. 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:

3.1.1.7..1. Fixed platform suitable to reach any equipment,
3.1.1.7..2. Handles of manual operation of CB, D/S, E/S and
3.1.1.7..3. any special tool required for the operation of the switchgear.
3.1.1.7..4. 2 nos. of 63 A sockets shall be provided in the GIS room at suitable location for the gas handling plant and HV test set.

3.1.1.8. 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.

3.1.1.9. 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.

3.1.1.10. 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:

3.1.1.10..1. Not affected by SF6 gas
3.1.1.10..2. Non-hygroscopic, containing no silicon
3.1.1.10..3. Non-aging and non-shrinking
3.1.1.10..4. Retain resilience for long periods under stress

3.1.1.10..5. 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.

3.1.1.11. 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.

3.1.1.12. Earthing System

- 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.

3.1.1.13. Partial Discharge

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

3.1.1.14. Gas Handling Equipment

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

- 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.

- Technical Data:

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

- 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.

3.1.1.15. Nameplates

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

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

- **GIS common nameplates**

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

- **GIS ratings nameplate**

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

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

- **One-line diagram nameplate**

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

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

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

- **Insulating gas system nameplate**

The insulating gas system nameplate shall contain the following information:

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

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

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

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

3.1.1.16. GIS equipment nameplates

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

When common information of the GIS is stated on the ratings nameplate (5.10.1.1), individual equipment nameplates can be simplified.
Equipment nameplates shall provide information according to its relevant standard. As a minimum, the information in the following sections is required:

- **Circuit breakers**

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

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

- **Disconnect switches**

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

- **Grounding switches**

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

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

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

- **Operating mechanisms**

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

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

- **Surge arresters**

The nameplates for surge arresters shall contain the information described in applicable surge arrester standards. As a minimum, they shall contain the following information:
a) Manufacturer's name, type and designation, and serial number
b) Year of manufacture
c) Maximum continuous operating voltage (MCOV)
d) Duty cycle voltage rating
e) Nominal discharge current
f) Identification of assembled position (vertical or horizontal)
g) Nominal gas pressure (at 20 °C)

- **Current transformers**

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

a) Manufacturer's name, type and designation , and serial number
b) Year of manufacture
c) Rated frequency
d) Accuracy class and the ratio for which the accuracy is expressed
e) Rated maximum voltage (if applicable)
f) Rated lightning impulse withstand voltage (if applicable)
g) Rated switching impulse withstand voltage (if applicable)
h) Rated primary current
i) Rated secondary current
j) Rated continuous thermal current factor and the associated ambient temperature
k) Rated thermal short-time current
l) Nominal gas pressure (at 20 °C)
m) A connection diagram showing:

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

- **Voltage transformers**

The nameplates for voltage transformers shall contain the information described in IEEE Std C57.13 and IEC 60044-2. As a minimum, they shall contain the following information
a) Manufacturer's name, type and designation , and serial number
b) Year of manufacture
c) Rated power frequency
d) Rated primary voltage
e) Rated lightning impulse withstand voltage
f) Rated switching impulse withstand voltage (if applicable)
g) Rated power-frequency withstand voltage
h) Ratio or ratios
i) Thermal burden rating or ratings at ambient temperature or temperatures, in voltamperes (VA)
j) Accuracy rating at thermal burden rating
k) Nominal gas pressure (at 20 °C)
l) A connection diagram

- **High-voltage cable terminations**

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

a) Manufacturer's name, type and designation, and serial number
b) Year of manufacture
c) Rated maximum voltage (Ur)
d) Rated lightning impulse withstand voltage (Up)
e) Rated switching impulse withstand voltage (if applicable) (Us)
f) Rated power-frequency withstand voltage (Ud)

g) Rated maximum and minimum ambient temperature
h) Rated continuous current (Ir) at maximum ambient temperature
i) Rated short-time withstand current (Ik)
j) Rated duration of short-circuit (tk)
k) Rated peak withstand current (Ip)
l) Nominal gas pressure (at 20 °C)
m) Maximum allowable force applied in any direction at the external terminal

- **Bushings**

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

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

~~i. Manufacturer name~~
~~ii. Country of origin~~
~~iii. Applicable standard~~
~~iv. Type of circuit breaker~~
~~v. Type of operating mechanism~~
~~vi. Rated voltage~~
~~vii. Rated lighting impulse withstand voltage~~
~~viii. Rated switching impulse withstand voltage~~
~~ix. Rated frequency~~
~~x. Rated current~~
~~xi. Rated duration of short circuit~~
~~xii. Rated short time withstand current~~
~~xiii. Rated short time withstand current of a no-load OHL~~

~~xiv. Average making time~~
~~xv. Rated operating sequence~~
~~xvi. Class of CB (Electrical,Mechanical,Capacitive switching)~~
~~xvii. Rated gas pressure on 20°C~~
~~xviii.Mass of a SF6 gases~~
~~xix. Weight of a circuit breaker~~
~~xx. Year of production~~
~~xxi. Factory number~~
~~xxii. Factory number (numbers) of operating mechanisms~~

3.4.2 Circuit Breakers

3.4.2.1 The requirements of IEC 62271-100 in respect of type tests, routine tests, service, operation and the making and breaking of fault currents shall apply to the specified circuit breakers.

3.4.2.2 Circuit breakers shall be complete with spring or hydraulic or spring hydraulic operated mechanisms.

3.4.2.3 Attention is drawn to the transient recovery voltage (TRV) requirements of the IEC Standards. where not specifically stated in the test certificates submitted with the Tender, the Tenderer shall certify that the TRV to which the circuit breaker was subjected during the short circuit tests was the most severe condition that could be imposed by the available test plant for a first phase-to-clear factor of 1.3. Also, GIS(CB) manufacturer shall submit the EMTP study report for TRV.

3.4.2.4 Any device incorporated in a circuit breaker to limit or control the rate-of-rise of restriking voltage across the circuit breaker contacts shall likewise be to PGCB's approval and full descriptions of any such device shall be given.

3.4.2.5 Evidence shall be submitted with the tender to verify that all circuit breakers when interrupting faults on the secondary side of a transformer the transient recovery voltage conditions, that could arise will not exceed the tested interrupting capabilities of the circuit breaker proposed.

3.4.2.6 In addition to the requirements of IEC 62271-100 for interrupting terminal faults all circuit breakers shall be capable of coping with the interrupting duties produced by the switching of low inductive currents associated with reactors and transformer magnetizing currents and by the switching of capacitive cur-rents associated with overhead lines, cables and capacitors banks as may be applicable. Circuit breakers for these duties shall be of the restrike-free type only.

3.4.2.7 All circuit breakers shall also be capable of interrupting currents associated with short-line faults

and the out-of-phase switching conditions that may occur in service.

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

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

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

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

3.4.2.12 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.

3.4.2.13 Suitable facilities shall be included for gas sampling and for draining and replenishing the gas volume for maintenance. Absorption of moisture and the decomposition products of arcing or discharge in the gas shall be achieved by integral filters.

3.4.2.14 Sufficient nos. of N/O and N/C auxiliary electrical contacts shall be provided for using interlocking circuits and for states indication at the remote and supervisory control centres and any other requirement. At least 10% spare N/O and N/C contacts shall be wired up to LCC for future use by PGCB.

3.4.2.15 Operating Mechanisms

3.4.2.15.1 The circuit breaker operating mechanism shall be power operated and of the type specified. Operation will normally be from a remote or supervisory position but facilities shall be provided for operation locally by electrical release and by direct manual release from stored energy devices when the circuit breaker is isolated for maintenance. It shall be possible to padlock each local control function in the open position. Operation counters shall be fitted to all circuit breaker mechanisms.

3.4.2.15.2 *The mechanism and its control scheme shall be such that, in the event of an electrical tripping pulse being applied to the circuit breaker during the closing stroke, or of the mechanism falling to latch in the closed position, the circuit breaker shall open fully and in such a manner as to be capable of interrupting its rated breaking current.*

3.4.2.15.3 *The mechanism and its control scheme shall be such that the mechanism shall not make repeated attempts to close the circuit breaker when the control switch is held in the CLOSE position in the event of failure to latch on the first closing attempt or in the event of a trip signal being given to the circuit breaker i.e. anti-pumping facility to be provided.*

3.4.2.15.4 *The electrical closing and tripping devices, including direct acting solenoid coils and solenoid operated valves, shall be capable of operation over the ambient temperature range when the voltage at their terminals is any value within the voltage range stipulated in IEC 62271-100 and in addition over the range of all operating conditions of the batteries and chargers supplied under this Contract.*

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

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

3.4.2.15.7 *Power closing mechanisms shall be recharged automatically for further operations as soon as the circuit breaker has completed the closing operation and the design of the closing mechanisms shall be such that the circuit breaker cannot be operated inadvertently due to external shock forces resulting from short-circuits, circuit breaker operation, or any other cause.*

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

3.4.2.15.9 *Means shall be provided for the CB manual (non-electrical) tripping of the circuit breaker, preferably by a shrouded push button and facilities shall be provided for locking off this means of tripping. It shall not be possible to lock mechanically the trip mechanism so as to render the electrical tripping inoperative. Facilities shall be provided to permit manual slow closing and slow opening of the circuit breaker for maintenance purposes. It shall not be possible to "slow close" or "slow open" a circuit breaker when connected in the normal service condition.*

3.4.2.15.10 *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 O-C-O or 2 C-O 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.

3.4.2.15.11 Hydraulically Operated Mechanisms

- Hydraulically operated mechanism shall comprise of operating unit with power cylinder, control valves, high and low pressure reservoir, motor etc.
- The hydraulic oil used shall be fully compatible for the temperature range to be encountered during operation.
- The oil pressure switch controlling the oil pump and pressure in the high pressure reservoir shall have adequate no. of spare contacts, for continuous monitoring of low pressure, high pressure etc. at switchyard control room.
- The mechanism shall be suitable for at-least two close open operations after failure of AC supply to the motor starting at pressure equal to the lowest pressure of auto reclose duty plus pressure drop for one close open operation.

- The mechanism shall be capable of operating the circuit breaker correctly and performing the duty cycle specified under all conditions with the pressure of hydraulic operated fluid in the operating mechanism at the lowest permissible pressure before make up.

- Trip lockout shall be provided to prevent operations of the circuit breaker below the minimum specified hydraulic pressure. Alarm contacts for loss of Nitrogen shall also be provided.

- All hydraulic joints shall have no oil leakage under the site conditions and joints shall be tested at factory against oil leakage.

3.4.2.16 Controlled Switching Device (CSD)

3.4.2.16.1 ***400kV & 230kV Circuit Breaker shall be equipped with controlled switching device with consequent optimization of switching behavior, when used in:***

i) **Switching of transformer (from 400kV and 230kV side circuit breakers only)**
ii) **Switching of shunt reactor**

3.4.2.16.2 ***The CSD shall be provided in 400kV/230kV Circuit breakers for controlling transformers and reactors (i.e. for breakers of switchable line reactor and in Main& Tie circuit breakers of Transformers, Transmission lines with non-switchable line reactors and Bus reactors). The requirement of CSD shall be explicitly specified in price schedule.***

3.4.2.16.3 ***Technical Requirement for Controlled switching device:***

i) **The CSD shall be designed to operate correctly and satisfactorily with the excursion of auxiliary A/C & DC voltages and frequency.**
ii) **The CSD shall meet the requirements of IEC-61000-4 16 class IV regarding HF disturbance test and fast transient test shall be as per IEC-61000 – 4-4 level IV and insulation test as per 60255 – 5.**
iii) **The CSD shall have functions for switching ON & OFF the circuit breakers.**
iv) **The CSD shall get command to operate the breakers manually or through auto reclose relay at random. The controller shall be able to analyze the current and voltage waves available through the signals from secondaries of CTs & VTs for the purpose of calculation of optimum moment of the switching the circuit breaker and issue command to circuit breaker to operate.**

v) **The CSD shall have an adaptive control feature to consider the next operating time of the breaker in calculation of optimum time of issuing the switching command. In calculation of net operating time of the breaker the controller must consider all factors that may affect the operating time of the breaker such as, but not limited to, ambient temperature, control voltage variation, SF6 gas density variations etc. Schematic drawing for this purpose shall be provided by the contractor. The accuracy of the operating time estimation by the controller shall be better than + 0.5 ms.**

vi) **The CSD shall have communication port to facilitate online communication of the control switching device with SCADA directly on 61850 or through gateway which shall be under present scope.**

vii) **The CSD shall be PC compatible for the setting of various parameters and down loading of the settings and measured values date time of switching etc. Window based software for this purpose shall be supplied by the contractor to be used on the owner's PC.**

viii) **The CSD shall be suitable for current input of 1 amp from the secondary of the CTs. and 110 V (Ph to Ph) from the VTs. The controller shall withstand transient and dynamic state values of the current from the secondary of the CTs and VTs.**

ix) **The CSD shall have time setting resolution of 0.1 ms or better.**

x) **The CSD shall have sufficient number of output/input potential free contacts for connecting the monitoring equipment and annunciation system available in the control room. Necessary details shall be worked out during engineering the scheme.**

xi) **The CSD shall also record and monitor the switching operations and make adjustments to the switching instants to optimize the switching behavior as necessary. It shall provide self-diagnostic facilities, signaling of alarms and enable downloading of data captured from the switching events.**

xii) **The provision for bypassing the Controlled switching device shall be provided through BCU and SCADA both so that whenever, the CSD is not healthy due to any reason (including auxiliary supply failure), uncontrolled trip/close command can be extended to the circuit Breaker. Alternatively, in case of any nonoperation of the CSD after receiving a close/trip command after a pre-determined time delay, the CSD should automatically be bypassed so as to ensure that the trip and close commands are extended to the Trip/Close coils through subsequent command.**

xiii) **The CSD shall be provided with a communication port to facilitate online communication of the CSD with Substation automation system directly on IEC 61850 protocols. If the CSD does not meet the protocols of IEC 61850, suitable gateway shall be provided to enable the communication of CSD as per IEC 61850.**

3.4.3 Disconnectors and Earthing Switches

3.4.3.1 Disconnectors including the Earthing Switches shall be supplied as shown on the con-tract drawings and as indicated in the Schedules. Each DC and E/S shall be labeled with SCADA numbers as per SLD by providing permanent engraved stickers.

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

3.4.3.3 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.

3.4.3.4 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.

3.4.3.5 Power operated drives shall be provided which shall be suitable for local, remote and supervisory control (supervisory control of earth switches is not required) and should be fitted with a removable emergency manual operation facility. It should be possible to lock-off the manual and local facility and pad-lock the mechanism in the open and closed positions with the motor automatically disengaged (isolator and earth switch).

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

3.4.3.7 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.

3.4.3.8 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.

3.4.3.9 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.

3.4.3.10 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.

3.4.3.11 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.

3.4.4 High Speed Earthing Switches

3.4.4.1 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.

3.4.4.2 They shall be located at all feeder terminal points and busbars or other location where there is no certainty that the point to be earthed is not energized.

3.4.4.3 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.

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

i. The closing spring shall remain in discharged position when the switch contacts are in open position. The closing spring shall be charged only when the closing command is given either electrically or manually and the contacts shall close automatically after the spring is fully charged.
ii. If earthing switch is provided with the design in which closing spring is charged and latched in the open & close position of the switch, then mechanical locking arrangement shall be provided to avoid un-intentional closing of the switch either electrically or manually.

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

3.4.4.6 Facilities integral with the earthing switch for primary current injection or low voltage checks shall be insulated from earth and incorporate a dis-connectable earth strap.

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

3.4.5 Transformers

3.4.5.1 Current transformers shall be supplied suitable for the duty specified and comply with the requirements of IEC 60044-1 and BS 3938 as appropriate.

3.4.5.2 Current transformers, where specified, shall be SF6 gas insulated, shall be compatible with the switch-gear and shall preferably not contain any hygroscopic insulating material which could affect the SF6 gas in either the current transformer or in the associated switchgear chamber.

3.4.5.3 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.

3.4.5.4 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.

3.4.5.5 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.

3.4.5.6 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.

3.4.5.7 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.

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

3.4.5.9 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.

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

i. For overcurrent protection, they shall not saturate, change ratio or produce harmonic voltages in the secondary winding which will affect the accuracy of the relay with primary currents up to 20 times rates full load current.
ii. For earth fault protection and balanced forms of protection, when connected as in-service, they shall not produce spill currents in excess of half the minimum

operating current of the relay but provide stable equipment with primary currents up to 20 times rated full load.

iii. (c) Each protection scheme shall be provided with appropriate current transformers for optimum operation of the scheme. Provision should be made to carry primary injection test of bushing CTs for 100% rating.

3.4.5.11 Terminal boards shall have shorting/disconnecting links to allow testing with the circuit in service and on load. It shall be possible to carry out primary injection testing of the CTs with 100% rating when the switchgear is fully assembled, or retesting of the CTs during the service life of the switchgear without interruption of supply to adjacent circuits or any part of busbar. The testing facilities provide in the design for site testing shall be stated by the Tenderer.

3.4.5.12 The contractor should clearly mention the continuous rating of earth switches and their associated cables for the purpose of primary injection tests. The secondary windings of each set of current transformers shall be capable of being open circuited for one minute with the primary winding carrying the rated current. The secondary wiring of all CT's shall be brought to a common terminal block located within the local control cubicle.

3.4.5.13 The polarity of the primary and secondary windings of each transformer shall be clearly indicated at the respective terminals and in addition labels shall be fitted in a readily accessible position to indicate the ratio, class and duty of each transformer winding.

3.4.5.14 Neutral CT for REF protection and any other CTs which require to be matched with switchgear CTs will be manufactured by switchgear manufacturers and hand over to transformer manufacturer for installation. Suitable mounting arrangement is to be made by the transformer manufacturer.

3.4.6 Voltage Transformers

3.4.6.1 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.

3.4.6.2 Voltage transformers shall comply with the common sections of this Specification, comply with the requirements of IEC 60044-2 and shall be provided with requirement mentioned in Appendix.

3.4.6.3 The rated secondary voltage per phase shall be $110/\sqrt{3}$ volts in the case of star connected windings and the rated voltage factor shall be 1.2 continuous; 1.5 for 30 seconds.

3.4.6.4 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.

3.4.6.5 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.

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

3.4.6.7 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.

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

3.4.6.9 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.

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

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

3.4.6.11 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.

3.4.6.12 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.

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

3.4.6.14 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.

3.4.6.15 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.

3.4.6.16 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.

3.4.7 Bushing and Feeder and Transformer Connections

3.4.7.1 Where stated in the Schedule of Requirements, GIS are to be provided with bushing insulators to connect facilities as drawings.

3.4.7.2 All bushings shall comply with IEC 60137, 61639, 62271 & 60815.

3.4.7.3 The current rating of each bushing shall be equal or greater than the current it will carry at the maximum rating.

3.4.7.4 Approved suppliers of bushings are *ABB (Sweden,* Switzerland*)*, *Trench (France/USA), HSP (Germany), (and/ as specified in Appendix of Requirement).*

3.4.7.5 Bushing outline drawings with stud sizes identified shall be submitted with GIS approval drawings. 4-hole IEC bushing terminal connectors shall be supplied for each bushing. Connectors shall be tinned copper-bronze and finished on both sides. Cut sheets shall be provided showing materials, dimensions and current rating of terminal connectors. Type test of the Busing for Short circuit force withstand capability shall be submitted with the Bid and the same shall be submitted during execution for approval.

3.4.7.6 On all condenser bushings, a tapping shall be brought out to a separate terminal for testing purposes on site.

3.4.7.7 Special precautions shall be taken to exclude moisture from paper insulation during manufacture, assembly, transport and erection.

3.4.7.8 The minimum creepage distance for outdoor bushings shall not be less than 25mm per kV of rated voltage between phases.

3.4.7.9 Bushings shall be of sealed construction suitable for service under the very humid conditions at Site and, additionally, for the very rapid cooling of equipment exposed to direct sunlight when this is followed by sudden heavy rainstorms.

3.4.7.10 Typical sections of bushing insulators showing the internal construction, method of securing the top cap and methods of sealing shall be included in the Bid.

3.4.7.11 Connections shall be suitable for the specified continuous and short circuit current ratings. Where necessary, expansion joints shall be provided to accommodate differential movements between the switch-gear phase terminals and conductors.

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

3.4.7.13 To reduce the effect of solar gain all SF6 or other types of insulated bus ducts exposed to direct sunlight shall be covered with metallic sun shielding, for part of outdoor installation.

3.4.8 Surge Arresters (Gas type)

3.4.8.1 Surge arresters in GIS shall be of the type metal oxide arresters without gaps complete with surge counters and shall fulfill requirements as per IEC 60099-4, IEC 60099-5 and PGCB specification.

3.4.8.2 ~~The Contractor shall demonstrate and verify by EMTP that the surge arresters will adequately protect the switchgear arrangement proposed~~.

3.4.8.3 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.

3.4.8.4 SF6 gas pressure monitors for the surge arresters shall comply with clause 3.3.1 and 3.3.7.

3.4.9 Bus bar (GIB)

3.4.9.1 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).

3.4.9.2 The SF6 enclosures shall be constructed from the same materials as the bus bar enclosures provided with the main GIS switchgear. The materials used shall prevent overheating at the specified rated cur-rents. To reduce the effect of solar gain, all SF6 insulated bus duct exposed to direct sunlight may be covered with metallic sun shielding as per the Owner's request. The bus duct shall be complete with all components, enclosures, gas seals, gas monitors, gas compartments, gas filters, gas barrier and sup-porting insulators. The design of the bus ducts shall make full allowance of the thermal expansion associated with the switchgear, bushings and any other equipment between which the bus ducts are connected. The Contractor shall fully co-ordinate the requirements of the SF6 insulated bus duct connections between the GIS switchgear feeders and the overhead line landing gantries, especially with regards to the differential settlement of the concrete floors of the switchgear room and the bus duct supporting structures

3.4.9.3 The bus ducts and their supports shall be designed and tested for the specified rated normal and short time currents and for the maximum system voltage and specified test voltages. The ducts and their supports shall include any nonmagnetic material or insulation necessary to prevent overheating or the induction of over-voltages in the secondary circuits.

3.4.9.4 The GIL shall be supplied & assembled by the manufacturer of GIS. GIL length shall be counted from the end of the last GIS equipment toward line/transformer feeder entry to the bottom of the bushing at the GIL terminal for each phase of each circuit.

3.4.10 Local Control Cubicle

3.4.10.1 Each circuit breaker bay shall be provided with a local control cubicle containing local control switches and a mimic diagram for the operation and semaphore for status indication of the circuit breaker and all associated isolators and earth switches together with selector switches to prevent local and remote and supervisory controls being in operation simultaneously. Closing of the circuit breaker from the local control unit shall only be available when the breaker is isolated for maintenance purposes. Local control cubicle shall be suitable for installation in a separate place or mounted with the GIS bay. Status indications in the local control cubicle shall be semaphore type or LED type.

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

3.4.10.3 If a disconnector or earth switch is not the fully open or closed position a "Control Circuit Faulty" alarm shall be initiated, and electrical operation shall be blocked. Local manual release facilities

shall be pro-vided for closing and tripping the circuit-breaker. The operation of both releases shall be subject to lockout if insufficient stored energy is available. Local manual releases shall be provided with locking off facilities.

3.4.10.4 Sufficient electrical terminals shall be provided for the termination and interconnection of all cabling associated with remote and supervisory control, alarms, indications, protection and local ring main sup-plies. Where control cabling between the local control cubicle and the switchgear are connected by plug and socket boxes, the plugs and sockets shall not be interchangeable.

3.4.10.5 Hydraulic and SF6 auxiliary equipment necessary for the correct functioning of the circuit breakers, disconnectors and earth switches shall be located in a separate cubicle compartment.

3.4.10.6 Operating mechanisms, auxiliary switches and associated relays, control switches, control cable terminations, and other ancillary equipment shall be accommodated in sheet steel vermin proof cubicles. Local control cubicles shall be provided to be free standing or mounted on the GIS with front access, and shall be equipped with anti-condensation heaters. A suitable humidity stat and thermostat shall be included in the heater circuit. The electrical apparatus so protected shall be designed so that the maxi-mum permitted rise in temperature is not exceeded if the heaters are energized while the apparatus is in operation.

3.4.10.7 Cubicles shall be of rigid construction, preferably folded but alternatively formed on a framework of standard rolled steel sections and shall include any supporting steelwork necessary for mounting on the circuit breaker or on concrete foundations. Access to all compartments shall be provided by either removable panels or doors. All fastenings shall be integral with the panel or door and provision made for locking. Doors and panels shall be fitted with weatherproof sealing material suitable for the climatic conditions specified. Cubicles shall be well ventilated through vermin-proof louvers having anti insect screen.

3.4.10.8 The interior of each cubicle shall be finished with a semi-gloss white surface. An interior lamp suitable for the local LVAC supply, controlled by a door operating switch, shall be fitted at the top of each section.

3.4.10.9 The arrangement of equipment within cubicles shall be such that access for maintenance or removal of any item shall be possible with the minimum disturbance of associated apparatus.

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

3.4.11 Anti-condensation Heaters

3.4.11.1 Anti-condensation heaters of an approved type shall be provided inside each cubicle. They shall

be shrouded and located so as not to cause injury to personnel or damage to equipment. The heaters shall have individual humidity stat and thermostatic control and shall be arranged to cut off when the cubicle internal temperature exceeds between 30-35°C and humidity less than 30%. A master heater circuit switch shall be provided on the switchboard or panel with an indicating lamp to show whether the supply is on or off. The location of the heater circuit switch and indicating lamp shall be either on a common panel or in such a location that it does not require moving when extensions are provided. The heaters shall operate from the specified single phase a.c. supply. Isolation facilities for a.c. supply shall be provided in each panel.

3.4.12 Auxiliary Switches and Contactors

3.4.12.1 Auxiliary switches positively driven in both directions shall be provided on all circuit breakers and isolators for local and remote indication, control and interlocking and repeat relays where necessary. Busbar protection has direct driven auxiliary contacts for CT circuits. With each circuit breaker, isolating device, and earthing device, there shall be supplied all necessary auxiliary switches, contactors and mechanisms for indication, protection, metering, control, interlocking, supervisory and other services. All such auxiliary switches shall be enclosed in dust free housing. Not less than eight (4 NO + 4 NC) spare auxiliary switch ways shall be provided with each circuit breaker and not less than six (3 NO + 3 NC) on all other devices. All auxiliary switches shall be wired up to a terminal board in the local control cubicle of the switchgear whether they are in use or not in the first instance and shall be arranged in the same sequence on appropriate busbar coupling and sectioning equipment that sections or sets of busbars cannot be paralleled by means of the busbar isolating devices unless a parallel circuit is already closed through the circuit breakers of the all equipment.

3.4.12.2 Switches shall be provided to interrupt the supply of current to the tripping mechanisms of the circuit-breakers directly the operation of the latter has been completed. All such switches and mechanisms shall be mounted in approved accessible positions clear of the operating mechanism and shall be adequately protected. The contacts of all auxiliary switches shall be strong and shall have a positive wiping action when closing.

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

3.4.12.4 Auxiliary contactors shall be provided only where the circuit requirement cannot be met by the auxiliary switch arrangements and multiple contactors and relays will not be accepted in lieu of auxiliary switches except as specifically approved by PGCB.

3.4.13 Interlocking

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

i. To safeguard maintenance personnel who may be working on one section of the equipment with other sections live.
ii. To prevent incorrect switching sequences which could lead to a hazardous situation to plant, equipment and personnel.
iii. To be designed for the final substation arrangement, avoiding the need for the future modifications

3.4.13.2 The interlocking scheme shall be electrical for all operational interlocks but shall be effective when the equipment is being controlled locally, under emergency hand or from a supervisory position.

3.4.13.3 All electrical interlocks shall so function as to interruption the operating supply and a system of interlocks shall be provided which cover the emergency hand operation of apparatus which is normally power operated. Failure of supply or connections to any electrical interlock shall not produce or permit faulty operation. Visible indication shall be provided to show whether the mechanism is locked or free. Means, normally padlocked, shall be provided whereby the bolt can be operated in the emergency of a failure of interlock supplies.

3.4.13.4 Where mechanical key interlocks are employed, they shall be effective at the point where hand power is applied so that stresses cannot be transferred to parts remote from that point.

3.4.13.5 Where key interlocking is employed, tripping of the circuit breaker shall not occur if any attempt is made to remove the trapped key from the mechanism. Any local emergency tripping device shall be kept separate and distinct from the key interlocking.

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

3.4.13.7 Disconnecting switches shall be so interlocked that they cannot be operated unless the associated circuit breaker is open except that where double busbar arrangements are specified, on-load transfer of feeder circuits from one busbar to another shall be made possible by interlocks which ensure that the associated bus coupler and its isolators are closed.

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

3.4.13.9 All isolating devices shall be interlocked with associated circuit-breakers and isolators in the same station so that it shall not be possible to make or break current on an isolating device unless a parallel circuit in that station is already closed.

3.4.13.10 In double busbar stations where provision for on-load changeover of busbars is specified, the busbar isolating devices shall be so interlocked with the appropriate busbar coupling and sectioning equipment. In all other circumstances, the busbar isolating devices of equipment other than busbar sectioning and coupling equipment shall be so interlocked that their respective circuit breakers can only be coupled to one set of busbars at a time. It shall not be possible to parallel sections of busbars except through the circuit breakers of the busbar coupling and sectioning equipment.

3.4.13.11 For each primary circuit, an interlock bypass switch shall be provided, mounted on the local control cubicle, for use during commissioning of the Switchgear. The switch shall be key operated (common key for each circuit) spring return to normal and provided with sufficient direct drive contacts to enable operation' of the- circuit breaker, isolators and earth switches independent of the electrical interlocking circuitry. By-passing of interlocks shall only lye possible in the local (Maintenance) position.

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

3.4.14 Locking Facilities

3.4.14.1 Locks and locking facilities shall be provided on each item of substation equipment as detailed below and shall be additional to the mechanical interlocking devices specified in the above clause.

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

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

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

3.4.15 Special Equipment and Tools

3.4.15.1 The Contractor is obliged to deliver all equipment and tools required for installation, dismantling, testing and maintenance of equipment. Special equipment and tools shall be of the highest quality and suitable for field work.

i. A handle for manual operation shall be found in all operating mechanisms.
ii. SF6 gas cylinder with valve and instruments for refilling and SF6 leakage detector

3.4.15.2 All materials to be used shall be new. A list of a special equipment and tools shall be delivered with a bid. The Employer reserves the right to request any other special equipment or tools during training or testing, which he finds necessary, free of charge, although such equipment or tools were not on the list of special equipment.

(a)SF6 Gas leakage detector:

The detector shall be portable, battery operated, hand held type and having a minimum SF6 gas leakage sensitivity of 5gm/year. The sensor shall be connected through a flexible wand for easy accessibility to joints, seals and couplings in GIS equipment and provided with a protection filter. The equipment shall have on/off switch & suitable indicating lamps/LEDs, variable pitch audible signal for leakage indication. The equipment shall have automatic zeroing of background signals suitable for detecting SF6 gas leakage in charged switchyard. The test kit shall be compatible for EMI/EMC environment as per IEC 1000.

(b) Gas filling and evacuating plant: Gas Processing unit

i) **The plant necessary for filling and evacuating the SF6 gas in the switchgear shall be supplied to enable any maintenance work to be carried out. This shall include all the necessary gas cylinders for temporarily storing the evacuated SF6 gas. The capacity of the temporary storage facilities shall at least be sufficient for storing the maximum quantity of gas that could be removed from at least one phase of one complete bay (switchgear and associated equipment).**
ii) **Where any item of the filling and evacuating plant is of such a weight that it cannot easily be carried by maintenance personnel, it shall be provided with lifting hooks for lifting and moving with the overhead cranes.**
iii) **The minimum capacity parameters of evacuation plant will be as under:**
iv) **Oil Free Suction (Recovery) Pump: 30 m3/hour**
v) **Compressor (Two Stage): 15 m3/hour**
vi) **Oil Free Vacuum Pump: 100 m3/hour**
vii) **The evacuation equipment shall be provided with all the necessary pipes, couplings, flexible tubes and valves for coupling up to the switchgear for filling or evacuating all the gases. Details of the filling and evacuating plant that will be supplied, as well as the description of the filling and evacuating procedures shall be furnished.**

(c)SF6 gas analyzer:

The SF6 gas analyzer should be of portable type and instruments shall have following features.

i) **In-built calibration facility.**
ii) **Sensitivity of the equipment shall not be affected by any atmospheric conditions like dust, humidity, heat, wind etc.**
iii) **Equipment shall work on zero gas loss principle i.e. gas should be pumped back to the compartment after measurement without any exposure to the atmosphere.**
iv) **Equipment shall be supplied with suitable regulator which can be used to connect SF6 cylinder if required.**
v) **Following acidic/impurities products should be detected as per IEC 60480 and IEC 60376**
vi) **SF6 purity – Range: 0-100 % & Accuracy: +/- 2 deg**
vii) **Dew point - Range : -60 to +20 deg C & Accuracy: +/- 4 deg C**
viii) **SO2 - Range : 0-150 ppm & Accuracy : +/- 2 %**
ix) **HF - Range : 0-10ppm & Accuracy : +/- 10 %**
x) **Instrument should work on AC source as well as on rechargeable battery**
xi) **Input pressure: up to 10 bar**
xii) **It should be housed in a robust IP67 case with wheels**

(d) Portable Partial Discharge(PD) monitoring system

i) **The equipment shall be used for detecting different types of defects in Gas Insulated Stations (GIS) such as Particles, Loose shields and Partial Discharges as well as for detection of Partial discharges in other types of equipment such as Cable Joints, CTs and PTs.**
ii) **It shall be capable for measuring PD in charged GIS environment as EHV which shall have bandwidth in order of 100 MHz–2GHz with possibility to select a wide range of intermediate bandwidths for best measurement results. The principle of operation shall be based on UHF principle of detection. The instrument should also be able to detect partial discharges in cable joints and terminations.**
iii) **Detection and measurement of PD and bouncing particles shall be displayed on built in large LCD display and the measurement shall be stored in the instrument and further downloadable to a PC for further analysis to locate actual source of PD such as free conducting particles, floating components, voids in spacers, particle on spacer surfaces etc. Software for display and diagnosis of PD signals and an expert software system for accurate interpretation of cause of PD shall also be supplied and installed by the contractor.**
iv) **The equipment shall meet the following requirements**
v) **Measurement shall be possible in noisy environment.**
vi) **Stable reading shall be possible in presence of vibrations within complex GIS assemblies, which can produce signals similar to PD.**
vii) **Equipment should have necessary synchronizing circuits to obtain PD correlation with power cycle and power frequency.**
viii) **The equipment shall be battery operated with built-in-battery charger. It shall also be suitable for 230V AC/50 Hz input.**

ix) **Measurement shall be possible in the charged switchyard in the presence of EMI/EMC. Supplier should have supplied similar detector for GIS application to other utilities. Performance certificate and the list of users shall be supplied along with the offer.**

x) **Instrument shall be supplied with standard accessories i.e., re-locatable sensors with mounting arrangements, connecting cables (duly screened) to sensors, Laptop PC, diagnostic and expert interpretation software, carrying case, rechargeable battery pack with charger suitable for 230V AC, 50Hz supply connecting cables (duly screened) to view in storage.**

xi) **The function of software shall be covering the following:**

- Data recording, storage and retrieval in computer
- Data base analysis
- Template analysis for easy location of fault inside the GIS
- Evaluation of PD measurement i.e, Amplitude, Phase Synchronization etc.
- Evaluation of bouncing/loose particles with flight time and estimation on size of particle.
- Expert software system for accurate interpretation of cause of PD.
- Report generation.
- To prove the suitability in charged switchyard condition, practical demonstration shall be conducted before acceptance.
- Supplier shall have “Adequate after sales service” facility in India and shall provide the document in support of this.
- Necessary training may be accorded to personnel to make use of the kit for locating PD sources inside the GIS.
- Instrument shall be robust and conform to relevant standard.

xii) **Calibration: The UHF Couplers have to be first calibrated as per CIGRE Document No. 654 as part of factory acceptance tests to guarantee detection sensitivity of 5pC or better. The GIS of same design shall be used as test specimen during the coupler calibration. The pulse injection level determined through above factory calibration tests shall only be used as reference for site sensitivity checks during commissioning of PDM system. The data sheet/frequency response characteristics shall be submitted for reference.**

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

3.4.16 Spare Parts

3.4.16.1 Contractor is obliged to enclose with the bid a list of recommended spares required for operation and maintenance necessary for 2 years period.

3.4.17 Packing, Shipment and Transportation

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

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

3.4.17.3 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.

3.4.17.4 Sufficient quantity of SF6 gas must be delivered for the first gas filling and eventually refilling.

3.4.18 Inspection and Tests

3.4.18.1 Tests shall be carried out in order to determine whether the material and equipment comply with the required properties. All tests on the materials and equipment shall be made in accordance with IEC 62271-203. Testing shall not impair the properties and reliability of a test object or reduce its lifetime.

i. Type tests shall be performed on each type and rating of the specified equipment with the purpose of proving its properties. Detailed list of type tests shall be attached to the bid along with the copies of the Type tests certificates.
ii. Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.
iii. Factory acceptance test shall be conducted in the Manufacturer's factory in a presence of three representatives of the Employer, before delivery. All costs including visa fee, health insurance, transport, accommodation, food, daily allowance as well as costs for the tests shall be borne by the Contractor and included in the contract price. Acceptance test will be conducted in accordance with the program of routine tests.

3.4.18.2 Type Tests

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

(a) Complete Swithchgear
  i) **Dielectric tests**
    iii. Power frequency withstand voltage test (wet and dry)
    iv. Lightning impulse voltage tests
  ii) **Measurement of the resistance of the main circuit**

iii) **Temperature rise test**
iv) **Short time and peak withstand current tests**
v) **Pressure test on partitions**
vi) **Test under conditions of arcing due to internal fault**
vii) **Insulator tests**
viii) **Tightness test**

(b) Circuit Breaker
i) **Mechanical and environment tests**
ii) **Test circuits for short circuit making and breaking tests**
iii) **Single-phase and double-earth fault tests**
iv) **Short line fault tests**
v) **Out of phase making and breaking tests**

(c) Disconnector & Earthing Switch
i) **Tests to prove the short circuit making performance of earthing switches**
ii) **Operating and mechanical endurance tests**
iii) **Bus-transfer current switching tests**
iv) **Induced current switching tests**

(d) Current Transformer
i) **Short-time current tests**
ii) **Temperature-rise test**

(e) Voltage Transformer
i) **Temperature-rise test**
ii) **Lightning Impulse test**

3.4.18.3 Routine Tests

The following type tests shall be conducted on each piece the equipment to be supplied for the purpose of revealing faults in material or construction:

(a) Complete Swithchgear
i) **Dielectric tests**
v. Power frequency withstand voltage test (wet and dry)
ii) **Measurement of the resistance of the main circuit**
iii) **Pressure test on partitions**
iv) **Tightness test**

(b) Circuit Breaker
vi. Mechanical and environment tests

(c) Disconnector & Earthing Switch

vii. Operating and mechanical endurance tests

3.4.18.4 On Site Tests

After the GIS Switchgear has been fully installed at site and SF6 gas filled at rated filling density, the complete assembly shall be subjected to the site tests as per IEC-62271-203. Method statement/ procedure of On Site high voltage testing, PD measurement and relevant tests shall be submitted by contractor in advance.

3.4.19 Documentation

3.4.19.1 Documentation attached to the bid shall include minimum the following:

(a) Manufacturer's Authorization
(b) Manufacturer's Quality control certificate
(c) Detailed list of type test for each type and class of the specified equipment
(d) Copies of type test reports
(e) Equipment-related catalogues
(f) Reference list for previous five years
(g) Drawings, schematic diagrams and similar
(h) List of special equipment and tools
(i) List of recommended spare parts
(j) Training plan (if any, as required by specification)
(k) Instruction manuals for installation, testing and maintenance
(l) Test protocol of acceptance testing

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

3.4.19.3 The contractor shall prepare and submit to the employer, drawings, details that show the GIS design in order for the employer to verify the equipment conform to the specifications. The Design Document to be submitted for review and approval are as follows:

(a) Design Review Document as per clause no. 3.3.3 of this specification
(b) Single Line Diagram/
(c) Gas Schematic Diagram / Interlocking scheme
(d) GTP-Guaranteed Technical Particulars
(e) GIS layout (Plan and Section) including 3D drawing

(f) GIS Component Drawings
(g) Interface modules drawing for GIS extension
(h) Rating and Name Plate Drawing
(i) GIS/LCC Schematics Drawing
(j) Foundation loading plan and detail
(k) GIS Support Structure Drawing
(l) GIS platforms and Walkway Drawing
(m) GIS grounding plan and details along with design calculation for GIS grounding
(n) GIS key Diagram enlisting and marking each and every GIS Module clearly and separately identifiable (indoor and outdoor). This separately identified module shall be complete along with its enclosure, gasket and all active parts such as conductor, conductor joints, corona shield etc.
(o) Method Statement along with sequential instruction for dismantling and assembling of all major components of GIS exhibiting service continuity requirement
(p) Type Test Reports
(q) Seismic Analysis Report
(r) Study report of VFTO generated for GIS installation for 400 kV and above.
(s) The general arrangement drawing of interconnecting bus-duct from GIS bay module to XLPE cable termination end
(t) The general arrangement drawing of Terminal connection arrangement to connect GIS duct to SF6/Oil bushing and duct mounting arrangement details
(u) Gas handling procedure
(v) The design & construction proposal of the building along with necessary information, data, and drawings according to the complete requirements
(w) Capacity calculation of EOT crane for GIS hall considering a factor of safety
(x) Method statement/ procedure of ON SITE high voltage testing with PD measurement and Switching Impulse test
(y) Additional CB data to be furnished during detailed engineering:
    i) **Design data on capabilities of circuit breakers in terms of time and number of operations at duties ranging from 100 % fault currents to load currents of the lowest possible value without requiring any maintenance or checks.**
    ii) **Curves supported by test data indicating the opening time under close open operation with combined variation of trip coil voltage and hydraulic pressure.**
    iii) **Contact Travel: Operating mechanism operating shaft travel and contact overlap of Circuit Breaker to be provided**

(z) The Sub-station GIS layout as a separate drawing indicating position of spacers, spread over of PD sensors with distance, sensor identification, the detector unit identification etc., total numbers of offered UHF Sensors along with attenuation calculation. And data sheet for the UHF couplers.
(aa) Installation and Operation & Maintenance Manual

3.4.20 Installation of GIS

3.4.20.1 Civil works of GIS Hall shall be completed in all respects before taking up the installation and it shall be ensured that Ventilation System is operational and all dust and dirt in the hall are removed. The GIS hall needs to be in positive pressure before starting Installation.

3.4.20.2 The installation area shall be secured against entry of unauthorized personnel. Only certified manufacturer's engineer and supervisor shall undertake the erection works. Engineers and supervisors of the manufacturer shall submit authorization and competency certificate to PGCB.

3.4.20.3 Un-packaging of GIS modules shall be done outside the GIS hall and in no case module to be taken inside GIS hall with packing.

3.4.20.4 All assembly work shall be done by qualified personnel only who are to be identified and list submitted to PGCB before starting of erection work.

3.4.20.5 Assembly drawing for GIS erection for the section under progress shall be available and displayed in GIS hall at the time of erection work.

3.4.20.6 Working personnel shall clean their shoes or apply covers on shoes before entering the immediate working area. The working clothes of authorized personnel shall be made of non-fluffy material.

3.4.20.7 GIS hall door shall have automatic close facility after entry of personnel to avoid dust and moisture entry. Walls and ceiling shall be in a condition so that neither dirt nor plaster might fall or rub off and formation of condensation water in ceiling shall be prevented under any circumstances.

3.4.20.8 Floor in the installation area shall have a firm surface and shall be kept dust free with a vacuum cleaner. Vacuum cleaning to be done on regular basis.

3.4.20.9 Only T&P and consumables required for GIS erection shall be kept in GIS during erection.

3.4.20.10 In case of outdoor installation of GIS or of GIS components open gas compartments shall be protected from dust and moisture ingress (by tarpaulin covers/protective enclosure/chamber etc).

3.4.20.11 Bus duct exits in the GIS hall's wall shall be kept covered by suitable means until permanent cover is provided after installation of bus ducts.

3.4.20.12 Maintenance room (as a part of LCR room) shall be constructed for carrying out repair works/ small part assembly. All excess material (not required for immediate installation works) test equipment and tools and tackles to be stored separately from GIS hall in this room for rework.

3.4.20.13 Erection agency shall submit method statement and make available formats for checking during each stage of hall preparation, assembly process and final checks to be approved by PGCB before start of erection. Shock recorder down loaded data and analysis shall be submitted preferably before commencement of erection work. In case of violation of shock limits, expert from manufacturer shall visit and do the joint internal inspection and shall submit analysis report before giving clearance for erection. If required the module shall be taken back to factory for further analysis and testing.

3.4.20.14 Cleaning is of utmost importance and hence before assembly, all the loose metal parts, subassemblies and all contact & sealing surfaces shall be cleaned before installation. Cleaning shall be carried out with specified cleaning agents of the manufacturer, in no condition water is to be used except for external surfaces. Further, prior to opening of gas compartment, the same shall be thoroughly cleaned externally. The vacuum cleaning of the installation area shall also be done specially the immediate vicinity of the flanges to be connected.

3.4.20.15 All Civil Work inside building including internal cable trench shall be completed before GIS installation.

3.4.20.16 Installation of flanges shall be done immediately after removal of transport covers. Transport covers, O-rings and other packing material of GIS shall be taken out immediately after removal.

3.4.20.17 O-Rings shall be properly stored and taken out only before installation. O-Rings are also to be cleaned before use with manufacturer authorized cleaning agent.

3.4.20.18 At all points of time during installation authorized personnel shall use suitable gloves to avoid contamination.

3.4.20.19 Cable termination work shall commence only after completion of GIS equipment

3.4.20.20 erection, as during GIS installation period laying and termination of cables interferes with the GIS erection work and affects cleanliness.

3.4.20.21 Approved Field Quality Plan, which should be included Check-list, Witness-point, Holding-point etc., shall be followed during site work.

3.5 AIS SWITCHGEAR (OUTDOOR TYPE)

3.5.1 Surge Arresters (Outdoor type)

3.5.1.1 Scope

3.5.1.1.1 ***This section covers the ratings, design, equipment requirements, inspection and testing of the equipment. It states only those general aspects that are meant to ensure minimum requirements with respect of quality and performance. Other details and specific data are contained in the Technical Data Schedules.***

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

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

3.5.1.2 General Design

3.5.1.2.1 ***Surge arresters will be metal-oxide, gapless, outdoor. Design shall comply with the requirements of IEC 60099 and other relevant standards, if it is not requested in different manner in this specification. Surge arresters be shall be hermetically sealed type, composite housing, on insulating basement and with counter. Insulating basement shall be delivered together with the Surge arresters.***

3.5.1.2.2 ***The Contractor shall demonstrate and verify by EMTP that the surge arresters will adequately protect the equipment such as Transformer, Sh.R, etc proposed.***

3.5.1.2.3 ***If the additional Surge Arresters are required different from the Surge Arresters proposed on the Single Line Diagrams, those Surge Arresters have to provided free of charge and included in the final Bid price.***

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

3.5.1.3 High-Voltage Terminals

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

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

3.5.1.4 Insulating Basement

3.5.1.4.1 Surge arresters shall be equipped with appropriate insulating basement that is part of delivery. They shall be fixed and electrically connected to insulating basement. Earthing shall be fixed and electrically connected to surge arrester directly.

3.5.1.5 Earthing

3.5.1.5.1 Surge arresters will be equipped with appropriate earthing connector.

3.5.1.6 Surge Arresters Housing

3.5.1.6.1 Housing shall be made from silicon and/or composite material in accordance with Technical specification. The connection itself shall be handled with such manner so as to prevent retaining or intrusion of moisture. Minimum creepage distance is 31.5 mm/kV.

3.5.1.7 Environmental Protection

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

3.5.1.8 Nameplates

3.5.1.8.1 Nameplates should have data written in a English language:

i. Manufacturer name
ii. Type of surge arrester
iii. Rated voltage of surge arrester Ur
iv. Continuous operating voltage of surge arrester Uc
v. Nominal discharge current of an arrester (8/20 µs)
vi. Rated short circuit current
vii. Rated frequency
viii. Line discharge class
ix. Number of a unit position in a set (for multi units surge arrester)
x. Mass of surge arrester
xi. Year of production
xii. Serial number

3.5.1.9 Special Equipment, Tools and Drawings

3.5.1.9.1 ***The Contractor is obliged to deliver all equipment and tools required for installation, dismantling, testing and maintenance of equipment. Special equipment and tools shall be of the highest quality and suitable for field work. All materials to be used shall be new. A list of special equipment and tools shall be delivered with the bid. The Employer reserves the right to request any other special equipment or tools during training or testing, which he finds necessary, free of charge, although such equipment or tools were not on the list of special equipment.***

3.5.1.10 Spare Parts

3.5.1.10.1 ***The Contractor is obliged to enclose with the bid a list of recommended spares required for operation and maintenance necessary for 10 years period. All spare parts to be used shall be new. A list of spare parts shall be delivered with a bid.***

3.5.1.11 Packing, Shipment and Transportation

3.5.1.11.1 ***The Contractor is obliged to arrange for preparation, packing and transport of the equipment to the destination point. The equipment shall be packed and ready to be stored for a longer period.***

3.5.1.12 Inspection and Tests

3.5.1.12.1 ***Tests shall be carried out in order to determine whether the material and equipment comply with the required properties. All tests on the materials and equipment shall be made in accordance with IEC standards. Testing shall not impair the properties and reliability of a test object or reduce its lifetime.***

i. Type tests shall be performed on each type and rating of the specified equipment with the purpose of proving its properties. Detailed list of type tests shall be attached to the bid along with the copies of the Type tests certificates.
ii. Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.
iii. Special tests shall be performed on each piece of equipment before delivery, during the acceptance test

3.5.1.13 Type Tests

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

i. Dielectric tests
    a. Power frequency withstand voltage test of arrester housing
    b. Lightning impulse voltage tests
    c. Power frequency voltage wet and dry test
ii. Residual voltage test
    a. Steep current
    b. Lightning impulse
    c. Switching impulse
iii. Test to verify long term stability under continuous operating voltage
iv. Repetitive change behaviour verification
v. Operating duty tests
vi. Power frequency voltage versus time
vii. Short circuit test
viii. Weather aging test

3.5.1.13.2 Short circuit test shall be conducted by the STL – Short Circuit Testing Liaison and Short circuit test report shall be certified from STL – Short Circuit Testing Liaison authority.

3.5.1.14 Routine Tests

3.5.1.14.1 The following type tests shall be conducted on each piece the equipment to be supplied for the purpose of revealing faults in material or construction:

i. Measurement of reference voltage
ii. Residual voltage test
iii. Partial discharge and contact noise tests

iv. Seal leakage test

3.5.1.15 Documentation

3.5.1.15.1 Documentation attached to the bid shall include minimum the following:

i. Manufacturer's Authorization
ii. Manufacturer's Quality control certificate
iii. Detailed list of type test for each type and class of the specified equipment
iv. Copies of type test reports
v. Equipment-related catalogues
vi. Reference list for previous five years
vii. Drawings

3.5.1.15.2 For each surge arrester, the following documentation shall be delivered:

i. Drawings
ii. Instruction manuals for installation, testing and maintenance
iii. Test protocol of acceptance testing

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

3.5.2 Post Insulators

3.5.2.1 Scope

3.5.2.1.1 This Section covers the ratings, design, equipment requirements, inspection and testing of the equipment. It states only those general aspects that are meant to ensure minimum requirements with respect of quality and performance. Other details and specific data are contained in the Technical Data Schedules.

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

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

3.5.2.2 General Design

3.5.2.2.1 ***Post insulators should be solid core type post insulators, made of porcelain, for outdoor installation in AC system. The post insulators shall comply with the requirements of following standards: IEC 60273, IEC 60437, 60815, 60672, IEC 60168, EN1562, EN1563, EN ISO 1461 and other relevant standards if it is not required in this Specification.***

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

3.5.2.3 Insulator Material

Insulators should be made of high quality aluminium oxide porcelain. Porcelain material shall fulfil requirements of a class C130, which confirms to the standard IEC 60672. Insulators shall be cylindrical with a hard core and metal base. Glazing shall be in brown colour.

3.5.2.4 RIV

The RIV performance of post insulator styles shall be tested in accordance with the standard IEC60437. If corona rings are necessary to reach a certain RIV level for a single insulator column, the appropriate ones shall be delivered with the insulator column.

3.5.2.5 Fittings

Fittings shall be made in malleable cast iron according to standard EN1562 or spheroidal graphite cast iron according to standard EN1563. All fittings shall be hot dip galvanized according to standard EN ISO 1461 with a zinc weight of min. 600 g/m2 (min. 85 µm) as average value. Connection method of Support insulators shall be in accordance with standard IEC 60273. Connection holes shall be equally arrange on a circle meaning concentric with eight insulators. Holes in upper and lower part of connection equipment should be in line and so arranged to allow usage of standard screws with six-angle heads.

3.5.2.6 Cementing

Any connection between porcelain and flange shall be made with Portland cement. The connection itself shall be handled with such manner so as to prevent retaining or intrusion of moisture by a silicone or any other manner.

3.5.2.7 Insulation Level

Post insulators should be designed for standard value of lightning impulses voltage according IEC 60071-1. Minimal value for the height depends of lightning impulses voltage in dry, power frequency voltage in wet and switching withstand voltage in wet where it is in accordance with relevant requirement from coordination insulation point.

3.5.2.8 Dimensions

Rated dimensions of insulator shall be in accordance with values defined in the Technical Data Schedules, with appropriate tolerances referring to parallelism, eccentric and angle deviation, in accordance with standard IEC 60272. Minimum creepage distance is 31.5 mm/kV.

3.5.2.9 Packing, Shipment and Transportation

The Contractor is obliged to arrange for preparation, packing and transport of the equipment to the destination point. The equipment shall be packed and ready to be stored for a longer period.

3.5.2.10 Inspection and Tests

Tests shall be carried out in order to determine whether the material and equipment comply with the required properties. All tests on the materials and equipment shall be made in accordance with IEC standards. Testing shall not impair the properties and reliability of a test object or reduce its lifetime.

i. Type and special tests shall be performed on each type and rating of the specified equipment with the purpose of proving its properties. Detailed list of type tests shall be attached to the bid along with the copies of the Type tests certificates.
ii. Routine tests shall be performed on each piece of equipment to be supplied, for the purpose of revealing faults in material or construction.

3.5.2.11 Type Tests

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

3.5.2.11.1 Dielectric tests

i. Lightning impulse voltage tests
ii. Power frequency voltage wet and dry test
iii. Power frequency withstand voltage test of arrester housing
iv. Long-duration current impulse withstand test
v. Residual voltage test

vi. Internal partial discharge tests
vii. Mechanical failing load test

3.5.2.12 Special Tests

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

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

3.5.2.13 Routine Tests

The following type tests shall be conducted on each piece the equipment to be supplied for the purpose of revealing faults in material or construction:

i) Routine thermal shock test
ii) Routine visual examination
iii) Routine electrical test
iv) Routine mechanical test

3.5.2.14 Acceptance Tests

The following tests shall be conducted:

i) Verification of dimensions
ii) Temperature cycle test
iii) Dimension tests
iv) Mechanical test
v) Puncture test
vi) Porosity test
vii) Galvanizing test

3.5.2.15 Documentation

3.5.2.15.1 Documentation attached to the bid shall include minimum the following:

i) Manufacturer's Authorization
ii) Manufacturer's Quality control certificate
iii) Detailed list of type test for each type and class of the specified equipment
iv) Copies of type test reports
v) Equipment-related catalogues

vi) Reference list for previous five years
vii) Drawings

3.5.2.15.2 Following documentation shall be delivered together with the equipment:

i) Drawings
ii) Instruction manuals for installation, testing and maintenance
iii) Test protocol of acceptance testing

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

3.5.2.16 **Portable Lightning Arrester Diagnostic System** (PLADS)

Contractor shall provide two PLADS (one per S/S) to diagnose of the aging state of lightning arrester for condition test and MRE. The specification of PLADS is as follows:

i) Such diagnosis items are able to be measured.
ii) Total leakage current
iii) Resistive leakage current
iv) Harmonics (3rd, 5th, 7th, 9th) current
v) Detected sensor shall be a CT sensor.
vi) The electric field shall be reduced in a shielding case.
vii) HMI shall be provided for analyzing the data

3.5.3 HVAC Circuit Breakers

3.5.3.1 This specification of technical conditions and technical requirements for Circuit Breakers covers the ratings, design, equipment requirements, inspection and testing of the equipment.
3.5.3.2 Here are stated only those general aspects that are meant to ensure minimum requirements with respect of quality and performance.
3.5.3.3 Other details and specific data are contained in the Technical Data Schedules.
3.5.3.4 Properties, testing and ratings of the equipment shall at least conform to the latest edition of the relevant IEC and British standards.
3.5.3.5 The Contractor is obliged to provide complete equipment, even if the details are not mentioned specifically in the following specifications.

3.5.3.6 General Design

3.5.3.6.1 Circuit breaker shall be, for outdoor installation. The circuit breaker shall be with SF6 gas as the arc-quenching and insulating medium. For 33kV voltage level, vacuum type circuit breaker may be acceptable. The circuit breakers shall comply with the requirements of IEC 60273, IEC 60694, IEC 60815, IEC 62271-100.

3.5.3.6.2 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.

3.5.3.6.3 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.

3.5.3.6.4 The Contractor shall provide and deliver suitable horizontal and vertical supporting structure that shall be galvanized.

3.5.3.7 Operating Mechanism

3.5.3.7.1 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.

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

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

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

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

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

3.5.3.7.7 Manual spring release shall be provided.

3.5.3.7.8 The operating mechanism shall have hand and electrically charging.

3.5.3.7.9 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.

3.5.3.7.10 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.

3.5.3.7.11 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.

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

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

3.5.3.7.14 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.

3.5.3.7.15 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).

3.5.3.7.16 Detachable plates for cable insertion rings shall be provided at the bottom of each operating mechanisms cabinet.

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

3.5.3.8 High Speed Reclosing

3.5.3.8.1 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.

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

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

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

3.5.3.9 Control Circuits

3.5.3.9.1 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.

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

3.5.3.9.3 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.

3.5.3.9.4 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.

3.5.3.9.5 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.

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

3.5.3.9.7 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.

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

3.5.3.9.9 Provide enough number of contacts of density-meter to fulfil previous preconditions.

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

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

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

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

3.5.3.9.14 Housing protection shall be at least of IP54.

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

3.5.3.9.16 Provide anti-pumping devices.

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

3.5.3.10 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.

3.5.3.11 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.

3.5.3.12 Operating Counter

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

3.5.3.13 SF_6 Gas

3.5.3.13.1 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:

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

3.5.3.13.3 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.

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

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

3.5.3.14 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.

3.5.3.15 Cables

3.5.3.15.1 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.

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

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

3.5.3.16 Support Metal Structure

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

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

3.5.3.17 Environmental Protection

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

3.5.3.18 Insulators

3.5.3.18.1 Insulators shall be made of brown porcelain or Silicon/Composite type, 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.

3.5.3.18.2 Minimum creepage distance is 31.5 mm/kV.

3.5.3.19 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

3.5.3.20 Special Equipment and Tools

3.5.3.20.1 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.
3.5.3.20.2 A handle for manual winding shall be found in all operating mechanisms.
3.5.3.20.3 SF_6 gas cylinder with valve and instruments for refilling and
3.5.3.20.4 SF_6 leakage detector
3.5.3.20.5 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.

3.5.3.21 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.

3.5.3.22 Packing, Shipment and Transportation
3.5.3.22.1 The Contractor is obliged to arrange preparation, packing and transport of the equipment.
3.5.3.22.2 Each circuit breaker shall be separately packed. It is not allowed to pack parts for more circuit breakers in single package.
3.5.3.22.3 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.
3.5.3.22.4 Sufficient quantity of SF_6 gas must be delivered for the first gas filling and eventually refilling.

3.5.3.23 Inspection and Tests

3.5.3.23.1 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.

3.5.3.23.2 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.

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

3.5.3.23.4 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.

3.5.3.24 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

3.5.3.25 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

3.5.3.26 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.

3.5.4 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.

3.5.4.1 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.

Operating Mechanism

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

3.5.4.1.2 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.

3.5.4.1.3 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.

3.5.4.1.4 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.

3.5.4.1.5 Alarm (signalling) and control voltage shall be 110V/125V/220V, DC. (Based on existing system) 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.

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

3.5.4.1.7 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.

3.5.4.1.8 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.

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

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

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

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

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

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

3.5.4.1.15 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.

3.5.4.1.16 All operating mechanisms shall have copper latches at the bottom of the cabinet for

earthing of the cable sheath.

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

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

3.5.4.2 Control Circuits

3.5.4.2.1 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

Control switch for operation mode local / neutral (manual) / remote, with an option of electric blocking in "neutral" position,

3.5.4.2.2 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.

3.5.4.3 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

3.5.4.4 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.

3.5.4.5 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.

3.5.4.6 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.

3.5.4.7 Environmental Protection

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

3.5.4.8 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 31.5 mm/kV.

3.5.4.9 Special Equipment AND Tools

3.5.4.9.1 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.

3.5.4.9.2 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.

3.5.4.9.3 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.

3.5.4.10 Spare Parts

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

3.5.4.11 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.

3.5.4.12 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 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.

3.5.4.13 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
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.

3.5.4.14 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.

3.5.5 HV Instrument Transformers

3.5.5.1 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.

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

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

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

3.5.5.5 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.

3.5.5.6 General Design- Current Transformers

3.5.5.6.1 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.

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

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

3.5.5.6.4 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

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

3.5.5.6.6 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

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

3.5.5.6.8 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.

3.5.5.6.9 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.

3.5.5.6.10 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.

3.5.5.6.11 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

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

3.5.5.6.13 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.

3.5.5.7 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

3.5.5.8 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.

3.5.5.9 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 31.5 mm/kV.

3.5.5.10 Environmental Protection

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

3.5.5.11 Mechanical Terminal Loads

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

3.5.5.12 Mechanical Protection

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

3.5.5.13 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.

3.5.5.14 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.

3.5.5.15 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.

3.5.5.16 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.

3.5.5.17 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

3.5.5.18 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

3.5.5.19 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

3.5.5.20 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

3.5.5.21 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

3.5.5.22 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.

3.5.6 Neutral Grounding Resistor

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 31.5mm/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.

3.5.7 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 (50c) 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.

Flexible Bus-Bars shall be used for 400kV, 230kV,132kV & 33kV busbar. Other configuration of the busbar shall be as specified in the drawings of bid document.

3.5.7.1 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) The welds in the aluminium tubes shall be kept to the minimum and there shall not be more than one weld per span. The procedure and details of welding shall be furnished for approval of the Employer. Material for welding sleeve shall be same as the Aluminium tube.

Parameters

The size and other parameters of tubular bus conductors suitable for the busbar specification stated in Appendix A1 in Volume 3 of the bid document shall be determined by the Contractor.

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.

3.5.7.2 Flexible Busbars and Earth Wire

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

a) 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.

b) 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.

c) 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 Contractor.

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.

a) 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 0C as per relevant IEC Standard.

b) 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.

c) 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

d) 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.

e) 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.

3.5.7.3 Clamp and Connectors

General

a) Conductor clamps shall be compression type except for shield wire in accordance with BS 3288 and shall be made of materials listed below :

For connecting ACSR conductors: Aluminium alloy casting

For connecting equipment terminals made of copper with ACSR conductors: Bimetallic connectors made from aluminium alloy casting with 2mm thick Bimetallic liner

For connecting G.I. Shield wire : Galvanised mild steel

Bolts, nuts & Plain washers: Electro galvanised for sizes below M12, for others hot dip galvanised

Spring washers: Electro-galvanised mild steel suitable

b) Equipment shall be supplied with the necessary terminals and connectors, as required by the ultimate design for the particular installation. The conductor terminations of equipment shall be either expansion, sliding or rigid type. The requirements regarding external corona and RIV as specified for any equipment shall include its terminal fittings and the equipment shall be factory tested with the connectors in position. In case the connector is not available then equivalent connector may be used. If corona rings are required to meet these requirements they shall be considered as part of that equipment and included under this scope of Work.

c) Where copper to aluminium connections are required, bi-metallic clamps shall be used, which have been properly designed to ensure that any deterioration of the connection is kept to a minimum and restricted to parts which are not current carrying or subjected to stress. The design details of joint shall be furnished to the Employer.

d) Low voltage connectors, grounding connectors and accessories for grounding all equipment as specified are also included in the scope of Work.

e) No current carrying part of any clamp shall be less than 10 mm thick. All ferrous parts shall be hot dip galvanised. Copper alloy liner of minimum 2mm thickness shall be cast integral with aluminium body for Bi-metallic clamps. When copper alloy is not cast integral with aluminium body, a bimetallic washer or strip shall be used to meet the functional requirement.

f) All casting shall be free from blow holes, surface blisters, cracks and cavities. All sharp edges and corners shall be blurred and rounded off.

g) Flexible connectors, braids or laminated straps made for the terminal clamps for bus posts shall be suitable for both expansion or through (fixed/sliding) type connection of IPS Aluminium tube as required. In both the cases the clamp height (top of the mounting pad to centre line of the tube) should be same.

h) Clamp shall be designed to carry the same current as the conductor and the temperature rise shall be equal or less than that of the conductor at the specified ambient temperature. The rated current for which the clamp/connector is designed with respect to the specified reference ambient temperature, shall also be indelibly marked on each component of the clamp/connector, except on the hardware.

i) All current carrying parts shall be designed and manufactured to have minimum contact resistance.

Constructional Feature

All casting shall be free from blow holes, surface blisters, cracks and cavities. All sharp edges and corners shall be blurred and rounded off. Size of the terminal/connector for which the clamp/ connector is suitable shall be embossed/punched (i.e. indelibly marked) on each components of the clamp/connector, except on the hardware. The clamp shall be designed to carry the same current as the conductor and the temperature rise shall be equal or less than that of the conductor at the specified ambient temperature. The rated current for which the clamp/ connector is designed with respect to the specified reference ambient temperature, shall also be indelibly marked on each component of the clamp/connector, except on the hardware. All current carrying parts shall be designed and manufactured to have minimum contact resistance. The Corona extinction voltage for 400 kV and 230 kV class clamps shall not be less than 320 kV and 156 kV respectively.

Tests

The clamps and connectors shall be subject to type and routine tests as per relevant IEC Standard. Type tests as per IEC Standard shall be carried out on one sample of each type and design. One sample of each type and design shall also be type tested for:

a) Temperature rise test

b) Short time current test

c) Dry corona and RIV test

d) Resistance test and tensile test

3.5.7.4 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.

3.5.8 Insulators, Bushing, Buses and Hardware

3.5.8.1 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/Contractor 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 Contractor, however the minimum performance parameters for the 400kV, 230 kV, 132 kV and 33kV 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.

3.5.8.2 String Insulators and 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 Contractor 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/Contractor 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 Contractor and the Employer.

3.5.9 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 energised 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.

3.5.10 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.

3.5.11 Interface 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.

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

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

4.3.1.2 Electrical clearances shall not be less than those in the appropriate sections of BS 7354, or as stated in the System Electrical Parameters of the scope of works in section-1 of volume-2 or 3, whichever is the greater.

4.3.1.3 Following types of transformer is generally available in Transmission system and covered by this specification-

SL	Voltage rating	Delta Tertiary winding, kV	Type of transformer	Use
1	400/138/34.5	Yes, 34.5 kV	3-phase Auto-Transformer	Power Transmission
2	230/138/34.5	Yes, 34.5 kV	3 -phase Auto-Transformer	Power Transmission

3	132/34.5	No	3-phase Power Transformer	Power Transmission

4.3.1.4 Both Auto & Power Transformer shall be designed, manufactured & tested in accordance with this specification. Power Transformer shall have separate HV & LV windings & auto transformer will have no electrical isolation between HV & LV windings.

4.3.1.5 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

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

4.3.2.2 Drawings shall have to be provided for each transformer being supplied in accordance with this specification. Each drawing shall contain a Title Block which includes the following information:

- 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

4.3.3.1 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.

4.3.3.2 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

4.3.4.1 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.

4.3.4.2 In addition to one Instruction Book provided with the transformer in the control cabinet, four (4) additional Instruction Books per transformer shall be sent to the Engineer within 4 weeks after shipment of the transformer. Each instruction book shall include the followings:

1. Instruction books shall clearly indicate the Customer's name, the substation name and number, Project Name and the Manufacturer's identification number.
2. Certified Test Report for each transformer, including all results of tests required in relevant section of this specification (Routine & Factory Acceptance test) Section 15.
3. 297 x 420 copy of the transformer nameplate drawing, with all data filled in.
4. Assembly instructions
5. 3.5.2.5 Bill of material (identify parts removed for shipment, all parts with manufacturer name/model #, cross reference to applicable drawings by item # or electrical device #)
6. Complete set of “As-Built” drawings (reduced size is acceptable)
7. Arrester and Bushing outline drawings.
8. Instructions for all accessories including Annunciator, relays, counters, Electronic Temperature Monitor (if supplied), and LTC control equipment, etc.
9. Certified test reports for Metering accuracy CT’s.
10. Relay class CT data. For each CT of a different accuracy class or ratio, the following information shall be supplied:
    - Saturation curves
    - Thermal rating factor
    - Secondary resistance in ohms per turn
    - Lead resistance in ohms per lead
    - Ratio correction factor curves
    - Metering accuracy at the full tap ratio
    - One (1) set of 8” x 10” 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.

4.3.5.1 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

4.3.6.1 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

4.3.6.2 Loading other than rated conditions:

4.3.6.2.1 ***All transformers specified may be exposed to an emergency loading in excess of***

nameplate rating, in accordance with IEC 60076-1,2. The transformer may be loaded above nameplate ratings in emergency situations with the knowledge that there will be some sacrifice of life.

4.3.6.2.2 ***All transformers shall be suitable for operation with an average ambient temperature of 40°C or as specified in Technical Data Sheets or in scope, whichever is higher.***

4.3.6.3 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

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

4.3.7.1.2 The circulation mechanism for the internal cooling medium shall be natural convection for all stages of cooling. The external cooling mechanism shall be natural or forced flow of air. The required number of cooling stages will be identified in the specific transformer Technical Data Sheets.

4.3.7.1.3 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.

4.3.7.1.4 Transformers shall be fitted with at least two coolers or two banks of radiators each capable of dissipating 50 per cent of the losses at continuous maximum rating. They shall be capable of remaining in operation at full load for 20 minutes in the event of failure of blowers associated with one half of coolers or radiators, without the calculated winding hot spot temperature exceeding 140˚C or as stated in the Schedule of Requirement/Technical Data sheets . Such shall be verified by design during design approval stage and taken approval from the Employer.

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

4.3.7.1.6 The Continuous capacities of each cooling stage as per voltage level are defined in the

Schedule of requirement (Technical Data Sheets) of Volume 3 of 3 of the bidding document.

4.3.7.2 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 or five-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.

The three winding transformers shall be designed for arithmetic loading in such a way that the tertiary winding can be loaded continuously for the specified MVA rating. Both continuous thermal capacity & short circuit capacity shall be guaranteed for the tertiary winding. Design shall be such that, when the transformer is loaded with full MVA capacity at its' all windings specified, the transformer temperature rise is within specified limit.

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 1.7.6 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 1.7.2 of this specification, and with tap voltages as identified in the specific transformer Data Sheets.

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

4.3.7.8.1 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.

4.3.7.8.2 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%).

4.3.7.9 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.

4.3.7.10 Insulation Levels

4.3.7.10.1 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.

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

4.3.7.10.3 No internal devices of a linear or nonlinear nature (such as surge arresters) shall be installed for any reason, that would alter, cause abnormal variations or otherwise affect Factory dielectrics testing and/or affect routine maintenance test results such as "doble".

4.3.7.11 Temperature rise and loading conditions:

Temperature rise to be as stated in the Data Sheets.

4.3.7.12 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

4.3.9.1 Transformer windings shall be connected in accordance with the IEC 60076-1 (clause 6) group symbol specified in the Schedule of Requirements (Technical Data Sheets).

4.3.9.2 All electrical connections within windings shall be brazed, subject to approval, mechanically crimped joints may be used for round stranded conductors on tapping, bushing or earthing connections and on bundle conductors where design has been proved by type test and application is subject to rigorous quality control.

4.3.10 Stabilizing Windings

4.3.10.1 Unless otherwise specified in the Schedule of Requirements, the product of the number of

turns of the

4.3.10.2 stabilizing windings and the cross- sectional area of one such turn must not be less than 20 percent of the corresponding product for the untapped main winding.

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

4.3.10.4 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

4.3.11.1 Guaranteed values for component losses of the total loss of the transformers shall be as low as is consistent with transport restrictions, reliability and economic use of materials, shall be as stated in the Schedule B of Particulars and Guarantees.

4.3.11.2 For the evaluation of the bid as per section 3 (Evaluation and qualification criteria) capitalization cost (Evaluated price of transformer losses) due to transformer guaranteed losses shall be added with the bid price. The evaluated price of the Power Transformer shall be the sum of the quoted bid price of the transformer plus evaluated price of the transformer losses. The evaluated price of transformer loss shall be:

For each unit of the three-phase transformers,

Evaluated price of transformer loss = N * a + L * b + M * c

Where

N= Average No-load loss (core loss) in kW

L= Average Load loss (copper loss) at 75 °C 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

4.3.13.1 The transformer noise levels shall be measured as a type test and in accordance with IEC 60551. The acceptance level of the transformers shall be as stated in the Schedule of Requirements (Technical Data Sheets).

4.3.13.2 Where the bottom plate of the transformer tank will be in direct contact with the surface of the foundation, anti-vibration pads shall be provided under the contract for insertion between

the transformer and its foundation.

4.3.13.3 The anti-vibration mountings shall be of an oil and weather resisting rubber or other approved material, capable of operation at temperatures from minus 10°C to plus 80°C. Due regard shall be given to irregularities in the tank under base and the plinth surface. Anti-vibration mountings for separately mounted coolers, pumps, etc. are not required.

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

4.3.13.5 When loaded to the same pressure as in service, the anti-vibration mountings shall give, at normal room temperature, a vibration attenuation at 100Hz of not less than 32dB (assuming an infinite ground impedance value).

4.3.13.6 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

4.4.1.1 The design of the magnetic circuit shall be such as to avoid static discharges, development of short circuit paths internally or to the earthed clamping structure, and the production of flux components normal to the plane of the laminations. Each lamination shall be insulated with a material stable under the action of pressure and hot oil.

4.4.1.2 The winding structure and major insulation shall be designed to permit an unobstructed flow of cooling oil through core cooling ducts to ensure efficient core cooling.

4.4.1.3 With the earthing link removed, the magnetic circuit shall be insulated from all structural parts, and shall be capable of withstanding a test voltage to core bolts and to the frame of 2,000 volts RMS for one minute.

4.4.2 Core: Design & Construction

4.4.2.1 General

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 either a three-legged core-form or a five-legged core-form construction using mitred 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

4.4.2.6.1 ***If the core is constructed with cooling channels separated by insulating material, each core section ground shall be brought up separately through cover mounted bushings. The core sections shall be externally bonded and grounded. A bridging strap or other means of internal electrical connection of the core sections is not acceptable.***

4.4.2.6.2 ***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.

4.4.2.8 Windings and internal leads

4.4.2.8.1 ***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.***

4.4.2.8.2 ***The windings shall be located in a manner that will ensure that they remain electromagnetically balanced and that their magnetic centres remain coincident under all conditions of operation.***

4.4.2.8.3 ***The windings shall also be thoroughly dried and shrunk by the application of axial pressure for such length of time as will ensure that further shrinkage will not occur in service.***

4.4.2.8.4 ***The windings and leads of all transformers shall be braced to withstand the shocks that may occur through rough handling and vibration during transport, switching and other transient service conditions including external short circuit.***

4.4.2.8.5 ***If the winding is built up of sections or of disc coils separated by spacers, the clamping arrangements shall ensure that equal pressures are applied to all columns of spacers.***

4.4.2.9 Winding Design

4.4.2.9.1 ***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.***

4.4.2.9.2 ***Layer type windings will be accepted only for regulating windings. When layer windings are used, the radial build shall be a minimum of 12 mm. Only one conductor in the radial direction is allowed unless CTC conductor is used.***

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

4.4.2.9.4 ***If CTC (continuously transposed conductor) is used, the following requirements shall be-***

- When conductor insulation on CTC is cellulose, it shall be Weidmann (Dennison) paper. On strap conductor, at least the outside 2 layers of conductor insulation shall be Weidmann paper. The insulating paper shall be applied in either single or multiple strands in such a manner that 30% overlaps.

- Brazes in CTC shall not be used unless the required conductor length exceeds the maximum available reel capacity. When required due to conductor length limitations, brazes shall be strand-to-strand, i.e. each strand shall be individually brazed and insulated separately.

- Epoxy-bonded CTC shall not soften during any type of fault based on the short-circuit temperature rise calculation in IEC 60076-5. The allowable temperature for this condition is less than 140 °C.

- When using CTC that is insulated with paper, the radial cooling duct shall be a minimum of 4.5 mm.

- Formvar insulated conductors are not acceptable except with CTC.

4.4.2.9.5 The dielectric stress at any location in the core-and-coil assembly shall not exceed 2.65kV RMS/mm with the transformer energized at 100% voltage on the maximum stress tap position. Applicable stresses include but are not limited to turn-to-turn, winding-to-winding, winding-to-ground, phase-to-phase and lead-to-lead.

4.4.2.9.6 Windings subject to inward radial buckling shall be designed to withstand "free"(unsupported) buckling in addition to "forced" (supported) buckling. The control of inward radial forces shall not depend on bracing to the core. The use of epoxy bonded CTC is required for windings subject to inward radial buckling. Short circuit calculations shall be based on an infinite bus. When layer windings are used, each layer shall be designed for "free" buckling independent of the other layers.

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

4.4.2.10 Winding and lead insulation

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

4.4.2.10.2 ***All cellulose winding insulation shall be Dennison paper insulation. All insulating materials that could come in contact with the winding conductors or leads shall have rounded edges.***

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

4.4.2.10.4 ***One-piece top and bottom clamping rings shall be used. There shall be no reduction in the thickness of the top clamping ring in the core window.***

4.4.2.10.5 ***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.***

4.4.2.10.6 ***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.***

4.4.2.11 Connections

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

4.4.2.11.2 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.

4.4.2.12 Internal Earthing

4.4.2.12.1 ***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.

4.4.2.12.2 ***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.

4.4.2.12.3 ***Earthing of Magnetic Circuits***

4.4.2.12.3.1 The magnetic circuit shall be earthed to the clamping structure at one point only through a removable link placed in an accessible position just beneath an inspection opening in the tank cover and which, by disconnection, will enable the insulation between the core and clamping plates, etc., to be tested at voltages up to 2 kV. The link shall have no detachable components and the connection to the link shall be on the same side of the core as the main earth connection. These requirements are compulsory.

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

4.4.2.12.4 ***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.

4.4.2.12.5 ***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

4.5.2.1 Equipment provided under this specification shall be analyzed and found to be functional for the physical loading conditions described below. The equipment shall be designed so that there will be neither damage nor loss of function during and after the loading conditions delineated below. In addition, equipment shall maintain correct operational state during these conditions.

4.5.2.2 The manufacturer/supplier is responsible for assuring that their analytical methodologyis consistent with industry standards and guidelines listed below and that the results are reported accurately to the Employer.

4.5.2.3 The manufacturer's analysis shall consider the higher of seismic load or wind load to act concurrently with the other applicable loading conditions as follows. Design criteria shall be clearly noted on the outline drawing.

i) **Wind Load:** The equipment shall be analyzed to the appropriate state building code for a wind load 120 mph applied to the component's entire projected are abnormal to the wind.

ii) **Seismic Load:** Seismic analysis of equipment shall be performed utilizing the Static Analysis Method as described in IEC60068-3 . A horizontal seismic coefficient of 0.2g and a vertical seismic coefficient of 0.2g shall be applied to the component's center of gravity and the resulting forces determined. Appendages such as electrical bushings, radiators, and pipes shall be designed for twice the horizontal and vertical seismic loads.

iii) **Dead Load:** Consider the weight effects of the equipment including all ancillary equipment and fluids.

iv) **Operating Load:** Equipment mechanical operating loads shall be evaluated for impact on anchorage and other support points. If operating loads are negligible, then a statement shall be clearly noted on the drawings.

v) **Terminal Connections:** Allowable loads for terminal connections shall be determined by the manufacturer for the lug design shown on their equipment drawing. Allowable loads shall be noted on the drawings.

4.5.2.4 The core clamp shall be isolated from the tank. Bolted joints are not preferred. It is preferred that the tank be fabricated in one piece for each side of the main tank. Tank corners shall be bent with seams welded inside and outside at least 6 inches/ 150mm from the corner.The top shall be welded, not bolted to the tank. The tank and cover shall be designed in such a manner as to leave no external pockets in which water can lodge, no internal pockets in which oil can remain when draining the tank or in which air can be trapped when filling the tank, and to provide easy access to all external surfaces for painting. Each tank cover shall be of adequate strength, must not distort when lifted.

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

4.5.2.6 Both the tank and cover shall be provided with lifting lugs.Lifting lugs shall be provided, suitable for the weight of the transformer, including core and windings, fittings, and with the tank filled with oil. Each tank shall be provided with at least four jacking lugs, and where required, with lugs suitably positioned for transport on a beam transporter. Haulage lugs should also be provided to enable a cable to be used safely for haulage in any direction.

4.5.2.7 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.

4.5.2.8 The base of each tank shall be so designed that it is possible to move the complete transformer unit in any direction without injury when using rollers, plates, or rails. Transformers shall have wheel bases, unless otherwise specifically approved by the Engineer.

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

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

4.5.2.11 The tank and cover shall be designed in such a manner as to leave no external pockets in which water can lodge, no internal pockets in which oil can remain when draining the tank or in which air can be trapped when filling the tank, and to provide easy access to all external surfaces for painting.

4.5.2.12 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.

4.5.2.13 All manhole, bushing, and pressure relief device openings in the tank cover shall utilize raised flanges with thru - bolts or blind tapped holes. Studs welded to the tank cover will not be accepted. All bushing adapters shall be equipped with air bleeder valves when a conservator - type oil preservation system is specified. These valves shall be used to purge air from the main tank during oil filling.

4.5.3 Manholes

4.5.3.1 There shall be two or more 24 - inch/600mm manholes in the top of the transformer to facilitate the removal and installation of bushings and current transformers (CTs) and to provide access to terminal boards (when used) without disturbing the leads, un - tanking the transformer, removing the cover, or removing radiators. Manhole covers shall include lifting handles. Covers and flanges shall be sufficiently stiff to prevent gas or oil leakages after bolts are tightened. Sufficient manholes shall be provided on the tank cover of core form transformers to permit access to each side of the core and coil assembly, with at least one on each side of the core and coil.

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

4.5.3.3 All manhole covers, whether on top or walls, shall be on raised flanges. Covers for maintenance or field assembly access shall be secured with nuts, bolts and gaskets, with those on walls having two concentric gaskets in separate grooves. Any and all wall access provisions are subject to specific approval by the Engineer during the bid evaluation process, regardless of past history of acceptance.

4.5.3.4 Covers for wall mounted access points shall be equipped with hinges and handles regardless of weight. Covers of access points used solely for factory assembly and testing shall be sealed using at least two full passes with no oil in the tank during welding.

4.5.3.5 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.

4.5.3.6 At no time during normal operation of the transformer, up to and including full loading above nameplate capabilities, shall the:

a) Exterior surface of the tank, or any appurtenances, become hot enough to cause injury to personnel upon momentary contact or to cause personnel to react in an unsafe manner upon such contact.
b) Interior surface of the tank, or any interior metallic members, become hot enough to generate gas in the insulating oil.

4.5.3.7 Sufficient clearances shall be provided between the core and coil assembly and the tank wall sand cover of core form transformers to permit comfortable internal inspection of the transformer by an average sized individual.

4.5.3.8 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.

4.5.3.9 Fall protection shall include two Lifting Lug weld - on base plates. The top of the main tank shall be painted with non - slip coarse grit paint compatible with the Manufacturers normal finish. Grit paint shall be on the tank top only and not on raised flanges or covers.

4.5.3.10 All valves, pipes or other extensions shall be strong enough to support a 100kg person or shall be provided with a guard that can support a 100kg person. Guards shall not restrict maintenance or operating access to the equipment being guarded.

4.5.3.11 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.

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

4.5.3.13 Pockets shall be provided for a stem type thermometer and for the bulbs of temperature indicators where specified. These pockets shall be located in the position of maximum oil temperature and it must be possible to remove any bulb without lowering the oil level in the tank. Captive screwed caps shall be provided to prevent the ingress of water to the thermometer pockets when they are not in use.

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

4.5.3.15 A ladder shall be provided on one side of the tank as a means for inspection and access to the top of the transformer. The lower section of the ladder shall be equipped with a barrier complete with provision for locking with a padlock.

4.5.4 Conservator Tanks, Breathers and Air Dryers

4.5.4.1 Each transformer shall be provided with an overhead conservator tank formed of substantial

steel plates and arranged above the highest point of the oil circulating system (see also Clause 4.6. 1). Connections into the main tank shall be at the highest point to prevent the trapping of air or gas under the main tank cover.

4.5.4.2 The capacity of each conservator tank shall be adequate for the expansion and contraction of oil in the whole system under the specified operating conditions. Conservator tanks shall also be provided with a cleaning door, filling cap, drain valve with captive cap and an oil level indicator with minimum and maximum levels indicated. The normal level at an oil temperature of 25˚C shall be indicated and the minimum and maximum levels shall also be correlated with oil temperature markings. The temperature markings shall preferably be integral with the level indicating device.

4.5.4.3 The location of the conservator tank shall be so arranged that it does not obstruct the passage of high voltage conductors immediately above the transformer.

4.5.4.4 The pipework between the conservator and the transformer tank shall comply with the requirements of Clause 4.6.1 and a valve shall be provided at the conservator to cut off the oil supply to the tank.

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

4.5.4.6 Schedules for Indoor Surfaces Finishes

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

Treatment at Factory	Treatment at Site after Completion of Erection
	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).

4.5.4.7 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 microns) of two pack epoxy zinc phosphate primer followed by two coats two pack epoxy micaceous iron oxide (250 microns total).	Thoroughly clean to remove oil, grease and dirt. Paint coats to be touched up where necessary. Then apply one tie coat to match finish (30 microns) and one coat alkyd gloss (25 microns)
(b) Steel floors, chequer plates, galleries, stairways, treads, kick stops	
Galvanised to BS 729	Thoroughly clean to remove oil, grease and dirt. Where galvanising is damaged, wire brush to BS 7079 3rd quality (SA2) and apply one coat zinc rich epoxy primer (50 microns). Then apply: 1st coat epoxy etch primer

Treatment at Factory	**Treatment at Site after Completion of Erection**
	2nd coat epoxy zinc chromate (30microns) 3rd coat two pack epoxy micaceous iron oxide (100 microns) On galleries and stairways top surfaces apply: 4th coat non-skid epoxy deck paint (30 microns).
(c) Galvanised iron and steel requiring paint finish	
Galvanised to BS 729	Thoroughly clean to remove oil, grease and dirt. Then apply: 1st coat etch primer 2nd coatzinc chromate primer (30microns) 3rd coat alkyd undercoat (30 microns) 4th coat alkyd gloss (25 microns).
(d) Stainless steel, aluminium alloys and non-ferrous alloys requiring paint finish	
Not applicable.	Thoroughly clean to remove oil, grease and dirt. Then apply: 1st coat alkyd undercoat (30 microns) 2nd coat alkyd gloss (25 microns).

4.5.5 Breather

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

4.5.5.2 The dehydrating breather of a maintenance-free and self-supervision type shall be mounted on the conservator of the transformer and the tap changers. Silica gel shall be used as a drying agent. It is automatically regenerated by the internal heater element controlled by a microprocessor control unit. The relative humidity of the air flow must be controlled by a humidity sensor. The device should have a service-friendly design: The humidity and temperature sensor, the silica gel and the PCB shall be replaceable in the field.

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

4.5.5.4 Beta-control: The maintenance-free breather shall be equipped with a self-learning algorithm that enables the regeneration process only when the conservator is exhaling. This algorithm is based on humidity monitoring and the temperature-dependent determination of the most advantageous time to perform heating.

4.5.5.5 There shall be no moving parts to restrict or redirect the air flow from the desiccant chamber. The use of fans to expel condensed water out of the desiccant chamber is also not permitted. Weight cells are not accepted, as well. The flange of the breather (Conservator piping) must be with rigid metal flanges (Hose/flexible connection won't be accepted). The flanges shall be in accordance with the norm DIN 42562-3. The grade of protection of the device shall be IP66/67. The device

shall be of MESSKO – MtraB or equivalent.

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

4.5.6 Valves

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

4.5.6.1 Main Tank

(A) One 50mm bore filter valve located near to the top of the tank.

(B) One 50 mm bore filter valve located near to the bottom of the tank and diagonally opposite to the filter valve required against (A). Where design permits, this valve may be combined with item (C).

(C) One 50mm drain valve with such arrangements as may be necessary inside the tank to ensure that the tank can be completely drained of oil as far as practicable. This valve shall also be provided with an approved oil sampling device.

(D) One valve between the main tank and gas actuated relay, complete with bypass facility to facilitate removal of relay and maintain oil flow.

4.5.6.2 Conservator

(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.

4.5.6.3 Tap Changer

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

4.5.6.4 Diverter Switch

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

4.5.6.5 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.

4.5.6.6 The two valves (D) and (E) arrangement across the gas-actuated relay are to be connected with an oil pipework bypass facility to facilitate removal of the relay, due to failure etc., and still maintain the oil flow system between the conservator and main tank.

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

4.5.6.8 The omission of any, or the provision of alternative arrangements to the above requirements, will not be accepted unless approved in writing by the Engineer before manufacture.

4.5.7 Joints and Gaskets

4.5.7.1 All joint faces shall be arranged to prevent the ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of oil or air.

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

4.5.7.3 Gaskets shall be as thin as possible consistent with the provision of a good seal and full details of all gasket sealing arrangements shall be shown on the Plant drawings. Gaskets shall be of nitrile rubber.

4.5.7.4 All gaskets shall be of closed design (without open ends) and shall be of one piece only. Gaskets are not allowed to be re-used and needs to be replaced on all locations where the connection has been opened.

4.5.7.5 Metal surfaces to which gaskets are applied shall be finished smooth, seamless, and shall be designed with sufficient rigidity to assure proper compression of the gaskets.

4.5.7.6 Machine grooves shall be provided so that over-compression of the gaskets cannot occur, unless it is demonstrated to the Purchaser's satisfaction that the manufacturer is using another gasketing system of high quality and reliability.

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

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

4.5.8 Pressure Relief Device

4.5.8.1 An approved pressure relief device of sufficient size for the rapid release of over pressure that may be generated in the tank, and designed to operate at a static pressure lower than the hydraulic test pressure called for in Section 15, shall be provided. It shall be of the spring operated valve type (Qualitrol/ Messko or equivalent) and shall be provided with one set of normally open signalling contacts that will be used for trip alarm purposes.

4.5.8.2 The relief device is to be mounted on the tank cover and is to be provided with a skirt to project at least 25mm into the tank to prevent gas accumulation. Discharge of oil shall be directed away from the transformer top cover and clear of any operating position. Means shall be provided to direct the oil discharge to the oil collecting pit.

4.5.8.3 The Pressure Relief Device (PRD) for main tank shall consist of double synthetic coated and cathode corrosion protected springs made of spring steel acc. to Class 1 European Standard EN10270-1-SH to make sure that the springs transmit the pressure equally to the entire opening plate and neither lose their tension nor corrode.

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

4.5.8.5 The release time of the device shall not be more than 2 ms. A semaphore for clear indication of a signalling event shall be provided. A routine leak test with Helium Gas shall be performed, the device shall pass a leakage test at 1.50E-05 mbar l/sec or below and test report of each device shall be submitted.

4.5.8.6 To protect the device against environmental influences such as water and UV exposure, all important parts such as springs, valve disc, switching contacts and gaskets shall be mounted under the aluminum cover.

4.5.9 Earthing Terminals

Two substantial steel flag type terminals each having two 14mm diameter holes on 55mm centres shall be located one on either side and near to the bottom of the transformer to facilitate connection to the local earthing system.

4.5.10 Rating, Diagram and Valve Plates

4.5.10.1 The following plates, or an approved combined plate, shall be fixed to each transformer tank at an average height of 1500mm above the ground level:-

(A) A rating plate bearing the data specified in IEC 60076 Part 1. This plate shall also include the short-circuit current rating and time-factor for each winding & the data mentioned in clause no.1.3.7.11

(B) A diagram plate showing in an approved manner the internal connections and the voltage vector relationship of the several windings, in accordance with IEC 60076 Part I with the transformer voltage ratio for each tap and, in addition, a plan view of the transformer giving the correct physical relationship of the terminals.

(C) A plate showing the location and function of all valves and air release cocks or plugs. This plate shall also if necessary warn operators to refer to the Maintenance Instructions before applying vacuum.

4.5.10.2 Plates are to be of stainless steel or other approved material capable of withstanding the rigours; of continuous outdoor service at site.

4.6 Cooling Plant

4.6.1 Cooling Plant General

4.6.1.1 Radiators and coolers shall be hot-dip galvanised, designed so that all painted surfaces can be thoroughly cleaned and easily painted in situ with brush or spray gun. The design shall also avoid pockets in which water can collect and shall be capable of withstanding the pressure tests specified in Section 15 for the transformer main tank.

4.6.1.2 The transformer cooling equipment shall be arranged to provide a uniform distribution of cooling within the transformer with either or both stages in operation. The clearance between any oil or other pipework and live parts shall be not less than the minimum clearances stated in the Schedule of Requirements.

4.6.2 Radiators

4.6.2.1 The design and construction of the radiators shall be such as to eliminate pockets where moisture can accumulate or which can prevent application of a continuous film of paint. Radiators shall have the necessary piping, fittings, valves, drains, and bleeder connections so that individual radiators may be removed and replaced with the transformer in service.

4.6.2.2 Where built-on radiators are used, each radiator shall be connected to the main tank through flanged valves. Plugs shall be fitted at the top of each radiator for air release and at the bottom for draining.

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

4.6.2.4 Radiators shall be connected to the main tank through flange mountings with shut off valves at the top and bottom to permit shut - off of oil from the main tank for removal or installation of the coolers. Valves shall be designed to withstand maximum differential forces that can be applied during normal vacuum type oil filling operations.

4.6.2.5 The radiators shall have solid steel plugs provided at the top and ball type drain valves at the bottom shipped with solid steel plugs. All radiators shall be galvanized and shall use plate type radiators. All radiators shall be flushed out prior to shipment. Pipe caps shall be provided at the top and pipe plugs at the bottom of each cooler to permit field flushing when desired.

4.6.2.6 The oil flow pattern to and from the coolers and through the transformer coils shall be designed to be free of turbulence and shall not cause impinging of oil on any part of the solid insulation system.

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

4.6.2.8 Refer to the Data Sheets for unusual service conditions that can affect radiator efficiency during the life of the transformer.

4.6.3 Cooler Banks

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

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

4.6.5.2 The oil piping shall be of approved material with machined flanged joints. Copper pipework is to comply with BS 61.

4.6.5.3 Dimensions of steel pipes shall be in accordance with BS 3600 and the drilling of all pipe flanges shall comply with BS EN 1092.

4.6.5.4 An approved expansion piece shall be provided in each oil pipe connection between the transformer and each oil cooler bank.

4.6.5.5 All necessary pipe supports, foundation bolts and other attachments are to be provided.

4.6.5.6 It shall be possible to drain any section of pipework independently of the rest and drain valves or plugs shall be provided as necessary to meet this requirement.

4.6.6 Air Blowers

4.6.6.1 Air blowers for forced air cooling shall be of approved make and design and be suitable for continuous operation out-of-doors. They shall also be capable of withstanding the stresses imposed when brought up to speed by the direct application of full line voltage to the motor.

4.6.6.2 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.

4.6.6.3 It shall be possible to remove the blower, complete with motor, without disturbing or dismantling the cooler structure framework.

4.6.6.4 Blades shall be of material subject to approval.

4.6.6.5 Blower casings shall be made of galvanised steel of thickness not less than 2.6mm (14 S.W.G.) and shall be suitably stiffened by angles or tees.

4.6.6.6 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

4.6.7.1 Where forced cooling using multiple small single-phase motors is employed, the motors in each cooling bank shall be grouped so as to form a balanced three-phase load.

4.6.7.2 Each motor or group of motors shall be provided with a three-pole electrically operated contactor and with control gear of approved design for starting and stopping manually.

4.6.7.3 Where forced cooling is used on transformers, provision shall be included under this contract for automatic starting and stopping from contacts on the winding temperature indicating devices as specified. The control equipment shall be provided with a short time delay device to prevent the starting of more than one motor, or group of motors in the case of multiple cooling, at a time.

4.6.7.4 Where motors are operated in groups, the group protection shall be arranged so that it will operate satisfactorily in the event of a fault occurring in a single motor.

4.6.7.5 The control arrangements are to be designed to prevent the starting of motors

totalling more than 15kW simultaneously, either manually or automatically. Phase failure relays are to be provided in the main cooler supply circuit.

4.6.7.6 All contacts and other parts that may require periodic renewal, adjustment or inspection shall be readily accessible.

4.6.7.7 All wiring for the control gear accommodated in the marshalling kiosk, together with all necessary cable boxes and terminations and all wiring between the marshalling kiosk and the motors, shall be included in the contract.

4.6.7.8 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

4.7.1.1 Transformers shall be provided with tap changers for varying the effective transformation ratio. Control schemes shall utilise voltage derived from the 400V, 3 phase, 4 wire system. Phase failure relays shall be provided to ensure a secure supply.

4.7.1.2 Winding taps as called for in the Schedule A of Requirements shall be provided on the high voltage winding.

4.7.1.3 All terminals shall be clearly and permanently marked with numbers corresponding to the cables connected thereto.

4.7.1.4 Tap positions shall be numbered consecutively, ranging from one upwards. The tap positions shall be numbered so that by raising the tap position the LV voltage is increased.

4.7.2 On-Load Tap Changers

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.

4.7.2.1 Capabilities and Ratings

4.7.2.1.1 ***Load-tap changing equipment shall provide plus and minus 10% in-phase regulation of the high voltage winding in 17 steps of approximately 5/8% each. All voltages listed on the nameplate shall reflect the actual design voltages, rounded to the nearest 10 volts.***

4.7.2.1.2 ***All taps shall be full capacity taps.***

4.7.2.1.3 ***The tap changer is required to regulate the secondary voltage for a varying primary voltage on the transformer as well as for the increased voltage drop due to increased load on the transformer.***

4.7.2.1.4 ***The transformer shall be capable of full MVA output should the LTC stall in any off-tap position. The tap changer shall be capable of completing a tap change if a thru-fault occurs after a tap change has begun.***

4.7.2.1.5 LTC's shall be capable of parallel operation with circulating currents not to exceed 20% of rated current.

4.7.2.1.6 All components of the transformer shall be capable of carrying maximum rated current at all tap positions.

4.7.2.1.7 Series load tap changer windings, if any, shall be so sized and arranged that they, or any of their associated leads, do not become the transformer hot spot or generate gasses if the transformer is operating at full buck at maximum current above nameplate capacity.

4.7.2.2 Tap changer operation mechanism

4.7.2.2.1 A mechanism for hand operation shall be provided. A permanently legible lubrication chart shall be provided and fitted inside the tap change mechanism chamber.

4.7.2.2.2 The tap change mechanism shall be designed such that when a tap change has been initiated, it will be completed independently of the operation of the control

relays and switches. If a failure of the auxiliary supply during tap change or any other contingency would result in that movement not being completed, an approved means shall be provided to safeguard the transformer and its auxiliary equipment.

4.7.2.2.3 LTC drive motor shall include the following:

i) A driving motor suitable for operation from the station service source described in the Appendix. 230 VAC motor is preferred. Motors rated 240 VAC or 415 VAC shall be capable of operating at either voltage.Proper working of the drive motor shall be ensured up to 25% below the rated voltage.
ii) Suitable thermal & overload protection and motor starting contactors for the driving motor control.
iii) An ammeter to monitor the drive motor.
iv) Under-voltage relays sensing loss of power to the LTC motor and controls.

4.7.2.2.4 Thermal devices or other approved means shall be provided to protect the motor and control circuit. Mechanical position indicator with provisions to show maximum raise and lower positions of the mechanism by means of manual reset indicators. The drag-hand reset device shall be located less than five feet above the base of the transformer. The dial-type indicator shall be configured so that the dial moves in the clockwise direction for tap changes in the raise direction (increasing LV voltage).

4.7.2.2.5 Two operation counters; one will display total operations and the other will be resettable and will have an alarm contact for excessive operations. The number of operations for which the alarm contact closes shall be user-adjustable.

4.7.2.3 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.

4.7.2.4 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.

4.7.2.5 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.

4.7.2.6 Paralleling facilities

4.7.2.6.1 Transformers supplied against each item shall be designed to operate satisfactorily, one with the other, when operating on the same tap position.

4.7.2.6.2 A circulating current paralleling scheme shall be used for parallel operation of the transformer's regulating equipment with a similar unit as described in the Specific Transformer Data Sheets. This scheme shall insure that the transformers are within two steps of each other while they are operating in parallel.

4.7.2.6.3 Equipment shall be installed to block operation of the load tap changing equipment in a direction which would increase circulating current for an abnormal condition.

4.7.2.6.4 Suitable current transformers shall be provided for line drop compensator operation and/or for input to a circulating current paralleling scheme. Phase(s) to be used for LDC CT’s are identified on the Specific Transformer Data Sheet. Secondary leads shall be connected to terminal blocks in the CT cabinet. Auxiliary CT’s (1:0.2 amp) shall be provided as necessary.

4.7.2.6.5 A 52Y (Interposing relay) with (2 NO and 2NC) contacts shall be provided for use by the Customer in the paralleling scheme.

4.7.2.6.6 Provisions shall be made to permit either phase-to-neutral or phase-to-phase voltage input along with corresponding CT connections.

4.7.2.6.7 A 17 step resistor (25 ohm, 3 watt resistor per step, 800 ohms total) shall be provided for use by the Employer to indicate tap position as per standard practice.

4.7.2.7 OLTC Accessories:

4.7.2.7.1 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).

4.7.2.7.2 Necessary equipment to permit parallel operation with the transformers specified. This equipment shall include:

a) An adjustable time delay relay, to start timing on operation of the circulating current relay.
b) Current test facilities, testing LDC current transformer and circulating current relay.
c) An auxiliary relay used in conjunction with the LTC control relay, to block tap changer operation and transmit remote alarm on time out of the time delay relay. Alarm contact(s) shall be connected as required to the HIGH CIRCULATING CURRENT ALARM point on the local annunciator. Auxiliary relay shall have contacts rated for 125VDC.

4.7.2.7.3 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.

4.7.2.7.4 Limit switches shall be provided to prevent over-running of the tap changing mechanism. These shall be directly connected in the operating motor circuit. In addition, mechanical stops shall be fitted to prevent over-running of the mechanism under any conditions. For on-load tap change equipment these stops shall withstand the full torque of the driving mechanism without damage to the tap change equipment.

4.7.2.7.5 Lamp receptacle controlled by a door switch and located remote from control wires. Receptacle shall be for IEC standard medium base lamps. IEC grounded convenience receptacle with GFI protection in the control cabinet.

4.7.2.7.6 Parts or components of the tap changer that will require periodic adjustment or replacement shall be built to IEC Standards permitting the use of standard tools.

4.7.2.7.7 Space heater(s) with protective guard(s), located to prevent overheating wiring or equipment or accidental contact by personnel checking wiring.

4.7.2.7.8 Space heaters shall be uncontrolled and sized to maintain internal cabinet temperature at least 5°C above external ambient, with external ambient temperature as per Section 4.4, Service Conditions.

4.7.2.7.9 Multiple heaters safely distributed over bottom of control cabinet shall be provided if more than 350 watts (net) is required. To be controlled by 20A circuit breaker.

4.7.2.7.10 Rated voltage of space heaters shall be at least 67% higher than the applied voltage.

4.7.2.7.11 All LTC control wiring shall be stranded copper, with thermosetting 600V insulation, 90°C or higher, electrically, thermally and mechanically suitable for its environment and application. Flame, oil and heat resistant wiring with higher voltage thermosetting insulation or higher operating temperatures are acceptable without prior approval.

4.7.2.7.12 A Non-GGCI outlet (refer to section below for rating) to be provided.

4.7.2.7.13 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.

4.7.2.7.14 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.

4.7.2.7.15 The power supply for the LTC motor shall be as specified in the Data Sheets in the Appendix. AC and DC auxiliary power for LTC motor and controls shall be routed from the cooling equipment control cabinet as separate branches.

4.7.2.7.16 A hand crank shall be provided for operating the LTC for maintenance or due to a defective motor. It shall not be necessary to take the transformer out of service to

manually operate the LTC. Interlocks shall be provided to de-energize motor while hand crank is in place for manual operation. Heavy duty limit switches shall be provided to cut off the LTC motor circuit and control circuit at the end of the desired travel. Separate contacts shall be provided for the motor circuit and the control circuit. Limit switches shall not be located in any oil filled compartments.

4.7.2.7.17 Torque switches for motor and/or control circuit shutoff are not acceptable. LTC drive motor and controls may be in a common control cabinet. The control cabinet for OLTC drive motor and controls shall be separate from the control cabinet for transformer cooling controls, miscellaneous controls, alarms and CT lead terminations unless otherwise specified.

4.7.2.7.18 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.

4.7.2.7.19 The top of the LTC control cabinet shall not be more than six feet above the base of the transformer. Exposed operating shafts between the LTC and the control cabinet shall be equipped with removable shrouds for personnel safety.

4.7.2.7.20 The following equipment shall be housed in all LTC control cabinets. No control or indicating devices shall be mounted on the outer cabinet doors.

4.7.2.7.21 Voltage test terminals to permit monitoring voltage regulating relay input voltage and to permit impressing external voltages for calibration and setting of voltage regulating relay. (Accessible from ground with doors open)

4.7.2.7.22 All control wiring shall terminate with insulated full ring lugs on one side of 600V, 25A (or higher), double row barrier type terminal blocks with screw terminals and captive links. Barrier spacing shall be sufficient to permit termination of wiring using Insulated Full Ring Terminal with Seamless Barrel or Braised Barre

4.7.2.7.23 No more than two wires shall be terminated under any given screw terminal. Manufacturer's wiring to terminal blocks intended for extension by Employer shall terminate on one row, with the other row kept clear of Manufacturer's wiring. The row used for Manufacturer's wiring and Customer's wiring shall be consistent on all terminal blocks in a vertical column, with rows arranged so Customer's cables may rise between two adjacent rows and fan out in each direction. There shall be a wiring extension to a connection box where plug/ receptacle type connectors shall be used for quick connection of wiring into modular substation.

4.7.2.7.24 All wiring associated with tripping, including lockout relays and initiating devices, shall be unfused.

4.7.2.7.25 All Manufacturer's LTC control wires shall be provided with indelible marker sleeves at

each termination designating the location of the opposite end termination.

4.7.2.7.26 All wiring inside the LTC control cabinet shall be run in wire duct with snap on covers to permit easy tracing of circuits. Open wiring bundles with wraps are not acceptable.

4.7.2.7.27 All components in the LTC control cabinet shall be capable of continuous operation with an air temperature inside the cabinet that is 10°C above the outdoor ambient temperature as specified in Section 4, Service Conditions. Any load tap changer shall be capable of successfully completing a tap changing operation without damage if an external short circuit occurs while the load tap changer is changing taps.

4.7.2.7.28 Line drop compensator, control relays, time delay relays and facilities for readily reversing polarity of reactance compensation. See Data Sheets for specific transformer.

4.7.2.7.29 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 the snap-action contact 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. The volume of gas shall thereby be reduced by around ***80-90%***.

4.7.2.7.30 Typically it is named as The Active Gas Inhibition/Reduction System (AGIS/AGRS) ***.***AGIS/AGRS shall be provided for high-voltage & high Power Transformer***.***

4.7.2.8 Local and Remote Control

Equipment for local manual and electrical operation shall be provided in an outdoor cubicle complying with Section 2. A thermostat controlled anti-condensation heater is to be provided in the cubicle. Electrical remote control equipment shall also be supplied as specified in the Schedule A - Schedule of Requirements.

The following operating conditions are to apply to the on-load tap changer controls:

(A) It must not be possible to operate the electric drive when the manual operating gear is in use.

(B) It must not be possible for two electric control points to be in operation at the same time.

(C) Operation from the local or remote control switch shall cause one tap movement only, unless the control switch is returned to the off position between successive operations.

(D) It must not be possible for any transformer operating in parallel with one or more transformers in a group to be out of step with the other transformers in the group. Any deviation in the position of tap changers has to stop further function of the AVR. (Out of step protection)

(E) All electrical control switches and local manual operating gear shall be clearly labelled in an approved manner to indicate the direction of tap changing, i.e. raise and lower tap number.

(F) Emergency stop push-button at local and remote control positions.

4.7.2.9 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

4.7.4.1 Automatic voltage control shall be initiated by a voltage regulating relay of an approved type and suitable for flush mounting. The relay shall operate from the nominal reference voltage stated in the Schedule of Requirements derived from a circuit mounted LV voltage transformer having Class 1.0 or 0.5 accuracy to IEC 60044-5 (for capacitive) IEC 60044-2 (for inductive) and the relay voltage reference balance point shall be adjustable.

4.7.4.2 The relay bandwidth shall preferably be adjustable to any value between 1.5 times and 2.5 times the transformer tap step percentage, the nominal setting being twice the transformer tap step percentage.

4.7.4.3 The relay shall be insensitive to frequency variation between the limits of 47Hz and 51Hz. The relay shall be complete with a time delay element adjustable between 10 and 120 seconds. The relay shall also incorporate an under voltage blocking facility which renders the control inoperative if the reference voltage falls below 80 percent of the nominal value with automatic restoration of control when the reference voltage rises to 85 percent of

nominal value.

4.7.4.4 On each transformer the voltage transformer supply to the voltage regulating relay shall be monitored for partial or complete failure. The specified indicating lamp and alarm will be inoperative when the circuit breaker controlling the lower voltage side of the transformer is open and also that when the tap changer is on control other than automatic control.

4.7.5 Remote Control Panels

4.7.5.1 The remote control panels specified in the Schedule of Requirements shall be floor mounted sheet steel cubicles of approved type, layout and colour to Munsell notation 5Y-7/1 and shall be provided for each transformer. The control cabinet shall be of weather - proof construction with dip edge over 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.

4.7.5.2 One (1) 20 Amp, 230 VAC, single phase, wire grounded duplex convenience receptacle(GFI protected) shall be provided in the control cabinet.

4.7.5.3 Weather - shielded, screened breather holes shall be furnished at the top and bottom of the cabinet.

4.7.5.4 The bottom of the control cabinet shall have a removable plate suitable for the Customer's conduit connections. The removable plate shall be 8" x 20" or larger. The dimensions and center line location of this plate shall be clearly shown on the outline drawing.

4.7.5.5 Each shall form a complete enclosure with lockable rear doors and shall be fitted with interior lamp, door switch, heaters, cable gland plates for bottom entry of cables and all other equipment to provide the features specified, the standard requirements (which may be varied to suit Manufacturer's design) being as follows:

- Instruments:
  - Voltmeter (voltage at the low voltage terminals of the transformer)
  - Tap position indicator with integral or separate scale to indicate the no-load (LV) Voltage in kV appropriate to each winding tap.
- Relays:
  - Automatic voltage control
- Controls:
  - Automatic/Non-automatic voltage control selector switch
  - Remote/Supervisory tap change control selector switch
  - Pistol grip selector switch with centre zero
  - Independent/Master/Follower selector switch
  - AVR voltage reference adjuster
- Indications and Alarms:
  - Tap change in progress - white lamp

- Tap change out of step - amber lamp
- Tap change incomplete - amber
- Tap change control on "local"
- Tap change control on auto/manual
- Group 1 Air forced cooling equipment running - white
- Group 1 Air forced cooling overcurrent alarm - amber
- Group 2 Air forced cooling equipment running - white
- Group 2 Air forced cooling overcurrent alarm - amber
- Forced cooling failure-amber lamp
- VT Fail alarm - amber
- Supply voltage to OLTC failure - amber lamp

Remote control schemes shall be entirely suitable for operation with the distance between the transformer and remote control panels as shown on the Specification drawings.

4.7.6 Off-Load Tap Changers

4.7.6.1 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.

4.7.6.2 A positive type position indicator shall be furnished, complete with provisions for padlocking the DETC in any on‑tap position with padlocks having 3/8" shanks and 2" x 2" x 7/8" bodies. A suitable weather shield shall be provided over the padlock and positioning pin and shall be designed to eliminate the need for tools for access. Any exposed portion of the mechanism, such as a position indicator or geneva gear, shall also be furnished with a weather shield.Off-load tap-changing shall be carried out by means of an external hand-operated tapping switch mounted on the side of the tank. All phases of the tapping switch must be operated by one hand wheel.

4.7.6.3 All DETCs on a transformer shall be operated by a suitable single external manual handle device, conveniently and safely operable from the ground, with the handle no more than 3 to 5 feet above the tank base. Multiple DETC operating handles are not acceptable.

4.7.6.4 The DETC operating handle is to be readily accessible for operation without interference from adjacent parts. All taps shall be rated for loading above maximum nameplate capabilities of the transformer as specified in Data Sheets.

4.7.6.5 Any shaft penetration designs directly through the tank wall at a location below the top of the core/coil assembly shall have double sealing on the rotating shaft and on the mounting flange.

4.7.6.6 Under no conditions shall a sprocket and chain drive arrangement be acceptable for connecting the DETC assemblies on each phase to the common operating shaft.

4.7.6.7 The tapping switch shall have a spring-loaded captive bolt or other approved means on the moving part that positively locates the switch correctly at each tapping position. This bolt must be lockable at each tapping position and shall be provided with a suitable padlock and keys. Moving the switch from one tapping position to another shall require that the bolt be

withdrawn by hand from its locating socket on the transformer tank against the spring pressure.

4.7.6.8 Tap-position numbers corresponding to the tapping switch bolt-locating sockets shall be cast or engraved in a metal indication plate fixed to the tank and a keyed metal pointer on the tapping switch operating handle shall show clearly at which tapping number the transformer is operating.

4.7.6.9 All tap-position indicators shall be marked with one integer for each tap position, beginning at number 1. Adjacent taps shall be numbered consecutively in such a manner that when moving a tap to a new tapping position that has a higher number, the no-load output voltage of the untapped winding increases.

4.7.6.10 DETCs shall be prevented from being left between taps and shall be prevented from moving off tap due to vibrations or bumping.

4.7.6.11 All tapered pins used in DETC assemblies shall be fully driven into the holes, slightly below the surface of the entrance side of the holes, and the entrance side of the holes deformed.

4.8 Supervisory Control

4.8.1 Requirements

Transformer tap change control will be affected from the substation control room with facilities for remote control from the Load Despatch Centre. All necessary connections, indications, auxiliary switches, relays and changeover switches to meet supervisory control requirements shall be provided and connected under this contract to terminal blocks in the remote control panels. The supply and installation of the multicore control cables between the remote control panels and the plant/telecontrol interface cubicle shall be provided under the contract.

4.8.2 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

4.9.1.1 Where stated in the Schedule of Requirements, transformers are to be provided with outdoor type bushing insulators.

4.9.1.2 All bushings shall comply with IEC 60815& IEC 62217. The minimum creepage distance for outdoor bushings shall not be less than 25mm per kV of rated voltage between phases.

4.9.1.3 Outdoor bushing insulators shall be provided with adjustable arcing horns where applicable and for rated voltages of 33kV and lower these shall be of the duplex gap type.

4.9.1.4 Bushings shall be of sealed construction suitable for service under the very humid conditions at Site and, addition, for the very rapid cooling of equipment exposed to direct sunlight when this is followed by sudden heavy rainstorms.

4.9.1.5 Typical sections of bushing insulators showing the internal construction, method of securing the top cap and methods of sealing shall be included in the Bid.

4.9.1.6 The bushings shall be located on the top of the tank so that a bushing may be replaced without the need to reduce the oil level below the top of the windings.

4.9.1.7 n all bushings a tapping shall be brought out to a separate terminal for testing purposes on site.

4.9.1.8 Special precautions shall be taken to exclude moisture from paper insulation during manufacture, assembly, transport and erection.

4.9.2 Type, rating & Construction of Bushings

4.9.2.1 All bushings shall be Resin Impregnated Paper (RIP) bushings oil-free dry and clean technology. All terminal bushings (unless otherwise noted on the Specific Transformer Data Sheet) shall be located on the tank cover and shall be in accordance with IEC Standards where applicable.

4.9.2.2 The current rating of each bushing shall be equal to or greater than the current it will carry at the maximum forced-cooled rating and overload rating. Additionally, the current rating of each neutral bushing shall not be less than the current rating of the associated line bushings. The H0X0 bushing, when required, shall be rated to sustain the maximum operating current of the common winding.

4.9.2.3 Bushing leads shall be accessible from the bushing cover. Accessibility to leads shall not require personnel to enter the transformer tank. draw-lead connection is required for all bushings whenever possible. In cases where the transformer winding leads are bolted to the bottom of the bushings, two-bolt connections shall be used; single-bolt connections are not acceptable.

4.9.2.4 Approved suppliers of bushings are: ABB (Sweden), Trench (France/USA), HSP (Germany), (and as specified in Technical data sheets). For low voltage ELMEK (Turkey) & CEDASPE (Italy) are acceptable.

4.9.2.5 Bushing outline drawings with stud sizes identified shall be submitted with transformer approval drawings.4 ‑ hole IEC bushing terminal connectors shall be supplied for each bushing. Connectors shall be tinned copper ‑ bronze, and finished on both sides. Cut sheets shall be provided showing materials, dimensions and current rating of terminal connectors. Type test of the Busing for Short circuit force withstand capability shall be submitted with the Bid and the same shall be submitted during execution for approval.

4.9.3 Bushings for Buried Z-Terminals

4.9.3.1 Where a buried delta tertiary is specified, the corner of the delta shall be brought out through bushings. The corner of the delta shall be completed externally and grounded through an external connection. The two winding terminals at one corner of the tertiary delta shall be separately brought through 15 kV bushings mounted on the tank cover. Removable straps shall be furnished to connect the external bushing terminals together and to the tank. The bushings shall be located and labeled to avoid confusion with other bushings, and shall be protected with a removable, weatherproof metal cover.

4.9.3.2 An instruction plate shall be furnished and mounted near these bushings, specifying that the external bushing terminals must be connected together, and to the tank, whenever the transformer is energized. The same instructions shall be shown on the main transformer nameplate.

4.9.4 Porcelain (Not used)

4.9.4.1 Hollow porcelain shall meet the test requirements of IEC 60233 and shall be sound, free from defects and thoroughly verified. Designs based on jointed porcelains will not be acceptable. The glaze must not be depended upon for insulation. The glaze shall be smooth, hard, of a uniform shade of brown and shall cover completely all exposed parts of the insulator. Outdoor insulators and fittings shall be unaffected by atmospheric conditions producing weathering, acids, alkalis, dust and rapid changes in temperature that may be experienced under working conditions.

4.9.4.2 The porcelain must not engage directly with hard metal and, where necessary, gaskets shall be interposed between the porcelain and the fittings. All porcelain clamping surfaces in contact with gaskets shall be accurately ground and free from glaze.

4.9.4.3 All fixing material used shall be of suitable quality and properly applied and must not enter into chemical action with the metal parts or cause fracture by expansion in service. Cement thicknesses are to be as small and even as possible and proper care is to be taken to centre and locate the individual parts correctly during cementing.

4.9.4.4 All porcelain insulators shall be designed to facilitate cleaning.

4.9.5 Silicone Rubber

4.9.5.1 Resin Impregnated Paper (RIP) Condenser Bushing shall use Silicone Rubber composite insulator as housing of the bushing.

4.9.5.2 Bushings shall be robust and designed for adequate cantilever strength to meet the requirement of seismic condition, substation layout and movement along with the spare Transformer/ Reactor with bushing erected and provided with proper support from one foundation to another foundation within the substation area. It shall have Low dielectric losses.

4.9.5.3 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.

4.9.5.4 The bushing shall be provided with tap for capacitance and tan delta test. Test taps relying on pressure contacts against the outer earth layer of the bushing is not acceptable.

4.9.5.5 Where current transformers are provided, the bushings shall be removable without disturbing the current transformers.

4.9.5.6 Bushings of identical rating shall be interchangeable to optimise the requirement of spares.

4.9.6 Polymer / Composite Insulator

4.9.6.1 Different composite insulating materials are available like EP, PTFE, EPDM or silicone for use as Composite Insulator. For Bushing application under this specification, silicone rubber (SiR/SR) shall be used.

4.9.6.2 The hollow silicone composite insulators shall comply with the requirements of the IEC

publications IEC 61462 and the relevant parts of IEC 62217.

4.9.6.3 The material shall be non-inflammable, have no partial discharge during whole lifetime, Secondary insulation shall be Dry material filler, i.e., no oil or gas shall be used inside the bushing and maximum operating temperature shall be 120°C or more.

4.9.6.4 The SiR generally ha◌ the following component –

- Basic polymer
- Filler, normally AluminiumTriHydrate, ATH
- Catalyst
- Other additives, for instance mould release agent

4.9.6.5 Proper combination shall be made to meet specific requirement of this specification. Silicone rubber shall withstand ozone and UV light. The Material shall be suitable for outdoor use, i.e. temperature range, as mentioned in the bidding document.

4.9.6.6 The design of the composite insulators shall be tested and verified according to IEC 61462 (Type & Routine test).

4.9.6.7 The insulator shall have Epoxy resin tube supported with fiber glass as mechanical reinforcement. On each end of the tube there shall be a flange made of cast aluminum alloy.

4.9.6.8 Polymer / composite insulator shall be seamless sheath of a silicone rubber compound. The housing & weather sheds should have silicon content of minimum 30% by weight. It should protect the bushing against environmental influences, external pollution and humidity.

4.9.6.9 It shall be extruded or directly moulded on the core. The interface between the housing and the core must be uniform and without voids. The strength of the bond shall be greater than the tearing strength of the polymer. The manufacturer shall follow non-destructive technique (N.D.T.) to check the quality of jointing of the housing interface with the core.

4.9.6.10 The weather sheds of the insulators shall be of alternate shed profile as per IEC 60815 The weather sheds shall be vulcanized to the sheath (extrusion process) or moulded as part of the sheath (injection moulding process) and free from imperfections.

4.9.6.11 Different formulations of silicone rubber require different processing when producing high voltage insulators. For example –

4.9.6.12 Low pressure moulding (up to **10** bar) with relatively low curing temperatures (**50**–**80** °C) is used with low viscosity RTV (Room Temperature Vulcanised) or LSR (Liquid Silicone Rubber) rubber.

4.9.6.13 High pressure injection moulding (up to **250** bar) with high curing temperatures (**130**–**180** °C) is used with HTV (High Temperature Vulcanising) rubber. Helical winding of an extruded profile to give an insulator with a thread shaped shed is used with HTV when a high degree of production flexibility is desired.

4.9.6.14 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 **1**A**4.5** according to IEC **60587.**

4.9.6.15 The strength of the weather shed to sheath interface shall be greater than the tearing strength of the polymer. The composite insulator shall be capable of high pressure washing.

4.9.6.16 End fittings shall be free from cracks, seams, shrinks, air holes and rough edges. End fittings should be effectively sealed to prevent moisture ingress, effectiveness of sealing system must be supported by test documents.

4.9.6.17 The surface shall be Water repellent & self-cleaning, High hydrophobicity over the whole life time. All surfaces of the metal parts shall be perfectly smooth with the projecting points or irregularities which may cause corona. All load bearing surfaces shall be smooth and uniform so as to distribute the loading stresses uniformly. It must be confirmed that, the surface colour shall not degrade over it's lifetime.

4.9.6.18 Clamps and fittings shall be of stainless steel. Bushing turrets shall be provided with vent pipes, to route any gas collection through the Buchholz relay. No arcing horns shall be provided on the bushings. The terminal marking and their physical position shall be as per IEC: **60076.**

4.9.6.19 Bushing handling and lifting tools with nylon rope / belt, chain block (**2** nos.) and D-Shackle shall be supplied for which cost shall be deemed included. Valid type test report conducted at third party lab or witnessed by third party shall be submitted.

4.9.6.20 Lifetime

The bushings shall be designed to withstand service for the life of the equipment it serves, normally at least 30 years.

4.9.6.21 Plug-In Type Bushing

Where possible, Tertiary Bushing shall be Plug-In type.

4.9.7 Marking

4.9.7.1 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.

4.9.7.2 When a batch of insulators bearing a certain identification mark has been rejected, no further insulators bearing this mark shall be submitted and the Contractor shall satisfy the Engineer that adequate steps will be taken to mark or segregate the insulators constituting the rejected batch in such a way that there can be no possibility of the insulators being re-submitted for the test or supplied for the use of the Employer.

4.9.7.3 Each complete bushing shall be marked with the Manufacturer's name or identification mark, year of manufacture, serial number, electrical and mechanical characteristics in accordance with IEC 60137:1973.

4.9.8 Mounting of Bushings

4.9.8.1 Bushing insulators shall be mounted on the tank in a manner such that the external connections can be taken away clear of all obstacles. Neutral bushings shall be mounted in a position from which a connection can be taken to a neutral current transformer mounted on a bracket secured to the transformer tank. The current transformer will be supplied by the switchgear Manufacturer but provision shall be made on the tank for mounting to the Engineer's requirements.

4.9.8.2 The clearances from phase to earth must not be less than those stated in the Schedule of Requirements.

4.9.8.3 A flexible pull-through lead suitably sweated to the end of the winding copper shall be provided for the bushings and is to be continuous to the connector that is housed in the helmet of the bushings.

4.9.8.4 When bushings with an under-oil end of a re-entrant type are used the associated flexible pull-through lead is to be fitted with a suitably designed gas bubble deflector.

4.9.8.5 The bushing flanges must not be of re-entrant shape that may trap air.

4.9.8.6 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

4.10.1 General

4.10.1.1 Except where otherwise specified, each terminal bushing, including neutral, shall be equipped with bushing-type current transformers that meet the following requirements:

4.10.1.2 All CT’s shall have a continuous thermal current rating factor (RF) of 2 or higher. The

thermal factor requirement shall be met during all loading requirements including planned overload. Multi‑ratio (MR) CT's shall have 5 leads and fully distributed windings. All CT secondaries shall be rated 1 ampere with a continuous thermal rating of 5 amperes on all taps.

4.10.1.3 CTs shall conform to the latest IEC Standard for 5‑lead, multi‑ratio current transformers. Multi‑ratio CTs supplied with the transformer for relay purposes shall have a metering accuracy of 0.3% up to B2.0 when at the full tap winding. Single‑ratio (SR) CTs supplied with the transformer for metering purposes shall have an accuracy of 0.3% up to B2.0. See the Appendix for the number of CTs on each bushing and their ratios.

4.10.2 CT wiring

4.10.2.1 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.

4.10.2.2 All CT secondary leads shall be brought out to an external junction box with stud, nut and lock washer connections. All CT secondary leads shall be continuous except at the external junction box. No internal or external splices shall be allowed. Split lock washers are not acceptable. Moulded type junction blocks using splices are not acceptable. Note that this applies to all CT wiring termination, including connections at Electronic Temperature Monitoring devices where provided. CT connections via "set‑screw" type connectors or wire wrapped around screw terminals is not acceptable. Wiring shall be installed in a weather proof metal conduit system which shall be effectively sealed. Wire fill in conduit shall meet IEC/NEC requirements for both # of wires per conduit and % fill.

4.10.2.3 All CT leads longer than 12 inches inside the tank shall be run in non‑metallic tubes instead of being tied directly to supports. All wiring entrances and exits from the tube shall be flared round to prevent sharp edges that could damage wiring during shipment or other movement. Leads shall be tied off with cotton tape where they enter and exit the tubing to prevent unnecessary movement.

4.10.2.4 If CT turrets require removal for transformer shipment, CT lead junction boxes shall be installed on the removable turret with the CT's factory installed in the turrets and wired out to the junction boxes. Prefabricated and pre terminated extension cable pigtails and short sections of liquid tight flexible conduits shall be used for reconnecting the CT's during field assembly. The cabinet containing the CT terminal blocks shall also be equipped with one States type MTS test switch with 2 current shorting poles and sufficient, properly braced, space for future field installation of a 5/5A single ratio auxiliary current transformer.

4.10.2.5 The short-circuiting strips of the blocks shall be grounded. Terminal Blocks shall be located in a separate cabinet or, if located in the main control cabinet, they shall be positioned so as

to minimize the possibility of personnel making inadvertent contact. If a separate CT Cabinet is provided, it shall meet the following requirements:

4.10.2.6 The CT Cabinet shall be weather proof and shall be large enough to provide sufficient room to pull in and terminate the user's 4/C 2.5mm^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 centreline location of this cabinet shall be clearly shown on the outline drawing. Wire-ways shall be provided for customer wiring.

4.10.2.7 Stainless steel hinges and latching door handle shall be provided. Winding temperature (hot-spot) current transformer leads shall be brought to a short - circuiting type terminal block (EB-27 or Employer approved equivalent) in the CT cabinet so that the temperature indicators can be field calibrated. Calibration information shall be included in the test report (CT current correlation to hot spot adder; and heater calibration data).

4.10.2.8 A current transformer nameplate shall be mounted adjacent to the respective terminal block and shall contain the following information. (If space adjacent to the terminal blocks is limited, a single data plate may be mounted on the inside of the door which includes the below information.)

- Manufacturer's name
- Manufacturer's type designation
- Rated frequency
- IEC accuracy class
- Connection chart showing winding development, taps, and ratio in terms of primary and secondary current, polarity, pole and pocket location.
- Curve sheet numbers
- Thermal Rating Factor

4.11 Auxiliary Power and Control Cables

4.11.1 Scope of Supply

4.11.1.1 This Contract includes the supply, installation and termination of the necessary auxiliary power and control cables within items of plant supplied under the contract.

4.11.1.2 The Contractor shall produce, during the currency of the contract and in any case, before shipment of plant commences, detailed cable core schedules for each transformer.

4.11.1.3 All the control wiring for the control equipment on the transformer must run through rigid conduit piping in order to prevent it from environmental influences. The last 50 cm can be done with flexible conduit in order to make the connections to the devices and the control cabinet.

4.11.1.4 Cabinet bottoms shall have ample space for the entrance of the Customer's conduits. In general, two 3 inch IPS conduits will enter the OLTC control cabinet and three 3 inch IPS conduits will enter the cooling equipment control cabinet.

4.11.1.5 All external control wiring to accessories, current transformer junction boxes, etc., shall be run in weather proof raceway systems to either control cabinet as required for local control connections and the Customer's connections. Raceway systems that fill with water during normal use will be remedied at the Manufacturer’s expense.

4.11.1.6 Tank bracing is not to be used as a raceway for any control wiring. Flexible conduits or armoured cables between devices and rigid conduits or tank bracing shall be weather proof and their lengths as short as possible and no longer than 3 feet. Loose ends of flexible connections ending in tank bracing shall be sealed against entry of moisture until field connections are made.

4.11.1.7 Intermediate terminal blocks between external devices and the control cabinets shall be barrier type. No splices shall be used.

4.11.1.8 Terminal blocks shall be made of phenolic plastic with captive screws. All control wiring, with the exception of CT and VT secondary leads and sudden pressure trip leads, shall be stranded copper, #12 AWG minimum, with oil resistant thermosetting 600V insulation, 90°C or higher, electrically, thermally and mechanically suitable for its application. Flame, oil and heat resistant wiring with higher voltage insulation or higher operating temperatures are acceptable.

4.11.1.9 All wiring inside control cabinet shall be run in wire duct with snap on covers topermit easy tracing of circuits.

4.11.1.10 All control wiring shall terminate with insulated full ring lugs on one side of 600V,25A (or higher), double row barrier type terminal blocks with screw terminals and captive links, GE type EB‑25 or equivalent. Barrier spacing shall be sufficient to permit termination of #10 AWG wiring using Insulated Full Ring Terminal with Seamless Barrel or Braised Barrel. No more than two wires shall be terminated under any given screw terminal.

4.11.1.11 Manufacturer's wiring to terminal blocks intended for extension by Customer shall terminate on one row, with the other row kept clear of Manufacturer's wiring. The row used for Manufacturer's wiring and Customer's wiring shall be consistent on all terminal blocks in a vertical column, with rows alternating every other vertical column so Customer's cables may rise between two adjacent rows and fan in each direction.

4.11.1.12 All Manufacturer's wires shall be provided with indelible marker sleeves at each termination designating the location of the opposite end termination. All wiring in the control cabinet shall be run in wire duct with snap on covers to permit easy tracing of circuits.

4.11.1.13 External wiring that is not in conduit shall be type SOW. All relays, relay terminals, and terminal blocks shall be easily accessible even if the installation of a hinged door or a hinged panel is required. Control devices shall not be more than five (5) feet above the transformer base.

4.11.1.14 All unused relay contacts provided for the Customer shall be wired to terminal blocks and clearly identified in the control cabinet. At least 20% of the terminal points shall be provided as spares and evenly distributed among the occupied terminal points.

4.11.1.15 All relay and control devices shall be identified by engraved nameplates.

4.11.2 General

4.11.2.1 Auxiliary power and control cables shall have copper conductors, PVC insulated, armoured and PVC sheathed overall. The cable design shall generally be in accordance with BS 6346 and Section 6 of this Specification.

4.11.2.2 All cables installed under the contract shall utilise compression glands of type El to BS.6121 or otherwise designed to secure armour wires and bond them to earthed metal and to provide seals between sheath and gland and between inner sheath and threaded fixing component.

4.11.2.3 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

4.11.3.1 The transformers shall be provided with approved devices of Kihlstrom or equivalent for indicating the top oil temperature and hottest spot winding temperatures. The devices shall have a dial type indicator and, in addition, a pointer to register the highest temperature reached. Each winding temperature device shall have four separate contacts fitted, two of which shall be used to control the two groups of cooling plant motors (i.e. AF1 and AF2), one to give an alarm and one to trip the associated circuit breakers.

4.11.3.2 To simulate indication of the hottest spot temperature of the winding the device shall comprise a current transformer associated with one phase only and a heating device designed to operate continuously at 130 percent of transformer CMR current and for 30 minutes at 150 percent of CMR current, associated with a sensing bulb installed in an oil tight pocket in the transformer top oil.

4.11.3.3 The winding temperature indicators (WTI) shall be housed in the marshalling cubicle. The tripping contacts of the winding temperature indicators shall be adjustable to close between 80˚C and 150˚C and to re-open when the temperature has fallen by not more than 5˚C.

4.11.3.4 The alarm contacts and the contacts used to control the cooling plant motors on the above devices shall be adjustable to close between 50˚C and 100˚C and to re-open when the temperature has fallen by a desired amount between 5˚C and 10˚C.

4.11.3.5 All contacts shall be adjustable to a scale and must be accessible on removal of the relay cover. Alarm and trip circuit contacts shall be suitable for making or breaking 150 VA between the limits of 30 volts and 250 volts AC or DC and of making 500 VA between the limits of 110 and 250V DC. Cooler motor control contacts shall be suitable for operating the cooler contactors direct or, if necessary, through an interposing relay.

4.11.3.6 The temperature indicators in the marshalling kiosk shall be so designed that it is possible to move the pointers by hand for the purpose of checking the operation of the contacts and associated equipment.

4.11.3.7 The working parts of the instrument shall be made visible by the provision of cut-away dials

and glass-fronted covers and all setting and error adjustment devices shall be easily accessible.

4.11.3.8 Connections shall be brought from the device to terminal boards placed inside the marshalling cubicle.

4.11.3.9 Terminals, links and a moving iron ammeter shall be provided in the marshalling kiosk for each WTI for:

(A) Checking the output of the current transformer.

(B) Testing the current transformer and thermal image characteristics.

(C) Disconnecting the bulb heaters from the current transformer secondary circuit to enable the instrument to be used as an oil temperature indicator. Links shall be provided as shown on the drawing enclosed with this Specification.

4.11.4 Fiber Optic Based Temperature Sensing System

4.11.4.1 Fiber optic based direct temperature sensing shall be provided for power transformer winding. The purpose is to provide for faster and more appropriate response to sudden load increases. Hot spot temperature shall also be measured with the help of fiber optic sensors. Instead of one point of measurement, multiple point of measurement shall be used for more accurate result. The probe shall be distributed evenly & suitably to have comprehensive results. Probes shall be such designed and inserted so that winding insulation is not compromised. Typically, 2 probes will be mounted at the hot spot location in each phase. The Fiber Optic Based Temperature Sensing System will be incorporated mainly for the voltage levels of 230 kV & above

4.11.4.2 The winding sensors are typically located at:

- Near top of upper primary oil duct, X-winding -- 2/ph
- Near bottom of lower primary oil duct, Y-winding--- 2/ph
- Near bottom of lower primary oil duct, Z-winding--- 2/ph when applicable
- One (Total 3 for 3-legged core/total 5 for 5-legged core design) more on each core legs

4.11.4.3 Sensors located other than specified locations which are well adopted in the industry shall be deemed to finalized during detail design prior to Employers approval.

4.11.4.4 Design having one probe in the lateral phases (A/C) is acceptable subject to justification that, such design is reliable and does not affect the performance considering the sensors life-time.

4.11.4.5 Design of Fiber optic probe must be robust. Ideally, long-life probes should have the following characteristics:

- The sensing technology must be absolutely stable with time, immersed in harsh chemical environments, and at elevated temperatures
- The probes must be designed so they can mechanically survive steady vibrations and frequent thermal cycles inside the power transformer.

- The technology that converts the light signal into temperature information must be insensitive to light intensity variations. This is required to avoid problematic compensation for any aging effects in the optical fiber link and any interconnections
- Fiber connectors must be leak-proof, reliable and maintenance-free. Oil in optical path should not interfere with signal.

4.11.4.6 Although it may seem more accurate to mount fiber optic probes directly on the conductors, however, it can also be mounted in radial spacers. Also, it appears that the temperature under the spacer is higher by 1 or 2°C than the surrounding conductor. Hence, the manufacturer must take approval from the employer during design approval about the place of mounting of fiber optic probes.

4.11.4.7 The HMI for temperature monitoring shall be of modular type and shall be mounted in the RTCC panel of transformer with IP54. However, transformer body mounted module is also acceptable with higher IP (i.e. IP66) & EMC rating. Operating temperature shall be -200C to +550C. All accessories like Fiber optic cables, couplers, RS-485 port etc. shall be provided. Approved communication protocols are IEC 61850, shall be used in the system. Serial or TCP/IP communication shall also be available. SCADA integration option shall be made available. Any software (if required) shall be furnished. Spare items like light source, probes etc. vulnerable parts shall be supplied with sufficient numbers along with the system. Light source shall have a minimum MTBF of 300 years. Calibrated accuracy shall be of ± 01°C

4.11.5 Gas and Oil-Actuated Relays

4.11.5.1 Each transformer shall be fitted with gas and oil-actuated relay equipment having alarm contacts that close on collection of gas or low oil level, and tripping contacts which close following oil surge conditions.

4.11.5.2 Each gas and oil-actuated relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay.

4.11.5.3 Each relay shall be fitted with a calibrated glass window for indication of gas volume.

4.11.5.4 To allow gas to be collected at ground level, a small bore pipe shall be connected to the gas release cock of the gas and oil-actuated relay and brought down to a point approximately 1400MM above ground level, where it shall be terminated by a cock which shall have provision for locking to prevent unauthorised operation.

4.11.5.5 The design of the relay mounting arrangements, the associated pipework and the cooling plant shall be such that mal-operation of the relay will not take place under normal service conditions, including starting or stopping of oil circulating pumps, whether by manual or automatic control under all operating temperatures.

4.11.5.6 The pipework shall be so arranged that all gas arising from the transformer will pass into the gas and oil-actuated relay. The oil circuit through the relay must not form a delivery path in parallel with any circulating oil pipe, nor is it to be teed into or connected through the pressure relief vent. Sharp bends in the pipework shall be avoided.

4.11.5.7 When a transformer is provided with two conservators, the gas and oil-actuated relays shall be arranged as follows:

a) If the two conservators are connected to the transformer by a common oil pipe, one relay shall be installed in the common pipe.

b) If the two conservators are piped separately to the transformer, two relays shall be installed, one in each pipe connection.

4.11.5.8 The clearance between oil pipework and live metal shall be not less than the minimum clearances stated in the Project Requirements of Section 1.

4.12 Shipment & Drying Out

4.12.1 Shipment

4.12.1.1 Each transformer, when prepared for shipment, shall be fitted with a shock indicator or recorder which shall remain in situ until the transformer is delivered to site. In the event that the transformer is found to have been subjected to excessive shock in transit, such examination as is necessary shall be made in the presence of the Engineer.

4.12.1.2 Where practicable, transformers shall be shipped with oil filling to cover core and windings but, when shipped under pressure of gas, shall be fitted for the duration of delivery to Site and for such time thereafter as is necessary, with a gauge and gas cylinder adequate to maintain internal pressure above atmospheric.

4.12.1.3 All earthing transformers shall be shipped full of oil.

4.12.2 Drying Out

4.12.2.1 All transformers shall be dried out by an approved method at the Manufacturer's works and so arranged that they might be put into service without further drying out on site.

4.12.2.2 Clear instructions shall be included in the Maintenance Instructions regarding any special precautionary measures (e.g. strutting of tap changer barriers or tank cover) which must be taken before the specified vacuum treatment can be carried out. Any special equipment necessary to enable the transformer to withstand the treatment shall be provided with each transformer

4.13 Fire Protection/Prevention System

4.13.1.1 General

4.13.1.1.1 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.

4.13.1.1.2 The system design shall also conform to TAC/ NFPA norms (NFPA 850). The offered system shall comply with the relevant international standards. Reference standards are listed below. Relevant international standards other than BS standards shall be subject to approval by the Employer:

4.13.1.2 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

4.13.1.3 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.

4.13.1.4 The system shall be reliable without making any mal operation.

4.13.1.5 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

4.13.2.1 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).

4.13.2.2 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.

4.13.2.3 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.

4.13.2.4 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 cause 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.

4.13.2.5 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 m³ - 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.

4.13.2.6 Requirement

4.13.2.6.1 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.

4.13.2.6.2 ***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.***

4.13.2.6.3 ***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).***

4.13.2.6.4 ***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.***

4.13.2.7 Experience and Tests

4.13.2.7.1 ***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.

4.13.2.8 Automation Requirement

4.13.2.8.1 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.

4.13.2.8.2 ***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)

4.13.3.1 When required by schedule of requirement, the Contractor shall provide the water spray system arrangements specified below for each of the transformer:

4.13.3.2 The water spray system shall be provided with a valve station including the necessary control and monitoring cabinet to be capable of extension to serve in total four transformer units.

4.13.3.3 The water spray system is to be designed for manual, automatic and electrical remote operation and must be provided in free-standing and self-supporting design, with the following basic equipment:

- The required number of triggering and fire extinguishing nozzles with galvanized pipes and mountings
- The necessary galvanized connecting lines from the appropriate valve station to the nozzle pipe network
- The necessary drainage valves, struts, diaphragm sleeve valves, single chamber valve stations with all fittings and connections, pressure-sensitive switches for signalling and air pressure drop, with the possibility of extension by four transformers
- The necessary tank feed pump
- Pressurizing air vessel for maintaining a reserve of fire-fighting water

4.13.3.4 The required water discharge rate shall be 10litter / m2 / min. Design wind velocity shall be 10m / sec. The required water volume shall be considered for spraying for any one unit of the power transformers.

4.13.3.5 The pressurizing air vessel is to be designed for a minimum spraying time of 20 minutes and is to be fully equipped with all necessary fittings and connecting pipes, pressure controllers, low water level alarm, reducing valves and all other equipment essential for trouble-free operation.

4.13.3.6 The pressurizing air vessel is to be installed above ground.

4.13.3.7 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

4.13.3.8 Installed completely on a sturdy base frame with all necessary anti-vibration mounts and fixing material.

4.13.3.9 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

4.13.3.10 Assembled completely and ready for operation, the volume of air being matched to the time sequence of the transformer extinguishing operation.

4.13.3.11 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

4.13.3.12 With terminal board and cable entry glands as well as the necessary local fault and indicator lamps and spare contacts for remote monitoring and the necessary interlock criteria.

4.13.3.13 One complete compressed air distribution system with the necessary signalling pressure gauges, contact pressure gauges, pressure relief valves, pressure gauge valves, drain valves, pressure reducing valves, hand-operated shut-off valves and copper piping in the diameters shall be provided for the compressed air distribution.

4.13.3.14 Standby Diesel Generator (DG) set of appropriate capacity shall be provided for emergency power supply to WSS system in case of substation auxiliary supply fail. Calculation for determining the capacity of DG set considering the WSS power supply requirement shall be submitted to PGCB during execution stage for review and approval.

4.13.3.15 For, quality and maintenance requirement, major components (such as deluge valve, spray nozzle, air compressor, pressure gauge, vent valve, non-return valve, pressure relief valve, Y-strainers, water feed pump, fire extinguishing panel, local control panel, water pump with air compressor control panel, temperature sensor, emergency DG set etc.) of the Watery Spray System (WSS) shall be from Europe/USA/Canada/Japan origin.

4.13.3.16 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 [Not Applicable]

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.

4.13.4.1 General

4.13.4.1.1 ***A water mist system is a fire protection system which uses very fine water sprays (i.e. water mist). The small water droplets allow the water mist to control, suppress or extinguish fires by:***

- cooling both the flame and surrounding gases by evaporation
- displacing oxygen by evaporation
- attenuating radiant heat by the small droplets themselves

4.13.4.1.2 ***The effectiveness of a water mist system in fire suppression depends on its spray characteristics, which include the droplet size distribution, flux density and spray dynamics, with respect to the fire scenario, such as the shielding of the fuel, fire size and ventilation conditions.***

4.13.4.1.3 ***The use of water mist fire suppression, shall have following characteristics:***

- Proven performance
- Immediate activation
- High efficiency in the suppression of a wide variety of fires
- Minimized water damage
- No toxic problems
- Quick control and suppression of fire
- Efficient cooling preventing the fire from spreading
- Low water usage, minimal damage and downtime
- Safe for people and Environmentally sound characteristics
- Small stainless-steel piping and water supply to spray heads
- Easy installation
- Fully scalable to cover new protection needs

4.13.4.1.4 ***The NFPA 750 defines three pressure regions for water mist-generating technologies: low, intermediate and high pressure systems. Among different types, High pressure HI-FOG technology shall be used for transformer Fire detection & suppression agent. HP-HIF has the following benefits:***

- Better penetration into the seat of the fire
- Superior coverage of the protected volume
- An improved cooling effect from better mixing of gases and high evaporation rate
- Lower overall system weight
- Less water consumption

4.13.4.1.5 ***Since oil is a combustible liquid, when a transformer fault or failure occurs, the transformer itself can provide both the ignition source, and fuel for a fire. Once ignition occurs, the oil will sustain combustion until thoroughly consumed, unless oxygen is depleted or significant cooling is applied to limit the fire from propagating. The technical characterization of a flammable liquid fire is a Class B Fire. Class B fires have hazards primarily associated to the fuel loading, fuel configuration, flashpoint, and burning rate of the fuel.***

4.13.4.1.6 ***Note that, the fine (that is smaller than 400 microns) droplets are essential for extinguishment of Class B (flammable liquid) fires.***

4.13.4.2 Applicable Standard

IEEE National Electrical Safety Code

IEEE 979 Guide for Substation Fire Protection

IEEE 980 Guide for Containment and Control of Oil Spills in Substations

NFPA 13 Standard for the Installation of Sprinkler Systems.

NFPA 15 Standard for Water Spray Fixed Systems for Fire Protection

NFPA 25 Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems

NFPA 70 National Electric Code

NFPA 72 National Fire Alarm Code.

NFPA 750 Standard on Water Mist Fire Protection Systems

NFPA 850 Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

DIN 2391, 3861, 3865, 20078, 17457, 17458

FM Approval Standard for Water Mist Systems Class Number 5560.

4.13.4.3 System Operation

4.13.4.3.1 ***Upon fire detection, the fire detection and control panel shall provide a signal to the control system for the water mist system activation. The water mist control signal shall remain energized for 15 seconds (the system control valve is a self-latching/self-resetting valve).***

4.13.4.3.2 ***A single unit of water mist system shall protect a single transformer. For more than one unit of transformer placed side by side, the second unit shall not be activated until fire is caught in the second unit.***

4.13.4.3.3 ***The system shall discharge completely over a period of minimum 10 minutes.***

However, when design requires longer time (i.e., for larger transformer) , the same shall be provided.

4.13.4.4 Principle of Extinguishment

4.13.4.4.1 ***The extinguishment of fire by water mist is based on the principles of cooling and oxygen depletion. Based on the triangle of fire, i.e., fuel, oxygen and heat, if any of the three elements is removed, the fire should in principle extinguish itself. It is necessary however that the cooling be not only of the fuel, thus the evaporating combustible fumes, but that also of the radiant heat which will prevent re-ignition from taking place.***

4.13.4.4.2 ***Fire shall be detected at the very initial stage using fire detection system. Immediately after detection, stored water mist shall be sprayed over the transformer body.***

4.13.4.4.3 ***The water mist shall be drawn into the fire by the air, where due to the high heat, it quickly evaporates. Actually, after spraying, when the water droplets come into contact with the fire, they extract the heat until they evaporate. As the water droplets evaporate, there is enormous increase in the volume of the water droplets & sub-sequently, the oxygen is displaced at the source of the fire. The large water surface formed by the small droplets creates the conditions for an optimal exchange of energy between the water mist and the surrounding area. Of all known extinguishing materials, water has the highest evaporation enthalpy (2442 J / g). A complete void shall be created to evacuate oxygen from transformer fuel so that fire is self-extinguished.***

4.13.4.4.4 ***Water mist shall be sprayed at high pressure (500-4000 psi) & water mist (droplet size 10-100 μm) shall be created before spraying.***

4.13.4.4.5 ***The water droplet shall have a volumetric diameter where Dv0.99 shall be less than 100 µm at the beginning of the discharge and it shall not be more than 50 µm after eight minutes of discharge.***

4.13.4.4.6 ***Three major characteristics establish the uniqueness of every water mist system: droplet size, flux density and spray momentum. A high pressure system offers the advantage of a finer and more efficient water droplet combined with the high pressure discharge which translates into higher momentum and more efficient fire plume penetration.***

4.13.4.4.7 ***The relativistic aspects of the drop size are also very important. Therefore for larger fires, larger droplets (100 µm) are essential while for smaller fires it is very important to have a large fraction of smaller droplets than can easily be entrained by small, less dynamic flamelet type or residual fires (these flamelets can be the source of re-ignition if not completely extinguished).***

4.13.4.4.8 ***The water mist shall effectively suppress the fire and avoid spreading of fire to next transformer or further area of substation even under turbulent air flow that typically occur during typical transformer fire.***

4.13.4.5 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 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.

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%)

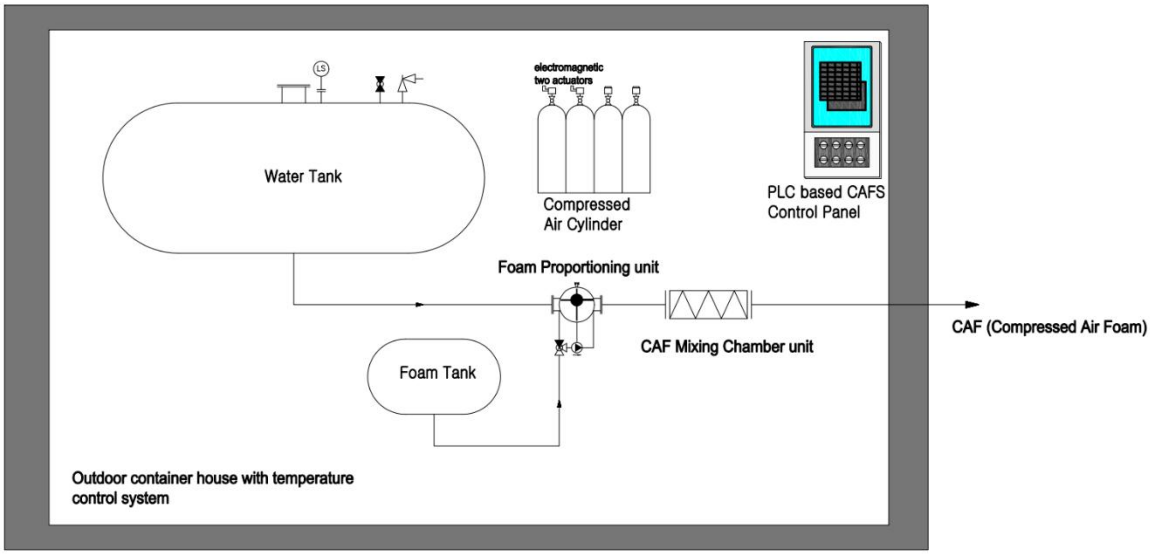
The required CAF discharge rate shall be 1.63 lpm / m2 (foam solution). The required CAF volume shall be considered for spraying for any one unit of the power transformers.

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. 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.

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.

4.13.6 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 Transformer Oil

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.

4.15 Auto-Transformers

4.15.1 General

4.15.1.1 Auto-transformers for interconnection between the 400kV & 132kV and 230kV and 132kV system shall comply with the general requirements of the Specification and the particular requirements of this Section.

4.15.1.2 The auto-transformers will be star connected and the system will be solidly earthed at each auto transformer neutral.

4.15.1.3 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 in 132 kV output, for conditions of input from the 400 kV system or 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

4.15.3.1 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.

4.15.3.2 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 Transformers

4.16.1 General

4.16.1.1 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 33kV Bus.

4.16.1.2 The neutral point of the interconnected star winding shall be brought out of the tank through a bushing insulator. This point is to be connected to earth directly in order to provide an earthing point for the neutral of the system.

4.16.1.3 The earthing transformers shall have a secondary winding to supply the substation auxiliary load. The voltage ratio shall be 33/0.415kV. 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 as stated in the Schedule of Requirements and shall conform to IEC 60076.

4.16.2 Electrical and Short Circuit Characteristics

4.16.2.1 Earthing transformers will normally have their neutral points connected to earth via a

resistance which limits earth fault current to the full load current at the associated power transformer. However, when required by schedule of requirement, provision shall be made for solidly earthing the neutral points and, under this condition, the earthing transformers shall be capable of withstanding, both thermally and mechanically without damage, for a period of 1 seconds the application of normal three phase line voltage to the terminals of the interconnected star winding with one line terminal earthed. The current density of the winding under this condition shall not exceed 70A/mm².

4.16.2.2 In addition, the interconnected star winding of each earthing transformer, when at its maximum temperature due to continuous full load on the auxiliary winding, shall be designed to carry for 3 seconds without injurious heating an earth fault current in the neutral connection as specified. The current density under such conditions shall not exceed 40A/mm².

4.16.3 Tanks and Fittings

Earthing transformers shall be provided with the following fittings:

(A) Conservator vessel with removable end cover and prismatic oil gauge.

(B) Buchholz relay.

(C) One thermometer pocket with captive screw cap.

(D) Silica gel breather of the oil seal type with a minimum capacity of 1 kg.

(E) Pressure relief device.

(F) Filter valve and combined filter and drain valves.

(G) Oil sampling device.

(H) Rating plate.

(1) Tank earth terminals.

(J) Lifting lugs.

4.16.4 Secondary Windings

4.16.4.1 The three-phase, four-wire secondary windings shall be terminated at a three-pole MCCB unit with bolted neutral link and gland entry for a four-core solid dielectric cable. This shall be accommodated in a lockable, fully weather proof 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.

4.16.4.2 The windings shall be fitted with off-load tap changer to vary the voltage ±5 percent of the nominal open circuit value in 2.5 percent steps.

4.16.5 Terminal Connections

The 33 kV side of the earthing transformers shall be fitted with oil/air terminal bushings. The earth point connection to the neutral earthing resistor shall be via a 33 kV conductor.

4.17 Transformer Online Dissolved Gas Analyser (DGA)

4.17.1 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 IP55 Stainless Steel enclosure, suitable for 55oC ambient temperature and EMI and EMC compatibility. The Equipment must carry a minimum of two (2) years manufacturer's Warranty.

g) The equipment shall connect to the transformer's main body in two locations. One connection is for the supply of oil from the transformer. Second connection is for the return of the oil to the transformer. The connecting oil lines must be of Stainless Steel rigid pipes or flexible hoses.

h) The equipment shall be able to measure gas concentration and when downloaded should immediately compare it with user selected alarm & caution level for immediate display. The sampling rate shall be selectable as 2 or 4 or 6 or 12 hours, etc. The equipment shall have inbuilt memory to store these results for complete one year even if sampling is done at the lowest interval.

i) The Equipment must have an automatic Calibration facility at fixed intervals. For calibration if anything required including cylinder must be mounted with the equipment.

j) The technical feature of the equipment shall be as under:

Accuracy + 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 Fiber Optic Based Temperature Sensing System

4.18.1 Fiber optic based direct temperature sensing shall be provided for power transformer winding. The purpose is to provide for faster and more appropriate response to sudden load increases. Hot spot temperature shall also be measured with the help of fiber optic sensors. Instead of one point of measurement, multiple point of measurement shall be used for more accurate result. The probe shall be distributed evenly & suitably to have comprehensive results. Probes shall be such designed and inserted so that winding insulation is not compromised. Typically, 2 probes will be mounted at the hot spot location in each phase. The Fiber Optic Based Temperature Sensing System will be incorporated mainly for the voltage levels of 132kV & above.

4.18.2 The winding sensors are typically located at:

- Near top of upper primary oil duct, X-winding -- 2/ph
- Near bottom of lower primary oil duct, Y-winding--- 2/ph
- Near bottom of lower primary oil duct, Z-winding--- 2/ph when applicable

- One (Total 3 for 3-legged core/total 5 for 5-legged core design) more on each core legs

4.18.3 Sensors located other than specified locations which are well adopted in the industry shall be deemed to be finalized during detail design prior to Employers approval.

4.18.4 Design having one probe in the lateral phases (A/C) is acceptable subject to justification that, such design is reliable and does not affect the performance considering the sensors life-time.

4.18.5 Design of Fiber optic probe must be robust. Ideally, long-life probes should have the following characteristics:

- The sensing technology must be absolutely stable with time, immersed in harsh chemical environments, and at elevated temperatures
- The probes must be designed so they can mechanically survive steady vibrations and frequent thermal cycles inside the power transformer.
- The technology that converts the light signal into temperature information must be insensitive to light intensity variations. This is required to avoid problematic compensation for any aging effects in the optical fiber link and any interconnections
- Fiber connectors must be leak-proof, reliable and maintenance-free. Oil in optical path should not interfere with signal.

4.18.6 Although it may seem more accurate to mount fiber optic probes directly on the conductors, however, it can also be mounted in radial spacers. Also, it appears that the temperature under the spacer is higher by 1 or 2°C than the surrounding conductor. Hence, the manufacturer must take approval from the employer during design approval about the place of mounting of fiber optic probes.

4.18.7 The HMI for temperature monitoring shall be of modular type and shall be mounted in the RTCC panel of transformer with IP54. However, transformer body mounted module is also acceptable with higher IP (i.e. IP66) & EMC rating. Operating temperature shall be -200C to +550C. All accessories like Fiber optic cables, couplers, RS-485 port etc. shall be provided. Approved communication protocols are IEC 61850, shall be used in the system. Serial or TCP/IP communication shall also be available. SCADA integration option shall be made available. Any software (if required) shall be furnished. Spare items like light source, probes etc. vulnerable parts shall be supplied with sufficient numbers along with the system. Light source shall have a minimum MTBF of 300 years. Calibrated accuracy shall be of ± 01°C

4.19 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.

4.19.1 Factory Acceptance Tests

Factory acceptance tests shall be carried out at the Manufacturer's laboratory, following a mutually agreed programme, in presence of Employer's authorized Engineer.

4.19.1.1 Type Tests

The following type tests shall be conducted on the first power transformer in a single FAT schedule:

- **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. 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**
  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

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.

4.19.1.2 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 overvoltages.

Note: The transformer's capability to withstand thermal and dynamic effects of short circuit without any damage should be presented by design analysis and calculation.

4.19.2 Detailed Testing Requirements

4.19.2.1 All applicable standard and special test requirements shall apply to each transformer, whether manufactured separately or at the same time as other identical units. Data from identical or similar transformers is not acceptable.

4.19.2.2 Transformers shall be fully assembled including all auxiliary devices, surge arresters, DGA monitoring equipment, conduits and the wiring of the control cabinet, (the transformer shall be completely assembled and ready for energization) before testing.

4.19.2.3 All test results, measurements, and calculated values shall be recorded on the supplier's certified test report.

4.19.2.4 The Employer shall have the option of witnessing all tests. The Seller shall advise the Employer at least two weeks in advance of test dates so travel arrangements may be made.

4.19.2.5 In the event of a test failure, no corrective action shall be taken until authorized by the Employer.

4.19.2.6 In no case shall a transformer be shipped without clearance from the Employer if test values do not meet the requirements of this specification or other requirements stated in the purchase order.

4.19.2.7 If a Z-winding is specified, whether the terminals are specified to be brought out or buried, the Z-winding voltage and capacity ratings shall be shown on the test report.

4.19.2.8 The following tests shall be performed on each unit in accordance with IEC Standards 60076-1

1) Transformer winding resistance measurements of all windings at all winding tap positions shall be taken for each phase of each winding and included in the test report.

2) Transformer turns ratio tests shall be performed at all tap positions listed in IEC Standard 60076-1. The applied voltage, the calculated ratios for each tap position and the measured ratios for each phase of each connection shall all be included in the test report.
3) Polarity and phase relation tests shall be performed, and the phasor diagram shall be included in the test report.

4) Excitation (no-load) loss tests shall be performed at the rated voltage tap by the "Three Wattmeter Method" as in IEEE C57.12.90-2015 or as per IEC 60076-1.

- No-load losses shall be recorded prior to dielectric testing and then again after dielectric testing has been completed. Both test readings shall be included in the test report. Temperature corrections shall be reported as per IEC standards 60076-2.
- No-Load Loss measurements shall be taken at rated voltage of the tap position which results in maximum excitation of all cores. (At an LTC position that results in the series transformer and/or preventive autotransformer being excited at 100% rated voltage. i.e. at 16R when only a series transformer is provided, at 15R when both series and PA transformers are provided, or 1R when only a PA is provided.)
- Excitation current measurements shall be taken at 100% and 110% of the rated voltage.
- Current readings for each phase at both voltage levels shall be included in the test report. These current values shall be recorded prior to dielectric testing and then again after dielectric testing has been completed.
- A one-hour core excitation test shall be performed after the completion of all dielectric tests at rated frequency and 110% of the rated voltage. All cores shall be excited to 110%. Therefore, the test shall be performed at an LTC position that results in series transformer and/or preventive autotransformer being excited at 110% rated voltage.
- The one-hour core excitation test shall be followed by the No-load loss test after dielectric.

5) Cooling system loss measurements shall be taken at all stages and shall be included in the test report.

6) Impedance and load loss measurements shall be taken using the three-watt meter method (IEEE C57.12.90) at all tap positions listed in IEC 60076-1.

All measurements shall be performed at the base nameplate and maximum 65°C rating for that tap position and recorded in the test report.

Impedance and Load Loss data shall be included in the test report for the following tap positions:

• HV at Tap “1” or “A” – LV at Neutral

• HV at Tap “2” or “B” – LV at Neutral

• HV at Tap “3” or “C” – LV at Neutral

• HV at Tap “3” or “C” – LV at 9a (If LTC provided)

• HV at Tap “3” or “C” – LV at 9c (If LTC provided)

• HV at Tap “4” or “D” – LV at Neutral

• HV at Tap “5” or “E” – LV at Neutral

The transformer's actual impedances for each OLTC tap shall not differ from the quoted impedances by more than IEC tolerances.

7) Zero Sequence impedance measurements shall be taken and shall be included int he test report.

For Wye-Wye transformers, zero sequence impedance measurements shall be taken in accordance with IEC60076-1. A “T” network diagram shall be included in the test report and shall include complex values for Z1, Z2, and Z3. Complex values shall be shown as %R and %jX at base MVA.

8) Temperature tests shall be performed on each transformer.

- Each transformer shall be tested in accordance with this spec. Test data from a “thermal duplicate transformer” is unacceptable
- Tests shall be performed at the HV and LV tap positions that produce the highest losses.

- A standard liquid temperature rise test shall be performed per IEC 60076-2 at the current required to produce total losses. The test report shall include the top oil temperature and the bottom oil temperature rise above ambient temperature. The test report shall also include the ambient temperature during the test.

- A standard temperature rise test shall be performed per IEC 60076-2, using constant rated current. The average winding temperature rise shall be reported for both ONAN rating as well as top nameplate rating (ONAF/ODAF), and shall not exceed 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.

4.19.3 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

4.19.4 Shipment

4.19.4.1 Each transformer, when prepared for shipment, shall be fitted with a shock indicator or recorder which shall remain in situ until the transformer is delivered to site. In the event that the transformer is found to have been subjected to excessive shock in transit, such examination as is necessary shall be made in the presence of the Engineer.

4.19.4.2 The transformer shall be shipped with the standard shipping connections as per IEC 60076, unless otherwise specified in the “special requirements” on the data sheet.

4.19.4.3 Factory test data in accordance with this specification shall be provided to the Employer for review and approval prior to shipment:

1) All Dielectric testing results including waveforms and test values.
2) All temperature test results.
3) All Doble test results (single phase excitation test, power factor and capacitance)
4) Impedance, load loss and no-load loss.
5) DGA results.

4.19.4.4 The transformer shall be designed to withstand a minimum shipping force of 2G in the lateral direction, 5G in the longitudinal direction, and 3G in the vertical direction. Shipping terms are delivery to the pad at the location specified in the Data Sheets and as per section above with the Seller to bear all risk of loss or damage while in transit.

4.19.4.5 Bidders shall verify their ability to ship to Purchaser's specified shipping destination and shall submit written confirmation of this with the submission of bids. Shipment of the transformer via truck is preferred.

4.19.4.6 Transformers shall be shipped under at least 3 pounds (at 30°C) positive pressure of breathable quality dry air. A gauge with valves and fittings to permit sampling or adding air shall be provided to monitor air pressure until transformer is filled with oil. Shipping accessories shall include appropriate pipe plug or pipe cap to replace shipping gauge.

4.19.4.7 A recording impact meter with two horizontal and one vertical axis indicator shall be mounted on each vehicle used for shipping the core and coil to its destination. The recording shall be made available to the Customer for review. If meter is not tamper proof then it shall be sealed to show evidence of tampering. Impact meter shall only be opened by the Manufacturer’s representative in the presence of a Customer representative. The recorder shall be capable of recording the entire transport plus 30 days.

4.19.4.8 Shipment shall include one complete set of fresh gaskets to replace all those used on

equipment removed after factory testing and two sets of fresh gaskets for all access covers on the tank and tap changer compartments. Gaskets used during factory test and shipping shall not be reused once disturbed. Gaskets shall be packed in plastic bags for protection and identified as to intended location on the transformer.

4.19.4.9 All radiators and associated piping that are disassembled for shipment shall be kept water - tight by using gasketed and bolted metal blanking plates. Pressure vacuum gauges shall be provided by the Seller for the monitoring of gas pressure in the main tank of the transformer during shipping. Gauges shall be mounted so as to be well protected during shipment.

4.19.4.10 Final shipping information and required delivery dates are specified in the Appendix. Delivery earlier than the date listed in the Appendix is not permitted without prior approval from the Employer.

4.19.4.11 Delivery of the transformer and all parts and accessories shall be made on the same day. The Purchaser reserves the right to hold a truck so that all offloading can be done on the same day.

4.19.4.12 The Seller shall email complete packing list of parts to the Engineer at least 48 hours prior to shipment. Packing list shall include number of shipping groups or separate containers, contents of each container, expected date of arrival, shop order number and substation name.

4.19.4.13 No transportation media transfers are to be made without written approval from the Employer.

4.19.4.14 The Seller shall provide satisfactory trip lease arrangements where rail shipments to private rail sidings are used.

4.19.4.15 Where practicable, transformers shall be shipped with oil filling to cover core and windings but, when shipped under pressure of gas, shall be fitted for the duration of delivery to Site and for such time thereafter as is necessary, with a gauge and gas cylinder adequate to maintain internal pressure above atmospheric.

4.19.4.16 Small transformers may be shipped oil - filled. When the Contract also includes the provision of oil, the seller shall fill the transformer with oil at site.

4.19.4.17 All earthing transformers shall be shipped full of oil.

4.19.5 Receiving

4.19.5.1 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.

4.19.5.2 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.

4.19.5.3 The Seller shall provide receipt inspection criteria.

4.19.5.4 Field supervision by a qualified employee of the Manufacturer is to provide technical assistance during the initial field assembly of the transformer.

4.19.6 Site Tests

4.19.6.1 Tests During Installation

The following tests shall be performed during and after installation on the entire equipment in order to ensure correct assembly of the equipment as well as to prove that the equipment has been correctly installed:

- Verification of proper and complete erection
- Verification of the proper condition of porcelains, sealing and external surfaces
- Verification of proper connection to the earthing system
- Verification of transformer bolted connections by torque spanner
- Voltage tests of all electrical LV circuits
- Verification of the proper cabling and operation of all electrical LV equipment
- Verification of control and protection circuits and wiring.

4.19.6.2 Commissioning Tests

4.19.6.2.1 Main objective of the commissioning tests is to check proper and safe operation of the equipment, and in particular to verify and confirm the factory acceptance test results.

4.19.6.2.2 The following commissioning tests will be performed before putting the transformers into operation:

- Measurements of insulation resistances of windings and magnetic core.
- Capacitance (C), dielectric losses (tanδ) and winding inductance.
- Measurement of winding resistance at all tap changer positions.
- Measurement of voltage ratio at all tap changer positions and check of winding connection.
- Operation test of all protection units, measuring and alarm (signalling) units, Buchholz

relay, contact thermometer, thermal image unit, etc.

- Operation test of cooling-system controls and alarms.
- Operation test of tap changer controls and alarms.
- Oil dielectric strength.
- Physical, chemical and electrical characteristics of oil.

4.19.6.3 Handling on Site

4.19.6.3.1 ***For installation purposes and to permit the moving of any three phase unit, the transformers are to be equipped with castors (rail wheels). A permanent rail transfer track system shall be provided, integrated with the transformer foundations. The castors should be able to swivel in both the longitudinal and transverse directions.***

4.19.6.3.2 ***A system of wedges shall be included to stop any unwanted movement of the transformer during its operating life. The distance between rails must be compatible with the transformer dimensions and also the rail gauge prevailing at existing substation sites.***

5. 36kV Capacitor Bank

5.1 General

This Specification covers the design, manufacture, pre-assembly and acceptance testing in the Contractor's workshops as well as the supply, delivery, unloading, erection, adjusting, painting, identification, commissioning and acceptance testing of 36 kV capacitor banks for identified substations for each Lot, complete in every respect and suitable for satisfactory operation.

5.2 Layout

Capacitor banks installation layout and scopes including additional works shall be referred to Schedules and drawings which are attached. The location to be installed of the 36 kV capacitor banks can be observed by field visit is strongly recommended to reduce deviations of related estimation and clarify any possible mistakes during bidding process.

5.3 Scope of Supply and Services

This Subsection sets out the scope of installations covered by this Specification as well as the requested supplies and services, but without excluding other necessary components and services not mentioned. The relevant "Prices for Equipment and Spare Parts" can be found in Price Schedule.

The following main equipment has to be provided:

36 kV capacitor banks for outdoor installation, composed of ungrounded double-Y-connected capacitors, sized of 15 MVar (Operation output at 33kV) with fully insulated neutrals and current transformers for unbalance protection and series connected inrush current limiting (damping) reactors.

Technical requirements of capacitor bank are as follows:

Normal system voltage	33kV
Highest system voltage	36kV
Highest voltage for equipment	36kV
Maximum system voltage unbalance	2%
Ambient air temperature	-5/B
Minimum reactive power at normal system voltage	15 MVar as per schedule

No of phase	Three (3)
Frequency	50Hz +/- 0.5
Capacitor tolerance	0 to 10%
Discharge time	<75V within 600 seconds
Case	Stainless steel or Mild steel
Paint	Epoxy coated double layer \ Urethane
Bushing	Two porcelain bushings
Dielectric	All polypropylene synthetic film
Impregnate	Non PCB
Connection of capacitor bank	Double star with neutral floating
Rating of capacitor unit voltage	M.R
kVar rating of capacitor unit	M.R
Fuse type	Internal fuse
Power frequency withstand voltage (rms)	70kV
Basic impulse withstand voltage (peak)	170kV
Symmetrical short circuit level	31.5kA

The total reactive power with this is 405MVar and number of capacitor banks to be installed at the individual substations and parallel operation group shall be as follows:

36kV Capacitor Bank		
Sl. No.	Name of the Substations	Proposed compensation Block (MVar)
1.	Panchogar 132/33	2x15
2.	Thakurgaon 132/33kV	3x15
3.	Purba-Sadipur 132/33kV	3x15
4.	Naogaon 132/33kV	2x15
5.	Niyamotpur 132/33kV	2x15

6.	Joypurhat 132/33kV	2x15
7.	Coxbazar 132/33kV	4x15
8.	Chuadanga 132/33kV	2x15
9.	Bhandaria 132/33kV	3x15
10.	Kishorganj 132/33kV	2x15

The supply shall include all necessary structure and accessories i.e. clamp connectors, bus extension work, wiring etc.

5.4 Construction Requirements

5.4.1 General

The 36 kV capacitor bank design has to meet the requirements of the latest edition of IEC 60871.

5.4.2 Capacitor Banks

Each capacitor bank shall comprise of disconnect switch, dedicated circuit breaker, current transformer, surge arrester, inrush current limiting reactor, capacitor unit, neutral current transformer, support insulator, busbar, interconnection cable, terminal connector and structure with associated hardware and accessories. When it is required to be made for the existing bus extension, all necessaries for the complete work shall be include as well.

Each capacitor bank shall have a reactive power of 15 MVar at 33 kV, 50 Hz with considerations of inductive reactive losses of the current inrush current limiting reactors, that means the reactive power of the capacitors must be increased corresponding the losses of the current inrush current limiting reactors to ensure that a nominal/rated reactive can be fed into the network.

The capacitor units of a capacitor bank shall be connected as three phase, double star, and neutral tied together with neutral ungrounded.

The capacitor bank shall operate at the voltage specified in technical specification and relevant drawing and shall be switched on and off by respective circuit breakers at the substation. The design shall ensure that the required total capacity shall not below at nominal voltage.

Each capacitor bank shall comprise a suitable number of two bushing single phase units in series and parallel combination connected in an ungrounded double star configuration to facilitate incorporation of a capacitor unbalance detection scheme.

Individual capacitor voltage rating shall be selected by contractor to form an economical and compact design; however, number of parallel units in each of the series string shall be such that at least two (2) elements faults shall not create an overvoltage on the units in parallel with it. Contractor shall inform the numbers of fault elements for the alarm setting and trip setting of capacitor bank.

Layout of the equipment shall be arranged to occupy the minimum practical space, however, all components shall be readily accessible for inspection, cleaning and repairs.

Design shall incorporate all necessary precautions and provisions for the safety of those concerned in operation and maintenance of the apparatus.

The capacitor banks shall be installed in the locations stated in sub clause 4.3 of this section, The Contractor shall optimize the design of the capacitor banks which is subject to approval of PGCB.

5.4.3 Capacitor Units

The capacitor units shall be modern designed and shall be in accordance with relevant latest standards described in Section 1. All capacitor units shall be single phase with identical voltage and kVar ratings.

The capacitor shall have two bushings and clearance between two terminals shall be 220mm or more for the 2 series connection & 320mm or more for the one series connection.

Each unit shall satisfactorily operate at 130% of rated current including harmonic currents as per IEC. Units shall be capable of continuously withstanding satisfactorily any overvoltage up to a maximum of 10% above rated voltage as per IEC.

5.4.4 Containers

All Capacitors shall be hermitically sealed and bushing shall be assembled on the top of the case in a welding process.

The containers of the capacitor units shall be made of stainless steel. The containers shall withstand all stresses which may occur during service (normal conditions and internal faults) without bursting. Capacitor units shall be treated suitable anti corrosion protection. A painting system for containers shall be proposed by the Contractor and will be subject to the approval of PGCB.

5.4.5 Capacitor Elements

All capacitor elements shall be synthetic film (polypropylene) with aluminum electrode. The aluminum foil shall be edge folded type.

All the capacitor elements shall be dry voltage withstand tested before assembly made.

The individual elements shall be of the all-film type. The maximum element voltage shall not exceed 2000V at rated voltage. In case of all-film capacitors the dielectric stresses shall not exceed 60V/micron at rated voltage. Information about the connections of capacitor elements (number of parallel/series connected elements) shall be included to the tender documents by the contractor.

5.4.6 Internal Fuses

The capacitor units shall have internal fuses to protect each element. Type test protocols according IEC 60871-4 shall be enclosed to the tender.

Capacitor unit shall be of internally fused type. All internal fuses shall be withstood for the inrush current.

5.4.7 Impregnant

The capacitor elements shall be vacuum dried inside the case prior to impregnation with the dielectric fluid. The capacitors shall be dehydrated under high vacuum and temperature not to leave any gas or impurities in the case, which may cause deterioration of the dielectric.

Impregnation fluid is forbidden using polychlorinated biphenyl (PCB). The manufacturer shall submit certificate to demonstrate Non PCB type fluid and fluid characteristics data. Detail information and test results of the impregnant offered shall be supplied with the bidder. The impregnation fluid shall be biodegradable and after impregnation the capacitor unit shall be sealed immediately upon removal impregnant reservoir.

5.4.8 Discharge Resistor

The capacitor units shall be supplied with discharge resistors inside the containers to discharge the capacitors from rated voltage to 75 V within 10 minutes. This requirement must be fulfilled under consideration that three capacitor units are connected in series. If this cannot be achieved by internal discharge resistors additional external discharge devices shall be installed.

5.5 Design Temperature

The capacitors shall be designed according the following temperatures:

Lowest ambient air temperature: - 5 ℃.

Upper limit of temperature category: +45 ℃.

5.6 Tolerances

The capacitor units of a capacitor bank shall be selected in such a way that the tolerances of the individual capacitor units shall be within -0% ~ +10% of the rated

capacitance and the tolerances of the total capacitance of different phases shall be less than +5%.

5.7 Evaluation of Losses

The loss of capacitor should not exceed 0.2 Watt/kVar. Evaluation price of the capacitor bank will be equal to total offered cost (CIF) of capacitor bank + monetization cost due to total losses of capacitor bank. Loss of series reactor shall not be considered for loss evaluation.

Guaranteed values for losses of capacitor bank in Watt shall be stated in Schedule E of Particulars and Guarantees by the Bidder.

The cost on losses will be monetized as follows:

Monetization cost due to total losses of capacitor bank = Tk. 200 x total losses in Watt

The acceptance of capacitors yielding losses higher than the guaranteed values shall be governed by either of the following:-

(a) Losses in excess of guaranteed values but within 0.2 Watt/kVar.

Capacitors shall be acceptable subject to full compliance with all technical particulars, and subject to the Bidder accepting deduction from the Contract Price of charges for each Watt thereof of losses in excess of the guaranteed values, at the above evaluation rates.

(b) Losses in excess of guaranteed values and exceeding 0.2 Watt/kVar.

The acceptance of capacitors 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 Watt thereof of losses in excess of the guaranteed values, at the above loss evaluation rates.

In the event of total losses which 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.

5.8 Voltage of Capacitor Banks/Capacitor Units

The rated voltage of Capacitor Banks shall be 33kV and the maximum permissible voltage shall be 36kV. The maximum permissible voltage of the capacitor bank units shall be 36 kV plus the voltage increase due to inrush current limiting reactors.

5.9 Inrush Current Limiting Reactor

Inrush current limiting reactors shall be provided for each capacitor bank. The contractor shall provide information and calculation that the selected reactor meets the requirements of the capacitors and 33 kV switchgear. The reactor shall be capable to withstand the same over-current as the capacitor bank.

5.10 Neutral Current Transformer

Neutral current transformer should be installed on neutral point of each double Y capacitor connection for unbalance protection. Relevant technical parameter are as follow:

-	Accuracy class	5P10
-	Burden	15VA
-	Rated current	5A or 1A (as per existing)
-	Test voltage	70 /170kV

5.11 Capacitor Bank Connection

All live parts of the capacitor banks (busbar, connections etc.) shall be fully insulated to avoid short circuits caused by vermin (snakes, lizards etc.). All exposed capacitor terminals and cable between capacitor units shall be shrouded or covered with PVC insulation. Each terminal shall be provided with a parallel groove clamp suitable for conductor of up to 2 x 12mm diameters with plain washer, spring washer, nut.

5.12 Harmonic Measurement

To consider the effect of harmonic currents all electrical equipment shall be designed for a continuous current of 1.43 times the rated capacitor bank nominal current.

The contractor shall measure the actual harmonic components at the step of installation and commissioning, related study report also shall be submitted. Details refers to the Schedule A and B of the Volume 3.

5.13 Lifting Device for Capacitor Unit

Each capacitor unit shall have two lifting device shall be installed on both narrow side for erection of capacitor banks and for maintenance (exchange of capacitor units).

The contractor shall include in his offer documentation about the proposed lifting device.

5.14 Nameplate

Name plate shall be stainless steel material to prevent rust. Name plate shall have all items described in IEC 60871.

i) Manufacturer
ii) Identification number and manufacturing year
iii) Rated output
iv) Rated voltage
v) Rated frequency
vi) Temperature category
vii) Discharge device
viii) Insulation level
ix) Internal fuses (if any)
x) Applied standard

5.15 Documentation for Capacitor Bank

The followings shall be included with the offer.

i) Completely filled in technical data schedule.
ii) Supply record with documentary evidence of the offered capacitor bank for last 10 years mentioning Purchasers name, quantity, year of supply.
iii) Printed catalogue indicating the offered type capacitor bank shall be submitted along with the Bid.

Bids not mentioning the technical specification of the tender or not fulfilling the requirements of serial No. 2 & 4 shall be rejected.

5.16 Type Test and Routine Test

5.16.1 Type test report of offered type capacitor unit shall be submitted as per relevant clause of Schedule G.

5.16.2 Type test items as per as per relevant clause of Schedule G (in accordance with IEC 60871) shall be submitted.

5.16.3 Every capacitor units shall be routine tested by supplier and contractor shall submit routine test report with test values at the time of delivery. Routine test report shall have following items as a minimum:

a). Capacitance measurement
b). Tangent of dielectric loss angle
c). Voltage test between terminals
d). Voltage test between terminals and container
e). Test of internal discharge device
f). Sealing test

g). Discharge test on internal fuses

capacitor units shall be partial discharge tested as a acceptance test and testing values shall be included in routine test report.

5.17 Series Reactor

5.17.1 Generally Inrush suppression series connected reactors are required to protect the capacitor bank form inrush current due to switching. Air cored, air cooled, dry type, copper wound outdoor reactor is envisaged to limit the inrush current. The normal current rating of the reactor shall be 143% of rated continuous current of the capacitor bank. The voltage rating of the base insulators shall be of 36kV. The Basic Impulse level shall follow the range of capacitor bank.
If it is required to change the type of the reactor based on the specified study (clause 4.11 herewith) then follow the statement of the Schedule A and price rate of the Schedule B.

5.17.2 For both capacitor and reactor, the method of mounting and minimum clearance required for, live parts shall be indicated clearly and shall be as per IEC 60071-2. The mounting structure arrangements for the reactor shall have consideration for the magnetic clearance between reactors and/or reactor and any metallic parts, covering in any design cases.

5.17.3 The reactor shall be free from annoying hum or vibration. The design shall be such as not to cause any undesirable interference with radio or communication circuits.

5.17.4 The complete assembly of the capacitor bank shall be on a hot dip galvanized steel structure. The details of mounting structure connections with relevant drawings shall be furnished. The mounting structure details for mounting the two groups of capacitor with neutral CTs and inrush current limiting reactor has to be furnished. The bottom most portion of the lowest post insulator shall follow the IEC 60071 and 61936, from the ground level. The two groups shall be mounted suitably ensuring sufficient clearances.

5.17.5 Test:
The test items as per IEC 60289 and 60076-6 included in type test as per relevant clause of Schedule G.

5.17.6 Every reactor units shall be routine tested by supplier and contractor shall submit routine test report with test values at the time of delivery. Routine test report shall have following items as a minimum

Routine Test:
a) Measurement of winding resistance
b) Measurement of inductance
c) Separate source voltage withstand test
d) Induced over-voltage test

5.18 Key Interlocking System

Each capacitor bank shall be fitted with a time delay electro-mechanical interlocking system to prevent access to the capacitors for a preset time interval following de-energization. This gives the capacitor unit's internal resistor time to discharge any stored energy within the unit. The time delay circuit is also used to inhibit immediate re-closure of the capacitor bank after an open/trip operation.

When the capacitor bank is switched off, an interlock key is released from the appropriate control/relay panel after the timer has been timed out (min 10 minutes). This key shall be used to gain access to the capacitor bank compound surrounded by fencing. The bank is only ready for energization when the key is returned back the control/relay panel.

6. Protection, Metering & Control and Substation Automation System

6.1 General

The protection and control facilities shall be suitable for the power system arrangement as shown on the bid drawings.

6.1.1 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
- AVR
- 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.

6.1.2 For the entire system, the following protection philosophy shall be applicable:

	Main Scheme		Scheme	Reclosing	Details
	Relay	Comm. Ch			
Main 1	Transfer Trip (PUTT/POTT)	Optical	Distance (21) 67/67N 68, VTF 50 Stub 50 SOTF	Multiple 1ph, 3ph, 1+3ph	Full scope of Distance and Multiple OC Function
Main 2	Transfer Trip (PUTT/POTT)	Optical	Distance (21) 67/67N 68, VTF 50 Stub 50 SOTF	Multiple 1ph, 3ph, 1+3ph	Full scope of Distance and Multiple OC Function
Backup	67/67N 68, VTF 50/50N 51/51N				For 145kV only

6.1.2.1 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 shall be from different manufacturers or different models from same manufacturer.

6.1.2.2 During the Design stage, the Contractor can propose different arrangement like:

- Main 1 Protection and Main 2 Protection in the same cubicle and separate Control cubicle or
- Both Protection and Control in the same cubicle for lower voltage class like 132kV & lowers

6.1.2.3 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.

6.2 Protection Relay - General

6.2.1 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), Alstom/GE (France / UK/USA), Siemens (Germany), or SEL (USA).

6.2.2 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.

6.2.3 All relays shall operate correctly within system frequency limits of 47Hz to 51Hz.

6.2.4 Installation, Testing and Commissioning of Control, protection and metering system shall be done by the Manufacturer(s) Engineer(s).

6.2.5 All the Auxiliary relays (Contactor, TCS, Tripping relays, thermostat, humidity controllers etc.) used for protection scheme shall be of Europe/USA origin.

6.3 Fault Clearance Times

6.3.1 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	160

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	160
72% of 100% of the line length where (@) plus protection signalling time	msec.	100	130	150	190

6.3.2 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.

6.4 Arrangement of Facilities

6.4.1 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.

6.4.2 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.

6.4.3 Backup Control panels shall incorporate all necessary control and indication facilities for the operation of the plant and equipment at the associated substation even in the case of failure of Substation Automation System. In addition, the plant may be remotely controlled and supervised from the National Load Despatch Centre (NLDC) in Dhaka.

6.4.4 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.

6.4.5 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.

6.5 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.

6.6 Test and Earthing Facilities

6.6.1 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.

6.6.2 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 mm^2.

6.6.3 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.

6.7 Protection Devices

6.7.1 Simplified arrangements of the main connections and protection for the various items of plant are shown in Bid Drawing.

6.7.2 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.

6.7.3 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.

6.7.4 Transformer Buchholz, winding temperature and tap changer protective 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.

6.8 Relays

6.8.1 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.

6.8.2 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.

6.8.3 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.

6.8.4 Electrically reset tripping relays shall be provided where necessitated by the system of control, such as for those circuits subject to remote supervisory control.

6.8.5 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.

6.8.6 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.

6.8.7 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.

6.8.8 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.

6.8.9 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.

6.8.10 Any auxiliary supplies needed shall be drawn from the main station batteries and not from separate internal batteries in the protection equipment.

6.8.11 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.

6.8.12 Attention is practically drawn to the tropical climate and relay designs should be entirely suitable for duty under full tropical conditions.

6.8.13 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.

6.8.14 Relay shall be suitable for operation on 110 V nominal, 121 V float DC systems without the use of voltage dropping resistors or diodes

6.8.15 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.

6.8.16 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.

6.8.17 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.

6.8.18 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.

6.8.19 Electromagnetic Compatibility

6.8.20 In certain cases, e.g. distance protection, current differential etc., electronic relays, or devices utilising microprocessors are specified and electromagnetic devices will not be accepted.

6.8.21 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.

6.8.22 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.

6.8.23 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.

6.9 Overhead Line Protection

6.9.1 400, 230 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.

6.9.1.1 Main 1 and Main 2 protection of 400 kV & 230 kV line shall be of distance protection with

directional overcurrent to earth fault protection as a backup. The Main 1 & backup protection of 132 kV line shall be of distance protection and Directional overcurrent & Earth fault protection respectively. Both main protections and directional earth fault protection operating in conjunction with tele-protection channels over optical fibre permissive underreach scheme of distance protection.

6.9.1.2 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.

6.9.1.3 Two sets of protection shall consist of different types of relays either from the same Manufacturer or from different Manufacturers. Separate elements shall be provided for phase and earth fault measurement. Separate elements shall also be provided for each zone. Phase and earth fault compensation features shall be incorporated to ensure accurate distance measurement for all types of fault and to allow for variation in the path of earth faults on the system.

6.9.1.4 Main Protection (Distance): The main protection (Main-1 & Main-2 for 400 & 230kV and Main-1 for 132kV) shall be of numerical type and shall be provided by distance relays for use with a signalling channel.

6.9.1.5 The relay scheme offered shall be suitable for use in the permissive under-reaching, permissive overreaching, blocking and unblocking modes. All these options shall be contained and selectable in the standard relay scheme. The relay should be applicable to all neutral ground possibilities and should be suitable for the protection of long or short overhead lines or cables, double circuit lines, heavily loaded lines, lines with weak infeed etc.

6.9.1.6 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.

6.9.1.7 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.

6.9.1.8 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.

6.9.1.9 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.

6.9.1.10 The Zone 3 elements shall provide a further time delayed back-up zone.

6.9.1.11 Distance protection back-up zones shall also trip the remote end circuit breaker(s) via a direct intertripping channel.

6.9.1.12 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. 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.

6.9.1.13 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.

6.9.1.14 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.

6.9.2 Single pole tripping and auto-reclosing are being employed and the auto-reclosing scheme requirements are given in Section 6.12. The distance protection shall be suitable for such a scheme and the Contractor shall substantiate by calculation or other means that phase selective tripping will be achieved under the system conditions anticipated in the daily operation.The Contractor may request whatever information he requires for carrying out the necessary calculations.

6.9.2.1 Auto reclosing shall be capable of being blocked for

i) any three-phase fault
ii) any Zone 2 or Zone 3 time delayed trip
iii) carrier channel out of service
iv) DEF aided trip
v) DEF back up time delayed trip
vi) Switch on to fault.

6.9.3 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 autoreclose 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.

6.9.4 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

6.9.5 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.

6.9.6 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.

6.9.7 Under no circumstances shall any line protection operate because of normal system switching including de-energisation of the line.

6.9.8 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.

6.9.9 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.

6.9.10 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.

6.9.11 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.

6.9.12 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

6.9.13 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.

6.9.14 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.

6.9.15 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.

6.9.16 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.

6.9.17 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.

6.9.18 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.

6.9.19 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.

6.9.20 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.

6.9.21 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.

6.9.22 Facilities shall be provided to block zones 1, 2 and 3 of the distance relay from the power swing blocking logic as required.

6.9.23 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.

6.9.24 The associated time delay relay shall have a setting range of 50-250 ms.

6.9.25 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.

6.9.26 Reset times shall be low to ensure the associated distance relay reverts to its normal role as soon as possible following a power swing.

6.9.27 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.

6.9.28 If the associated VT supplies are lost due to VT fuse failure the power swing blocking relay shall not operate.

6.9.29 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.

6.10 Busbar Protection

6.10.1 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. The protection shall be extensible to cover the final substation arrangements and Bidders shall state what extra material is required.

6.10.2 The busbar protection shall meet the fault clearance time of 80ms for 400kV under all conditions and have the following features:

6.10.2.1 In case of 400kV busbar protection, two independent measurement, protection & tripping criteria shall be applied.

6.10.2.2 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.

6.10.2.3 Two independent hand or electrically reset busbar protection trip relays shall be associated with each circuit-breaker. These trip relays may also be employed for circuit breaker failure. Operation of either of these relays shall block closing of the associated circuit breaker.

6.10.2.4 Each trip relay shall trip the circuit-breaker via both trip coils. Both relays on the transformer circuits shall trip the associated circuit-breakers.

6.10.2.5 The operating time of the measuring relays shall not exceed 30msecs at five times the relay current setting.

6.10.2.6 The busbar protection will be supplied from multi-ratio current transformers. The working ratio will be selected on the basis of maximum load transfer in the same manner as the line current transformer ratios.

6.10.2.7 The overall fault setting shall be between 10% and 30% of the minimum fault current available for any type of fault, unless otherwise specified. The minimum fault current for busbar faults will be advised at a later stage.

6.10.2.8 The rated stability limit of the protection shall not be less than the switchgear short circuit rating.

6.10.2.9 Automatic and continuous supervision of current transformer circuits shall be provided to give an alarm when the out-of-balance current reaches an undesirable value. Operation of current transformer supervision equipment should take the defective protection zone out-of-service by short-circuiting current transformer bus wiring.

6.10.2.10 The Contract shall include for all necessary current transformers, relay panels, marshalling boxes, isolating and shorting links, etc. A lockable Busbar protection ON/OFF switch shall be provided.

6.10.2.11 Current transformer secondary bus wiring should be suitably dimensioned to reduce current transformer burdens to a minimum.

6.10.2.12 Suitable voltage limiting devices shall be provided as necessary, including across the unused part of the CT secondary when tapings are employed.

6.10.2.13 Full details of the scheme offered, together with performance figures for stability and sensitivity shall be provided in accordance with Clause 5.12. 9.2

6.10.2.14 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 busbar protection shall be of decentralised with redundant DC/DC supplies type and the bay units shall be fixed as close to the CTs as possible reducing the copper wiring to a bare minimum and thereby also reducing the CT burden and CT dimension.

6.10.2.15 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.

6.10.2.16 The Busbar Protection Scheme shall be engineered for future bay also.

6.10.3 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.

6.10.4 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) The overall fault setting for any type of fault shall be between 10% and 30% of the minimum fault current available. The minimum fault current available for a busbar fault will be advised later.
iii) Current transformer knee point voltages shall not be less than twice the relay circuit setting voltage.
iv) The maximum peak voltage across current transformer secondary wiring shall not exceed 3 kV under maximum internal fault conditions.
v) Associated current transformers shall be 5P20, low reactance type. Split core type current transformers will not be accepted.
vi) 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.

6.11 Circuit Breaker Failure Protection

6.11.1 Breaker failure protection shall be fitted to all 420kV, 245 kV and 145 kV circuit breakers of the substation. The breaker failure protection on a circuit breaker shall be initiated by all the other protection devices which normally initiate tripping of that breaker including the receipt of a direct 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 initiate tripping of all adjacent circuit breakers. 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.

6.11.2 In the case of 420kV, 245 kV and 145 kV circuit breaker failure protection, the position of each circuit breaker shall be monitored by a current check relays fed from the protection current transformers as shown on the drawings. The relay outputs shall be connected in series in a "two out of two" arrangement. The relays shall have an operating time of approximately 10 msec. and a consistent reset time of less than 15 msec. The relays shall be capable of remaining in the operated position continuously and of carrying twice the circuit rated current continuously.

6.11.3 The scheme provided shall be suitable for use in a single pole and three pole tripping and auto reclosing schemes as appropriate.

6.11.4 The operating time from initiation to back tripping output shall be selected by means of duplicated timers with a setting range of 50-500 msec. The two timers per circuit breaker in the case of the 400kV and 230 kV scheme shall be connected in series in a two-out-two basis and shall energise both trip coils of all adjacent circuit breakers via two back tripping circuits from separate d.c. supplies. In the case of the 132 kV scheme the two timers shall also be connected in series in a two-out-two basis and energise both trip coils of all adjacent circuit breakers but via a single trip relay.

6.11.5 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 tripping.

6.11.6 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.

6.11.7 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.

6.12 Auto-Reclosing Scheme

6.12.1 Three pole and/or single pole, single shot repetitive auto-reclosing equipment, shall be provided for the overhead line circuit breakers.

6.12.2 Reclosure shall be initiated following tripping by either main protection operating in Zone 1 or in conjunction with a tele protection receive signal. Selection facilities shall also be provided to enable or block three pole delayed auto-reclosing following operation of the directional earth fault protection aided trip output. Reclosure shall not be initiated in the event of a three phase fault, nor any type of fault in the second or third back-up zones, nor when a direct 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.

6.12.3 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.

(d) No auto reclosing: Three phase tripping without auto-reclose shall take place for any type of fault.

6.12.4 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.

6.12.5 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.

6.12.6 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).

6.12.7 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.

6.12.8 A counter shall be provided to record the number of reclosures and lockout after a pre-selected number of reclosures has been reached.

6.12.9 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.

6.12.10 Reclosing schemes shall include voltage monitoring and check synchronising relays as appropriate.

6.12.11 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).

6.12.12 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.

6.12.13 Check synchronising relays shall comply with the requirements of Clause 5.24. 1. The same relays may be used as for manual closing.

6.13 Overcurrent and Earth Fault Protection

6.13.1 The overcurrent and earth fault relays shall be fully Numerical and have multi characteristics (inverse, very inverse, extremely inverse) to IEC 60255.

6.13.2 Overcurrent relays shall have a current setting range from at least 50% - 200% in 25% setting steps.

6.13.3 Earth fault relays shall have a current setting range from at least 20% - 80% in 10% setting steps.

6.13.4 Time multiplier settings shall be continuously adjustable from 0 to 1 or, as an alternative in steps of 0.025 from 0.05 to 1.0.

6.13.5 In the case of transformer circuits relays shall be provided with high set instantaneous units which can be set to 1.25 times the fault current in the HV winding for a fault on the LV terminals computed using the transformer minimum impedance and assuming negligible source impedance. The instantaneous unit shall have a low transient overreach (less than 5% for system X/R ratio of 10) and an operating time of less than 40 msec. at two times the current setting.

6.13.6 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.

6.13.7 Overcurrent and earth fault relays shall trip via the CB duplicate trip coils and initiate duplicated direct intertripping to the remote line end CB.

6.13.8 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.

6.13.9 Directional back up overcurrent and earth fault relays shall be provided for underground Cable feeders and the directional elements shall be voltage polarised.

6.13.10 Directional units for directional overcurrent protection shall be quadrature connected with a relay characteristic angle setting of 30° or 45° current leading voltage.

6.13.11 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.

6.13.12 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.

6.13.13 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.

6.13.14 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.

6.14 Coupling Bay Protection

6.14.1 The Coupler bay shall be provided with overcurrent instantaneous trip relay protection (50 BF) and overcurrent time delay relay protection (51, 51N). Relays shall comply with the requirements of clause 5.12.

6.14.2 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.

6.15 Transformer Protection

The auto transformers and the two/three winding power transformers shall be provided with Main 1 & Main 2 biased differential protection. Main 1 & Main 2 shall be preferably from two different manufacturers or different models from same manufacturer. Directional over current relay and over current relays also shall be installed for back up protection. Additionally, over flux (V/Hz) relay shall be provided in order to avoid any overheating. Relay and protection connections refer to the Drawing, and detailed protection scheme shall be approved by Employer.

400kV shunt reactor shall be provided with Main 1 & Main 2 biased differential protection. Main 1 & Main 2 shall be from different Manufacturer or different models from same manufacturer. Over current relay and earth fault relays also shall be installed for back up protection.

6.15.1 Biased Differential Protection

6.15.1.1 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.

6.15.1.2 Overall differential protection shall be of the biased differential type and capable of detecting phase and earth faults.

6.15.1.3 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.

6.15.1.4 The protection shall be designed to ensure stability on any transformer tap position under maximum through fault conditions with maximum d.c. offset. An infinite source is to be assumed and the through fault current calculated using the transformer impedance only.

6.15.1.5 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.

6.15.1.6 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.

6.15.2 Restricted or Balanced Earth Fault Protection

6.15.2.1 Where specified, or shown on drawings, transformer/reactor windings and connections shall be protected by restricted earth fault protection. 2 (two) separate Restricted Earth Fault (REF) Protections have to be established for auto transformers/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.

6.15.2.2 The 2nd REF protection will be of high impedance type with necessary protection against over voltages. For reliability reasons the restricted earth fault relay shall be separate from the transformer differential relay.

6.15.2.3 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.

6.15.2.4 Delta connected windings shall be protected by balanced earth fault protection.

6.15.2.5 33kV winding of Earthing transformer (if any) will also be protected with low impedance type REF protection. Relays shall have maximum sensitivity and minimum operating times consistent with stability for faults outside the protected zone and on magnetising inrush surges.

6.15.2.6 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.

6.15.2.7 For the purpose of calculations, it shall be assumed that any neutral earthing impedance is short circuited.

6.15.2.8 The Contractor shall prepare for approval calculated performance for instantaneous high impedance restricted earth fault protection in lieu of heavy current tests, subject to the conditions in Clause 6.10.4 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.

6.15.3 Transformer Back-up Overcurrent Protection

Three-pole inverse time back up overcurrent and earth fault protection shall be provided as shown on the drawings. This shall comply generally with Clause 5.12 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.

6.15.4 Gas Pressure (Buchholz) Protection

6.15.4.1 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.

6.15.4.2 All necessary flag indication, tripping relays and alarm relays associated with this protection shall be provided, mounted and connected under this contract.

6.15.5 Oil and/or Winding Temperature

6.15.5.1 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.

6.15.5.2 All necessary flag indication, tripping relays and alarm relays associated with this protection shall be supplied and connected under this contract.

6.15.6 Low Oil Level and Pressure Relief Devices

6.15.6.1 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.

6.15.6.2 The alarm relays associated with these devices shall be supplied and connected under this contract.

6.15.7 Tap Changer Oil Surge

6.15.7.1 Transformers will be provided with an oil surge or pressure operated device having contacts for purposes of remote alarm and trip.

6.15.7.2 A relay associated with this device shall be supplied and connected under this contract.

6.15.7.3 All necessary flag indication, tripping and alarm relays associated with tap change oil surge shall be provided.

6.15.8 Standby Earth Fault Protection

6.15.8.1 Standby earth fault protection shall be provided for all earthing transformers/resistors, fed from a current transformer in the transformer/resistor neutral connection.

6.15.8.2 The operating current shall be adjustable between 10 and 40 per cent of the resistor value. The time delay shall be adjustable between 1 and 10 secs. As an alternative to a definite time relay, a long inverse time relay may be offered.

6.15.9 Tripping Relays

6.15.9.1 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

6.15.9.2 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.

6.15.9.3 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.

6.15.9.4 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

6.15.9.5 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.

6.16 DC Auxiliary Voltage Operating Range

DC operated relays, coils, elements, etc. will be operated from a 110V rated dc. battery, which under float charging conditions operates at about 125V. DC operated relays coils elements etc. shall be suitable for operation over a voltage range of 66V to 143V. i-e. 110 - 40% + 20%.

6.17 Teleprotection Signalling

Details of protection initiation and various permissive and direct inter-tripping signals are as specified in Section-14, of Vol. 2 of 3.

6.18 Digital Fault and Disturbance Recorder (DFDR) [If Applicable]

6.18.1 The DFDR shall be delivered only for all new 400/230/33kV, 400/230/132kV and 400/132 kV substations.

6.18.2 The DFDR in PGCB's system are manufactured by Qualitrol, Belgium, BEN 6000/5000.

6.18.3 For the purpose of standardization, the DFDR to be supplied under this project shall be from Qualitrol (Belgium/UK), SIEMENS (Germany), SEL (USA).

6.18.4 Installation, testing & commissioning of the DFDR shall be done by the DFDR Engineer(s) of the DFDR Manufacturer(s).

6.18.5 The DFDR shall have the following features:

6.18.5.1 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.

6.18.5.2 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.

6.18.5.3 The DFDR system shall be modular in design for easy expansion, upgrade and maintenance.

6.18.5.4 The acquisition system or its storage unit shall not be based on a PC platform.

6.18.5.5 The independent DFDR system shall be equipped with a minimum of 40 digital and 8 analogue signals per bay and shall be suitable for AC/DC measurement without any hardware changes.

6.18.5.6 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.

6.18.5.7 All input signals shall be able to scan and record simultaneously at least 2 or 3 user-programmable sampling rates from 500Hz to 6kHz for fast (short-term) transient monitoring and from 1Hz to 500Hz for slow phenomena (long-term) monitoring in order to detect and record fast (short-term) and slow phenomena (long-term) events.

6.18.5.8 At least 25 sec. of memory for transient fault data recording (at 6 kHz sampling rate) and over 1000 sec. for slow (at 30 Hz) phenomena recording shall be provided in addition to the auto-maintained, inbuilt hard disk unit which shall be installed for data storage. The inbuilt hard disk unit shall be managed and operated by the identical industrially proven operating system of the DFDR.

6.18.5.9 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.

6.18.5.10 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.

6.18.5.11 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.).

6.18.5.12 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.

6.18.5.13 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.

6.18.5.14 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.

6.18.5.15 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.

6.18.5.16 The system shall be equipped for time synchronization by the external GPS clock receiver for real time synchronizing (including antenna).

6.18.5.17 Local printing facility shall be provided with the system.

6.18.5.18 The master station (a latest version of PC) and the relevant software shall be supplied with the equipment for analysis and communication.

6.18.5.19 Power quality monitoring or continuous monitoring (periodical recording) shall be made available for at least 4 feeders.

6.18.5.20 In addition to above, manufacturer shall provide warranty for its product at least for 5 years.

6.18.6 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.

6.19 Tripping Relays

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 Clause 5.15.9. The relay used shall be of USA/Europe/Japan origin.

6.20 Protection Settings

6.20.1 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.

6.20.2 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. Hence, Contractor is requested to consider this software for simulation. Other software is also acceptable with the consent & approval of Employer. Contractor shall submit soft copy files of software for review & approval from Employer. A Power point demonstration is to be foreseen by the contractor for final approval.

6.20.3 Any additional information needed by Contractors should be requested.

6.21 Substation Automation System

6.21.1 Scope of Supply

6.21.1.1 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.

6.21.1.2 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.

6.21.1.3 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 for 400/230/132 kV substation and one (1) communication gateway for 132/33 kV substation to NLDC, inter-bay bus, intelligent electronic devices (IED) for bay control and protection as shown in the enclosed general system architecture drawing.

6.21.1.4 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.

6.21.1.5 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.

6.21.1.6 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.

6.21.1.7 The system shall be capable of having its computing power increased in the future through the addition of additional computing systems.

6.21.1.8 The system design life shall be not less than 20 years.

6.21.1.9 The capacity of the SA system shall be sufficient for the ultimate development of the substation as set out in the project requirements.

6.21.1.10 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.

6.21.1.11 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.

6.21.2 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.

6.21.3 Compliance with Standards

For design and type-testing of the protection and control equipment, the following standards shall apply:

6.21.3.1 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

6.21.3.2 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

6.21.4 Design and Operating Requirements

6.21.4.1 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.

6.21.4.2 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.

6.21.4.3 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.

6.21.4.4 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).

6.21.4.5 400kV, 230 kV and 132 kV substation, can also be controlled from the control panel installed in the control room. The following modes of operation shall be possible:

a. Emergency operation of breaker, disconnector, earthing switch etc. from the LCC.
b. Emergency operation of breaker, disconnector, earthing switch etc. from the backup mimic panel located in the new control room. Both, bay controller-guided and unguided operation shall be possible from this panel.
c. Normal operation of breaker, disconnector, earthing switch etc. from the station automation system's HMI located in the new control room.

6.21.5 Architecture & Components

6.21.5.1 The SAS design shall consider Rapid Spanning tree Protocol (RSTP) for 230kV & 132kV level. For 400kV and higher voltage level, Parallel Redundancy Protocol (PRP) shall be applicable.

6.21.5.2 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.

6.21.5.3 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 10% 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.

6.21.6 Modes of Operation

The operator stations and specified remote users shall have the following operational modes, each password protected.

6.21.6.1 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.

6.21.6.2 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.

6.21.6.3 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.

6.21.6.4 System Manager: To provide access to all system functions, including assignment of passwords and system maintenance activities.

6.21.6.5 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.

6.21.6.6 A series of passwords shall be personally assigned to operators in each of the above categories.

6.21.6.7 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.

6.21.6.8 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.

6.21.6.9 Similarly, an operator's manual entry applied at one workstation shall be immediately displayed at other workstations where this data is presented.

6.21.7 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

6.21.8 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).

6.21.9 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.

6.21.10 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

6.21.11 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.

6.21.12 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 minimising maintenance time to repair.

6.21.13 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.

6.21.14 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.

6.21.15 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 parameterisation, 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).

6.21.16 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.

6.21.17 The substation monitoring/protection system shall supply data for maintenance, repair and remote parameter setting of protection and control devices in the switchyard.

6.21.18 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.

6.21.19 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.

6.21.20 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 minimise maintenance.

6.21.21 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.

6.21.22 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 parameterisation) shall be provided with associated tools and equipment. The required engineering tools and analysing 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.

6.21.23 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.

6.21.24 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.

6.21.25 System Hardware

6.21.25.1 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.

6.21.25.2 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.

6.21.25.3 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.

6.21.25.4 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

6.21.25.5 The information fields above shall be structured in columns for maximum readability.

6.21.25.6 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.

6.21.25.7 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.

6.21.25.8 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.

6.21.25.9 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.

6.21.25.10 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 fulfil the hardened requirements concerning temperature, EMC and power supply (110 V DC from the station battery) suitable to be installed in substations shall be provided, i.e. the same data as common for numerical protection.
- The use of Ethernet hubs is not permitted as they do not provide collision-free transmission.
- The switches shall support priority tagging and open standards for ring management like fast spanning tree to ensure that e.g. for later system extension the utility has not to rely on one switch supplier only.
- External switches shall be supplied as they have the advantage that there is no interruption or 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.

6.21.25.11 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.

6.21.25.12 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.

6.21.25.13 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.

6.21.25.14 The 400kV, 230 kV 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

6.21.25.15 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.

6.21.25.16 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.

6.21.25.17 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.

6.21.25.18 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.

6.21.25.19 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.

6.21.25.20 Main and backup protection shall not be incorporated in the bay control unit. Main & backup protection shall be provided separately.

6.21.25.21 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.

6.21.26 Software Structure

6.21.26.1 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.

6.21.26.2 Confirmation that the software programs will be supported for a minimum of 20 years is required to be submitted with the bid.

6.21.26.3 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.

6.21.26.4 Station Level Software:

6.21.26.4.1 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.

6.21.26.4.2 Operating System

A Windows NT workstation operating system shall be used for the operator station as it supports several standard system features, e.g. support for several Windows office applications, multitasking, security levels, data exchange mechanisms (DDE, OLE), open data base communication standards (ODBC) and a standardised, user-friendly look & feel HMI.

6.21.26.5 Bay Level Software

6.21.26.5.1 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.

6.21.26.5.2 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.

6.21.27 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).

6.21.28 System Functions

6.21.28.1 Control Unit Functions

6.21.28.1.1 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

6.21.28.1.2 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.

6.21.28.1.3 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 decentralised 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 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.

6.21.28.1.4 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.

6.21.28.1.5 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.

6.21.28.1.6 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.

6.21.28.1.7 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.

6.21.28.1.8 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.

6.21.28.2 HMI Functions

6.21.28.2.1 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.

6.21.28.2.2 An acoustic alarm shall indicate abnormalities and all unacknowledged alarms shall be accessible from any screen selected by the operator.

6.21.28.2.3 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

6.21.28.2.4 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.

6.21.28.2.5 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.

6.21.28.2.6 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.

6.21.28.2.7 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.

6.21.28.2.8 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.

6.21.28.2.9 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.

6.21.28.2.10 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

6.21.28.2.11 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.

6.21.28.2.12 This report shall be printed automatically at pre-selected times. It shall also

be possible to print this report on request.

6.21.28.2.13 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.

6.21.28.2.14 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.

6.21.28.3 Event List

6.21.28.3.1 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.

6.21.28.3.2 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.

6.21.28.3.3 A printout of each display shall be possible on the hard copy printer.

6.21.28.3.4 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.

6.21.28.3.5 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

6.21.28.3.6 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

6.21.28.4 Alarm List

6.21.28.4.1 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.

6.21.28.4.2 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

6.21.28.4.3 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.

6.21.28.4.4 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.

6.21.28.4.5 Filters for selection of a certain type or group of alarms shall be available as for events.

6.21.28.5 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.

6.21.28.6 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.

6.21.28.7 User Authority Levels

6.21.28.7.1 It shall be possible to restrict the activation of the process pictures of each object (bays, apparatus, etc.) to a certain user authorisation 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

6.21.28.7.2 For maintenance and Engineering purposes of the station HMI, the following authorisation levels shall be available:

1) No Engineering allowed
2) Engineering/configuration allowed
3) Entire system management allowed

6.21.28.7.3 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.

6.21.29 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

6.21.30 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

6.21.31 Configuration Tools

6.21.31.1 The configuration of the station HMI shall be made using the operator station working in Windows NT 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.

6.21.31.2 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.

6.21.31.3 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

6.21.31.4 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.

6.21.32 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 6.21.25.11 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.)

6.21.33 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.

6.21.34 Availability Calculations

The Contractor shall submit availability calculations for the offered substation automation system.

6.22 Trip Circuit and Power Supply Supervision

6.22.1 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.

6.22.2 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.

6.22.3 The trip circuit supervision scheme shall operate satisfactorily and correctly under such conditions.

6.22.4 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.

6.22.5 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.

6.22.6 Relay alarm elements should be equipped with self-resetting flag indicators.

6.22.7 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.

6.23 Busbar Voltage Selection

Where required, selected voltage references, one for each busbar, shall be employed for all indications, metering, protection and synchronizing where appropriate. The correct voltage selection for the requirements of each circuit according to the busbar to which it is connected shall be obtained by direct use of auxiliary contacts on busbar selector switches.

6.24 Synchronising

6.24.1 Synchronising Scheme: Synchrocheck facilities are required at all circuit breakers controlling feeder circuits and bus coupler circuits, and LV circuit breakers controlling transformers. Interlocking is not required between the HV and LV circuit breaker on the transformer circuit since the transformer could be energised from either network.

6.24.2 The system provided under the Contract is to be to the approval of the Engineer and is to be such that the synchronising circuit must be established before the

circuit breaker can be closed. Check synchronising relays to prevent circuit breaker closing under adverse conditions are to be included where specified.

6.24.3 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.

6.24.4 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 check synchronising 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.

6.24.5 It shall only be possible to operate on one circuit at a time.

6.25 Diagrams

The Contractor shall submit schematic diagrams for consideration of the Engineer within six months of the contract commencement date. Prior to preparation of schematic diagrams, the Contractor shall provide single line, block and logic diagrams 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. The detail list of documentation is given under clause 5.19.9.6.

6.26 Current Transformer Calculations

The Contractor shall submit to the Engineer detailed calculations substantiating the parameters of the current transformers he proposes to provide. They shall be presented within six weeks of the contract commencement date.

6.27 Energy Meter (Tariff Metering)

For each substation, the Contractor has to foresee one (or more) separate Metering cubicle(s). During the Design stage, the Contractor has to propose the final solution, which will be subject of the Employer's final approval

6.27.1 Meter Requirements

1. Programmable meter
2. Adjustable different tariff
3. 0.2S accuracy class meter
4. 110-400V flexible input voltage setting

5. 1(10) A current rating
6. Accuracy class to be ±0.1 for kWh and ±0.5 for kVARh
7. RS232/485 port for modem interface
8. Meter shall be IEC 61850 compliant
9. Standard metering protocol for remote interface
10. Data storage of 16 channel@30min interval and of 90 days
11. Optical head and software to upload and download of meter data
12. Password protection for programming and for configuration
13. Configurable display, including meter ID, power quadrant display etc.
14. Provision for quick reading scroll, reset etc. (programmable)
15. Ability to measure synchrophasor
16. Communication facility to a remote centre
17. Power quality measurement with built-in HMI display

6.27.2 Additional Requirements

18. Online test facility of meter (with TTB) and with security sealing provision
19. TTBs should be at the suitable accessible panel front location with meter
20. Meter cabinet should be exclusively for tariff metering only and have sufficient security sealing provision, provided with 220V, 5A, two-pin socket outlet for modem power, auxiliary bias power, testing equipment power, etc.
21. All main metering CTs and VTs should be directly terminated to the metering panel including star point (4 wire)
22. The backup metering circuit may be shared for other purpose
23. The VT MCBs (both main and backup) should be located in the metering panel;downstream VT MCB rating should be less than that of upstream
24. All CT & VT terminals should have security sealing provisions.
25. Ability to measure Harmonics Angle, Power harmonics upto 60th or above order with THD
26. Storage capacity minimum 800MB

6.27.3 Normal Display List

Scroll Order	Display Item Name
1	Complete LCD test
2	Present date
3	Present time
4	Current billing total kWh-Del
5	Current billing total kWh-Rec
6	Current billing total kVARh-(Q1+Q4)
7	Current billing total kVARh-(Q2+Q3)
8	Current billing maximum kW-Del
9	Current billing maximum kW-Del Date
10	Current billing maximum kW-Del Time
11	Current billing cumulative kW-Del
12	Current billing maximum-Rec

Scroll Order	Display Item Name
13	Current billing maximum kW-Rec Date
14	Current billing maximum kW-Rec Time
15	Current billing cumulative kW-Rec
16	Phase A Voltage
17	Phase B Voltage
18	Phase C Voltage
19	Phase A Current
20	Phase B Current
21	Phase C Current
22	Phase A voltage angle
23	Phase B voltage angle
24	Phase C voltage angle
25	Phase A current angle
26	Phase B current angle
27	Phase C current angle
28	System PF-arithmetic
29	Line frequency

6.27.4 Alternate Mode Display List

Scroll Order	Display Item Name
1	Complete LCD test
2	Present date
3	Present time
4	Current billing total kWh-Del
5	Current billing total kWh-Rec
6	Current billing total kVARh-(Q1+Q4)
7	Current billing total kVARh-(Q2+Q3)
8	System PF-arithmetic
9	Line frequency

Load profile (cumulative meter reading) and Instrumentation profile data in the following format should be stored in intervals of 30 min for at least 100 days:

6.27.5 Interval Date (Load Profile)

Interval Data Mode: Cumulative Engineering Units

Time	kWh-Del	kWh-Rec	KVARh-(Q1+Q4)	kVARh-(Q2+Q3)
Date:				
00:00	0	0	0	0
00:30	0	0	0	0
01:00	0	0	0	0
01:30	0	0	0	0

6.27.6 Interval Date (Instrumentation)

Set-1

Time	End Phase A Voltage	End Phase A Voltage	End Phase A Voltage	Average System kW
Date:				
13:45	61.0544	61.1424	61.072	0

Set-2

Time	End Phase A Current	End Phase A Current	End Phase A Current	Average System PF-Arithmetic
Date:				
13:45	0.0008	0.0004	0.0004	-0.7002

Self-read feature for at least 12 months' billing history.

7. Protection, Metering, and Control of 36kV Capacitor Bank

7.1 PROTECTION, CONTROL AND MONITORING EQUIPMENT PART

7.1.1 General

This section is intended for the design of the protection, control and monitoring equipment and as for as applicable for interfaces. Requirement for technical performance of the equipment are stated in this Section.

Protection, Control & monitoring functions shall be incorporated in one single panel. Meters, mimic diagram & control switches, voltage & current test terminal and system monitoring devices shall be equipped.

Panel shall be installed for each capacitor bank respectively. However, when two capacitor bank feeders are connected with main circuit breaker, three panels shall be installed: one main panel and two feeder panels. Type of panel shall be simplex which incorporate all specified function in front. A typical protection and control function arrangement refers to bid drawing.

The contractor shall be responsible for ensuring the correct operation of the protective equipment and shall submit for approval recommended relay setting supported by design calculation for all protective equipment been supplied.

The contractor shall be responsible for ensuring the correct operation of the protective equipment and shall submit for approval recommended relay setting supported by design calculation for all protective equipment been supplied. The engineer reserves the right to ask the Contractor to get the design calculation approved by the manufacturer of the Protective equipment and/or get the confirmation for the suitability do 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 Employer.

7.1.2 Equipment General Requirements

The requirements are to be strictly observed with regard to design and execution.

The control and monitoring equipment to be provided shall be suitable for faultless and safe control and supervision of the entire substation during all phases of operation.

As a general rule, measuring points and measuring equipment for interlocking and protection purposes shall be separate and not be combined with measuring equipment for the automatic control equipment. Signal to be processed in several systems, e.g. remote and manual controls, event recording system etc. shall be suitable repeated and mutually decoupled to avoid interaction.

The material of all equipment shall fully meet the requirements regarding safety and operational conditions of the parameters to be measured. Instrument piping to dedicated control and measuring panel shall be of stainless steel.

All the equipment shall be suitable for the location in which it is to be mounted and in particular all outdoor equipment shall be suitable for the climatic conditions of the site.

The spare-free space capacities listed below shall be provided for the following items:

1) Panels	15% space for modules within each frame
	15% space for terminal block frames within each cubicle
2) marshalling rack	15% of space and terminals
3) multi-core control cables	15% of number of conductors.

The above spare capacities shall be available after final commissioning of the substation and shall be suitably distributed over the operating surface of the panel or cubicle in such a way that additional indicators, control equipment or modules may be added to any group of controls.

Each control or relay panels shall be provided with a copper earth bar of not less than 150sq.mm cross section and arranged so that the bars of adjacent panels can be joined together to form a common bus.

7.1.3 Panels

Panels shall be free standing and shall be constructed of adequate thickness to provide rigid support for the control and monitoring equipment which shall be mounted there.

Panels shall be mounted on channel base frames which shall provide at bottom recess. Panels Doors shall be provided with a lock which may be opened by a person within the panel without the use of a key.

The overall height of panels housed in the relay room shall not exceed 2.25m and the color shall be same as existing ones.

All instruments and control devices shall be easily accessible and capable of being removed for maintenance purposes.

Cable connections to panels must be equipped with suitable seals so as to prevent the ingress of dust or vermin or the propagation of possible fires. During installation, a provisional sealing of cable penetrations is required.

Panels which are installed in non air-conditioned rooms shall be provided with thermostatically controlled heating device. Each thermostat shall have an adjustable set-point which shall be adjusted during the commissioning period to such a value that no moisture shall occur on the equipment but also so that during periods of high ambient temperature the temperature rating of the equipment is not exceeded.

7.1.4 Power Supplies and Fusing

All monitoring and control equipment inside the substations shall preferably be connected to the d. c. system of the existing substation.

The contractor must however ensure that plant mounted equipment is not adversely affected by the long cable runs, particularly to the more distant unit.

Basically each panel should be supplied power via independent power distribution switch located station power distribution board. Interconnection and link from adjacent panels are not allowed.
If the Contractor needs a different control voltage but nothing available to use, contractor must design, supply and install all the necessary equipment.

The main power supply fuses (of any other type of current breaking equipment) shall be located in functional groups within separate power distribution panels.

Fuse ratings and time characteristics shall be such that in all cases, a fault within an individual item or module will cause the fuse associated with that item, to rupture and thus disconnect that item from the power supply, before the main fuse is affected.

7.1.5 Indication Instrument and Meters

Terminals and connecting cables from voltage and current transformers up to and including the meter (including all termination between voltage/current transformers and the meter) shall be made inaccessibility by sealed cover.

All indicating instruments shall be of the flush mounted pattern with dust and moisture proof cases complying with IEC 60051-1. Unless otherwise specified, all indicating instruments shall have 96mm or 144mm square cases or equivalent circular cases.

Instrument dials in general should be white with black markings and should preferable be reversible where double scale instruments are specified. Front of panel test terminal blocks shall be provided for all meters.

All electrical meters shall be of accuracy of 0.2

For capacitor bank, 33kV three phase voltages & current and reactive power, power factor meters shall me mounted on front panel. Power factor meter shall indicate factor of 33kV bus point.

7.1.6 Switches and Relays

Switches mounted in the control panels shall be clearly shown. Discrepancy switches shall be provided for the operation of switchgear and the initiation of drives. Discrepancies between the switch position and the plant state shall be indicated by an integral light which shall illuminate the switch in a flashing mode of operation.

7.1.7 Alarm Annunciation

The alarm system which has to be accepted by the PGCB shall consist of an initiating device, a display unit and front-mounted push buttons together with a continuously rated audible warning device and relays, The relays shall, wherever possible, be mounted inside the same panel.

Where it is necessary to differentiate between the urgency of alarms then various approved alarm tone devices shall be provided. In addition and where specified an alarms beacon shall be provided.

The Contractor shall be responsible for providing all the alarms required for the safe and efficient operation. General descriptions of alarm requirements are given in the specification, and the Contractor shall include any other alarms that he considers necessary.

The alarm annunciator unit shall be of electronic design and shall employ solid state technology. Printed circuit card modules of the plug-in type shall be used. The window of each fascia shall be translucent; the legend shall be inscribed on the inner surface and shall only be distinguishable when the alarm is activated.

The changing of annunciator fascia lamps shall be easily carried out from the front of the fascia, and failure of a fascia lamp shall not result in the loss of optical signal from that alarm. Two lamps per fascia may be used for this purpose.

Separate, clearly distinguishable optical signals are to be displayed for the following situations:

annunciation arrives, not acknowledged

annunciation is present, acknowledged

annunciation disappears, not acknowledged

annunciation disappears, acknowledged

The following requirements shall be fulfilled:

connection of audible alarms with horns or buzzers lamp check circuits are to be divided in such a way that the power supply will not be over loaded.easy forming of group signals in the input circuits of the unit

pushbuttons for tasks such as:

to silence horn

to acknowledge annunciation

to cancel annunciation

to check lamps

are to be installed in a suitable divided way in the control desk or panel. It shall not be possible to cancel the optical signal light unless the audible signal has been cancelled.

Alarm fascias are to be arranged in the control panels.

All alarms fascias shall, where possible, be located adjacent to the control and monitoring equipment of the plant with which they are associated. Panel mounted alarm fascias must be easily readable.

7.1.8 Wiring and Cabling Terminals

In particular wiring within panels etc. shall be supported on trays and shall be segregated according to voltage level. Wire carrying a.c. and d.c. voltage shall also segregated.

Spare cores shall be terminated at terminal strips in such a way so as to give a maximum length of core and shall be ferruled in such a way so as to indicate that are spare cores.

Terminal strips at the transmitters shall be of the screw type. Screw type terminals shall have a metal insert between screw and conductor. In the electrical, relay and control rooms advanced semi-automatic connection techniques, like termination-point, wire-wrap is preferred. Wire wrap and termination point connections shall be performed using an approved semiautomatic or automatic, power operated hand tool.

Terminal strips within panels shall be set at an angle to afford easy identification and access.

7.1.9 Labeling and Scales

The identification and lettering of scales and dials shall be in English.

The metric system shall be used for all scales according to the 'General technical requirements'.

The identification and classification of all measuring points, must be shown on diagrams to be produced by the Contractor and entered in the respective lists.

Each cubicle is to be clearly labeled. Each measuring point, transducer, binary transmitter etc. is to be provided with a firmly attached weather and temperature proof plate.

All such plates and cubicle labels shall be inscribed in English. All modules within the panels shall be inscribed in English.

7.1.10 Painting

The requirements specified have to be considered.

However, panels, control equipment are to be supplied with the final painting, whereby external surfaces shall be semi-gloss.

Local mounted panels, housing control and monitoring equipment shall be protected against rust and corrosion by a protective coating such as galvanized zinc, which shall be applied as a first factory coat.

In all cases where site erection work exposes bare metal, such as the drilling or punching out of holes for cable or pipe entry, these areas shall be protected by the immediate application of a protective first coat similar to the original.

The shade and grade of paint are to be agreed to by the Employer and must harmonize with the overall architectural design.

Any machined or bright faces and parts which are not painted must be protected against corrosion by suitable agents prior to installation.

After completion of installation and commissioning, but before Taking over the Contractor shall make good all marks, scratches and damage to the painted surface of all equipment supplied under this contract irrespective of the cause. The Contractor shall also take every reasonable precaution to prevent damage to panels and panels during the course of erection and commissioning. Repairs to panel and cubicle paintwork shall be carried out in such a way so as to restore the equipment to is its original factory condition and shall be to the satisfaction of the Engineer.

7.1.11 Diagram, List, and Charts

7.1.11.1 General

The preliminary ‘drafting and numbering procedure', the final version will be made available to the Contractor.

7.1.11.2 Instrument List

This list shall contain all primary sensors, instruments and signal processing equipment in the plant including but not limited to

local measurements

remote measurements

binary transmitters

limit switches

test measuring points

With all necessary design date such as text-in-clear, measuring ranges, settings, displays.

7.1.11.3 List of Documentation

7.1.11.4 List of Recorders/ Selectors Switch

This list shall be used for the allocation of measuring points to recorders, measuring points selector switches, automatic measuring point selector switches (scanners).

7.1.11.5 Logic Diagram

This kind of diagram shall as far as applicable be used for representation of remote and logic controls and interlocking circuits.

7.1.11.6 Block Diagram

This kind of diagram shall indicate in a simplified manner the function of closed-loop control

This is a simplified diagram of the essential electrical equipment and its connections. All circuits are represented by a single line only. In addition this diagram shall contain all required technical information on the equipment represented, e.g. voltage, ampere, output, code designation etc.

7.1.11.7 Single Line Diagram

Single line diagrams shall be drawn in a way easy to survey and shall contain as far as possible all technical information of the equipment represented. Except for the general single line diagram showing the basic design and connections all diagrams shall be prepared according to the classification system.

Standard symbols shall be used for the individual kinds of components and modules. The components or modules and the working principles shall be clearly explained in the diagram and in an attached description with legend.

7.1.11.8 Circuit Diagram

This diagram is resolved into separately drawn “current paths” each showing all its components. The individual circuits shall be drawn in a straight line sequence.

Wherever applicable, schematic and circuit diagrams shall be combined in one drawing.

7.1.11.9 Internal Connection Diagram

This diagram represents the wiring connections either within one apparatus or between several apparatus of one group. It shall contain the single components or apparatus of one group arranged in the proper positional order including terminal and terminal strips.

7.1.11.10 External Connection Diagram

This diagram represents the wiring connections between groups of apparatus inside an installation or between sections of the installation. External and internal connection diagrams shall always show the full terminal strips with all terminals in the correct sequence.

The terminal connection diagram as described above shall contain but not be limited to the following information:

Terminal numbers of technical strip with targets (terminal numbers and current paths) or incoming and outgoing cables.

- Cable designation

- Type of cable

- Number and cross section of conductors

- Assignment of conductors

- Number of spare conductors

7.1.11.11 Installation Diagram

This diagram represents the routing of cables and the position of associated equipment (e. g. lighting fixtures, socket outlets, loudspeakers, telephones, primary elements, transmitters, terminal junction boxes, etc.) according to their correct position in the building plan or arrangement drawing.

7.1.11.12 Terminal Connection Diagram

The terminal connection diagram used for terminal boxes, marshalling racks, switchboards etc. shows the terminals and/or terminal strips properly numbered in relation to the incoming and outgoing power and control cables.

7.1.11.13 Wiring List

The wiring list contains all connections within one apparatus (cubicle etc.) including all terminal numbers to be connected, the wire code and size and the bundle code.

7.1.11.14 Cable Schedule

The cable lists contain all required information for the design, erection and routing of all power, communication and control cables.

For easy reference the HV and LV power cables shall be listed in a Cable Schedule containing the following information:

- All types of cable used

- Insulation level

- Operating voltage

- All load reduction factors

- Permissible continuous load of all cables, taking into consideration the various load reduction factors

- Cross-section of all cables and number of cores

- Outer diameter of all cables

In connection with the general schedule, raceway diagrams shall be produced showing routing of cable racks and trays at different elevations, suitably sectionalized and numbered.

In addition, cable lists shall be provided for all power and control cables containing at least the following information:

- Cable designation
- Cable routing (from – to, via raceway)
- Type of cable, cross section and number of cores
- Permissible continuous load or burden (for measuring transformers) and load reduction factor.
- Length

7.1.11.15 Terminal List

The terminal list contains all connections for a terminal strip of a cubicle on both sides of the terminals, including the codes of wires and cables and their sizes.

7.1.11.16 Equipment List

The equipment list contains all devices to be installed within one cubicle or apparatus or one group of apparatus, but does not include fixing materials and hardware.

7.1.11.17 Parts List

The parts list contains all equipment, materials and accessories installed in the respective parts of the plant.

7.2 Equipment: Protection Equipment

7.2.1 General

This specification covers the design, manufacture, pre-assembly and acceptance testing in the Contractor's workshops as well as the supply, delivery, unloading, erection, adjusting, setting, identification, commissioning and acceptance testing of the protection equipment in every respect and suitable for satisfactory operation. The manufacturer of relays should be:

- ABB (Sweden, Switzerland)
- Siemens (Germany)
- Alstom/GE (France / UK/USA)
- SEL (USA).

The protection shall be sufficiently sensitive to cater for the minimum fault level condition. The protection shall also be suitable for a system fault level equal to the switchgear rating of 31.5kA (33kV). All current transformers shall be based on these fault level.

7.2.2 Layout

All equipment specified under this sub-section, unless otherwise stated, shall be located in the relay recess compartment of respective feeder panel of the switchgear.

7.2.3 Scope of Supply and Services

This section sets out the scope of the installations covered by this specification as well as requested supplies and services but without excluding other necessary components and services not mentioned. Prices of the offer shall include, whether explicitly mentioned or not, all the elements necessary to ensure proper function of the supplied protective and synchronizing equipment, coordinated with existing similar and related equipments. Faulty elements of the system shall be selectively isolated before mechanical or electrical damages or power system stability loss occurs.

Relay coordination study shall be conducted for the supplied protective relaying installations with existing (or under delivery in parallel works) protective equipment at all interface levels.

7.2.4 Requirements

7.2.4.1 General Requirement

The protection equipment requirements for the specified new installations are to be provided. Detailed relay requirements are described below for each type of protected primary equipment.

If not stated otherwise following basic design data apply:

DC control: 110V/125 V

VT phase secondary voltage: 110/√3

CT secondary current:1A/ 5 A

Rated frequency: 50 Hz

Relays shall be of approved types complying with IEC60255 or BS 142 and 5992, Parts 1, 2 and 3 as appropriate, fully tropicalized, and shall have approved characteristics. The Employer may reject any design he considers unsatisfactory or having insufficient field experience.

All protective relays should be numerical type incorporated with pc interface and power & fault analysis function. Also, relevant software and operational knowledge shall be provided. Voltage, power trends, harmonics, fault results and other prime factors shall be stored and analyzed. In addition, setting should be available either the software or button on front panel.

Incorporated respective relay functions (over current relay, under/over voltage relays and unbalance relay) shall provide the selective time characteristics. The relay shall provide setting values and running power trends in real time base.

7.2.4.2 Protection Configuration

1) Single CB single bank configuration (12.5MVar Bank)

(Reference diagram refers to Drawing ~~PGCB/EEP1/RCP/12,13,14~~)

- phase fault: over current relay (51)

- ground fault: ground over current (51G)

- voltage protection: over voltage (59)/ under voltage relay (27)

- capacitor unbalance protection: ground over current relay (51NC)

2) Main CB + Two Feeder Configuration

(Reference diagram refers to the Drawing ~~PGCB/EEP1/RCP/12,13,14~~)

For Main Protection:

- phase fault: over current relay (51),
- ground fault: over current relay (51G)
- voltage protection: over voltage(59) / under voltage relay(27)

For Capacitor Bank Feeders:

- phase fault: over current relay (51)
- ground fault: ground over current (51G)
- capacitor unbalance protection: ground over current relay (51NC)

7.2.4.3 Relays

1) Over current relay

The over current relay and earth fault relays shall have multi characteristics according to IEC 255.

Over current relay shall have current setting arrange form at least 50% - 200% in 25% setting steps. Earth fault relays shall have a current setting range form at least 20% - 80% in 10 % setting steps.

2) Unbalanced protection

Unbalanced protection shall be high sensitive with harmonic filters, alarm and trip stages.

3) Overvoltage and under voltage protection

Over voltage and under voltage relay shall have voltage setting range suitable for capacitor bank. The setting shall be finalized during detailed engineering.

7.3 Equipment: Control and Monitoring Equipment

7.3.1 General

This specification covers the design, manufacture, pre-assembly and acceptance testing in the Contractor's workshops as well as the supply, delivery, unloading, erection, adjusting,

identification, testing, commissioning, and acceptance testing of the control and monitoring equipment of the 36 kV switchgears complete in every respect and suitable for satisfactory operation. Control and monitoring equipment for 0.415 kV A. C. and D. C. switchgear are covered.

7.3.2 Scope of Supply and Services

This section sets out the scope of the installations covered by this specification as well as requested supplies and services but without excluding other necessary components and services not mentioned. The Bill of Quantity and the relevant "Prices of Equipment and "Spare Parts" can be found.

The following equipment shall be provided:

1) 33 kV control, indication and measuring equipment located in the new 36 kV switchgear panels
2) 33 kV remote control, indication and measuring equipment panels located in the existing control rooms

7.3.3 Construction Requirements

7.3.3.1 General

The purpose of this equipment is to provide reliable monitoring, measurement and control facilities for the 36kV capacitor banks including all ancillary systems.
Design data:

Control voltage 110V/125 V d.c.

Auxilliary voltage 415/240 V; 50 Hz

7.3.3.2 Description

The control and monitoring equipment for the 36 kV switchgears/capacitor banks have to be mounted in the respective control compartments of the switchgears.

For remote control from the existing control rooms the necessary equipment shall be installed. The control, indication, metering and monitoring requirements are shown in the TABLE OF INSTRUMENTATION being part of this Subsection.

The whole of the control, monitoring and measurement equipment is to be designed in conformity with the latest relevant IEC regulations according to Section Schedule A.

The Contractor shall ensure that in the event of failure of the air-ventilation system the control system remains in full operation, the outside ambient temperature being 45°C. Suitable heating elements in the cabinet must prevent any condensation forming.

For the colour scheme of the cabinets and the switchgears, the mimic diagram and the type of labeling, the contractor must produce a concept for approval by the Engineer. The Employermust have a free choice of colors without the price being affected.

The internal wiring of the cabinets must be carried out according to the provisions of Section 4A.

All switchgear auxiliary contacts, control, signaling and measuring devices are to be wired up to a separate terminal block within the switchgear itself.

1) For each substation the necessary control and measuring cabinets, and the respective 33 kV switchgear fully wired to the terminal strips shall be equipped as a minimum in accordance with the TABLE OF INSTRUMENTATION (being part of this Subsection) with:

a) Control-discrepancy switches with position indicator lamps with square front plate, for controlling the 33 kV circuit breakers.

b) Position indicators with round front plate for position indication for the earthing switches and longitudinal busbar isolator of 36 kV switchgears.

c) Change-over switches with the necessary positions and contacts for voltage and current measurements, etc.
d) Necessary push-buttons
e) Indicating instruments with square bezel (96 x 96) for voltage, and current having 240° scale.
f) Mimic diagram consisting of narrow strip painted
g) Alarm/indication tableau with the necessary alarms/indications
h) All 33 kV circuit breakers shall be equipped with an operating hour meter and counter of ON/OFF operations.

2) The necessary alarm devices completely wired to the terminal strips; equipped with the necessary:

a) Indicators of the respective control voltage
b) Change-over switches
c) Push-buttons
d) Flasher and auxiliary relay (d. c.)
e) Horn and warning gong (d. c.)

The necessary metering devices in the 36 kV switchgear compartments fully wired to the terminal strips and equipped with the necessary meters.

All equipment specified under (1) – (4) are to be factory-wired, supplied completely with all necessary fittings such as M. C. Bs, auxiliary relays, switches, lamps, heating elements, small fixing parts and terminals, earthing material, etc., installed and put into operation.

All terminal strips are to be so designed that at least 15% of spare terminal capacity remains available after commissioning.

7.3.3.3 Control-Discrepency Switches

For local operation of the 36 kV switchgears, control discrepancy switches with position indicator lamp with square front plate and the necessary contacts are to be provided for the circuit breakers.

7.3.3.4 Important Control Devices and Interlockings

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

Mechanical interlocking shall be effective at the point where hand power is applied so that stresses cannot be transferred to parts remote from that point.

Beside normal control and interlocking facilities special attention has to be paid by the Contractor to all necessary interlocking related to the switchgears at the different substations. However, he following have to be considered, not excluding any necessary items not mentioned:

All facilities for the interlocking between isolators and associated CB's respectively between isolators and associated earthing switches in the 36 kV switchgears have to be provided.

7.3.3.5 Control Voltage

The control voltage shall be made available at least twice for each switchgear installation. The Contractor has to provide a diode decoupling of the control voltages.

The decoupled control voltage has to be looped from panel to panel. In each panel, the control voltage is to be safeguarded by mini circuit breakers and the tripping of these is to be indicated locally. A further potential-free set of mini circuit-breaker auxiliary contacts is to be wired as a group signal for the remote indication.

Mini circuit-breakers are to be provided for

1) Local controls, interlocks
2) Local annunciation and fault indications
3) Power supply to motor-driven stored energy mechanism
4) Heating and lightning circuits.

7.3.3.6 Control of Switchgears

The 36 kV switchgears remain normally unattended and will be supervised from the existing control rooms. The switchgears shall be automatically controlled according the reactive power requirements of the substation and the voltage conditions in the 132 kV network.

Each circuit breaker must also be capable to be operated manual, local and remote.

7.3.3.7 Control

A change-over switch from automatic to manual control shall be provided for each automatic control device.

Each circuit-breaker must be capable of being operated locally by means of illuminated discrepancy switches which are covered in normal operation. If the control voltage fails, the

EMERGENCY OPEN operation of the circuit-breakers must also be capable of being operated locally.

Each 33 kV switchgear cubicle shall be equipped with a change-over switch for LOCAL/REMOTE operation. All circuit breakers must be capable of being operated remotely (from the control rooms) by means of push-buttons.

7.3.3.8 Special Interlocking Requirements

Closing of the circuit breakers for the capacitor banks shall only be possible if the capacitors are discharged, i.e. the capacitor bank voltage is less than 50 V.

The circuit breakers for the capacitor banks shall trip, if no reactive power can flow into the network, i.e. if the coupling breaker (s) for coupling with the outdoor switchyard trip or the corresponding 132/33 kV step-down transformer is switched off.

7.3.3.9 Test

Type Tests

The protection relays, including control switches, winding and oil temperature indicators, meters, annunciate relays, miniature circuit breakers, humidistat, etc., offered shall have been fully type tested to prove their capability to meet or exceed the requirements of this Specification and, in all other respects, the requirements of IEC 60255.

The type test shall have been carried out at an independent testing station or alternatively shall have been witnessed by a representative of an independent testing authority or other independent witness.

The Bidder shall list for each type test performed, the test specification, location and date of testing and the Type Test Certificates/Report No. In addition the Bidder shall submit with his Bid a copy of each Type Test Certificate/Report which shall incorporate full details of test parameter and results and shall state by whom the tests were witnessed.

Routine Tests

All protection relays, including control and discrepancy switches, winding and oil temperature indicators, oil thermostats, automotive voltage regulators, meters, converters, annunciate relays, miniature circuit breakers, humidistat, etc., shall be routine-tested in accordance with IEC 60255.

8. Auxiliary Power and Control Cables

8.1 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.

8.2 General Description of Installation

8.2.1 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.

8.2.2 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.

8.2.3 The Contractor shall provide an installation in accordance with the best modem practice and complete in every detail for continuous operation.

8.2.4 Cabling areas will include those which have natural ventilation. Cabling shall therefore be designed for the maximum ambient temperatures expected.

8.2.5 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.

8.2.6 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.

8.2.7 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.

8.2.8 The Contractor shall provide all necessary power, multicore and communications cables required as required and specified in the Project Requirements.

8.3 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.

8.4 Cable Installation

8.4.1 General

8.4.1.1 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.

8.4.1.2 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.

8.4.1.3 Cables shall be derated to allow for the likely number of cables following a given route.

8.4.1.4 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

8.4.1.5 Control and instrumentation cables shall be screened/shielded to minimise interference, where necessary.

8.4.2 Installation Criteria

8.4.2.1 Specific requirements shall be as detailed in the project requirements.

8.4.2.2 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.

8.4.2.3 In general, to minimise interference, control cables and instrumentation cables shall be separated from power cables.

8.4.2.4 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.

8.4.2.5 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.

8.4.2.6 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.

8.4.3 Reduced Fire Propagation

8.4.3.1 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.

8.4.3.2 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.

8.4.4 Type Approval

8.4.4.1 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.

8.4.4.2 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.

8.4.5 Cable Sizing and Routing

8.4.5.1 The Contractor shall be responsible for all cable sizing and routing design, procurement, installation and testing.

8.4.5.2 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

8.4.5.3 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.

8.4.5.4 Due allowance shall be made for the method of installation, depth of laying, spacing and grouping factors.

8.4.5.5 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.

8.4.5.6 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.

8.4.5.7 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.

8.4.5.8 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.

8.4.5.9 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.

8.4.5.10 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.

8.4.5.11 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.

8.5 Cable Construction

8.5.1 Oversheaths

8.5.1.1 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.

8.5.1.2 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.

8.5.1.3 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.

8.5.1.4 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.

8.5.1.5 The minimum thickness of oversheath shall not fall below the Manufacturer's stated value by more than 0.2mm plus 20 percent.

8.5.1.6 A means of identifying the Manufacturer shall be provided throughout the length of the cable.

8.5.2 Armouring

8.5.2.1 All multicore cables shall be provided with galvanised steel wire armour. Single-core cables shall have copper or aluminium wire or tape armouring.

8.5.2.2 The armour shall be protected by an overall PVC or plastic sheath.

8.5.3 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.

8.5.4 Cable Drums

8.5.4.1 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.

8.5.4.2 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.

8.5.4.3 Cable spare lengths shall be wound on to steel drums before they are handed over to the Employer's stores.

8.5.5 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.

8.5.6 Spare Cable

Spare cable and accessories, as detailed in the schedules, are required to be included in the Contract.

8.5.7 Jointing Accessories

8.5.7.1 Cables shall be installed in continuous lengths and straight through jointing between shorter lengths will not be permitted.

8.5.7.2 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.

8.5.7.3 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.

8.5.7.4 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.

8.5.7.5 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.

8.5.7.6 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.

8.5.7.7 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.

8.6 Types of Cable

8.6.1 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.

8.6.2 Control Cables and Instrumentation Cables

8.6.2.1 General

Two types of cable shall be provided for the control and instrumentation cabling.

8.6.2.1.1 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.

8.6.2.1.2 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 1.5 mm² minimum. 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.

8.6.2.1.3 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.

8.6.2.2 Multicore Control Cables

8.6.2.2.1 Cables shall comply with the construction here above and shall have cross-linked polyethylene (XLPE) insulation.

8.6.2.2.2 All cables shall be provided with a low smoke PVC oversheath.

8.6.2.2.3 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.

8.6.2.2.4 All these cables shall have galvanised steel wire armouring.

8.6.2.2.5 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.

8.6.2.3 Multi-Pair Instrumentation Cables

8.6.2.3.1 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.

8.6.2.3.2 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.

8.6.2.3.3 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.

8.6.2.4 Oversheaths

All the cable types above shall have a black flame-retardant low smoke PVC oversheath. In normally manned locations, especially the control building, cables shall have a low smoke, zero halogen oversheath, so as to minimise the generation of smoke and corrosive acid gases in the event of a fire.

8.6.2.5 Telephone Type Cables (TWPVC)

8.6.2.5.1 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.

8.6.2.5.2 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.

8.6.2.5.3 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.

8.6.2.5.4 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.

8.6.2.6 Pilot Cables

Telephone-type cable laid in the ground alongside HV power cables shall take into account the effects of induced voltages.

8.7 Straight-through Joints

Each cable shall be run in one continuous length. Straight-through joints will not be permitted.

8.8 General Methods of Cable Installation

8.8.1 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.

8.8.2 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.

8.8.3 All cables routed under roads and access ways usable by vehicular traffic shall be installed in ducts.

8.8.4 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.

8.8.5 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.

8.8.6 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.

8.8.7 Sunshields shall be provided in all locations where the cable would otherwise be

subjected to direct sunlight.

8.9 Cables laid Directlyin the Ground

8.9.1 The method of installation shall be as follows:

8.9.2 Trenches shall be excavated to the minimum depth shown in Drawing for cable trench. Covers shall be provided over cables laid in the trench.

8.9.3 Filling in of trenches shall not be commenced before inspection and approval by the Engineer of the cables and accessories in-situ.

8.9.4 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.

8.9.5 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.

8.9.6 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.

8.9.7 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.

8.9.8 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.

8.9.9 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.

8.10 Cables drawn into Ducts

8.10.1 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.

8.10.2 Ducts shall be of rigid PVC and shall be surrounded by concrete of minimum thickness of 150.

8.10.3 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.

8.10.4 Any ducts or pipes not used shall be sealed by plugs (detail subject to approval) supplied by the Contractor before backfilling.

8.10.5 The ducts shall be water and vermin proof sealed, after completion of cable installation.

8.11 Cables installed in Concrete Trenches

8.11.1 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.

8.11.2 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.

8.11.3 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.

8.12 Cables Supported on Racks, Trays, Etc.

8.12.1 General

8.12.1.1 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.

8.12.1.2 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.

8.12.1.3 Ample allowance shall be made in the design for additional cabling for future extensions.

8.12.1.4 Racks and trays shall be secured to channel or similar inserts installed in accordance with Building and Civil works section.

8.12.1.5 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.

8.12.1.6 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.

8.12.2 Supporting Steelwork

8.12.2.1 All supporting steelwork shall be hot dip galvanised after manufacture and shall be to the approval of the Engineer.

8.12.2.2 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.

8.12.2.3 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.

8.12.2.4 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.

8.12.3 Cable Clamps, Cleats, Saddles and Ties

8.12.3.1 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.

8.12.3.2 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.

8.12.3.3 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.

8.12.4 Trays and Racks

8.12.4.1 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.

8.12.4.2 Cables shall be installed on trays, in general as follows:

- Up to 16 mm²- double layer touching.
- 25to 70 mm² - single layer touching.
- Above 70 mm²- single layer with 25mm (minimum) spacing.

8.12.4.3 All cable trays shall be perforated.

8.12.4.4 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.

8.12.4.5 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.

8.12.4.6 The cable tray system shall have minimum of 20% spare cable capacity throughout.

8.13 Cables Installed on Structural Steelwork and Brickwork or Concrete

8.13.1 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.

8.13.2 Cables shall not be routed on tiled, lagged or other special finished surfaces.

8.14 Terminations

8.14.1 General

8.14.1.1 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.

8.14.1.2 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.

8.14.1.3 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.

8.14.1.4 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.

8.14.1.5 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.

8.14.1.6 PVC shrouds shall be supplied and installed over each gland.

8.14.2 Power Cables

8.14.2.1 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.

8.14.2.2 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.

8.14.2.3 Single core cables shall be similarly identified by coloured tape over the cable beneath the gland.

8.15 Terminating and Jointing Conductors

8.15.1 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.

8.15.2 For stud type terminals approved crimping lugs shall be used.

8.15.3 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.

8.16 Core Identification

8.16.1 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.

8.16.2 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.

8.16.3 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.).

8.16.4 Direct a.c. circuits shall be identified by a yellow end piece followed by an identification of the phase concerned.

8.16.5 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.

8.16.6 All markings for terminal blocks, cables, cable conductors and wiring shall be located on the corresponding fault finding drawing.

8.16.7 Characters suitably marked "TRIP" in white shall be fitted on all wires associated with trip circuits.

8.16.8 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.

8.17 Cable Identification and Schedules

8.17.1 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.

8.17.2 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.

8.17.3 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.

8.17.4 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.

8.17.5 In addition, the Contractor shall provide selected copies of the above schedules in a computer print-out form at agreed intervals.

8.17.6 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.

8.17.7 Where cables enter and leave ducts or pipes, suitable identification markers shall

be fitted.

8.17.8 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.

8.18 Inspection and Testing

Inspection and testing during manufacture and after installation on site shall be in accordance with Section 16 of this Specification.

9. Power Cable and Termination Accessories

9.1 Scope

These clauses describe the General Technical Requirements for the 230kV, 132kV, and 33kV power cables & cable terminating accessories and installation of cables and shall be read in conjunction with the Project Requirements, Schedules and Drawings in the specification.

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

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

The scope of work also includes supply and installation of cable sealing ends at both ends including terminating insulators.

9.2 Standard

The cable and accessories shall comply with this specification and the latest version of relevant IEC, BS or approved equivalent. Any international standards referenced in the specifications and our outdated shall be replaced with the corresponding replacement.

9.3 Condition of Operation

All cables shall be suitable for operation, at the guaranteed continuous ratings specified, throughout all seasons of the year. The nominal system voltage to which the cables will be connected is 230kV, 132kV & 33kV and the highest operating voltage Um will be 245kV, 145kV, and 36kV repectively.

Cable shall be designed to operate continuously at temperature of 90°C. Each conductor and the metal sheath/screen shall be capable of carrying the specified fault current for the specified time and its final temperature shall not exceed 250°C. Adequate measure should be taken to protect against ingress of moisture and water.

Short circuit earth fault rating of metal sheath/screen are 50 kA (for 1s) at 230kV, 40kA (for 1s) at 132kV, and 31.5 kA (for 1 sec) 33kV for one second.

The maximum continuous current carrying capacity and maximum permissible conductor temperature, and the factors for determining such rating and temperature, shall be based on IEC recommendation No. 287 and subsequent amendments, and all conditions obtaining on Site.

Other conditions for cables laid in concrete ducts/tunnels/buried pipes shall be assumed:-

- Max. ambient air temperature: 45°C
- Continuous conductor temperature: 90°C
- Max. conductor temperature under fault: 250°C

The contractor shall confirm that the cable sizes are adequate for the required circuit ratings based on the specified foregoing parameters, and he shall also confirm that the cables are adequate for the short-circuit requirements specified. The contractor will be required to produce cable design calculations to verify that the selected cable sizes are suitable for the selected cable laying conditions in concrete cable ducts, tunnels or buried pipes.

If the contractor considers that the conditions and the proximity to other power cables, spacing and method of installation are likely to reduce the maximum current carrying capacity he shall increase the cable conductor cross section accordingly.

The conductor section of the cable circuits shall be adequate for carrying the specified short-circuit current when operating under the specified load conditions without deterioration of the dielectric or other component materials of the cable.

9.4 Type Approval

Cables and accessories shall have satisfactorily passed type approval tests in accordance with the Specification and details of the cable designs offered shall be given in the Schedule of Particulars and Guarantees. Type test reports shall include cable design details and design drawings of each jointing accessory included in the type test.

The Contractor shall certify that the cables and/or accessories offered will be identical in all essential particulars in respect of design, materials and workmanship with the cables and/or accessories for which type approval certificates are offered in support of this bid.

The Contractor shall also ensure that all materials used will be subjected to and shall have satisfactorily withstood such tests as are customary in the manufacture of the types of cable specified.

Records of such tests shall be available for inspection, if required by the Engineer.

9.5 Cable Length

Cables shall be supplied in maximum drum lengths bearing in mind the transport limitations in gaining access to the site. No drum shall contain more than one length. Cables shall be installed in maximum possible lengths and straight through jointing between shorter lengths will not be permitted.

The cable routes on the drawings attached to the Bidding Documents are provided for information only, and it is Contractor's responsibility to establish the exact quantities of cables and accessories required to complete the whole of the works as described in the Specification.

9.6 Cable Drum

Cable drums shall be non-returnable and shall be made of steel suitably protected against corrosion. They shall be lagged with closely fitting battens in accordance with the relevant BS or equivalent IEC standard.

Each cable drum shall bear a distinguishing number on the outside of one flange. Particulars of the cable, i.e. voltage, conductor size and material, number of cores, type, length, gross and net weights shall also be clearly shown on one flange. The direction of rolling shall be indicated by an arrow on both flanges. The method of drum marking shall be to the Engineer's approval.

Cable maintenance lengths and spare lengths shall be wound on to steel drums before they are handed over to the Purchaser's stores. Particulars of the cable(as stated above) shall be clearly marked on one flange.

9.7 Spare Cable

In addition to the cable maintenance lengths supplied against the Schedule of Spares the Purchaser shall have the option to purchase from the Contractor at the rates stated in the Schedule any spare cut lengths of cable for future maintenance purposes.

Brass or other approved sealing caps of the correct size shall be supplied for each end of spare cut cable lengths to enable them to be properly stored for future maintenance purposes. The Contractor shall be responsible for the immediate sealing of such cut lengths and the cost thereof shall be deemed to be included in the contract price.

9.8 Spare Tools

Special tools used for the purpose of the cable installation, they shall be handed over to the purchaser's stores after the taking over of the installation.

Price for such special tolls is to be considered as included in the price schedule.

9.9 Cable Jointing Instructions and Drawings

Copies of the instructions for the jointing of each type of cable terminating and jointing accessories supplied shall be submitted to the Engineer for approval before any work is commenced at site. One copy of each instruction shall be bound into each copy of the Operating and Maintenance Instructions to be supplied to the Engineer at the completion of the Contract for the use of the Purchaser.

The following drawings shall be submitted by the Contractor for approval by the Engineer. "As installed" drawings of cable routes shall be drawn to a scale of 1/200. The route shall be dimensioned in such manner that it may be used for pinpointing accurately the cables in the future. All drawings shall be submitted for approval before the issue of the Taking-Over certificate.

9.10 Cable Specification

9.10.1 General

This Specification applies to single core cables with triple extrusion type solid dielectric. They shall be generally manufactured in accordance with the relevant International Electrotechnical Commission Publication (IEC) and British Standard (BS) where applicable.

9.10.2 Conductor

Conductors shall be of stranded plain annealed copper wires to IEC or BS filled to make the cables longitudinally watertight by extrusion during stranding. This shall be to prevent ingress of water into the cable should the outer sheath become damaged. The allowable operating temperature of conductor and waterproofing shall be 90°C.

9.10.3 Conductor Screen

Semi-conductive tape for preventing ingress of semi-conductive XLPE and gluing onto the stranded conductors temperature resistance up to 250°C. Semi-conductive extruded cross-linked material to provide a smooth cylindrical equi-potential surface to which the insulation can be intimately bonded. The material shall be compatible in all respects with its conductor and insulation materials.

9.10.4 Insulation

Cross-liked polyethylene (XLPE) melted together with the conductor screen capable to operate at continuous conductor temperature of 90°C and short circuit temperature of 250°C. Cross-linking process using curing is not permitted, dry

process shall be given.The insulation of the completed cable shall be substantially free from voids and contaminants.

9.10.5 Insulation Screen

Semi-conductive compound of extruded layer firmly bonded to the XLPE insulation. The conductor screen, the insulation and the insulation screen are to be extruded in a single process to keep the interface smooth.

9.10.6 Metallic Screen

Where the cable core screens are inadequate to meet the earth fault current specified, a metallic layer of adequate cross-sectional area shall be included in the design applied over the screen. The metallic layer shall be Copper screen with counter helix filled with swelling powder sheathed in accordance with latest BS or IEC Publication.

9.10.7 Intermediate Layer

An intermediate layer of suitable compound shall be provided in between metallic screen and aluminium sheath if necessary.

9.10.8 Corrugated Seamless Aluminium Sheath

Metallic sheath shall consist of the extruded corrugated seamless aluminum sheath. Aluminum used for the sheath shall have the minimum purity of 99.5% and shall be of best quality metal free from pinhole flaws and other imperfections. The minimum thickness at any point shall not fall below 85% of the specified nominal thickness by more than 0.1 mm.

9.10.9 MDPE Outer Sheath

After applying the bitumin compound over the aluminium sheath, the extruded MDPE with termite repellent outer sheath shall be applied.

The nominal thickness of outer sheath shall be not less the specified value. The minimum thickness at any point shall not fall below 85% of the specified nominal thickness by more than 0.1mm.

An outer graphite coating shall be applied to outer sheath as an electrode for the voltage test on the extruded outer sheath.

9.10.10 Identification of Cable

The outer sheath of all cables shall carry the following identification marks in three meter intervals approximately.

"ELECTRIC CABLES- 230000/132000 Volts/33000 Volts and cross section in sq. mm.cu. PGCB, the name of the manufacture and the year of fabrication."

The letters and numerals shall comply with IEC or BS Publication.

9.11 Sealing and Drumming

Immediately after the works tests, both ends of the cable shall be sealed against the ingress of moisture, dirt and insects and the end projecting from the drum shall be adequately protected against mechanical damage during handling. The cable drums shall be arranged to take a round spindle and be lagged with strong, closely fitting so as to take a round spindle and be lagged with strong, closely fitting battens so to prevent damage to the cable. Only steel cable drum shall be used.

The complete cable shall be rolled on steel cable drums capable of withstanding the rough handling during transport without damage of the cable and enabling easy and safe unrolling of the cable during erection.

Each drum shall have marked in indelible point on both flanges, the following indications besides the shipping instructions.

- Destination
- Type of cable
- Exact length
- Net and gross weight
- Trade mark
- An arrow pointing in the direction of unrolling.

9.12 Terminating Accessories

Detailed drawings showing the types of cable sealing ends, terminal boxes and glands proposed for the installation shall be submitted at the time of Bidding. All cable sealing ends and terminal boxes shall be designed with jointing faces below compound level which will ensure the retention of the filling medium and/or cable compound under operating conditions and exclude the entry of air, dust or moisture. Cable sealing ends and terminal boxes designed for use with fluid or semi-fluid filling media shall have fanged joints, the faces of which shall be machined.

An earthing strip shall be provided on all boxes terminating lead sheathed cables.

The external dimensions, fixing cables and terminal arrangements for all sealing ends and terminal boxes shall be agreed with the Engineer.

Sealing ends and terminal boxes shall be provided with all necessary fittings, including external flexible connections as required. The design of flexible connections shall be to approval.

Drain plugs shall be of ample size to permit the filling medium to be removed. The contact faces of the cable sockets shall be thoroughly cleaned, the lugs shall be placed in the most suitable positions and arranged as required to avoid unnecessary bending of cable cores inside the box. Provision shall be made for earthing the body of the box, and for expansion of the conductors in the box. Provision shall also be made for the expansion of the filling medium and arrangements made to prevent the formation of air spaces when filling.

9.13 Installation of Cable

9.13.1 Directly Buried Cable

The installation of underground cables inclusive excavation of cable trenches, cable laying, cable jointing and terminationand backfilling the cable trenches and testing and commissioningshall be carried out under the supervisionwith approvedcablemanufacturer's engineer(s)who shall have sufficient knowledge and experience in construction of underground 132 kV or higher voltage grade XLPE cable circuits.CV of cable engineers mentioning theirexperiences shall be submitted to the Employer by the Contractor before execution of installation of underground cable circuits for approval.

Cable trenches shall be constructed for directly buried cables as per drawings of Drawing Section. Cables shall be installed by direct burial at an average depth of 1.5 meter from finished ground level. Construction of trench for cable shall also include excavation,preparation of sieved sand bedding, riddled soil cover, supply and installation of concrete protective covers back filling and compacting supply and installation of route marker and joint marker.Back filling shall be by the material excavated. However, bigger stones and pieces of rock etc. shall be removed.

The cables shall be laid in trefoil formation and shall be surrounded by well compacted shifted sand of approximately100 mm thickness in all directions from cable surface for protection against damage. Concrete protective covers (RCC slabs) shall be installed/provided directly over the compacted sand over the cable surface, RCC slabs shall sufficiently cover the width of all the cables.

The installation of underground cables inclusive excavation of cable trenches, cable laying, cable jointing and terminationand backfilling the cable trenchesand testing and commissioningshall be carried out under the supervisionwith approvedcablemanufacturer's engineer(s)who shall have sufficientknowledgeand experience in construction of underground 132 kV or higher voltage grade XLPE cable circuits. CV of cable engineers mentioning theirexperiences shall be submitted to the Employer by the Contractor before execution of installation of underground cable circuits for approval.

9.13.2 Cable Trenches with Pits, Ducts, and Drains

The contractor shall design and construct cable Treches required for connecting/Laying 230kV, 132kV & 33kV power cables. Width and height of cable Treches shall conform to required cable spacing and working spaces. The structure of cable ducts is reinforced concrete and must be designed enough bearing capacity cause by some parts of cable ducts are under heavy equipment.

The contractor shall design and construct all trenches required for the work. The depth of the cable trenches shall be minimum 1.5 meter from the Substation switchyard, finished level and the width shall conform to required cable spacing and working spaces.

The thickness of cable trench wall and floor shall be minimum 150mm and should be designed to withstand the subsoil water pressure.

Cables in cable tunnels or trenches shall be laid on cable supports at every ½ (half) meter interval.

Cable trenches shall be covered with concrete trench covers. Trenches will be built with the top edge of the walls 50mm above the finished switchyard level.

The trenches shall have a suitable bed slope with sufficient number of drainage pits so that water could be drained off naturally as well as by artificial means.

The removable trench covers shall be of recast reinforced concrete adequately designed to safely withstand a load of 2,500 N at the center of each cover. The trench covers shall be of such size as to facilitate their handling by manual labor.

9.13.3 Supports and Racks

Cable laid supports and racks together with fixing clamps, bolts,nuts and screws for outdoor installations and in outdoor concrete lined trenches shall be of hot dip galvanized steel.

Cable support and rack designs shall be submitted for the written approval of the Engineer before manufacturer or erection.

The single core cables shall be clamped to the racks with smooth finish split packing pieces or cleats with bores of the correct size for the cable diameters. The cleats shall be of Silicon aluminium, glass filled nylon or other tough non-hygroscopic or non magnetic material. Wooden cleats are prohibited.

9.13.4 Bonding

The cables shall be installed as an insulated sheath system. Single core cable sheaths may either be solidly bonded (single bonding).

Bonding leads shall be of sufficient cross sectional area to carry the maximum imposed short circuit current level. A schematic diagram detailing the proposed bonding systems and stating bonding leads cross section shall be submitted with the Bid.

9.14 Tests

9.14.1 Type Test

The cable shall be tested and shall satisfy the most recent relevant IEC Publications.

The tests need not be carried out again if they can be provided by already existing type tests reports of recognized laboratories.

If the cable is not yet type tested, the relevant tests shall be carried out.

9.14.2 Routine / Sample Test

The cable shall be tested and shall satisfy the most recent relevant IEC Publication.

9.14.3 Test at Site

After completion of the erection and before commissioning, each cable shall be submitted to the following test:

a) Verification of the proper and complete erection of the cable and the terminals.
b) Verification of the proper conductor's of the external surface.
c) Verification of the proper earthing of the sheath.
d) Direct current voltage test no cables and cable terminals.
e) Power frequency test.

9.15 Earthing System

The cable sheath for single bonding of cable and cable end termination structures shall be earthed at earthing mat by extending the earthing system.

10. Earthing System and Lightning Protection

10.1 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.

10.2 References

10.2.1 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

10.2.2 German Standards

VDE 0140	Earthing Systems for Power Installations with Rated Voltages above 1 kV

10.2.3 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

10.3 General

An earthing system generally in accordance with the requirements of IEEE 80 and BS 7430 shall be designed under this Contract. Installation and the supply of all materials and equipment shall also be included. The earthing system shall include earth electrodes to provide the connection to the general body of the earth and all 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.

10.4 Extent of Work

10.4.1.1 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 supply of portable earthing devices.

10.4.1.2 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.

10.4.1.3 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.

10.4.1.4 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.

10.4.1.5 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.

10.5 Soil Survey

10.5.1.1 The preliminary bid design shall be based on a value of 100 ohm-m soil resistivity.

10.5.1.2 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 such as CDEGS or equivalent S/W. 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 resistivities to be used in the design of the earthing system.

10.5.1.3 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.

10.5.1.4 The surveys shall also determine the depth and nature of any underlying rock, which may limit the depth for driving earth rods or if boring will be necessary for installing earth rods.

10.5.1.5 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.

10.5.1.6 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.

10.6 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 of this specification. 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.

10.7 Earth Electrode System Design

10.7.1 Design Calculations

10.7.1.1 The design of the earth electrode systems shall be based on the approved earth resistivity data and the system fault currents and their duration.

10.7.1.2 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

10.7.1.3 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.

10.7.1.4 The earth potential rises shall not exceed the CCITT limits appropriate to the classification of the system unless special precautions are taken to cater for transferred potentials.

10.7.1.5 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.

10.7.1.6 For calculating the conductor size of main mesh a current distribution of 20% & 80% may be considered, where 80% is to be considered for the designed substation. 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.

10.7.1.7 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. Employer owns 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.

10.7.2 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

10.7.3 Mesh System

10.7.3.1 The mesh system shall be designed in accordance with sub clause 7.7.1 above 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 corners.

10.7.3.2 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. use of Conductor of lower size shall be proposed through proper design with consideration of aging, corrosion and other related factors. Final design is subject to approval of Employer.

10.7.3.3 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.

10.7.4 Earthing Rods

10.7.4.1 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.

10.7.4.2 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.

10.7.4.3 Copper cladding cannot be used as earthing rod. Hard drawn copper bar can be used as earthing rod, but proper arrangement need to be taken to keep the copper bar straight. However, it is subjected to the approval of the Engineer.

10.7.4.4 Individual rods may be connected directly to the mesh, provided the rod can be disconnected for testing.

10.7.4.5 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.

10.7.5 Other Conductors

10.7.5.1 As an alternative to rods to supplement a mesh, additional bare copper conductors with a cross-section area of not less than 150 mm² 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.

10.7.5.2 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.

10.7.6 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.

10.7.7 Conductors Outside Perimeter Fence

10.7.7.1 If the design calculations show that the step and touch potentials outside the perimeter fence or wall exceed the limits, then additional bare conductors shall be buried in the ground outside the fence in the form of rings encircling the whole site.

10.7.7.2 The distance of the conductors from the fence and the depth shall be determined in the design to ensure that step and touch potentials are within the limits.

10.7.7.3 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.

10.8 Design of Earthing System

10.8.1 Earthing System

10.8.1.1 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

10.8.1.2 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.

10.8.1.3 The design of earth system shall take into account the corrosiveness of the soil based on the soil survey.

10.8.1.4 The design comprising all the above mentioned items shall be submitted to the Engineer for approval within four months of the award of Contract.

10.8.2 Connection of System Neutrals and Earth

10.8.2.1 The system neutral points within a substation shall have duplicate connections to the closest earthing point.

10.8.2.2 The Transformer Neutrals shall be directly Buried to earth upto 15 meter 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).

10.8.2.3 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.

10.8.2.4 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.

10.8.2.5 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.

10.8.3 Main Earthing Bar

10.8.3.1 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.

10.8.3.2 The main earthing bar, or parts thereof, may also form part of the earth electrode system, providing this is bare conductor.

10.8.3.3 Each main earthing bar shall be connected by at least two widely separated conductors to the earth electrode system.

10.8.3.4 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.

10.8.4 Electrical Equipment and Structure Connections to Earth

10.8.4.1 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.

10.8.4.2 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.

10.8.4.3 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.

10.8.4.4 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.

10.8.4.5 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.

10.8.4.6 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.

10.8.4.7 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.

10.8.4.8 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.

10.8.4.9 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.

10.8.4.10 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.

10.8.4.11 GB Cable can be used for Electrical Equipment and Structure Connections to Earth, but the minimum cross section should be higher than the bare copper conductor.

10.8.5 Connections to Non-Electrical Structural Metalwork and Equipment

10.8.5.1 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.

10.8.5.2 Individual components of metallic structures of plant shall be bonded to adjacent components to form an electrically continuous metallic path to the bonding conductor.

10.8.5.3 Small electrically isolated metallic components mounted on non-conducting building fabric need not be bonded to the main earth bar.

10.9 Materials and Installation

The GTP of Earthing material along with its technical parameters as used in the design and the methodology of earthing system installation shall be submitted for approval.

10.9.1 Earthing Conductors

10.9.1.1 Conductors shall be of high conductivity copper in the form of circular conductors stranded to IEC 60228 (BS 6360) or solid rods or bars to BS 1433.

10.9.1.2 Conductor sheaths shall be of PVC to meet the requirements of BS 6746 Grade TM1 or IEC 60502 Grade ST1 with a minimum thickness of 1.5 mm.

10.9.1.3 Bare strip conductors only shall be used for earth electrodes or voltage control meshes.

10.9.1.4 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.

10.9.1.5 All conductors not buried in the ground shall be straightened immediately prior to installation and supported clear of the adjacent surface.

10.9.2 Earthing Rods (Not Applicable, only copper rods or copper conductor is acceptable)

10.9.2.1 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.

10.9.2.2 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.

10.9.2.3 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. 11igh 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.

10.9.2.4 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.

10.9.2.5 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.

10.9.2.6 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.

10.9.2.7 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.

10.9.3 Fittings

10.9.3.1 Clips for supporting strip conductors not buried in the ground shall be of the direct contact type and clips for circular conductors shall be of the cable saddle type. The clips shall support the conductors clear of the structure.

10.9.3.2 Conductors shall be connected to earth rods by a bolted clamp to facilitate removal of the conductor for testing the rod.

10.9.3.3 Disconnecting links shall comprise a high conductivity copper link supported on two insulators mounted on a galvanised steel base for bolting to the supporting structure. The two conductors shall be in direct contact with the link and shall not be disturbed by the removal of the link. Links for mounting at ground level shall be mounted on bolts embedded in a concrete base.

10.9.3.4 Disconnecting links mounted at ground level and the connections at the earth rods shall be enclosed in concrete inspection pits, with concrete lids, installed flush with the ground level.

10.9.3.5 All conductor fittings shall be manufactured from high strength copper alloys with phosphor bronze nuts, bolts, washers and screws. Binary brass copper alloys will not be acceptable. All fittings shall be designed for the specific application and shall not be permanently deformed when correctly installed.

10.9.3.6 Sheathed conductor support fittings may be of silicon aluminium, glass-filled nylon or other tough non-hygroscopic material for indoor installations.

10.9.3.7 Fittings not in direct contact with bare or sheathed conductors may be of hot-dip galvanised steel. Bi-metallic connectors shall be used between conductors of dissimilar materials and insulating material shall be interposed between metallic fittings and structures of dissimilar materials to prevent corrosion.

10.9.4 Joints

10.9.4.1 Permanent joints shall be made by exothermic welding below ground, or crimping for above ground connections.

10.9.4.2 Detachable joints shall be bolted and stranded conductors at bolted joints shall be terminated in exothermically welded lugs or a crimped cable socket. The diameter of any holes drilled in strip conductors shall not be greater than half the width of the strip.

10.9.4.3 Connections to electrical equipment shall be detachable and made at the earthing studs or bolts provided on the equipment by the Manufacturer. When an earthing point is not provided, the point and method of connection shall be agreed with the Engineer.

10.9.4.4 Connections to metallic structures for earthing conductors and bonding conductors between electrically separate parts of a structure shall be either by direct exothermic welding or by bolting using a stud welded to the structure. Drilling of a structural member for a directly bolted connection shall only be carried out to the approval of the Engineer.

10.9.4.5 Bolted joints in metallic structures, including pipework and which do not provide direct metallic contact, shall either be bridged by a bonding conductor or both sides of the joint shall be separately bonded to earth, unless the joint is intended to be an insulated joint for cathodic protection or other purposes.

10.9.4.6 When the reinforcing in concrete is used as a part of the earthing system, the fittings used to provide a connection point at the surface of the concrete shall be exothermically welded to a reinforcing bar. This fitting shall be provided with a bolted connection for an earthing conductor. The main bars in the reinforcing shall be welded together at intervals to ensure electrical continuity throughout the reinforcing.

10.9.4.7 No connections shall be made to reinforcing bars and other steelwork which do not form part of the earthing system and are completely encased in concrete.

10.10 Direct Stroke Lightning Protection

10.10.1.1 The Contractor shall provide adequate overhead shielding to effectively prevent direct lightning strikes to any equipment or energized bus within the switchyard areas. The system shall also be designed to provide "effective shielding" to ensure that no insulation flashover can result from atmospheric discharges striking the overhead shielding. The screens shall be of aluminium clad steel wires of not less than 50 sq.mm. total section, and connected to provide low impedance paths to earth.

10.10.1.2 The lightning protection scheme shall be designed by the Contractor using the latest version of the electro geometric model (EGM) or Razevig method. Detailed calculations demonstrating the adequacy of the proposed shielding shall be submitted to the Employer for approval prior to the overhead shielding design being finalized. The Detailed calculations shall accompany the layout with section drawing of the proposed system.

10.10.1.3 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.

10.10.1.4 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.

10.10.1.5 The overhead earthwire shall be suitable for extension to protect the substation equipment to be installed in future stages of development.

10.11 Earthing of Fences

10.11.1 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.

10.11.2 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.

10.11.3 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.

10.11.4 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.

10.11.5 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.

10.11.6 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.

10.11.7 Conductors

10.11.7.1 All copper conductors used for earthing and bonding the fences and components and for outer rings shall have a cross-sectional area of not less than 75 mm²

10.11.7.2 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.

10.11.7.3 Earth wires shall be held in clamps with free pin type joints between clamps and supports.

10.11.7.4 Connections shall be provided for the terminations of the earth wires of the overhead lines, including bimetal connectors where necessary.

10.11.7.5 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.

10.12 Portable Earthing Devices [Not Applicable]

Portable earthing devices for use with outdoor 230 kV and 132 kV apparatus in substations shall be supplied in the numbers stated in Schedule A of Requirements and shall comprise:

(a) Copper alloy earth end clamp for connection to the rigid loops in equipment earth bonding connections.
(b) Aluminium alloy line and busbar end clamp to suit the connectors of the type supplied under the Contract.
(c) Flexible stranded aluminium alloy conductor with clear protective PVC sheath, sized suitable for the specified fault level and duration.
(d) Telescopic operating pole of glass fibre or similar material, of sufficient length to reach the height of connections to high voltage equipment from ground, but retractable into a carrying length not exceeding 2.5 m, and complete with non-slip hand grips.

The preferred types of portable earthing devices are Ragnar Stalskog and Karl Pfisterer. However, device having origin at USA, Canada, Europe, Japan,korea is also acceptable.

11. Batteries, Chargers and DC Switchgear [Not Applicable]

11.1 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.

11.2 References

11.2.1 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

11.2.2 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.

11.3 Design Requirements

11.3.1 General

11.3.1.1 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.

11.3.1.2 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.

11.3.1.3 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.

11.3.1.4 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.

11.4 Batteries

11.4.1 Type of Battery

11.4.1.1 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.

11.4.1.2 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.

11.4.1.3 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.

11.4.1.4 A complete set of test and maintenance accessories, suitably boxed, shall be provided for each battery.

11.4.1.5 A syringe hydrometer and a durable instruction card shall be included in each set.

11.4.1.6 Cells shall be numbered consecutively and terminal cells marked to indicate polarity.

11.4.1.7 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

11.4.1.8 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.

11.4.2 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.

11.4.3 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.

11.4.3.1 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.

11.4.3.2 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. One closing operations on all circuit breakers (including future) supplied by the battery.
2. One 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.

11.4.3.3 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.

11.4.4 Location of Batteries

11.4.4.1 The batteries shall be housed in a ventilated battery room. The charging equipment and distribution switchboards shall be housed in a separate room.

11.4.4.2 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.

11.4.4.3 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.

11.4.4.4 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.

11.4.5 Battery Mounting Connections and Accessories

11.4.5.1 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.

11.4.5.2 Alternatively, batteries may be mounted in a similar manner on treated hardwood stands.

11.4.5.3 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.

11.4.5.4 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 cur-rent 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.

11.4.5.5 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.

11.4.5.6 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.

11.4.5.7 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.

11.4.5.8 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.

11.5 Control and Charging Equipment

11.5.1.1 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.

11.5.1.2 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.

11.5.1.3 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%

11.5.1.4 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.

11.5.1.5 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.

11.5.1.6 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.

11.5.1.7 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.

11.5.1.8 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.

11.5.1.9 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.

11.5.1.10 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.

11.5.1.11 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.

11.5.1.12 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.

11.5.1.13 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.

11.5.1.14 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.

11.5.1.15 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.

11.5.1.16 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.

11.5.1.17 The boost charging equipment shall be capable of recharging the battery within six hours following a one hour discharge period.

11.5.1.18 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.

11.5.1.19 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 voltagereturns 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.

11.5.1.20 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.

11.5.1.21 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.

11.5.1.22 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.

11.5.1.23 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.

11.5.1.24 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.

11.5.1.25 The charger shall also be fitted with a device to de-energise the charger in the event of a DC output float over voltage.

11.5.1.26 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.

11.5.1.27 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.

11.5.1.28 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.

11.5.1.29 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.

11.5.1.30 Each charger shall be equipped with a switch-fuse for the incoming AC supply and an off load isolator for the DC output.

11.5.1.31 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.

11.6 Service Manual and Spare Card

11.6.1.1 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.

11.6.1.2 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.

11.7 Distribution Switchboards

11.7.1.1 The switchboard shall comply with the requirements of BS 5468 (IEC.60439)

11.7.1.2 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.

11.7.1.3 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.

11.7.1.4 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.

11.7.1.5 A double pole switch or contactor shall be provided for the purpose of sectionalising the busbar.

11.7.1.6 A battery earth fault detecting relay, which will centre tap the system via a high resistance, shall be incorporated in the distribution panel.

11.7.1.7 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.

11.7.1.8 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.

11.7.1.9 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.

11.7.1.10 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.

11.7.1.11 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.

11.7.1.12 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.

11.8 Insulation Monitoring System

11.8.1 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.

11.8.2 Standard

IEC 61557-8

IEC 60364-4-41, IEC 62557-8: 1998-05

11.8.3 Principle:

11.8.3.1 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.

11.8.3.2 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.

11.8.3.3 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.

11.8.3.4 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.

11.8.4 Construction

11.8.4.1 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

11.8.4.2 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.

11.8.4.3 The system shall be capable of communicating with the Station SAS for signalling of DC fault.

11.8.4.4 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

<u>Control Circuit</u>

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.

11.8.4.5 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.

11.8.4.6 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.

11.9 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.

11.10 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

11.11 Inspection and Testing

Inspection and testing during manufacture and after installation on site shall be in accordance with Section 16 of this specification.

12. LV AC Distribution Switchgear

12.1 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.

12.2 References

IEC 61869-1	Instrument transformers-Part 1: General Requirements
IEC 61869-2	Instrument transformers-Part 2: Additional Requirements for Current transformers
IEC 61869-3	Instrument transformers-Part 3: Additional Requirements for Voltage transformers
IEC 61869-5	Instrument transformers-Part 5: Additional Requirements for Capacitive Voltage transformers
IEC 60269	Low voltage fuses
IEC 60439-1	Specification for low voltage switchgear and control gear assemblies.
IEC 60644	Specification for high-voltage fuse links for motor circuit applications.
IEC 60898	Electrical accessories - Circuit breakers for overcurrent protection for household and similar installations.
IEC 60947-1	Low-voltage switchgear and control gear -General
IEC 60947-2	Low-voltage switchgear and control gear -Circuit breakers
IEC 60947-3	Low-voltage switchgear and control gear -Switches, disconnectors and fuse combination units.
IEC 60947-4	Low-voltage switchgear and control gear -Electro mechanical contractors and motor starters.

12.3 Switchboard Design

12.3.1 General

12.3.1.1 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:

12.3.1.2 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.

12.3.1.3 The equipment shall be of the single busbar type with circuit equipment housed in separate compartments.

12.3.1.4 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.

12.3.1.5 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.

12.3.2 Rating

12.3.2.1 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.

12.3.2.2 The allowable tolerance level for busbar design is ±5% at 415 V and allowable tolerance level at load terminal is ±10% at 415 V.

12.3.3 Busbars

12.3.3.1 Busbars shall be capable of carrying the full rated current continuously without exceeding the maximum temperature specified in IEC 60439 under site ambient conditions.

12.3.3.2 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.

12.3.4 Busbar and Circuit Shutters

12.3.4.1 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.

12.3.4.2 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.

12.3.5 Circuit Labels

12.3.5.1 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.

12.4 Circuit Breakers

12.4.1.1 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.

12.4.1.2 Where circuit breakers incorporate thermal overload protection and short-circuit protection, their settings shall be subject to agreement with the Engineer.

12.4.1.3 Tripping arrangements shall be such as to ensure simultaneous opening of all phases. Arc extinction shall be by de-ionising arc chutes.

12.4.1.4 Circuit breakers on the incoming circuits shall have facilities for locking in the "off" position.

12.4.1.5 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.

12.5 Switch Fuses

12.5.1.1 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.

12.5.1.2 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.

12.5.1.3 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.

12.5.1.4 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.

12.6 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.

12.7 Inspection and Testing

Inspection and testing during manufacture and after installation on site shall be in accordance with Section 16 of this specification.

13. Buildings and Civil Engineering Works

13.1 BUILDINGS AND CIVIL ENGINEERING WORKS (FOR AIS)

13.1 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.

13.1.1 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. Any work essential for proper functioning of the modification project, shall be done by the contractor even if not mentioned in the scope/price schedule. Cost of all these works shall deem to be included within the quoted price. In bay extension/renovation works of existing substation, the contractor should assess the difficulties/obstructions for existing structure and or foundation (shallow or pile) by site visit of the project area. If dismantling of existing foundation is required, then all concrete work below (as required depth) and above ground level should be removed. The contractor should deem to the difficulties/obstructions costs within the quoted price. 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 13.1.4 and levelling as well as compaction.

(iii) Foundations for all gantry and equipment to be installed in outdoor switchyards and any other civil works required for the project

(iv) Modification of buildings consisting of structural reinforced concrete frames, brick walls, concrete roof and floor slabs.

(v) Internal road including road crossing for cable trench with sufficient drainage pipes, surfacing the entire area within site boundary and surface water drainage.

(vi) Cable trenches, cable tunnels, cable ducts and pipe ducts.

For all substations and for individual rooms in substations suitable nameplates, signs and labels shall be provided to ensure identification, safe operation of plant and warning of danger. The text, which shall be both in Bangla and English, shall be approved by the Employer. The substation sign board(s) shall be 3 mm, Aluminum sheet powder coated and the text (Bangla & English) shall be UV resistant, PGCB logo on a separate circular plate to be fixed at the centre of sign board. The inscriptions shall be engraved with colored lettering. All nameplates, signs and labels shall be non-deteriorating and non-warping under aggressive weather conditions and shall be guaranteed for a minimum period of 10 years. Plates, etc., will be securely attached using bolts and nuts or screws; adhesive will not be permitted.

Included in the scope of work is the detailing, construction and maintenance of the following items which shall generally be constructed to the Employer's standards but full working drawings shall be prepared by the Bidder:

(a) chain linked fence with gate

(b) internal road

(c) surface water and storm drainage

(d) soak well

(e) lighting, small power, external floodlighting, emergency lighting and fire protection

Chain linked fence as stated in item (a) shall be designed as per enclosed drawing.

Internal road stated in item (b) shall be designed as per enclosed drawings.

13.1.2 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

13.1.3 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.

13.1.4 Site Survey Drawings

For each site the Bidder shall prepare a survey at 1:200 scale showing existing ground levels on a maximum 10 meter grid and details of all features above and below the ground within the site boundary and up to 15 meters beyond it by the key date stated in the programme. Levels shall be related to bench marks clearly indicated on the plan. The plan shall be submitted to approval by the Engineer and the approved substation building plinth levels shall be given on site plan. The Bidder shall propose the building floor level to the Engineer. The Final Ground/formation Level (FGL) of the site will be 500mm above the crown of the nearest public road or 500mm above the

Highest Flood Level (HFL) whichever is greater. If the site is located within/adjacent to an existing switchyard/substation of the employer/other organization, then FGL of the site should be determined same as mentioned above but should not be less than the FGL of existing switchyard/substation. For bay extension within an existing switchyard, FGL of new bay shall be same as the FGL of existing bay. All building plinth level will be 600mm above the FGL.

13.1.5 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.

13.1.6.1 Engineer's and Employer's Accommodation/Surveying Equipment

On each major site the Contractor shall provide an office of approx size 5 x 8m equipped with desk, one executive chair, two visitor chairs, one multipurpose shelf, light, fan and air conditioner, toilet with wash basin *etc.* for the sole use of the Employer's Engineer and his inspectors. Similar facilities are to be provided for the supervision consultant of the Employer.

13.1.6.2 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.

13.1.7 Programme

The Bidder's programme shall at Bid stage define the following key dates. Where drawings are to be submitted for approval, they shall be submitted at least 28 working days before the key dates to allow for the Engineer to comment and his comments to be incorporated in the drawings:

1 Issue of approved site survey drawing within the site boundary and up to 15 meters beyond it complete with soil levels and floor levels

2 Issue of approved electrical layout drawings

3 Completion of Site Investigation field work

4 Issue of approved Site Investigation Final report

5 Completion of loading tests on a foundation on fill site and any other site where settlement is likely to be a problem

6 Issue of approved drawings required for Planning Permission

7 Issue of a full complete set of civil building drawings

8 Construction start date

9 Date access will be given for:

i) Installation of equipment in Buildings

ii) Installation of outdoor plant

10 Construction finish date

The drawing programme shall ensure that complete set of approved civil building drawings will be issued at least 14 days before construction start, in accordance with the Project Requirements.

The Construction programme shall be expressed in an 'S' curve for the whole project, with the percentage (of the total value of work in the schedules) each month.

13.1.8 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.

13.1.9 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.

13.1.10 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

13.1.11 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.

13.2 REFERENCES

13.2.1 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 13.2.2 below.

13.2.2 Design and Construction Standards

BS12	Portland Cement
BS EN 124	Gully and Manhole tops for vehicular and pedestrian areas
BS 812	Testing aggregates
BS 882	Aggregates from natural sources for concrete
BS 1377	Methods of test for soils for civil engineering purposes
BS 1722:	Part 10 Anti-intruder fences
BS 1881	Testing concrete
BS 2853	Design and testing of overhead runway beams
BS 3148	Methods of test for water for making concrete
BS 3921	Clay bricks
BS 4449	Steel bars for the reinforcement of concrete
BS 5262	External renderings
BS 5395	Stairs, ladders and walkways
BS 5572	Sanitary pipework
BS 5628	Code of practice for use of masonry
BS 5930	Code of practice for site investigations
BS 6031	Code of practice for earthworks
BS 6367	Code of practice for drainage of roofs and paved areas
BS 6399:	Part 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

13.3 DESIGN

13.3.1 Architectural and Structural Requirements of Buildings

All new buildings shall be designed to be architecturally pleasing in appearance and to withstand the tropical climate with minimal maintenance.

Architectural plan and all elevations of buildings shall be agreed before other detail plans are prepared.

Air conditioning units shall be provided in rooms listed in Section 16. Air conditioned rooms shall have a false ceiling such that the overall thermal transmittance of the roof shall be below 0.45 Watts/m^2°C. The false ceiling shall be made from non-combustible materials, and shall be easily removable to provide easy access to small power cables.

Control room building and switchyard panel room shall be reinforced by a reinforced concrete frame which shall be capable of resisting a horizontal earthquake force of 0.1G. An external concrete open staircase shall be provided up to panel room floor. An internal concrete staircase shall be provided up to the roof. The roof shall be a flat insitu concrete slab designed for 2.5 kN/m^2 live load. For other buildings shall be designed as per latest BNBC.

The roof shall be waterproofed with lime terracing 2:2:7 lime, shurki (powdered brick) and brick chips 0.75" down, which shall be beaten in accordance with local practice or with any other approved water proofing system. The entire roof area shall be laid in one continuous operation. For lime terracing waterproofing system the minimum compacted thickness of terracing shall be 25mm at the low points of the roof with a 1:150 slope to those points formed by a layer of terracing of increasing thickness. Once laid, the terracing shall be covered with a layer of bitumen emulsion and the edge of the terracing shall be protected against erosion into the downpipes. Downpipes shall be of 100mm diameter uPVC pipe placed outside the wall but shall be enclosed in a facing brick buttress. There shall be at least one downpipe per 100m^2 of roof. The Bidder shall guarantee the roof against leaks for a period of 3 years from the Taking over Certificate date. The roof shall project at least 450mm beyond the face of all walls or 150mm beyond the face of all columns whichever is greater to form a sunshade and rain shelter to the walls below. The upper surface of this projection shall be sloped and a drip provided.

The main entrance to all buildings shall be shaded, either by a projection of the roof over the entrance veranda or by a separate roof at a lower level. This area of roof shall also be lime terraced and drained by rainwater pipes.

The roof parapet wall shall be about 1.0 meter high with an in situ concrete coping of 75mm with *dpc* below it. Where facing bricks are used below the roof level, they shall also be used above roof level. An architectural feature shall be provided by panels of open decorative block work (Mirpur ceramics or similar approved) to ensure good air circulation over the roof. Minimum three open decorative blocks of size 1000mm X 500mm should be provided on each side in solid portions of parapet wall.

The head of each downpipe shall be fitted with an enlarged hopper of 200mm and purpose made cast iron grill set into a recess in the roof projection.

All external walls of main control room building/SPR shall be minimum 230mm first class brickwork plus one layer of Mirpur Ceramics or similar approved facing bricks. External walls of other buildings shall be minimum 230mm first class brickwork plus one layer of Mirpur Ceramics or similar approved facing bricks or rendered with cement render and painted as required by the architectural plan. The internal walls shall also be generally of minimum 115mm thick first class brickwork. Internal walls and ceiling outside & inside of false ceiling shall all be rendered and receive one sealer coat plus two finishing coats of emulsion paint. Externally, rendered walls shall receive primer plus two finishing coats of acrylic external quality paint or similar approved.

Particular attention must be given in the design of buildings and layouts to fire prevention and safety of personnel at all times. Buildings housing switchgear and control equipment shall be designed as far as practicable to exclude pollution under all likely weather conditions. Fire-proof or flame-retarding materials are to be used for floor, wall and ceiling finishes. Where areas are designed as having a fire resistance rating then materials shall be shown to have passed approved standard tests for that class of fire resistance.

The minimum height of ground floor of two story control room building shall be 3.0 meter and the minimum height of first floor control room shall be 4.0 meter. False ceiling should be provided in the control room floor. In the switchgear rooms, minimum 1 meter clearance shall be provided over the switchgear to the underside of the roof slab but the Bidder shall provide a greater clearance if it is required to remove equipment. The clearance maybe reduced below down stand beams provided no equipment is required to be removed from the top of the switchgear. All rooms in any building in a story shall be of same height.

The false ceiling shall be made from non-combustible materials, and shall be easily removable to provide easy access to small power cables. Suspended ceilings, with acoustic tiling and incorporating lighting and air-conditioning fixtures shall be used in corridors, offices, toilet, control and SCADA rooms of the buildings and as per schedule of finishes.

In main control room building, all structures shall be designed to carry the loads imposed by the structure itself, together with minimum floor live load (including stairs) of 5.0kN/m2 (minimum) or in accordance with an approved standard or code of practice. The roof shall be designed for 2.5 kN/m^2 live load.

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).

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.

13.3.2 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 13.1.4. The boreholes shall be located to an accuracy of ± 0.5m and shall be located to site layout considering existing obstacles at the field.

Boreholes shall be a minimum of 25 metres depth or twice building footing width or upto the level where the foundation/pile will be rest whichever is greater. All boreholes shall be backfilled with compacted sand.

Borehole log together with a summary of all required laboratory tests is required to be prepared. Soil test locations are required to be indicated on the geographical map.

In each borehole the following tests shall be carried out:

- Standard Penetration tests at 1.5 metre intervals.
- Undisturbed samples shall be taken at around 1.5 meters, 3.0 metres and 4.5 metres depth for unfilled site; 1.5 metres, 3.0 meters, 4.5 meters and 7.5 meters depth for filled site and tested by unconfined compression tests.
- One dimensional consolidation tests shall also be carried out on undisturbed samples taken at 1.5, 3 & 4.5 meters depth. The samples shall be saturated and the range of applied pressure shall fully reflect the in-situ conditions. Graphs showing void ratio (e) and applied pressure shall be submitted along with the Coefficient of Compressibility for the range of loading anticipated. Mv shall be in m^2/MN and shall be recorded at each stress increment. The coefficient of consolidation, cv, shall be given in m^2/year.
- Particle size analysis shall be carried out for each stratum and specific gravity, moisture content, liquid limit and plastic limit determined.
- Ground water level shall be determined by dipping the boreholes for 24 hours. Where collapse of the boreholes occurs, casing shall be used and left in until the water level remains constant for two days.
- In cohesive soils a vane test to BS 1377: Part 9 shall be carried out at three different depths. The Bidder shall check the sensitivity of soil and ground water at each site to concrete and take all measures necessary to ensure the long term durability of concrete.

The Bidder shall give the Engineer the requisite period of notice prior to commencing the geotechnical investigation at the field. The field sheets of each bore log shall be signed by the geo-technical engineer of Bidder and representative of the Engineer. The signed field sheets shall be include in site investigation report.

(d) Site Investigation Report

The site investigation and analysis of the data in a final report giving full details of foundation proposals shall be completed at each site by the programmed date. During site investigation, Geographical map shall be prepared indicating the locations of soil test.

The report shall be submitted by the key date at each site given in the programme. The Bidder shall submit 3 copies of the report to the Engineer. The report shall propose full details of foundations and loading thereon and shall provide estimates of likely settlements and differential settlements. The report shall be the work of the Bidder's own foundation engineers.

If the Bidder uses a local site investigation Bidder, he shall appoint one of his geo-technical engineer to oversee the entire operation and each piece of data shall be countersigned by this person.

Where estimated settlement exceeds 25mm, the Bidder shall construct one foundation at an early stage and test load this foundation to confirm settlement predictions.

(e) Foundations

Regardless of the result of soil investigation report, the foundations of Main Control Building and gantry structures shall be provided with pile foundation. The foundations of auto-transformers shall be provided with shallow or pile foundation as per soil condition. Others buildings foundation shall be provided with shallow or pile foundation as per soil condition. All earth retaining walls shall be RCC. Based on site and soil conditions, boundary walls with/without RCC retaining wall may be designed with pile foundation or shallow foundation. But, if width of footing perpendicular to wall exceeds 3000mm, then pile foundation must be provided for boundary walls (refer to enclosed drawing). Stability of surrounding & underlying soil and settlement of the wall foundation must be ensured by the contractor.

Piles shall be concrete (cast-in-situ or precast) complying with BS 8004. For structural design of cast in situ piles, guidelines provided in **Annexure 13.1** should be followed. One working piles shall be randomly selected by

the employer for pile load test in accordance with BS 8004. One working pile of control building and one of auto-transformers at each site shall be compression load tested and one working pile of gantry tower foundation at each site shall be uplift load tested to 100% of design load in accordance with BS 8004. 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.

For shallow foundations the minimum depth of foundations shall be 1.5m.

All formations shall be hand rammed or mechanically compacted before placing 75mm minimum thickness of Class B concrete blinding, within 24 hours of bottoming excavation, which blinding shall project 75mm minimum distance beyond all footings. Each footing shall be inspected by the Engineer. Where soil condition is poor (on fill sites or already filled sites) or where the Bidder leaves foundations exposed and soil conditions deteriorate, one of the following measures shall be carried out as agreed with the Engineer:

i) Blinding depth and projection shall be increased as necessary.

ii) Soft soil shall be removed and replaced with compacted filling sand with the top 300mm (Minimum) consisting of sand and khoa (brick chips) in 2:3 ratio with 95% level of compaction.

The cost of this work shall be borne by the Bidder.

The Bidder shall propose the allowable bearing pressure for all foundations based on soil strength parameters only and shall not be increased while wind loads exceeds 25% of dead load as well as shall not exceed 125kN/m^2. Between column footings all walls, including all internal walls, shall be provided with a reinforced concrete strip footing of minimum dimension 800mm wide by 250mm deep placed at the same

level as column footings and linked structurally to the footings. Column footings shall be tied at foundation/grade beam level and also floor level by beams to every adjacent column in both orthogonal directions.

The deepest parts of any foundations shall be completed first. All foundations shall be completed and backfilled, including all cable tunnel and cable trench work inside buildings, before walls are raised above floor levels. All other foundations shall be backfilled within 7 days of completing concreting.

All exposed concrete and the outer surfaces of cable trenches and cable tunnels shall receive three coats of bitumastic paint before backfilling to reduce ingress of water. The Concrete surface shall be ground smooth and all air holes *etc.* filled (rubbed down with a cement slurry) before painting.

The Bidder shall monitor settlement of all foundations each month and report this settlement to the Engineer until settlement has reduced to less than 1.5mm in 3 months.

The tops of all foundations shall terminate 200 mm above site average finished surface level. All exposed edges shall have 20 mm x 20 mm chamfers.

Excavation shall only be carried out when the ground water table is at least 1000mm below foundation level. The excavation shall be kept dry during the construction period by providing sumps and pumps as required. During the rainy season, shelters shall be erected over all open excavations. For dewatering, slurry wall with required specific gravity may be used.

Excavations shall be adequately supported or formed to ensure stability of the sides and prevent any damage to the surrounding ground or structures. The design of suitable sheet piling and/or timbering for excavation shall be in accordance with the recommendations of BS 8004 Section 5.

When the Contractor requested shall submit details of his temporary support to the Employer.

Excavation shall not be carried out below or adjacent to existing building foundations until under-pinning and 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.

13.3.3 Drainage

The entire surface within boundary walls shall be of uniform sloping site, sloping at 1 in 500 minimum slope to open channels around the entire perimeter. These channels shall be designed for a rainfall intensity of 60mm per hour. Outside the boundary wall the Bidder shall be responsible for drainage up to 20 metres from the wall and will at some sites need to construct outlets with suitable erosion protection down to paddy level.

The concrete wall of cable trenches shall project at least 50mm. above brick paving level to prevent run off entering the cable trench. The floors of all cable trenches/tunnels shall be sloped to soak well as described in 13.3.18.

The cable trenches will thus form barriers to surface water drainage. If the cutoff area exceeds $30m^2$ it shall be drained by constructing Water Catchment Pits (WCP) with a 200mm minimum diameter uPVC pipe to the boundary drain. The Bidder's drainage design shall avoid all ponded water to avoid forming a mosquito breeding ground.

All drainage pipework within buildings shall be uPVC type, generally of 100mm diameter or as per requirement. Floor drains shall be placed in each battery room and toilet.

External pipework shall be 150mm. minimum diameter uPVC pipes at a minimum depth of invert of 300mm. Where pipes, including existing pipes alongside site, are less than 400mm above adjacent foundations they shall be

surrounded in concrete. Where required, drainage pipes shall be kept below cables, allowing 1.1 m cover to top of pipes.

Manholes shall be of brick construction with minimum 450mm x 450mm clear openings and airtight RCC/ductile iron covers to BS EN 124. Manholes shall be located at each change of direction. Minimum fall on all pipelines shall be 1 in 150. Manholes shall not be located in roads.

The Bidder shall be responsible for all negotiations with local authority/WASA where a connection to a public sewer is proposed. Where high water levels in public sewers may cause effluent to back up into a site, no return valves shall be fitted. The Bidder shall provide all protection required to existing sewers and shall deepen foundations, including boundary wall foundations, where required to ensure all foundations are below adjacent sewers. The Bidder shall draw longitudinal sections of all pipelines.

Septic tank and soak well for Main Control Building shall be constructed as per provided drawings. The septic tank shall be located at least 15 meters from buildings/ water pumps. The pipe network for septic tank should be designed considering self cleansing velocity. Inspection pits should be provided at regular intervals. Other buildings shall have septic tanks designed for the required number of users. All foul drains shall be vented by a vent pipe to above roof level. The inner surface of all manholes and septic tanks shall be painted with 2 coats of bitumastic paint to protect it against sulphate attack. The septic tank shall have access holes directly over the inlet pipes and outlet pipes. Where public sewers exist alongside a site, the Bidder shall connect directly to the foul sewer, provided effluent from the sewer is treated.

The Bidder shall construct the drainage first to ensure that at no stage is rainwater ponded on any part of the site. All rainwater shall be able to run off the site or shall be immediately pumped off site by the Bidder. The Bidder shall complete all necessary drains before casting any roof and large concrete area which will create large run off. The condensate drains for the air conditioning shall also be connected to the drainage. Bottom of drain shall be sloped at 1:300 minimum.

If a town's water supply is unreliable, the roof rain water shall be collected in an underground tank of standard Employer's design.

13.3.4 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.

13.3.5 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.

13.3.6 Water Supply

The Bidder shall be responsible for providing a water supply both for construction and for operation of the completed sites. If a town's water supply is not available, the Bidder shall install a deep tube well of 40mm minimum diameter and 100m minimum depth with necessary pumps including all fittings, pipes *etc.* as required. But in that case guideline specified by WHO for drinking water is required to be satisfied. The Bidder shall supply and commission power supplies and all pumps required by tube wells.

If a town's water supply is available, the Bidder shall be responsible for making all necessary arrangements with local authority/WASA to connect a supply. If the pressure in the supply is inadequate to supply the roof tank continuously, the Bidder shall install a 1800 litre low level tank and pumps. This tank shall be below ground with a 200mm minimum air void around the tank to protect it from contamination. The pump control panel shall be located in the building. Water levels shall be controlled by float switches but the panel shall provide also for manual operation.

The supply shall be connected to a 2000 litre food graded plastic tank. This tank shall be raised 400mm clear of the line terracing on four brick piers of minimum 350mm square. All supplies in buildings shall be fed from the roof tank. The supply to the tank shall have a valve at waist height. The tank shall have an overflow returning to the location of this valve. No pipes shall pass through the roof directly over any room. Pipework shall be routed up the outside of the building and return pipes shall return down the outside of the building before entering through the wall. Pipework shall be CPVC secured by clamps at 1.5 metre intervals and painted with alkyd paint to match walls. All pipes should be concealed by brickworks on vertical walls.

13.3.7 Plumbing and Sanitary Fittings

The Bidder shall prepare a drawing of all plumbing and building drainage for each building. Sanitary fittings and plumbing materials shall generally be of approved local manufacture.

In main control building each toilet shall have a single western WC. Each toilet outlet shall be vented by a 100mm diameter uPVC vent pipe passing up the outside of the building to 2500mm above roof level. Beside each toilet shall be placed a low level tap. Main control Building toilets shall also have a wash basin and cold and hot water shower with 10gallon capacity geyser for each toilet. Toilets and showers shall have all walls tiled upto the bottom of false celling.

Every tap and cistern shall have stop cocks in the supply pipe. One external tap shall be provided on each building. Battery rooms shall be provided with a stainless steel sink of approximate dimensions 900 x 600 x 200mm with a draining board to one side. The battery room floor drain shall be connected to the foul drainage. All floor drains shall have P traps.

Mirrors shall be installed over toilet wash basins. Care shall be taken in orientation of toilets to avoid offending religious sensitivities. Toilets shall generally be orientated North South where possible. Each shower shall have a wall on two sides and a porcelain shower tray sunk into the floor. Soap dishes shall be provided beside each shower.

Only foul water from WC pans shall be connected to septic tanks. All other water shall flow to surface water drains.

13.3.8 Building Floors

All topsoil containing roots shall be removed and the insitu soil compacted before placing backfill. All backfill, including the backfill to column footings, below the floor shall be sand. The floor and all cable trenches shall be made

of Class A concrete. The ground floor slab shall have a minimum 125mm thick reinforced Class A concrete furnished with non-skid floor tiles and shall rest on the compacted fill. Below the slab shall be placed a layer of polythene 0.5mm and a layer of sand khoa (2:3) compaction of minimum100mm thick, hand rammed to a smooth upper surface.

All cables from cable trenches shall enter the building over grade beam level, no cable trench shall be allowed into main control room building. Where power cables traverse a building to reach a switchgear room on the far side they shall generally be contained within cable tray.

All sand backfill shall be compacted to 95% optimum density and shall be tested. The fill within a building, above ground level, shall not be placed until all backfill outside the building is completed. All floor slabs shall have a damp proof membrane of 0.5mm thickness.

Wherever required, control building shall have a ramp at a slope of approximately 1 in 7.5, of 1.5m minimum width with a Concrete Class A slab of min depth 125mm with a stiff brush concrete surface finish, or other agreed non slip surface.

All floors (including verandahs) except for cable basement, GIS room, control room and battery roomshall have 25mm homogeneous floor tiles topping. All external steps where public access is given to buildings shall have marble tiles toppings. Elsewhere, concrete surfaces shall be used for all external floors/steps. Verandahs shall have a minimum 1:50 slope to shed rainwater away from buildings. Concrete floors and steps shall also be treated with 3coats of Lithurin or other approved concrete dust proofer.

Verandahs shall have a minimum shed of 1:50 slope to rainwater away from buildings.

If floor tiles are not adequately durable to withstand switchgear movement when rolled out to the maintenance position, then galvanized steel chequered plates shall be inserted in the floor to resist the abrasion from switchgear wheels.

13.3.9 Cable Basement

Ground floor of the control room building shall be used as cable floor.

13.3.10 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.

13.3.11 Control Room Floors

No raised floor except for panel installation shall be used.

13.3.12 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.

13.3.13 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.

13.3.14 Windows

Even natural light shall be provided by windows to illuminate all areas of buildings. Window area shall be about 6% of floor area to limit solar heat gain. Tops of windows shall generally be minimum 2100mm from floor level but toilet windows may be higher. The bottom of windows shall be generally at least 0.45 metres above floor level. Each window shall be provided with a sunshade projecting about 350mm from the wall above and at the upper sides of the window. Few windows shall be placed on south facing walls. Windows shall be spaced to give a wide view of the switchyard.

Windows shall have single glazing with 6mm thick glass, reinforced with wire mesh where windows are placed in or over doors.

Window frames shall be anodised aluminium minimum thickness 1.5mm.

Glass panels shall be placed over doors to provide natural light to internal corridors and rooms where required.

External cills shall have a sloping tile or similar detail with drip.

The Bidder shall prepare a window schedule for each building.

The schedule shall clearly indicate both fixed and opening windows.

The Control and Switchgear rooms in particular shall have opening windows to allow adequate ventilation. Approved quality of MS grill shall have to be provided to all windows. All MS grill will be painted with one coat of red oxide primer and minimum two coats of approved quality synthetic enamel paint.

13.3.15 Doors

Internal doors and door frames shall be anodised aluminium. Main Entrance/Exit doors and door frames shall be steel or anodised aluminium.

The minimum size of the structural openings for doors shall be 1550mm wide for double doors and 930mm wide for single doors. Door height shall generally be 2100mm but switchgear and control rooms shall have a removable transom and removable panel over the door or a taller door to provide a total height of about 2100mm. All door sizes and widths shall be adequate to get in and get out all equipment and future equipment.

All external doors shall have weather boards, hydraulic closers and cabin hooks to hold the door open. External doors shall open inwards, except for switchgear room doors which must open outwards and be fitted with panic release latches.

Each wooden door leaf shall have minimum four 150mm heavy iron hinge. Door furniture shall be of approved local manufacture and shall generally be of brass. All corridor doors, external doors and rest room (toilet) doors shall be fitted with hydraulic closers. Door stops shall be fitted where required. Door frames shall generally be set 200mm off a wall junction to enable the door to open fully through 90˚.

All external doors shall be shaded by either the roof canopy of minimum 350mm or a separate precast concrete canopy over the top and the upper sides of a door.

The Bidder shall prepare a schedule of all doors and all door furniture for each building.

13.3.16 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 shall be approved quality and size from Mirpur ceramics or similar approved. Facing bricks shall be tied back to the main wall of control room building/SPR. External walls shall be 230mm thick brickwork, rendered internally and clad externally with facing bricks or rendered as required by the architectural plan.

Bricks shall be compacted down onto a full bed of mortar. Vertical joints shall be completely filled with mortar. Joints shall be raked out about 10mm deep where walls are to be rendered.

Brick walls shall be constructed so that tops of all meeting walls are about the same level. Only 18 courses per day shall be laid. New work shall be protected from sunlight and drying winds for 4 days.

Lime and cement for all brickwork shall be stored in a dry building with a raised dry floor.

Reinforcement by mild steel rods shall be provided where required by the design. Additionally openings over 500mm. wide shall be reinforced for 2 courses above and below the opening, minimum two 8mm bars per course extending 300mm beyond the opening both sides where possible.

All exposed brickwork shall be rendered and painted where not faced with facing bricks.

13.3.17 Expansion Joints, Joint Fillers and Sealants

Not used.

13.3.18 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 bitumastic paint. Walls and covers shall protrude at least 70mm above site finish level and the top of the wall shall be flat with no rebate. Floors shall be sloped at 1: 150 minimum slope to brick soakaways placed at the side of trench; the volume of each soakaway shall be 2.5m^3 per 150m^2 of trench.

Covers shall be of reinforced concrete Class A. Each cover weigh less than 55 kg. The minimum depth shall be 70mm, with down stand ribs along each side providing a minimum overall depth of 100mm. The ends of the cover shall overhang the wall by 15mm and in the centre of each end there shall be a hand hole of minimum size 100mm by 20mm high. This hole shall allow air to ventilate the trench so that heat built up in the trench shall be reduced. No gaps larger than 5mm shall be left between adjacent covers so that the cables are always shaded. Cover slabs shall sit squarely and uniformly on the trench walls without the need for bedding or shims. Because portable fire extinguishers will be rolled over and along trenches, each cover shall be capable of resisting a 250kg point load at mid span. The Bidder shall provide ramps up to the edge of covers in several locations, as agreed on site, to enable the wheeled extinguisher to mount the covers. Longitudinal edges may be inclined at 10˚ to the vertical, thus creating a larger gap at the bottom of

adjacent slabs, again to reduce heat build-up. The upper surface of covers shall have a stiff broom non slip concrete finish. All sharp edges shall be stoned smooth. Outer edges shall be chamfered.

Longitudinal fire separation walls and transverse fire separation walls as required by the cable section, may be of brick or reinforced concrete.

13.3.19 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 bitumastic paint. Cable trays may be supported by Unistrut P3300 inserts, or similar approved, or drilled anchor bolts.

The building layout shall minimise trench lengths. Where power cables pass through a building to reach the far side, this shall generally be in a tunnel section. The Bidder shall be responsible for providing all trenches and ducts in a building, including ducts for outgoing power cables up to the site boundary and including any pulling pits required.

Trench covers shall be sheets of composite board, PERMALI YA 729 or similar approved, consisting of wood fibres impregnated and compacted in synthetic resin, or a computer flooring composite board. The weight of each cover shall be restricted to about 30 kg. The upper surface shall be skid resistant. Deflection shall be limited to 1/250 of span under a load of 3kN/m^2. Only one thickness of board shall be used to standardize the edge support detail. The recess to receive the cover shall be protected by steel or brass on the vertical edge and bedding surface. Covers shall fit snugly around all cables. Where cables enter the building, all ducts/trenches shall be sealed. Fire/oil barriers shall be required to separate hazardous equipment. The ends of all ducts entering trenches shall be bell-mouthed.

Any beams used to support large span covers shall be removable. All metal work shall be painted as specified in the paint section.

All covers shall bed down evenly. Full detailed fabrication drawings shall be provided for all covers.

13.3.20 Rainwater Pipes

Down pipes shall be 100mm minimum diameter placed on the outside of walls but enclosed in a brick buttress of facing bricks. 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.

13.3.21 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.

13.3.22 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 bitumastic paint. The effective volume of the bund below the stone shall equal 125% of the total volume of oil in the transformer and its radiators.

Rainwater will tend to collect in the bund. To evacuate rainwater a fixed submersible pump controlled by sensors and switches (Aqua Sentry or equal) shall be provided at each bund with power supplies and drainage manhole conveniently located. The bund water control system shall differentiate between water and oil to ensure that the pump will not be activated while oil is present in the bund.

The transformer base and the bund shall be founded a minimum 1.0 metres below Finished Ground Level (FGL).

The skid walls shall be at least 600mm wide. RCC piles shall be provided below each jacking point to lift the transformer. Top level of jacking pad should be at the same level of skid wall. Steel plates shall be inserted at the top of jacking pad.

The entire concrete surface of the bund and the transformer base which is not buried shall receive two coats of bitumastic paint. Skids shall receive 3 coats of bitumastic paint before being cast in.

Adjacent road (perpendicular to rail) shall be extended upto 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.

13.3.23 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.

13.3.24 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,blastwalls and guard posts shall be painted with a fungicide, Snowcem primer and two coats of Snowcem. All exposed facing bricks and Snowcern painted surfaces shall be treated with one coat of clear silicone (5%) water proofing solution.

All exposed parts of foundations, the outer faces of cable trenches and cable tunnels shall be painted with three coats of bitumastic paint.

All ungalvanized metalwork shall receive two coats of red oxide paint at least 4 days before installation and shall receive two finishing coats of paint after installation, each coat being of different colour. Surface preparation before painting shall be SA 2.5 or an agreed rust convertor acid shall be used. All galvanized steel, boundary wall wire supports, cranebeams, baseplates and holding down bolts and concrete plinths shall receive two coats of bitumastic paint. Galvanized steel shall not be painted until the surface has weathered.

Internal walls when fully dry shall have the surface rubbed down with sandpaper and be painted with a sealer and 2 finishing coats of plastic emulsion paint before equipment is installed. A further finishing coat shall be applied after completion of installation.

One day shall be allowed for drying of each coat before the next coat is applied.

The interior of all septic tanks and manholes carrying foul sewage shall receive two coats of bitumastic paint.

13.3.25 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.

13.3.26 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 0.13% of gross cross sectional area respectively.

Minimum cover to rebars shall be 60mm where concrete is in contact with backfilled soil against a shuttered face, 75mm where concrete is cast against soil, and 38mm for all above ground concrete. In detailing bars which traverse a member, a reduction of 5mm shall be made for a bent bar and 10mm for a straight bar to ensure adequate cover. Exposed ends of sunshades and roof projection shall have 70mm minimum cover.

All concrete design shall ensure easy access for vibrators of 50mm. minimum diameter. Because of the slowness of concreting using local methods of transport, congested reinforcement details and shapes which are difficult to concrete should not be used. The location of all cold joints shall be agreed in writing with the Engineer and all joint surfaces shall be scabbled. All joints shall be horizontal or formed against vertical stop ends. Shear key shall be provided in joints. All cold joints shall be indicated on drawings. Roof slabs shall generally be cast in one continuous operation. Where curing compounds are used to protect exposed surfaces from solar radiation and improve moisture retention, they shall be subject to the approval of the Employer. This is a **Hold Point**.

13.3.27 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.

13.3.28 External Render

All brickwork which is not faced with facing bricks shall be rendered. Concrete columns and walls shall be rendered and painted in accordance with BS 5262 with a 3mm spatterdash coat a 12mm undercoat followed by a 9mm finishing coat. Surface preparation shall be as described in BS 5262. Joints shall be provided in all render where brickwork panels abut concrete columns and grade beams, as required by BS 5262.

A mix type II or III shall generally be used. The finishing coat shall be weaker than the undercoat.

The tops of all foundation blocks and all protruding concrete foundations shall also be rendered where required by the Engineer.

PVA Bonding agents shall not be used because of the risk of early drying in the tropics. All concrete surfaces to be rendered shall have the entire surface scabbled and brushed with a stiff brush to remove all loose material. The surface of the undercoat shall be roughened to ensure bonding of the finishing coat.

All render once completed shall be kept continuously damp for 10 days, after which if shall be treated with a fungicide. Any existing backgrounds shall be treated with a fungicide and all growth cleaned after 5 days of contact with the fungicide.

13.3.29 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 11 of this Contract for the high voltage switchgear.

13.3.30 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.

13.3.31 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 (38mm dia. for vertical railing & 50mm dia for horizontal railing).

All roofs which are not accessible by stairs shall be provided with a galvanised steel fixed ladder.

13.4 CONCRETE WORKMANSHIP

13.4.1 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.

13.4.2 Aggregates

Coarse aggregate shall be capable of passing through a 20mm sieve and be retained on a 5mm sieve. Fine aggregate shall be not larger than 5mm and not smaller than 0.06mm and shall be sharp in texture.

All aggregates shall be free of harmful quantities of organic impurities, clay, silt, salt or unsound particles. The amount of clay, silt and fine dust present in aggregate, whether as coatings or separate particles, may not be more than:

15% by weight in crushed sand 3% by weight in natural or crushed gravel sand 1% by weight in coarse aggregate.

If the Engineer considers that any aggregate which the Bidder proposes to use contains an excess of fine particles or any harmful substances, the Bidder shall either replace the aggregate or, at his option and entirely at his expense, institute a series of approved tests at an approved laboratory to determine the nature and extent of the fine particles and harmful substances. Following receipt by the Engineer of the results of the analysis and tests, he will advise the Bidder in writing whether the proposed aggregate may or may not be used. The Engineer's decision in this respect shall be final.

Tests to determine the extent of impurities or fine particles shall include (but shall not be restricted to) the relevant tests specified in BS 882:1992, ASTM. C40-79 (Colormetric test) and ASTM. C33-82.

13.4.3 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.

13.4.4 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.

13.4.5 Cement

Ordinary Portland Cement shall comply with BS 12A. The Bidder may obtain cement, bagged or in bulk, from any approved source in Bangladesh but shall always submit sufficient samples from each delivery, as required by the Engineer, to ensure that all cement complies with the minimum requirements of BS 12A. All cement shall be stored in a weather tight shed at least 300mm off the floor to prevent the moisture. Regular checks shall be made on the weight of cement in each bag.

13.4.6 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.

13.4.7 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.

13.4.8 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.

13.4.9 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.

13.4.10 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.

13.4.11 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.

13.4.12 Formwork

Formwork shall conform to the shape, lines and dimensions of the concrete as called for on the Plans and shall be sufficiently strong to carry the dead weight of the concrete without undue deflection or bulging, and sufficiently tight to prevent leakage of mortar. It shall be properly braced and tied together so as to maintain position and shape. Members used in forms at exposed surfaces shall be dressed to uniform thickness and shall be free from loose knots or other defects. Joints in forms shall be horizontal or vertical. At all unexposed surfaces and rough work, undressed timber may be used. Timber reused in shutters shall have nails withdrawn and surfaces to be in contact with concrete thoroughly cleaned before being reused. Formwork shall not be disturbed until a minimum of 48 hours has passed from time of placement and

concrete has hardened sufficiently to support any construction loads that may be imposed. When stripping forms, metal wedges or tools shall not be used to pry panels loose. If wedging is necessary, it shall be done with wood wedges lightly tapped to break adhesion. All columns and beams will have exposed edges chamfered 20 mm x 20mm. Formwork stripping time should be as per standard code and practice.

13.4.13 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.

13.4.14 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.

13.4.15 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.

13.4.16 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.

13.5 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.

13.6 Land development work:

13.6.1 Land development work shall be carried out by dredged filling material or by carried earth/filling sand using the following methods or any other suitable method:

(a) Land development by dredge filling material:

Land development by dredge filling materials means dredging by cutter suction dredger for collection and direct pumping of dredged fill materials by 18" dia. or more cutter suction dredgers from the pre-selected river bed through pipe line to the proposed fill site in wet and liquefied condition. The dredged material will be placed at site directly and excess water will be removed out of the site. Spreading and compaction of fill material will be carried out in layers. The layer thickness shall be determined on the quality of dredged fill material. Each layer should be compacted to a minimum of 95% optimum density as defined by the Proctor Test.

(b) Land development by carried earth/filling sand:

The responsibility of selecting proper location of collection of fill materials (such as earth/viti sand) will rest on the contractor, subject to the approval of the employer. The contractor shall obtain prior necessary permission from the concerned owner/authority paying royalties, all taxes, duties etc. as per prevailing Govt. / semi Govt. / Autonomous organization rule with the intimation to employer for collecting the required fill material. In this case mini suction dredger can be used to collect fill material from nearby river. The crops compensation resulting from the damage of crops during pipe line installation and any other activities shall be paid by the contractor and the cost deem to be included in the price. All fill shall be compacted in layers not exceeding 150mm deep to a minimum of 95% optimum density as defined by the Proctor Test.

13.6.2 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.

13.6.3 Before land filling, The Contractor has to construct necessary dyke/embankment for protection the developed land.

13.6.4 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.

13.6.5 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.

13.6.6 The Contractor is responsible to obtain the permission/approval from the competent authority for the works as mentioned in clause no. 4 & 5 above.

13.6.7 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.

13.6.8 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.

13.6.9 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.

13.6.10 The Contractor will arrange the testing of the samples of the fill materials & compaction tests of developed areas by Laboratory approved by employer. The cost of any or all such tests shall be borne by the Contractor.

13.6.11 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.

13.6.12 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.

13.6.13 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.

13.7 Fire Extinguisher:

13.7.1 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.

13.7.2 Outdoor Switchyard/Cable Room:

These areas shall be protected by portable dry type ABC powder fire extinguisher system. The system shall consist of all equipment required for directing the dry ABC powder discharge at a fire including, but not limited to, a wheel carriage(only for 15kg capacity) loaded with potable cylinders and necessary piping and a flexible hose along with a jet nozzle & pressure gauge. The extinguisher material shall be non-explosive, non-hazardous, non-corrosive, non toxic. The effective reach of jet release shall be sufficient to fight small fires that could develop in an outdoor switchyard, cable room & store room area. Fire extinguishers shall be placed at strategic locations as per instruction of project engineer. In addition sand buckets also shall be provided with a metal frame for hanging buckets and shall be placed at locations directed by project engineer. The quantity of extinguisher at each new substation given in Table-1.

Table-1: The quantity of fire extinguisher shall be provided at each new substation as follows:

Sl No	Description	Quantity

1	CO_2 Type: 3kg 5kg	 5Nos. 5 Nos.
2	ABC dry powder type: 5kg 8kg 15kg(including wheel carriage)	 6 Nos. 4 Nos. 3 Nos.
3	Sand bucket with metal frame	One(1)set with 5 buckets

ANNEXURE-13.1

DETERMINATION OF DEPTH OF FIXITY, LATERAL DEFLECTIONAND MAXIMUM MOMENT OF LATERALLY LOADED PILES

13-1. DETERMINATION OF LATERAL DEFLECTION AT THE PILEHEAD AND DEPTH OF FIXITY

13.1.1 The long flexible pile, fully or partially embedded, is treated as a cantilever fixed at some depth below the ground level (see Fig. 2).

13-1.2 Determine the depth of fixity and hence the equivalent length ofthe cantilever using the plots given in Fig. 2.

Where $$T = \left(\frac{EI}{K_1}\right)^{\left(\frac{1}{5}\right)}$$

(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.

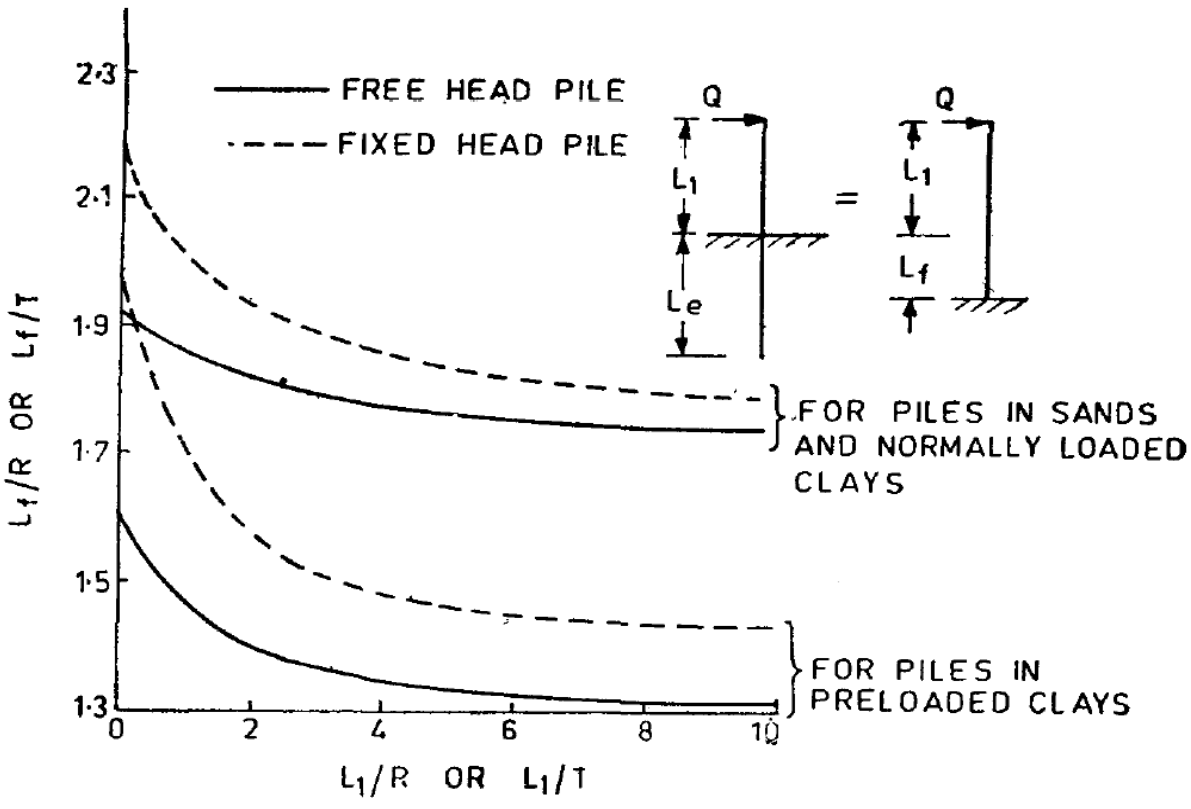


FIG. 2 DETERMINATION OF DEPTH FIXITY

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.

13.1.3 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

13.2. DETERMINATION OF MAXIMUM MOMENT IN THE PILE

13.2.1 The fixed end moment (M_F) of the equivalent cantilever is higher than the actual maximum moment (M) of the pile. The actual maximum moment is obtained by multiplying the fixed end moment of the equivalent cantilever by a reduction factor, m given in Fig. 3. The fixed end moment of the equivalent cantilever is given by:

$M_f = Q(L_1 + L_f)$ .....for free head pile

$= \frac{Q(L_1 + L_f)}{2}$ .....for fixed head pile

The actual maximum moment (M) = m (M_f)

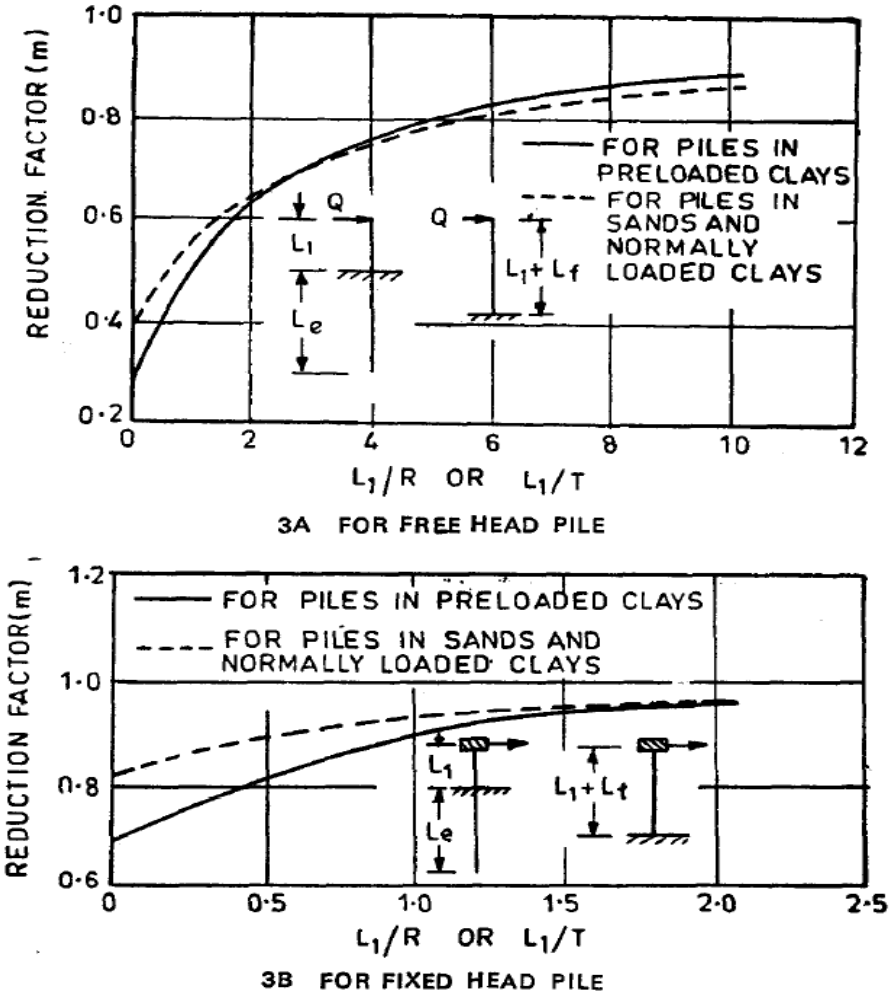


FIG.,3 DETERMINATION OF REDUCTION FACTORS FOR COMPUTATION OF MAXIMUM MOMENT IN PILE

13.2.2 Reinforcement of upper section of pile should be provided upto 1.25x L_f depth

14. Supporting Structures for Outdoor Equipment

SUPPORTING STRUCTURES FOR OUTDOOR EQUIPMENT

14.1 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.

14.2 STRUCTURE ARRANGEMENT

The arrangement of the high level structures supporting conductors and/or busbars shall be either lattice structures primarily composed of angle sections, or low visual impact A-frame type structures primarily composed of welded hollow or composite sections. Angle, hollow or composite sections shall be either steel or Aluminium as specified. For lattice structures a fully triangulated system of bracings shall preferably be adopted. For A-frame structures the primary connections between major components shall be bolted, for ease of transportation and erection.

Low level support structures shall be either lattice structures primarily composed of angle sections or 'moment' type structures primarily composed of welded hollow or composite sections.

The design and arrangement of supporting structures shall be subject to approval by the Engineer.

The type of arrangement of high level structures and acceptable materials for both high and low level structures shall be as specified in the Schedule of Technical Requirements.

14.3 DESIGN

14.3.1 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.

14.3.2 Assumed Loading Combinations

The supporting structures shall be designed to resist the ultimate applied loading, determined in accordance with the following load combinations:

Load Combination 1 - Design Wind, Coincident Temperature, (Ice)

(a) The wind pressure specified in the Schedule of Technical Requirements Appendix 11 of this Section, applied to the projected area of all conductors and electrical equipment;

(b) The wind pressure specified in the Schedule of Technical Requirements applied to the projected area of all members of the windward face of structure;

(c) Where appropriate the conductor and/or earthwire tensions or busbar forces, including due allowance for both horizontal and vertical deviations /inclinations;

(d) Self weight of the equipment and structure;

(e) When stated in the Schedule of Technical Requirements the effects of the specified radial ice thickness shall be taken into account in the determination of the wind area of the conductor, earthwire, busbar, electrical equipment and the supporting structure, the conductor and earthwire tensions and the self weight of the equipment and the structure.

The wind directions considered shall include transverse, longitudinal and if appropriate 45˚ to the major axis of the structure.

Load Combination 2 - Still Air, Short Circuit, Minimum Temperature or Maximum Operating Temperature

(a) Conductor and/or earthwire tensions or busbar forces including the dynamic affects calculated in accordance with IEC 865-1.

(b) Self weight of the equipment and structure;

Unless agreed to the contrary, the "resultant spring constant" (s) of both supports of one span for strained conductors shall be taken as 10^7 N/m for steel structures.

Load Combination 3 - Still Air, Seismic, Coincident Temperature (Ice)

(a) Conductor and/or earthwire tensions or busbar forces;

(b) Seismic forces;

(c) Self weight of the equipment and structure;

(d) When stated in the Schedule of Requirements the effects of the specified radial ice thickness.

Seismic forces shall be applied as a static horizontal force transversely and alternatively longitudinally to the major axis of the structure, and shall be equal in value to the seismic coefficient stated in the Schedule of Technical Particulars multiplied by the self weight of the conductor, earthwire, busbar, electrical equipment and structure, and applied at the centre of gravity of the equipment and structure as appropriate.

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.

14.3.3 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.

14.3.4 Partial Load Factors

The partial load factors to be applied to the loading combinations determined in accordance with Clause 14.3.2 shall be as specified in the Schedule of Technical Requirements.

14.3.5 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:

$$F_w = q_{ref} \left[\frac{H}{10}\right] \quad 15. \quad 2^{\alpha} \quad C_{shp} W_A$$

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 x 105< Re < 8.2 x 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.

14.3.6 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.

14.3.7 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.

14.3.8 Structural Design

The allowable ultimate unit stresses used in the determination of the nominal member strength of supporting structures shall be based on the following:

Lattice steel structures	ANSI/ASCE 10-90
Steel A frame or moment structures	BS 5950
Aluminium structures	BS 8118: Part I

Partial factors to be applied to member nominal strength determined in accordance with the above stated codes shall be as specified in the Schedule of Technical Requirements. For ANSI/ASCE 10-90 the appropriate reference stress levels shall be based on the values specified in BS 5950.

The maximum allowable slenderness ratios shall not exceed the following:

	Steel /Aluminium
For column or support leg members, beam chords	120
For other load bearing compression members	200
For secondary (redundant bracings)	250
For tension only members	350

Members shall be of such shape, size and length to preclude damage or failure from vibration or stress reversal, including the detailing of connections.

Minimum member thickness and diameter of bolts shall be as specified in the Schedule of Technical Requirements

Holding down bolts shall be used to connect the structures to their foundations. The design of holding down bolts shall make adequate provision for combined axial and shear forces.

The nuts of all bolts attaching conductors, busbars or earthwire tension sets etc, shall be locked with a locknut. No screwed threads shall form part of a shearing plane between members, and bolts shall not project more than 10mm beyond the nut.

14.3.9 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.

14.3.10 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.

14.4 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.

14.5 WORKMANSHIP

The Bidder shall submit panel assembly (fabrication) drawings which shall show all materials in place, complete with all fabrication and connection details. A complete tabulation listing all pieces, bolts, nuts, washers etc shall also be shown on the drawings. The Bidder shall make changes to the fabrication details which the Engineer determines necessary to make the finished structure conform to the requirements and intent of the specification.

The Bidder shall submit a detailed Method Statement of his proposed fabrication procedures including quality control procedures to ensure satisfactory assembly and erection, interchangeability of similar members, accuracy of dimensions, position and alignment of holes.

All welding shall be carried in accordance with BS 5135 for steel structures and BS 8118 Part 2 for aluminium structures. All members shall be stamped on before galvanising or other protective coatings, using characters 10mm high and shall be clearly legible after galvanising.

14.6 PROTECTIVE TREATMENT

Unless otherwise specified after fabrication, all structural steelwork, including bolts, nuts and washers shall be hot dipped galvanised to meet the requirements of BS 729. Bolt threads shall be cleaned of surplus spelter by spinning or brushing. Dies shall not be used for cleaning threads other than on nuts. Nuts shall be galvanised and tapped 0.4mm oversize and threads shall be oiled.

Excessively thick or brittle coatings due to high levels of silicon or phosphorous in steel, which may result in an increased risk of coating damage and/or other features that make the final product non-fit-for purpose shall be cause for rejection. Protective treatment for aluminiurn shall be in accordance with the requirements of BS 8118.

Galvanising thickness and aluminium protection procedure shall be as specified in the Schedule of Technical Requirements

14.7 QUALITY CONTROL

14.7.1 General

Routine tests on raw materials and fabricated individual members shall be undertaken in accordance with BS EN 10025, BS EN 10210 and BS 8118 as appropriate.

All steel ex-mills or received from merchant's stock shall be marked to identify the cast or casts from which it was rolled in accordance with Section 9 of BS EN 10025 and Section 10 of BS 102 10, and shall be covered by the appropriate (mill) certificate. The optional impact test BS EN 10210 option 1.6 for quality JO is required.

The material grades or alloy categories of individual pieces of steel/aluminium shall be capable of positive identification at all stages of the fabrication process.

Bolts and nuts shall be covered by the appropriate test certificate to prove compliance with BS 4190.

14.7.2 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.

14.7.3 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.

14.7.4 Galvanising

Tests on galvanised members and components shall be carried out at the works to ensure compliance with the requirements of BS 729.

14.7.5 Tolerances

The fabrication tolerances after galvanising for steel members, which are not to be considered cumulative shall be as follows:

(a) On linear dimensions of nominal sections as per BS 4, BS 4848, BS EN 10024, BS EN 10034 & BS EN 10056-2.

(b) On overall length of member ± lmm

(c) On centres of holes ± lmm

(d) On groups of holes ± 2mm

(e) On back-gauges ± lmm

(f) On corresponding holes in opposite faces of a member ± lmm

(g) On specified hole diameter on the punch side (in the black), ± 0.3%

or when drilled -0mm

(h) Taper on the punched holes as measured between the specified hole diameter on the punch side and the hole diameter on the die's side (in the black) ± l.0mm

(i) On specified bends, open and closed flanges ± 0.02%

The pennitted tolerances for straightness after galvanising shall not exceed an offset of 1: 1000.

Tolerances for aluminium structures shall be in accordance with BS 8118: **Part 2.**

14.8 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 14

Line	Description			
1.	Structure Arrangement [clause 14.2]			
	High Level		Lattice or A-Frame	
	Low Level		Lattice or Moment	
	Primary Material		Steel	
2.	**Load Combination 1** [clause 14.3.2]		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 14.3.3]		**Phase**	**Earthwire**
	Conductor Designation		Finch	7 x 4.0
	Type		ACSR	GSW
	Number of sub-conductors		2	-
	(All of the above three shall be finalized during execution)			
	Maximum working tension per Phase (132kV)	kN	14	4.5
	Maximum working tension per Phase (230kV)	kN	20	5.0
	Maximum working tension per Phase (400kV)	kN	40	5.0
	Wind pressure	kN/m2	1.40	1.76
	Radial ice thickness	mm	0	0
	Maximum downlead span	m	75	75
	Maximum angle of entry horizontal	deg.	45	45
	Vertical	deg.	0-30	0-30

Line	Description			
	Low duty tension set wind area	m2	0.7	-
	Mass	kgs	100	-
4.	**Partial Load Factors** [clause 14.3.4]		**Steel**	**Aluminium**
	Load Combination 1		1.35	N/A
	2		1.0	N/A
	3		1.0	N/A
	4		1.5	1.5

Line	Description		
5.	**Safety and Access Requirements** [clause 14.3.7]	**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 14.3.8]		
	Steel	0.85	
	Aluminium	-	
	Foundations	0.76	
7.	**Minimum Member Thickness** [clause 14.3.8]	**Steel**	**Aluminium**
	Main member mm	6.0	
	Other bracing members mm	5.0	
	Secondary (redundant) members mm	5.0	N/A
	Plates mm mm	6.0	
	Bolt diameters mm	16.0	
	Minimum thickness specified shall apply to both hot rolled and hollow sections		
	Minimum angle size mm	45X45X5	
8.	**Protective Treatment** [clause 14.6]		
	Galvanising thickness µm	85	N/A
	Protection procedure	BS 729	No

15. National Load Dispatch Centre (NLDC)

For the SCADA facilities required for any Power Station or Substation at the National Load Dispatch Centre (NLDC) the following provisions shall be made:

15.1 General scope:

15.1.1 The power system of Bangladesh is operated from NLDC SCADA/EMS system which is operated from Main & Backup Master Station situated at two different locations. The system is being in operation after successful installation & commissioning by M/S Areva T&D Ltd. (Now M/S GE T&D Ltd.) since 2010.

15.1.2 The SCADA/EMS system of NLDC is based on “e-terra platform” developed by AREVA T & D (Now owned by GE).

15.1.3 To provide the SCADA/EMS, tele-control & tele-metering facilities required for new Power Station or Substation to NLDC, the complete design, supply, delivery, installation, testing & commissioning of new hardware and software, extension of the existing equipment, necessary adjustment, adaptation, modification, integration and configuration of new and existing equipment in NLDC, shall be provided for integration of new power station or substation along with required modifications in existing power station or substations, are in the scope of the work of the Contractor.

15.1.4 All required electrical quantities digital (Status, Control, Alarms etc.) and analog (Measured Data for any bay i.e. MW, MVAR, kV, Amp) data shall be transmitted to NLDC through the RTU or the Industrial Gateway of the station automation system (SAS for Substations, DCS/PCS for Power Stations) using IEC 60870-5-104 protocol, integrated with the NLDC after the successful testing and commissioning.

15.1.5 Necessary CT, VT arrangements shall be facilitated for analog measurements. All the analog values should be floating type and frequency dead band should be zero.

15.1.6 Digital Status of the equipment’s, Events & Alarms for the network connected to the grid are to be monitored & archived from NLDC. Therefore, potential free auxiliary contacts are required whereas data should be time stamped at field.

15.1.7 All Circuit Breakers, motorized disconnecting switches, tap changer, etc. are required to be monitored and controlled from NLDC though the RTU/Industrial Gateway.

Therefore, necessary arrangements should be made to access those devices from NLDC along with local remote control switch.

15.1.8 Necessary Cabling and interfacing between the RTU/Industrial Gateway and the communication equipment are to be done by the contractor. The scope also includes the supply of any hardware (if any) required for the completion of NLDC Integration. Other works/activities which are not explicitly mentioned but are required for the NLDC integration shall be included in the scope of works.

15.1.9 The Integration of proposed RTU/Industrial Gateway for data communication with existing NLDC SCADA/EMS system at NLDC, Bangladesh is the scope of Contractor. Necessary modification in the hardware and software along with database and display at NLDC master station and backup station to accommodate all the new system extended with this contract are also in the scope of work.

15.2 RTU/Industrial Gateway for New Station

15.2.1 The RTU/Industrial Gateway for SCADA integration with NLDC shall be 02 (two) in number and shall be configured as Master and Hot Standby or One Gateway will report to Main NLDC and other Gateway will report to BACKUP NLDC simultaneously. Both the RTU/Industrial Gateway shall report to both NLDC Master Station (with two communication terminal server simultaneously through VLAN Network) & Backup Station (through Routed Network) at the same time.

15.2.2 In case of local station using SAS, the Industrial Gateway shall be physically separated device from SAS servers and provision of access shall be made from both local and remote location. SAS Servers and Gateway shall be configured to get the data directly from the BCU through switches for independent operation. Data Flow between SAS and Gateway shall not be occurred.

15.2.3 In case of existing RTU/Gateway data shall be interfaced to new RTU/Industrial Gateway or existing one as per NLDC requirements. Redundant power supply & control cards along with sufficient spares shall be provided for uninterrupted operation.

15.2.4 The RTU/Industrial Gateway shall be compatible with IEC 61850 for connection interface at station level and IEC 60870-5-104 protocol for connection interface with NLDC for SCADA integration.

15.2.5 The RTU/Industrial Gateway shall be configured according to provided signal list from

NLDC as per approved SLD of the new station, communication parameter, IP address and station address.

15.2.6 Connectivity from the RTU/Industrial Gateway to the Communication Equipment at respective Power Station or Substation along with Communication Equipment, Switch and Front End Server at both main & backup master station shall be provided.

15.2.7 For time synchronization properly configured GPS is required.

15.2.8 In order to ensure cyber security properly configured hardware firewall shall be used between the RTU/Industrial Gateway to communication equipment (SDH and PDH equipment).

15.2.9 The RTU/Industrial Gateway shall have adequate capacity to cater to the future extension of substation.

15.2.10 Maintenance tools for configuration and O&M purpose (necessary hardware, software, spare parts & accessories) shall be supplied.

15.3 RTU extension at Remote (Far End) Substation

15.3.1 Integration of new bays at nearest grid substation (remote end) for the new station along with modification in existing system is under the scope of the contractor to ensure updated NLDC SCADA/EMS system for smooth & reliable power system operation.

15.3.2 In case of nearest Substation (remote end) using RTU, contractor have to supply required no's of IED, Digital Input (DI) & Digital Output (DO) card in an extended sub-rack to integrate new bay with existing RTU. RTU wiring, database creation and download to respective RTU are also will be the scope of work. Connectivity between the existing RTU and the new RTU are also in the scope of work.

15.3.3 In case of nearest Substation (remote end) using SAS, required no's of BCU for Bay Extension with BCU panel shall be provided. All required configuration of BCU, SAS and Gateway are in the scope of work.

15.4 Integration Works

15.4.1 For the proper Integration of New Station with the NLDC, at least the following works shall be done at NLDC Main & Backup Master Station using the existing NLDC SCADA/EMS System (based on the software of e-terra Platform by GE) for all the New Station and Far-End Stations.

15.4.2 Pre-Database Works:

- Confirmation of Approved Hardware Architecture with sufficient redundancy and proper Cyber Security.
- Preparation of Signal List as per approved SLD for all the New Station and Far-End Stations.
- Confirmation of RTU/Gateway Configuration Parameter and Information.
- Collection of Network, Generation Parameter and related data for SCADA/EMS Modelling.

15.4.3 Database Modelling, Updatation and On lining Works:

1. SCADA Database Modeling as per field information and data
2. RTU/Gateway Database Modeling
3. RTUTOP file Creation and Import
4. SCADA Verification
5. Network Parameterization and Network Database Modeling
6. Network Verification
7. Network-SCADA Mapping
8. Network-Generation Mapping
9. DTS Database Modeling
10. DTS-Network Verification
11. DTS Database Validation
12. Alarm Database Modeling & Validation
13. Data communication path creation for both Master station and Standby station
14. Configuration & Updatation of communication network manager platform
15. Database Updatation and On lining both for NLDC Main & Backup Master Station
    a. On-lining of all databases in SCADA/EMS & Communication Front End Servers
    b. IP/VLAN configuration on Polling Servers (Communication Front End) and Switches as well as Network Management Servers.
    c. Compilation and On-lining of all the related displays on WEB servers.

15.4.4 Post Online Works:

1. RTU/Gateway Configuration and Updatation. Configuring the Gateway according to the requirements. (Required Signals with IEC address, IEC Protocol, data communication parameters, RTU/Gateway IP, NLDC Master/Backup Station IP etc.)

2. Field data confirmation by local test at site

a. Verification of all Analog Measurements and checking limit, dead band, polling time
b. Verification of Digital Signal Status (open/close, in between, invalid)
c. Verification of Alarms, Events etc.
d. Verification of Control and Interlock

15.4.5 Fault Rectification and Tuning of Data:

- End-To-End Test shall be carried out in Master station and in Standby station in NLDC
  a. Verification of all analog measurements
  b. Verification of all digital signals and controls
  c. Verification of displays including single line, popup, alarms etc.
  d. Verification of communication line for redundancy
  e. Verification of continuous and complete integration of the RTU/Gateway

- Tuning of Power system application for all available network and generation applications in SCADA/EMS server including AGC and DTS (Dispatcher Training Server)

15.4.6 The following activities are also in contractor's scope of work:

- Collection of required network and generation data for modeling of the network database
- All required works both in NLDC and at the site
  Adaptation work and configuration of the NLDC will mainly consist of:
- Modeling the new Substations/Power Stations and new bays of existing Substations.
- Configuration of communication network manager platform to display the single line diagrams, statuses, alarms, measurements of the new substations and new bays
- Creation/Modification and update of database at respective SCADA/EMS servers at master/backup station
- Creation of associate display and modification of existing displays wherever required
- Point to point test

15.5 Required Information for NLDC SCADA integration

15.5.1 Signal List

15.5.1.1 Busbar

Analog Input: kV, Hz.

Digital Input (Single Point):

1. Protection Class-3 Trip (Bus bar Trip),

2. Voltage Status.

15.5.1.2 Bus-Coupler

Status Digital (Single Point):

1. Remote/ Local Switch for Circuit Breaker.
2. Bay Fault.
3. Breaker Fault (Spring Charge, SF6 Low).
4. Protection Class-2 (Over current, Earth fault).

Status Digital (Double Point, Single Physical Address):

1. Circuit Breaker Open/Close.
2. Isolator Open/Close.
3. Earth Switch Open/Close.

Control Digital (Double point, Single Physical Address):

1. Circuit Breaker Open/ Close.
2. Motorized Isolator Open/ Close.

15.5.1.3 Line/Feeder

Analog Input: MW, MVAR, Amperes, kV.

Status Digital (Single Point):

1. Remote/ Local Switch for all Circuit Breaker.
2. Bay Fault (VT fail for Transmission Line).
3. Breaker Fault (Spring Charge, SF6 Low).
4. Protection Class-1 (Distance, Differential).
5. Protection Class-2 (Over current, Earth fault).
6. CB Auto Re-close.
7. CB Auto Reclosed Blocked.

Status Digital (Double Point, Single Physical Address):

1. Circuit Breaker Open/ Close.
2. Isolator Open/ Close.
3. Earth Switch Open/ Close.

Control Digital (Double point, Single Physical Address):

1. Circuit Breaker Open/ Close.
2. Motorized Isolator Open/ Close.

15.5.1.4 Transformer

Analog Input: MW, MVAR, Amperes, kV at both sides, Tap Position Indication (TPI).

Status Digital (Single Point):

1. Remote/ Local Switch for all Circuit Breakers.

2. Bay Fault (DC Fail for Transformer Panel).
3. Breaker Fault (Spring Charge, SF6 Low).
4. Protection Class-1 (Distance, Differential).
5. Protection Class-2 (Over current, Earth fault).
6. Transformer Alarm (Buchholz Alarm, Oil Level Low).
7. Transformer Trip (Buchholz Trip, PRD Trip)
8. Transformer Temperature Alarm (Oil Temp Alarm, Winding Temperature).
9. Transformer Temperature Trip (Oil Temp trip, Winding Temperature trip).
10. Tap Changer Alarm.
11. Tap changer trip.
12. Tap changer high limit.
13. Tap changer low limit.

Status Digital (Double Point, Single Physical Address):

1. Circuit Breaker Open/ Close.
2. Isolator Open/ Close.
3. Earth Switch Open/ Close.
4. Tap Changer SCADA/ Station Control.

Control Digital (Double point, Single Physical Address):

1. Circuit Breaker Open/ Close.
2. Motorized Isolator Open/ Close.
3. Tap Changer Raise/ Lower.

15.5.1.5 Substation Common Alarm

Status Digital (Single Point)

1. Control Disable Switch
2. RTU Fault Alarm
3. Station Communication Alarm
4. Main Substation LVAC Power Supply
5. Station DC Fault Alarm
6. Communication DC Fault Alarm
7. Check Synchronizing Over-ride

15.5.1.6 Filter & Reactor

Analog: MVAR

Status Digital (Double Bit, Single Physical Address)

1. Circuit Breaker Open/Close
2. Earth Switch Open/Close

15.5.1.7 Converter

Analog: Pole MW, Pole MVAR, Total MW, Total MVAR

Control Analog: Real Power Set Point

15.5.2 Network Parameters

Line length, Line Conductor type, Short Circuit data for Zero sequence (%R, %X, % of full charging Susceptance) etc.

15.6 Interfaces

15.6.1 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.

15.6.2 In case of Windows operating system based Gateway, at least the following shall be included: USB port, VGA port, HDD/flash memory and one spare, TFT monitor, mouse, key board, etc. Hard disc shall be at least 50 % free and CPU loading maximum of 30 % at any condition.

15.6.3 At least two additional control cards are required.

15.6.4 The Gateway shall be equipped with at least eight LAN ports and with redundant power supply

15.6.5 Complete cyber security shall be ensured at the site SCADA interface level.

15.6.6 At the existing substations, extensions of the existing gateway or RTU shall be provided and included in the contract price.

15.7 Detailed Description of the Scope of Supply for SCADA, Control & Monitoring System

15.7.1 Overall Scope of Work and Supply

The SCADA system will be based on:

- The communication with the NLDC shall be via the supplied gateway for Control and Monitoring System of the substation.
- Industrial gateway shall be implemented at each involved substation for remote monitoring & control from the National Despatch Centre. It shall provide all the necessary control and monitoring facilities for 230 kV level, 132 kV level and auxiliaries.
- At existing substation, monitoring shall be provided through existing RTU. Contractor shall supply & install of necessary equipment such as sub rack, IED/relay, transducers, DI, DO card etc for integrating new bays through existing RTU.
- For New Substation, Contractor shall supply, install 2 (two) numbers of Industrial gateway and will be configured as master - hot standby mode or one gateway will report to main station & another will report to backup station. Gateway shall be capable report to both Main master station at Rampura (through VLAN network) & Standby Master Station at Biddyut Bhaban (through routed network) simultaneously. It will be configured according to the signal list, communication parameter, IP address, station address etc

provided by PGCB. The Gateway shall have adequate capacity (minimum 25% additional spare point with license) to meet to the future extensions of substation.

- In case of windows operating system based gateway there should be USB port, VGA port, HDD/flash memory with one spare parts, TFT monitor with mouse and key board etc. Hard disk should be 50% free and CPU loading maximum of 30% at normal condition. If gateway is firmware based then 02(two) nos. of control card is required. Gateways also have minimum 06 nos LAN port & redundant power supply. There should be GPS facilities for time synchronization. In addition, cyber security has to be ensured at field level with firewall. Supported Protocol shall be IEC 60870-5-104, 61850 & MOD Bus etc.
- All necessary adaptation work and configuration of the existing SCADA platform of the NLDC to integrate the Substations and the new bays shall be provided.
- For 132kV, 230kV& 400kV Level, all feeders shall be controlled via SCADA, whereas, for 33kV Level, Minimum of five (05) numbers of 33 kV feeders, excluding 33kV side of Power transformer, shall be controlled from the SCADA system at each substation. All necessary equipment, including required numbers of BCU and panels shall be provided under the scope of the project

15.7.2 General Principle and Description of SCMS

15.7.2.1 The substation control and monitoring system shall have distributed client/server architecture. It shall consist of:

- The BCU equipment, which will be installed at the bay level,
- The substation level equipment, to be installed in the control room,
- A redundant communication network between station level and bay level for data exchange to limit the number of cables and ensure extension of the system. The exchange of information between distributed single bay unit and central substation control level shall be performed through redundant fibre optic wires. The communication network shall be based on the following architecture:
- One optical double-ring LAN with protection and BCU,
- One UPT CAT 5 redundant LAN at substation level.

15.7.2.2 The station level equipment will be power supplied from the two independent AC sources:

- One from the AC station auxiliaries 230 V AC 50 Hz,
- The second one from a UPS,
- An automatic change over shall prevent supply interruption.

15.7.2.3 In the event of loss of supply or disconnection for any reason, the system shall reboot automatically (without loss of stored information) and will update statuses of all devices when the power supply recovers. The updating process shall not inhibit control functions.

15.7.2.4 The substation control level must support future expansion of substation control system, having a 25% of resources as minimum.

15.7.2.5 At bay level, all control functions, data acquisition interlocking functions shall be done in the bay

control devices within the bay level equipment. Each feeder shall be equipped with an individual bay control device.

15.7.2.6 For the data acquisition of substation auxiliaries, information (LV/MV switchgear, station battery, charger, UPS etc.,) a local RTU (or BCPU) shall be provided and installed in the control building. The bay control devices shall be connected to the station level via a redundant optical fibre communication link.

15.7.2.7 The bay level equipment shall comprise at least the following elements:

- Bay control unit (BCU). Bay computer shall be separate unit (not incorporated in the protection unit).
- Input / output modules for digital and analogue signals,
- Communication with protection equipment and analogue signals,
- Redundant optical fibre communication with substation level or ring bus communication,
- Backup mimic panel for maintenance control and measurements. One two position switch shall be provided on control panel:
- Local: Only local control is enabled, the interlocking function is on bay level only, no synchronization,
- Remote: Only remote control is enabled.
- In both cases, all the data must be transmitted to the higher level (NLDC),
- Communication port for operation / maintenance from a laptop computer.

15.7.2.8 Bay control units shall be supplied from 110 V DC.

15.7.2.9 In the event of loss of supply or disconnection for any reason, the system shall reboot automatically (without loss of stored information) and will update statuses of all devices when the power supply recovers. The updating process shall not inhibit control functions. There should not be any loss of data due to the loss of auxiliary supply.

15.7.2.10 It shall be taken into consideration that additional bay control units can be added to the system, without disturbance of the system, for future expansion. A provision of 20% in bay units' expansion is required, as well as a provision of 10% in I/O signals, within each bay.

15.7.2.11 Control and supervision of the system will be possible from different levels:

- NLDC,
- Substation control level from the operator workstation,
- Bay control level.

15.7.2.12 On all levels, a correct interlocking will be ensured which provides the highest safety for staff and equipment. On the substation control level, the interlocking is managed by the microprocessor-based system, on the bay level it is performed by hard wiring.

15.7.2.13 The substation control system shall follow the specifications of IEC family 61850, 60870-5-101/104, 60870-5-102 and 60870-5-103. It is an obligatory requirement that the same Manufacturer supplies equipment and software for both the substation control and supervision system and the protection system.

15.7.3 Scope of Work and Supply at new Substations

15.7.3.1 The substation control system refers to the station level and bay level controls. The station level control equipment shall include the following:

15.7.3.2 Station Level:

- Arrangement of the all bays
- 2 (two) independent station computers operating on a main and hot standby basis,
- 2 (two) operator workstations including 2 x 21" colour monitors (complete with appropriate desk and chair).
- The second operator workstation shall have the capability to be used as Employer's Representative workstation,
- Two (2) numbers of independent SCADA Gateways
- Black & white A 4 laser printer,
- Colour A 3 laser printer,
- Common bay control unit for monitoring auxiliary power supply and all other equipment on a substation level (telemetry, telecommunication, HVAC, fire protection, etc.),
- Satellite clock, which should run on SNTP protocols. The satellite clock will provide the reference time to the comprehensive Substation Control and Monitoring System and protection relays through IEC61850 substation LAN., The satellite clock system will be complete with GPS receiver, antenna and time synchronization ports.
- Interface for laptop computer for maintenance, information transfer and emergency HMI,
- Non-fail power supply system,
- Communication network equipment (substation local area network, field communication network, optical couplers, etc.),
- Optical connection for data exchange with the NLDC.
- Configuration of the new/existing gateway.

15.7.3.3 The station computers in the substation must be separate machines from the station HMI (operator workstation) and should be located in the control panels, and not on the control desk with the HMI.

15.7.3.4 Bay Level:

The control system of the bay level at substation shall be carried out with microprocessor based Bay Control Unit (BCU) control system. All BCUs shall be provided with IEC 61850 Edition 2 communication ports.

15.7.3.5 The connections between BCUs and the station level shall be based on redundant fibre optic links. These communication ports will be used for control, indication and alarm systems to the substation automation system and SCADA. The BCU shall be provided for all:

- 400kV, 230 kV and 132 kV transmission line bays,

- 400/230 kV, 400/132kV, 230/132 kV and 132/33 kV power transformers,
- 400kV, 230 kV and 132 kV busbars
- Seven (7) or three (3) numbers, respectively, of 33 kV feeders (BCU and panels) and
- Auxiliaries.

15.7.3.6 A bay control unit (BCU) shall provide the following:

- Control for each individual circuit / bay with a LCD mimic and user interface for control and monitoring of the circuit / bay,
- Interface for protection devices that cannot directly interface with the substation control system local area network,
- Interface for laptop computer for maintenance, information transfer and emergency HMI,
- Interlocking functions (soft and hard wired).

15.7.3.7 Station level control functions shall include the following:

- Control of all switching devices,
- Real-time indication of events and alarms,
- Display of analogue values and high / low limit checking,
- Display of historical values,
- Data archiving,
- Disturbance monitoring and analysis,
- Trend display,
- Protection and control relay setting information,
- Protection relay fault and disturbance records,
- Time synchronization,
- Interlocking function to prevent unsafe operator action (display message if operator attempts an inappropriate action),
- Self-check and diagnostic,
- Manual data setting by the operator, including:
- Hand dressed data entry,
- Control inhibit setting,
- Alarm inhibit setting,
- Maintenance tag setting,
- High / low limit setting.
- Remote access to substation control system from SCADA system using a TCP / IP link.

15.7.3.8 All peripheral devices that constitute the substation automation system should be supervised and monitored by Control through IEC 61850 or any other compatible protocol.

15.7.4 Scope of Work and Supply at existing Substation

15.7.4.1 The existing SCMS shall be extended to integrate the new feeders.

15.7.4.2 The BCU shall be provided, with IEC 61850 Edition 2 communication ports, for each feeder.

15.7.4.3 The connections between BCUs and the station level shall be based on redundant fibre optic links. These communication ports will be used for control, indication and alarm systems to the substation automation system and SCADA.

15.7.4.4 A bay control unit (BCU) shall provide the following:

- Control for each individual circuit / bay with a LCD mimic and user interface for control and monitoring of the circuit / bay,
- Interface for protection devices that cannot directly interface with the substation control system local area network,
- Interface for laptop computer for maintenance, information transfer and emergency HMI, Interlocking functions (soft and hard-wired).

15.7.4.5 All necessary optical/Ethernet switches shall be provided to connect the new BCUs to the station level of SMS.

15.7.4.6 All necessary adaptation work shall be provided.

15.7.4.7 The signal list will follow the same rules as for new substations.

15.7.5 Engineering Services

General

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

15.8 Design Services

15.8.1 The Contractor shall design in detail the general layout of the SCADA and substation control system, based on the preliminary design and modifications agreed. This general layout shall be submitted to the Employer.

15.8.2 It shall also include all detailed structural drawings, detailed descriptions and reports required to permit an exact understanding of the solution adopted.

15.8.3 Once the general layout is approved, the Contractor shall include the following as a minimum requirement:

- Design of all works required for the implementation and extension of the SCADA and substation control system,
- General layouts for the SCADA and substation control system,
- Engineering of SCADA and substation control system,
- All necessary calculations.
- These engineering services shall also include:
- Design reports,
- Complete drawings of all systems,
- Integration in existing SCADA system.

16. Lighting, Small Power and Ventilation

16.8 Scope

16.8.1 This section of the specification includes for the interior and exterior lighting, small power and ventilation systems.

16.8.2 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.

16.8.3 The lighting and small power equipment and installation shall comply with other sections of this Specification as appropriate.

16.8.4 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.

16.8.5 This section includes required the interior and exterior lighting for capacitor bank yard, and small power systems. The lighting and small power equipment and installation shall comply with other sections of this Specification as appropriate.

16.8.6 The requirements of this section of the works are subject to the Main Conditions and Specifications laid down in other sections of the Bid Document. All cable shall be FRLS type.

16.9 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
• BS 5970	Code of Practice for thermal insulation of pipework and equipment
• BS 848	Fans for general purposes
• BS 6540	Method of test for atmospheric dust spot efficiency and synthetic dust weight arrestance
• BS 2871	Specification for copper and copper alloys: tubes
• BS 1470	Specification for wrought aluminium and aluminium alloys for general engineering purposes, plate, sheet and strip Institution of Heating and Ventilation, Engineers Guide to Current Practice. American Society of Heating Refrigeration and Air Conditioning, Engineers Recommendations Heating and Ventilation Contractors Association of U.K., Specification DW / 121

16.10 Defects Liability Period

The Contractor shall be responsible for the efficient and good working of the installations comprising this section of the Specification for the agreed period as set out in the Specification document.

16.11 Approvals

The Contractor shall submit to the Engineer for approval copies of all his calculations forming the basis for the designs of the specified systems, which shall be shown on the working drawings, also to be submitted for approval.

Any approvals shall not, however, relieve the Contractor of his contractual responsibilities which include obtaining local authority approvals for electrical wiring installations.

16.12 Lighting Requirements

16.12.1 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.

16.12.2 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.

16.12.3 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.

16.12.4 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.

16.13 Schedule of Design Requirements

16.13.1 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.

16.13.2 Lighting apparatus shall be of top quality, designed to ensure satisfactory operation and service life under all variations of load, frequency and temperature. LED Lighting Fittings & Fixtures shall be used for road and security lighting, Switchyard floodlighting (not less than 100W) & Indoor lighting unless otherwise specified.

Key to Abbreviations:

L	Local switches
S1, S2 etc.	Socket outlets or fused spur circuits
P.B	Pushbutton for remote control
T.S	Time switch control
C	Ceiling mounted
W	Wall mounted
P	Pole or earth mast mounted
M	Recessed modular mounting
D	Suspended
F	Flush installation

S	Surface installation
A	Automatic on mains failure.
BH	Behind ceiling diffuser.

16.14 Coding Systems

The Contractor shall, when preparing drawings showing the respective designs, use a code to identify each lighting fitting and socket outlet.

The code shall comprise letters and figures so compiled that the following information can be readily identified:

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.

16.15 Distribution Boards

16.15.1 The distribution boards and all component parts shall be manufactured and tested in accordance with the latest standards and designed to suit the fault level of the transformers supplied. The Contractor shall demonstrate by calculation that this has been complied with.

16.15.2 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.

16.15.3 Each distribution board shall have a rustproof metal case of sheet steel with either a galvanised or enamelled finish. The colour of the enamel finish shall match the colour of other switchgear. The metal casing is to be provided with a number of knock-outs or other approved form of cable entries, corresponding to the circuit capacity of the distribution board, and a suitable screened brass earthing stud.

16.15.4 Busbars, including neutral bar, shall be of high conductivity copper supported to withstand all normal and fault condition stresses.

16.15.5 All busbars, neutral bars and primary conductors are to be PVC sleeved in respective phase and neutral colours.

16.15.6 Distribution boards for exterior use shall be galvanised and weatherproof.

16.15.7 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.

16.15.8 The metal surface adjacent to any live part and all spaces between phases shall be protected by barriers of fireproof insulation material.

16.15.9 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.

16.15.10 Fuse bases and bridges, where used, shall be of an approved non- hygroscopic insulation suitable for the receipt of HRC fuses.

16.15.11 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.

16.15.12 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.

16.15.13 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.

16.15.14 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.

16.15.15 Switch fuse units or isolators connected on the incoming side of a distribution board shall be mechanically attached to the board with solid copper electrical connections between the units. A suitable insulated barrier is to be supplied to prevent copper or carbon dust released under fault conditions passing from one unit to the other.

16.15.16 Distribution boards for use on the direct current system shall be double pole types equipped with adequately rated fuses.

16.15.17 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.

16.15.18 For each of the new 36 kV switchgear & capacitor bank installation a sub distribution board 400/230 V ACshall be installed.

16.16 Miniature Circuit Breakers

Miniature circuit breakers shall comply with the requirements of the main electrical part of this Specification.

16.17 Cables

16.17.1 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.

16.17.2 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.

16.17.3 The conductor is to comprise multi-strands of 0.25 mm wire. The number of strands are to be not less than 30 and in all cases of a number suitable for the protection rating of the respective circuits.

16.17.4 All cables used for lighting and small power shall have copper conductors.

16.17.5 The Contractor is to select conductor sizes for the respective final circuits to meet the

following conditions:

(a) That the minimum conductor size for lighting circuits is to be 1.5 mm^2 and for socket outlets 2.5 mm^2.

(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.

16.18 Cable Terminations

16.18.1 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.

16.18.2 Earth bond terminal attachments are to be provided.

16.18.3 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.

16.18.4 Only one cable is to be terminated in each gland.

16.19 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.

16.20 Conduit

16.20.1 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.

16.20.2 Steel conduits shall be manufactured in accordance with BS 4568, Part 1 or equivalent, heavy gauge screwed and welded Class B and shall be galvanised. Conduit fittings are to be manufactured of good quality galvanised malleable cast iron and of small circular pattern to BS4568, Part 2 or equivalent, with internally tapped spouts minimum length 21 mm. threaded to the correct length at intersections, tees, draw throughs and stop-ends.

16.20.3 Conduit fittings of PVC shall be of the plain bore pattern suitable for a push-on compression type joint-and shall be sealed with a hard setting vinyl cement to prevent ingress of vermin, water, dust, etc. Inspection bends, solid or normal bends, elbows or tees are not to be used except with the approval of the Engineer.

16.20.4 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.

16.20.5 Where the system of wiring is concealed, the 'loop-in' system of conduit shall be used and the 'looping-in' boxes shall conform to BS 31, Class B3.

16.20.6 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.

16.20.7 Wherever the installation is specified as being flame-proof, the conduit runs entering these areas shall have a barrier box inserted in the run immediately before the conduit passes into the flame-proof area. All conduit work inside the flame-proof area shall be carried out with solid drawn galvanised conduit and all conduit fittings, sockets and accessories shall be galvanised and certified suitable for Group 1 hazard. At the completion of the wiring all machine faces on accessories shall be thoroughly cleaned and greased, prior to the screwing or bolting of all accessory cover plates into their final flame-proof secure position.

16.20.8 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.

16.20.9 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.

16.20.10 All conduit and accessories, after being installed, shall be examined and all parts where the surface has been chipped or scratched shall be painted.

16.20.11 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.

16.20.12 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.

16.20.13 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.

16.20.14 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.

16.20.15 The Contractor shall provide PVC tube ends and flexible covers to prevent ingress of concrete grout into the tubing and boxes.

16.20.16 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.

16.20.17 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.

16.20.18 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.

16.20.19 All conduit boxes shall be screwed on or in walls, ceilings etc. by countersunk wood screws of appropriate size. Holes in boxes shall be adequately countersunk to ensure the complete recession of the fixing screws. All inspection and draw-in boxes shall be provided with covers fixed by round head brass screws.

16.20.20 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.

16.20.21 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.

16.20.22 Conduits in ceiling cavities shall be supported independent of the suspended ceiling.

16.20.23 Where conduits cross expansion joints, the Contractor shall allow for the installation of expansion couplers at the positions of the expansion joint and at fight angles to it. He shall provide a bonding earth wire between each terminal fitted in the nearest conduit box each side of the coupler.

16.20.24 All flexible metallic tubing shall be galvanised watertight pattern fitted with sweated brass adaptors. External earth conductors, wrapped around the tubing, shall be provided.

16.20.25 Where conduits are laid in slab floor etc., the Contractor shall arrange for a competent person to be in attendance whilst the concrete pouting or screeding operation is being carried out, in order to avoid damage being caused to the conduits and also to ensure that the conduit work is in sound condition, properly and efficiently maintained during this installation period.

16.20.26 Particular care should be taken when setting out conduit runs to outlet points where they are to be fitted to furniture, kitchen fittings, etc. The Contractor shall ascertain exact details of the furniture and fittings construction in order that all conduit work shall wherever possible be concealed.

16.20.27 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.

16.20.28 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.

16.20.29 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.

16.20.30 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.

16.20.31 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.

16.20.32 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.

16.20.33 Conduit buried in the ground shall be wrapped with PVC self-adhesive tape half lapped. The taping shall be extended for a distance of 150 mm beyond the point where the conduit emerges from the ground. Joints in galvanised conduit systems shall be made watertight using lead, aluminium paint and hemp and/or gaskets. The joints shall be partially screwed up before the paint and hemp are applied to maintain continuity.

16.20.34 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.

16.20.35 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).

16.20.36 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.

16.20.37 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.

16.21 Cable Trunking

16.21.1 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.

16.21.2 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.

16.21.3 All cables installed in trunking shall be labelled and identified in an approved manner. Clips shall be at 600 mm from centres. Vertical cable trunking shall be fitted with cable pin racks arranged to avoid any strain on the cables.

16.21.4 All trunking shall be rust proofed, primed and painted and fixed at intervals not greater than 1,000 mm.

16.22 Cable Trays

16.22.1 Cable trays, where required as part of the Contract supply, are to be the perforated galvanised sheet type.

16.22.2 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.

16.22.3 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.

16.23 Cable Jointing

The Contractor shall be responsible for the sealing and jointing of all cables supplied and installed as part of this Section of the Contract. Straight jointing of cables is not permitted without the written consent of the Engineer.

16.24 Contactors

Contactors shall comply with BS 5424 or equivalent and shall be of the electrically held-in types contained in heavy gauge sheet steel cases suitable for panel mounting. Each contactor shall be continuously rated and suitable for thirty inductive switching operations per hour.

16.25 Switches and Pushbuttons

16.25.1 Switches shall be rated for 15 amps, shall be single pole types and be provided with an earth terminal.

16.25.2 Switches shall be one way, two-way or intermediate as required and, where mounted together, they shall be fitted in a common box.

16.25.3 Switches for use in areas designated for surface installation shall be quick-make-quick-break fixed grid industrial types mounted in galvanised malleable iron boxes with protected dolly and arranged where necessary for multi-gang switching.

16.25.4 Switches for use in areas designated for flush installation shall be micro-break types fixed to white plastic cover plates and mounted in galvanised steel flush type boxes.

16.25.5 Switch-boxes shall be galvanised and fitted with screwed stainless steel front plates having a 6 mm overlap minimum for flush installations. They shall be suitably barriered and labelled where two phases are connected in the same box.

16.25.6 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.

16.25.7 Where DC emergency lighting circuits are to be switched, double-pole quick make, quick break switches with pillar type terminals and earthing straps shall be provided.

16.25.8 Switches shall be mounted 1.4 m above finished floor level.

16.25.9 Pushbutton switches shall either be flush or surface types contained in galvanised steel boxes and be single pole rated for 5 Amps. Pushbuttons shall be made of non-hygroscopic material, be non-swelling and so fitted as to avoid any possibility of sticking.

16.25.10 The terminals for all switches shall be adequate to accommodate 2 conductors, each a minimum of 1.5 mm^2 in area.

16.26 Lighting Fittings

16.26.1 Illustrations and/or samples of all lighting fittings which the Contractor proposes to purchase shall be submitted to the Engineer for approval before issuing any sub-orders.

16.26.2 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.

16.26.3 Each fitting is to be complete with all lampholders, control gear, internal wiring, fused terminal block, earth terminal and reflectors or diffusers as specified. The design of each fitting is to be such as to minimise the effect of glare and such that the ingress of dust, flies and insects is prevented, where open type fittings are used it is to be impossible for insects to become lodged therein.

16.26.4 The control gear for use with fluorescent lamps is to be quick or resonant start type without starters.

16.26.5 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.

16.26.6 The built-in ballast units shall comply with IEC 60082 and shall include radio interference suppressors and capacitors to correct the fitting power factor to a minimum of 0.85 lagging. Control gear noise levels shall be minimal.

16.26.7 Fittings shall be supplied complete with closed end vitreous enameled metal reflectors or totally enclosed opal plastic diffusers, which shall be fully interchangeable.

16.26.8 Dispersive reflector fittings suitable for mercury bulb fluorescent or tungsten filament lamps shall be of heavy gauge sheet steel finished vitreous enamel. They shall be fitted with anti-vibrators and arranged for conduit box mounting, direct or pendant, on galvanised ball and socket dome type lids.

16.26.9 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.

16.26.10 Internal connections are to comprise stranded conductors not less than 0.75 mm^2 covered with heat resistant insulation to the requirements of BS 6500 or equivalent. All

internal wiring is to be adequately cleated to the fitting casing with an approved form of cleat. The finish of fittings for interior use is to be impervious to deterioration by atmospheric reaction. Fittings for exterior use shall have a vitreous enamel, natural aluminium or galvanised finish according to the Manufacturer's standard product.

16.26.11 Lampholders as applicable are to be suitable for the lamp specified.

16.26.12 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.

16.27 Fluorescent Lamps

Not used

16.28 Requirement of LED Lighting

16.28.1 Introduction

Lighting is an important parameter for a well working environment. Now a days power saving is a challenge with increasing demand of power . So, there is an emphasis on saving power. In this case LED lighting is taking place of tradition lighting like Fluorescent light, compact fluorescent light etc. In this section there will be discussion on standard requirement of LED Lighting in the interior & exterior of substation. When required by Schedule of Requirement, LED design shall comply with the following requirement.

16.28.2 LED lighting standards

- IEC (International Electrotechnical Commission) (60061-1,2, 6100-3-2)
-
- ANSI (American National Standard Institute) - Establishes definitions of solid state lighting devices and components. It also provides a common terminology.
- IESNA (Illuminating Engineering Society of North America) - Provides procedures for reproducible measurements of photometry, color and electrical characteristics of solid state lighting products.
- UL (UnderwritersLaboratories) - Writes safety standards for LED products including drivers, controllers, arrays, packages and modules.
- NEMA (National Electrical Manufacturers Association) - makes recommendations for mechanical, thermal and electrical interfaces between luminaires.

16.28.3 Design Considerations

The lighting system shall include provision for ease of erection, maintenance, cleaning, lamp replacement and future extension. Lamp replacement and maintenance should, unless otherwise approved, be possible without necessitating outages on main plant items.

The following basic criteria shall be considred —

16.28.3.1 Operating Voltage

The LED driver must have the capability of operating voltage from 85-265 V AC voltage range. Within this range the driver should be capable of driving LED load properly.

16.28.3.2 Total luminous flux

There is a standard luminous flux in various places like control room, battery room, staircase etc. and it is necessary to maintain proper lux .

16.28.3.3 CCT (Correlated Color Temperature)

There is a recommendation for Correlated Color Temperature (CCT) is to be 6000-6500K that is daylight in nature . As there will be control room, office room, battery room etc. 'daylight CCT' is necessary here. For beautification purpose there may be used warm light or accent lighting. In Roadway in substation there may be used daylight or warm light.

16.28.3.4 CRI (Color Rendering Index)

CRI is one of the important factors in lighting. The bidder must ensure that CRI should be greater than 80. Higher the value of CRI, the better the visualization. So higher CRI is recommended here.

16.28.3.5 Power Factor:

The power factor the LED lighting should be greater than .90 .The bidder must ensure that p.f. and the driver must contain power factor correction circuitry .

16.28.3.6 Total Harmonic Distortion:

Total harmonic distortion(THD) is an very important factor in substation. As very high frequency switching happens in the driver the THD is little a bit high in LED lighting but now the trend is changing. Well sophisticated driver is available now. In this case according to IEC 61000-3-2 standard the maximum permissible harmonic current is given :
But it is desirable have THD not more than 15% and It is strongly recommended.

ACCORDING TO IEC61000-3-2

Harmonic order (h)	Maximum harmonic current permitted (calculated in % compared to fundamental magnitude)
2	2
3	30*(power factor)
5	10
7	7
9	5
11< h≤ 39 (odd only)	3

16.28.3.7 Chromaticity Coordinates (x,y and u',v')

According to the standard IES LM-79-08 the chromaticity index of shall have color rendering values of X = 0.335 and Y= 0.342 (i.e., Color 2) on the CIE chromaticity scale. Basically the bidder has to ensure that the color temperature should be daylight type and in accordance with there should be matching of chromaticity coordinates x,y.

16.28.3.8 Thermal stabilization

The LED lighting should be thermally stable. The bidder has to ensure that the light can sustain both at high and low temperature. The heat generated inside diffuser or driver level ,the temperature should be as low as possible. Thermal test report should be properly documented. These Shall be tested for at least 3,000 hours with data collection at a minimum of every 1,000 hours

16.28.3.9 Driver efficiency

The LED driver which has AC to DC converter should have the efficiency of 90% or above. The driver should contain PFC(Power factor control) system inside it.

16.28.3.10 Current of voltage controlled LEDs

Current of voltage controlled LEDs should be in permissible level so that the heat generated and loss can be minimum. As there is variation in drive current according to various driver, in this case the bidder should be aware of the current level in driver of LED .

16.28.3.11 Efficacy

The efficacy of LED is very good now. The bidder should have the higher efficacy and must be greater than 100 Lumen per Watt. Higher efficacy is recommended. Here the efficacy must not be less than 97percent after 10, 000 hours of use.

16.28.3.12 Luminous intensity

The bidder must ensure that the LED lights, tubes have proper luminous intensity which is needed to maintain the standard lux and have to have the proper technical documents that can ensure the validity.

16.28.3.13 Zonal lumen summation

The bidder must have the knowledge of zonal lumen summation or calculation that is by the lighting fixture how much area can be covered.

16.28.3.14 Outdoor Specifications

For outdoor lighting in substation the lighting should have appropriate wattage and appropriate lux mentioned . The pole and circuit connection should be constructed in proper way.

The Ingress Protection(IP) should be at least IP65. Higher IP or protection from dust, water, shower should have higher priority at outdoor.

16.28.3.15 Maintenance

The LED lighting should be of low maintenance product. The bidder should include terms and conditions about maintenance of LED lighting what the bidder provides.

16.28.3.16 Lifetime

The lifetime is very important for LED lighting. The bidder must ensure that the lighting should have the lifetime of at least 3years, or having a lifetime of at least 30,000 hours. With this lifetime the efficacy must be above 97% within 10,000 hours.

16.28.4 Additional information to be included

16.28.4.1 Description of LED sources

There should be of data that how much LEDs are on the LED chip. There must be sufficient number of LEDs that is required to maintain required lumen what the bidder says. The LEDs may be in series or parallel connection. The number may be varied according to Lumen produced.

16.28.4.2 Description of auxiliary equipment

The bidder has to highlight if any auxiliary equipment is needed like battery setup, fixture, diffuser setup etc. But it is desirable to have dimming control if needed any time.

16.28.4.3 Ambient conditions including airflow, temperature and relative humidity

The LED lights should be capable of sustain at ambient airflow, temperature(25C-55C) and relative humidity and the bidder must be liable of taking all of considerations according to the location of substation.

16.28.5 LED Technology

16.28.5.1 SMD: Surface Mounted Device LED

This LED light chip is compact (flat design), versatile and incredibly popular today. It consists of a circuit board with LED's (light emitting diodes) directly attached to the surface. SMD lights can be found in many bulbs and can be used for colour-changing bulbs.

16.28.5.2 COB: Chip-on-Board LED

In contrast to the SMD technology, COB LED lights package multiple LED chips together, instead of spreading the LEDS on the surface. This makes COB lights brighter than SMD bulbs (lumen per watt ratio). COB lights shine bright, but cannot change colour like SMD bulbs. No Ceramic PCB Engine shall be used for COB, rather Aluminium PCB shall be used for COB LED.

16.28.5.3 DOB: Driver-on-Board LED

This new LED technology is often used for downlights, solving the problem of needing a separate LED driver. Unlike other non-DOB bulbs, the DOB technology used by ECO Lights uses an AC current instead of AC converted to DC. It makes downlights more reliable, energy efficient and reduces the heat a LED light can produce.

16.28.6 LED Fittings

16.28.6.1 Edison LED Screw Cap Bulbs - E27, E14

These are made of metal and heat resistant PBT plastic (polybutylene terephthalate, [C12H12O4]n, melting point 200°C, plasticity at 125°C). It meets European electrical regulations and have CE certification.

The small Edison screw (E14) has nine threads per inch, or about 2.8 mm per thread. The diameter is 14 mm.

The medium Edison screw (E27) has seven threads per inch, or about 3.6 mm per thread. The diameter is 27 mm.

Edison (E27) LED bulbs are energy efficient and last long, keeping maintenance costs at an all-time low. The Edison bulb can also be found in other bulbs, such as the Edison LED filament bulb and Edison cap corn bulbs. The cap is versatile and universally used.

16.28.6.2 Bayonet Bulbs - B22, B15, SBC

The Bayonet bulb can easily be identified with its special bayonet cap fitting. They are similar to the Edison LED bulbs, the only difference is the base.

The Bayonet Bulbs screw (B15) has no threads. Its diameter is 15 mm. The Bayonet Bulbs screw (B22) has no threads. Its diameter is 22 mm.

16.28.6.3 Edison LED Filament Bulbs

These are used for filament bulb.

16.28.6.4 Floodlights (including PIR floodlights)

Normally used for Outdoor lighting . They uses Latest LED COB/ SMD technology with classic Aluminium housing. The housing is Pure die-casting aluminium housing. They can be also Ultra slim die cast aluminium housing with powder coated surface for corrosion resistance.

They are typically used for streetlights or Outdoor switchyard or GIS Hall, as floodlights are capable of producing a huge amount of lighting. The light shall be of minimum IP65.

PIR stands for Passive InfraRed sensor. PIR floodlights are floodlights with a built-in motion sensor technology. This LED Floodlight with P.I.R shall be equipped with a 4th wire.

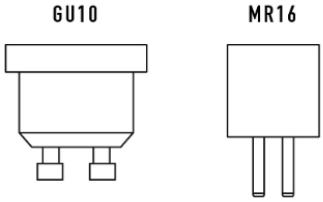
16.28.6.5 Spotlights (GU10, MR16)

Spotlights are very popular for decorative use and strong accent lighting. Spotlights can have a different base, such as GU10 and MR16. The number stands for the distance between the pins, in millimetres.

GU bulbs feature a twist-lock mechanism, which is the main difference between popular GU10 and MR16 bulbs. The GU10 bulb will run at 240 volts (which is the same voltage as supplied by the mains power supply), while MR16 bulbs run on just 12 volts.

Unlike GU bulbs, MR16 bulbs do not need to be twisted. The shall have Die-Cast Aluminium housing with Fire rated and adjustable fittings for tilting.

Light fittings may be white and modern brushed chrome finish . The spots are made of high quality aluminium die cast fittings, with fire-rated cans and the junction box that has an anti-fire cotton seal for extra fire resistance and acoustic protection.



16.28.6.6 Downlight (COB, DOB, GU10) recessed

Downlights illuminate spaces in a concentrated, ‘diluted’ way. Spotlights have a narrow beam which is used to play with light, creating a contrast between light and dark. Downlights, on the other hand, are not used for accent lighting, like spotlights or track lights. It gives soft, uniform lighting. Downlights provide basic lighting for space, such as a kitchen, entry or hallway.

COB LEDs are basically multiple LED chips (typically nine or more) bonded directly to a substrate by the manufacturer to form a single module. Since the individual LEDs used in a COB are chips and not traditionally packaged, the chips can be mounted such that they take up less space and the highest potential of the LED chips can be obtained. When the COB LED package is energized, it appears more like a lighting panel than multiple individual lights

Being multi-chip packaged, the light emitting area of a COB LED can contain many times more light sources in the same area that standard LEDs could occupy resulting in a greatly increased lumen output per square inch.

16.28.6.7 LED Panels

LED panel light supply is well known as long time . Stable cold mild source, epoxy resin, light physique. Drive energy requirements chip itself is lower than 0.5w, switching frequency necessities mandate larger than the 120hz, in order that while the prevalence frequency disturbance could be seen blinking. Minimum IP 42.

LED panel light shall be with Aluminum heat sink, No UV or RF interference, Patented heat sink and optical diffuser. No mercury, no ballast required, wide voltage and constant current design, solid state, high shock & vibration resistant, Mercury free, savings in energy consumption, quiet, no noise, no flickering, The products hall be in accordance with CE, UL and FCC testing standards.

16.28.6.8 LED Tube Bulbs

Typical Fittings are

- T5, T8 and T12
- UL Type A LED tube light – Ballast Compatible
- UL Type B LED tube light - Ballast Bypass
- UL Type C LED tube light - Remote Driver etc.

16.28.7 Safety considerations

16.28.7.1 Compatibility of Lighting Systems

In the substation there may be traditional lighting system . The LED lighting should be compatible of working with both traditional system and new LED lighting system. For example, Traditional fluorescent tube has magnetic ballast system or electronic ballast system, In that case The bidder should take the responsibility of changing the system without changing the fixtures in some cases.

16.28.7.2 Design Verification

The bidder should try to mention all the technical standard documents, safety documents and design verification documents.

16.28.7.3 Electrical characteristic

It is desirable to have the documents of electrical characteristics of lighting, Driver efficiency, temperature characteristics etc.

16.28.7.4 Environmental

The LED light or the product should be certified by ROHS , EnergyStar, CE for Energy Saving etc.

16.29 Socket Outlets and Fused Spur Outlets

16.29.1 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.

16.29.2 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.

16.29.3 Each socket outlet and fused spur outlet shall be equipped with a galvanised metal box with earth terminal.

16.29.4 Each group of five socket outlets is to be provided with a matching fused plug top.

16.29.5 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.

16.30 Time Switches

16.30.1 Time switches for use with lighting systems shall be the synchronous motor wound types protected by a suitably rated fuse for 230 volts operation with a nine hour reserve

spring and are to be fitted with a twenty-four hour hand set dial, two "OFF" and two "ON" levers and manual operation pushbutton. The main contacts shall be rated for 20 Amps on a 230 Volt 50 Hz AC supply.

16.30.2 Time switches shall be suitable for mounting in the distribution boards supplying the circuits to be controlled.

16.31 Poles

16.31.1 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.

16.31.2 Each pole shall be equipped with a base section compartment of 470 mm by 150 mm to house an inspection trap, lockable door, fused cut out, cable entry and terminations for both the incoming and outgoing power cables and secondary cables feeding the light sources.

16.31.3 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.

16.31.4 The Contractor shall ensure each pole is provided with foundations suitable for the ground conditions occurring at each site.

16.32 Interior Installations

16.32.1 Wiring for the lighting and socket outlet installations shall comprise PVC cables drawn into conduits attached to walls, structural or roof steelwork or ceilings as appropriate (see chapters 16.20 and 16.21).

16.32.2 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.

16.32.3 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.

16.32.4 Cleats with two screw fixings shall be used for supporting conduits at not greater than 2m intervals.

16.32.5 All switchboxes, socket outlet boxes and items of a similar type shall be fixed with two screws or bolts.

16.32.6 Switches and pushbuttons for lighting circuits shall be mounted at 1400 mm above finished floor level.

16.32.7 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.

16.32.8 Lighting fittings shall be attached to ceilings, walls, trunking or roof steelwork or suspended therefrom as appropriate.

16.32.9 Where fittings are to be suspended, rod type suspension units shall be employed.

16.32.10 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.

16.32.11 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.

16.32.12 All cables not contained within conduit for their whole route shall be terminated with a cable gland.

16.32.13 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.

16.32.14 Earth continuity shall be maintained throughout the entire wiring installation with separate insulated earth continuity conductors of adequate cross-section ultimately connected to a common earth terminal at the respective distribution board.

16.32.15 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.

16.32.16 Each and every trunking route shall be bonded across all joints with external copper bonding links supplied for the purpose.

16.33 Exterior Installation

16.33.1 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.

16.33.2 When locating the floodlights for the switchyard lighting, the Contractor shall ensure that all floodlights are outside safety clearance for the high voltage switchgear at the particular location.

16.33.3 Cables to exterior lighting shall be laid direct in ground, laid in concrete trenches or cleated to buildings structures as appropriate to the route requirement. The cables shall be terminated at a cut-out located at the base of each support. Wiring between the cut-out and the control gear or lantern shall be with multicore cable run within poles or with cable drawn into galvanised steel conduit attached to the supporting structure.

16.34 Emergency Lighting

16.34.1 Emergency lighting shall comprise lighting fittings of the types indicated in the schedule appended to this section of the Specification.

16.34.2 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.

16.34.3 Sufficient fittings of Type E3 shall be provided in each room to enable the rooms and building to be evacuated safely.

16.34.4 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.

16.34.5 The security lighting scheme shall illuminate the area to 6 metres inside the perimeter wall to the lighting level specified.

16.35 Telephone System

16.35.1 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.

16.35.2 Telephone instruments, the PABX and connections to PTT exchange lines shall be carried out by other Contractor.

16.36 Schedule of Lighting Fittings and Socket Outlets

16.36.1 All lighting schemes are to utilise fittings and lamp types which are available locally in Bangladesh to ensure that replacements are readily acceptable.

16.36.2 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 lampholders for one fluorescent lamp, equipped with an open ended metal reflector having upwardlight slots.

Type F2 Shall indicate a fitting which shall comply generally with the descriptionfor Type Fl but be equipped for use with two lamps.

Type F3 Shall indicate a recessed modular fitting suitable for mounting in a suspended ceiling and equipped with a clear prismatic controller. The metalwork and trim are to comprise a rigid welded unit so arranged as to be invisible when erected complete with controller. The fitting is to be equipped with a pre-wired removable gear tray and adjusting facilities to enable levelling relative to the ceiling to be carried out after erection. The assembly is to be complete with control gear and 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 dust-tight, 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 self-contained, self-sustained (normally off) emergency lighting unit, complete with integral batteries and control gear, with the words "EXIT" in white letters on red background in English and Arabic. It shall be energised from the batteries under mains failure conditions. The mains failure device shall be sensed by an unswitched phase connection from the local lighting circuit.

Type E2 Shall indicate a self-contained, self-sustained (normally off) wall mounted emergency lighting unit comprising a pilot light and two 100 watt spotlights complete with integral batteries and control gear. The pilot light shall be energised under mains failure conditions with manual "on demand" switches for the spotlights. The mains failure device shall be sensed by an unswitched phase connection from the local lighting circuit.

Type E3 Shall indicate a self-contained, self-sustained (normally off) wall or ceiling mounted emergency lighting unit complete with integral batteries and control gear. The lamps shall be energised under mains failure conditions. The mains failure device shall be sensed by an unswitched phase connection from the local lighting circuit.

Type E4 Shall indicate a 110V DC wall or ceiling mounted emergency lighting unit which shall be manually switched and be similar to type E3.

Type H1 Shall indicate forward throw floodlight fitting comprising a sheet steel vitreous enamelled or spun aluminium reflector housing a 500 Watt Halogen lamp. The fittings to be complete with wall mounting bracket.

type H2 Shall indicate a semi cut-off roadway and perimeter security lantern with housing manufactured from a one piece LM6 aluminium alloy casting enamelled white internally and equipped with reflector bowl of heat resisting glass, all suitable for housing the 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.

Type S4 Shall indicate a 15 amp 3 phase 4 wire switched socket outlet with plug flush mounted.

16.37 Design for Lighting level

16.37.1 The lighting distribution board shall be designed for operation in a 400 V, 3 phase, 4 wire, 50 Hz. neutral grounded system with a fault level of 15 kA at 400 V. The emergency lighting system operating from 220 V +/- 10% DC system shall be automatically placed into service in the event of loss of AC main supply.

16.37.2 The overall maintenance factor shall be taken as 0.8 and 0.75 for different outdoor and indoor lighting systems respectively.

16.37.3 The minimum lux level to average lux level ratio should not be less than 0.3 i.e. Emin/Eav> 0.3.

16.37.4 Measuring Units of Light Level - Illuminance Illuminance is measured in foot candles (ftcd, fc, fcd) or lux (in the metric SI system). A foot candle is actually one lumen of light density per square foot; one lux is one lumen per square meter.

1 lux = 1 lumen / sq meter = 0.0001 phot = 0.0929 foot candle (ftcd, fcd)
1 phot = 1 lumen / sq centimeter = 10000 lumens / sq meter = 10000 lux
1 foot candle (ftcd, fcd) = 1 lumen / sq ft = 10.752 lux

16.37.5 The design calculation shall be made using software. Dialux is the preferable software.

16.37.6 Schedule of Lighting Requirements

A) Indoor Areas

Location	Service Illuminance (Lux)	Glare Index
Control relay room	350	19
Behind panels	100	-
Manger Room/Tea Room	350	19
Battery room	100	-
toilet	100	-
Corridors, stairs	100	22

Location	Service Illuminance (Lux)	Glare Index
GIS Hall	200	
Corridor	100	
Stairs	100	
ACDB- DCDB room / Store	150	
Tiffin room / Kitchen	150	
Maintenance room	150	
Conference room	350	

B) Outdoor Areas

Location	Service Illuminance (Lux)	Glare Index
Switchyard floodlighting	30	-
Transformer compounds	120	-
Roadway lighting	30	-
Perimeter wall security	10	-
Control building exterior	15	-
Road within campus including colony area		

1) The surface for lux measurement shall be at 0.5 m high from ground for Indoor and 1 m for outdoor Areas except transformer Yard. In case of Transformer compounds, surface at 1.5 m height from ground shall be considered for lux measurement.

16.38 Air Conditioning and Ventilation [Not Applicable]

16.38.1 Scope of Work

This Section of the works covers the design, supply, delivery, installation, commissioning and setting to work of the ventilating systems for the control building.

All ventilating systems shall be fully automatic in operation and shall be capable of maintaining internal conditions within the bands of temperature and humidity specified hereafter.the substations are normally manned and allowance shall be made for at least four persons on site in the design.

16.38.2 Air Conditioning

The following areas shall be air conditioned:

- Office
- Control & Relay Protection room
- Telecommunication/SCADA/PLC room
- AC 6 DC Auxiliary Power Supply room

Air conditioning shall be provided in the form of Air Cooled Split System Air Handling Units or cassette type Air Handling Units. The systems shall handle predominantly recirculated air with a controlled quantity of fresh air introduced either at each unit or independently via a separate supply and extract system. Supply air distribution ducts for the Control/Relay room shall be located in the false ceiling serving supply diffusers. Return (recirculated) air shall be drawn in through the front of each unit.

The cooling medium for the Cassette type System Air Handling Units shall be direct expansion provided by air cooled refrigeration condensing units located on the roof of the building or wall mounted on building exterior, and interconnected by refrigerant pipework to multi circuit direct expansion cooling coils.

Air conditioning system shall be thermostatically controlled to maintain internal conditions under continuous operation within the limits stated. Plant shall be arranged to facilitate maintenance and future replacement of equipment.

16.38.3 Mechanical Ventilation

Supply and extract ventilation shall be provided to serve the following areas:

- Battery Room
- 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 louvered discharges to atmosphere. Individual extract fans shall be provided for Battery room and toilets.

Extract fans for battery room shall be corrosion resistant throughout, with a 4 mm PVC lining.

16.38.4 Basis for Design

(a) External Design Conditions

The external conditions for the calculation of duties for the mechanical services shall be with mean monthly, maximum and minimum values as below:

• Maximum ambient shade temperature:	40 °C
• Minimum ambient shade temperature:	4 °C
• Maximum daily average temperature:	35 °C
• Maximum annual temperature:	25 °C
• Relative humidity:	maximum 100%, minimum 80%
• Solar radiation:	100 mW / m²

All plant and equipment installed externally, or which can be affected by external condition shall be capable of withstanding without damage or deterioration the effects of solar radiation, rain, wind, dust, sand storms or other weather phenomena prevalent in the area in which particular building is located.

(b) Internal Design Conditions

Air conditioningsystems shall be capable of maintaining internal conditions in all air conditioned areas within the following bands or, if necessary for the satisfactory operation of the equipment housed, more stringent requirements:

For substations 22+4 °C DB, 40 to 70% R.H.

The following air change rates/hour shall be provided in mechanically ventilated area:

Battery rooms	10
Toilets	12 (extract only)
Cable basement	6
Other general areas	4

All air conditioning and ventilating systems shall be designed for continuous operation. Plant shall be arranged to facilitate maintenance and future replacement of equipment.

The Contractor shall calculate heat gains and losses under the specified conditions for each part of each building, taking into account solar radiation, thermal transmittance through roofs, walls, floors and windows, fresh air requirements, heat emission from installed e1ectrical equipment and lighting, personnel, infiltration and any other sources. The Contractor shall be responsible for determining the heat transfer coefficients for all materials used in building construction. In the event of any change in materials. design or method of building construction, the Contractor shall at all times be responsible for rechecking the design of all systems to ensure that they are capable of meeting the specified design requirements.

16.38.5 Air Cooled Condensing Units

The cooling medium for the air conditioning shall be direct expansion refrigeration provided by air cooled condensing units located externally.

The condensing units shall be of the fully packaged type requiring only site connection of refrigeration pipework, isolated electrical supply and input from the control system.

The individual item of refrigerant equipment shall be matched such that the required performance of the evaporator is achieved concurrently with the satisfactory operation of the compressor and adequate heat rejection at the condenser. Each system as a whole shall maintain the correct duty at the design ambient and operate at the maximum ambient conditions stated without exceeding the safe operational limits of any individual item of equipment and without causing any safety device to operate.

All electrical equipment, control, magnetic coils and solenoids shall be manufactured specifically for operation at the electrical characteristics specified herein and such items designed for any other characteristics shall not be used.

Air cooled condensing units and air handling units that are inter-connected on site with refrigerant piping shall all be supplied by the same Manufacturer.

The casings of the condensing unit shall be weatherproof and shall incorporate adequate access and inspection panels secured in place by rustproof fasteners.

The whole of the casing shall be treated for corrosion and weather resistance and ungalvanized mild steel shall not be used (even if painted). The unit shall be finished in not less than two coats of weather resistant finish, such as baked enamel of a light reflective colour.

The access panels shall be adequately sized for the service and removal of all working parts of l the unit. All panels shall be stiffened and supported to prevent flexing and drumming.

Electrical equipment shall he contained in a fully weatherproofed enclosure with internal division between the power connections and equipment and the control connections and equipment.

16.38.6 Refrigeration Systems

Liquid lines shall be insulated where they are in direct sunlight or where they pass though non-air conditioned areas.

Suction lines shall be insulated over their entire length.

All insulation to refrigerationpipework shall be of flexible, closed cell l foam phenolic rubber type with a temperature range of -40°C to +105°C. They shall havea thermal conductivity of 0.0375 w/m °C at 21°C and a water vapour transmission of less than 6.0 ng/Ns.

The thickness of insulation shall be in accordance with the following tables:

Location	Insulation Thickness for O.D.	Pipe Size Range
Suction Lines		
	6-10mm	12-22mm
Exposed to weather	13mm	19mm
In air conditioned spaces	9mm	19mm
In non-air conditioned spaces	9mm	9mm
Liquid Lines		
Exposed to weather and in non-air-conditioned spaces	9 mm	19 mm

The refrigerant used shall conform to BS 4334 Group 1 or equivalent and shall be non-explosive, non-combustive, non-toxic and non-irritating.

Packaged air conditioning plant items requiring interconnection with refrigeration piping on site shall be leak tested by the Manufacturers and delivered to site with a holding charge of refrigerant.

16.38.7 Console Air Conditioning Units

Console model room air conditioners shall be of the slim-line pattern and complete with 4-way adjustable grilles, heavy gauge zinc coated stove enamelled sheet steel casing with single or two colour decorative finish. Electrical-heaters shall not be fitted.

The casing and position shall be such as to protrude not more than 250 mm into the air-conditioned space and no external projection beyond the building line will be permitted other than the fixing of the condenser cooling air grille.

The units shall be extremely quiet ill operation, the noise level not being higher than 30 dB. All sections of the casing shall be acoustically and thermallyinsulated.

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 aluminiumfins 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.

16.38.8 Ductwork

All sheet metal ducting shall be manufactured andinstalled in accordance with the Institution of Ventilation Engineers Guide to Current Practice Section B 16, the American Society of Heating,

Refrigeration and Air Conditioning Engineers, or the Heating and Ventilating Contractors Association of United Kingdom Specification DW/142 or equivalent international standards for sheet metal ductwork for low velocity low pressure air system with air velocity of up to 10 m/s.

Ail ductwork and fittings serving hazardous areas, such as battery rooms where corrosive fumes are expected, shall be of rigid PVC materials.

16.38.9 Condensate Drains

Provision shall be made for condensate to be passed into the rainwater drainage system. Condensate drains must be routed directly into the drainage system or individual soakaways. Pipes discharging onto substation or building brick paving will not be permitted.

16.38.10 Extract Ventilation Units

This clause covers fan powered extract ventilation units for mounting in walls and windows, on roofs and in plant rooms.

Extract units shall incorporate propeller. aerofoil, axial, centrifugal or hybrid type fans which shall be constructed in accordance with the relevant sections of this Specification.

Roof units shall comprise a galvanised sheet steel base suitable for use as a weathering skirt, a mild steel fan/motor mounting frame and a spun aluminium cowl. The sheet steel base shall be constructed to support the fan/motor without distortion and where the fan is belt driven shall incorporate a rigid subframe for motor mounting. Fans shall be diaphragm mounted or fitted with a cylindrical casing 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.

16.38.11 Air Filters

All filter media hall be properly bonded and protected against filter fibre or particle migration. The direction of air flow shall be clearly marked on all filter panels and on installation frames.

Access to filters shall be through removal panels fitted with quick release fasteners and rubber sealing gaskets.

Each disposable panel filter system shall be provided with 4 complete spare sets for use during the commissioning period. These sets shall be in addition to any filter cells supplied as spares in accordance wit11 the general clauses of this specifications.

Filter performance shall, unless otherwise noted, be taken to mean the Overall Gravometric Efficiency against BS 6540:Part I Duct Test or equivalent.

Filter media of all types and sizes shall be supported in rigid peripheral frames with internal or external wire support of the media to ensure that the media shall not collapse under air flow. The
holding frames shall incorporate accurately sized channel sections to provide agood fitting for the filters.

The type of washable and/or disposal panel filters shall be subject to the Engineer's approval.

16.38.12 Grilles and Louvres

Grilles shall be of aluminium construction and shall be fixed by means of subframe with spring clips or screw fixings.

The corners of front flanges of grilles and subframes shall be mitred and jointed to produce a clean unbroken appearance and visible aluminium sections shall be free from extrusion marks.

Front flanges shall be at least 30mm wide and shall incorporate a lip of at least 4.5 mm and a felt gasket. Blades shall be fixed at even centres with intermediate mullions giving support for blades of more than 550 mm long. Grille finish shall be anodised natural aluminium colour except where otherwise indicated.

Allgrilles shall be fitted with an opened blade damper for regulation purposes and shall be fittedwith 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 inthe building structure shall suit the concrete block or brick modules and shall be fixed to a hardwood frame.

16.38.13 Control Equipment

Each item of shall be provided with local isolation and/or emergency stop buttons to facilitate maintenance, inspection and emergency operation.

The control system shall be of the electronic type, capable of providing the degree of thermostatic control specified. The Contractor shall provide full wiring diagram of all control circuits giving terminal connection reference.

The control system shall incorporate all necessary safety interlocks for the successful operation of the mechanical plant and system. All of the individual control elements shall be provided by the same Manufacturer.

Temperature sensors shall be of the resistance type using nickel based elements and shall be accurate to + 1°C over the range of 0 °C to 30 °C. The sensor resistance shall be compatible with the measuring bridge of the matching control box.

16.38.14 Electrical Connections

All electrical power control cables and wiring associated with the air conditioning and ventilation systems, including all connections between control panels, valves, thermostats, sensing probes and other like items shall be supplied, installed and connected up as part of this Contract.

The cabling and wiring system shall comply with the requirements of the relevant clauses of this Specification and be either surface or flush installation as appropriate.

Cables and wiring shall comprise either PVCWPVC laid in cleats or trenches, or PVC drawn into galvanised conduits and trunking.

Final connections to electric motors and all other items of plant subject to movement and vibration shall comprise flexible cable in flexible conduit.

16.38.15 Manufacturers

Wherever possible all air conditioning and ventilating plant shall be selected from a single Manufacturer's product range and origin. Where this is not possible, because of practical or technical constraints. then the number of different sources of origin shall. be kept to a minimum. Local service facilities shall be available for the equipment proposed.

The Contractor shall provide, with his submission, illustrated technical literature covering all plant and equipment offered.

The preferable manufacturer are Hitachi, Mitsubishi, General & York.

16.38.16 Standards

All air conditioning and ventilation equipment shall conform to British Standards, Chartered Institution of Building Services or ASHRAE recommendations or other recognised International Standards.

16.38.17 Approval

The Contractor shall submit to the Engineer for approval copies of all his calculations forming the basis for the selection of all air conditioning and ventilating plant, plant selection details and full working drawings. Such approval shall not relieve the Contractor of his contractual responsibilities.

16.38.18 Maintenance

The Contractor shall be responsible for the maintenance of all installations covered by this section of the Specifications for the period stated elsewhere in the Specification.

16.39 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.

16.40 Testing and Commissioning

The Contractor shall be required to prove that the installed system meets the design requirements and Specification to the satisfaction of the Engineer.

17. Fibre-Optic Multiplexer Equipment for Communication and Protection [Not Applicable]

17.1 Scope of Specification

This specification describes the communication requirements for the transport of voice, data and protection signals between the new substations existing substations and the National Load Dispatching Centre (NLDC) in Rampura, including engineering, configuration, testing, installation, commissioning and training.

The scope of work is to connect the Substation Automation System to the existing communication 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 current differential protection of the 400kV, 230kV & 132kV line.

All materials and equipment offered shall be brand new, from the Manufacturer's normal and standard construction, designed and manufactured according the latest technological methods.

For the purpose of standardisation of operating performance and facilities offered equipment shall be compatible with the existing ones.

For standardization of operation performance, facilities and spare requirements, the fibre optic multiplexer equipment for communication and protection to be supplied under this project shall consist of equipment which can totally be integrated into the existing telecommunication system in PGCB'snetwork, including the telecommunication network management system. The fibre optic multiplexeres presently used in PGCB’s network are:

- ABB FOX 515/615, and
- Areva MSE 5001

The Manufacturer of Telecommunication system – Fibre optic multiplexer equipment for communication and protection shall be: ABB (Switzerland), GE (former Alstom/Areva) , ZTE/HUAWEI (China).

Only Manufacturer Authorization Letter is required to be submitted with the bid. Since, above mentioned manufacturers are approved, all other requirements mentioned in sub-clause 2.7. of Section 3 of Volume 1 are not required.

Any other Manufacturer of Telecommunication system shall have to fulfil the Qualification Criteria required in sub-clause 2.7. of Section 3 of Volume 1 of Tender documents

17.2 Summary of Standards

The Equipment shall comply with the latest ITU-T recommendations for the plesiochronuous and synchronous hierarchies.

The equipment shall be KEMA type tested.

17.2.1 PDH Interfaces

The PDH interfaces shall conform to the following recommendations:

ITU

ITU-T G.702	General aspects of digital transmission systems - Terminal equipment Digital hierarchy bit rates
ITU-T G.703	Digital transmission systems - Terminal equipment - General Physical/electrical characteristics of hierarchical digital interfaces
ITU-T G.704	Digital transmission systems - Terminal equipment - General Synchronous frame structures used at 1544, 6312, 2048, 8448 and 44 736 kbit/s hierarchical levels
ITU-T G.706	General aspects of digital transmission systems - Terminal equipment- Frame alignment and cyclic redundancy check (CRC) procedures relating to basic frame structures defined in recommendation G.704
ITU-T G.71 1	Pulse code modulation (PCM) of voice frequencies
ITU-T G.712	Transmission performance characteristics of pulse code modulation channels
ITU-T G.732	General aspects of digital transmission systems - Terminal equipment - Characteristics of primary PCM multiplex equipment operating at 2048 kbit/s
ITU-T G.735	Characteristics of primary multiplex equipment operating at 2048 kbit/s and offering synchronous digital access at 384 kbit/s and/or 64 kbit/s
ITU-T G.736	General aspects of digital transmission - Characteristics of a synchronous digital multiplex equipment operating at 2048 kbit/s
ITU-T G.737	Characteristics of external access equipment operating at 2048 kbit/s and offering synchronous digital access at 384 kbit/s and/or 64 kbit/s
ITU-T G-823	The control of jitter and wander within digital networks, which are based on the 2048 kbit/s hierarchy
ITU-T G.826	Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate

17.2.2 Architecture of Optical SDH Interfaces

The architecture of optical SDH interfaces shall conform to the following recommendations:

ETS/EN

ETS 300 147:	Synchronous digital hierarchy multiplexing structure
ETS 300 417:	Transmission and Multiplexing (TM); Generic requirements of transport functionality of equipment
ETS 300 417-1-1 / EN 300 417-1-1 V 1. 1.2:	Generic Processes and Performance
ETS 300 417-2-1 / EN 300 417-2-1 VI.1.2:	SDH and PDH Physical Section Layer Functions
ETS 300 417-3-1 / EN 300 417-3-1 V 1. 1.2:	STM-N Regenerator & Multiplex Section Layer Functions
ETS 300 417-4-1 / EN 300 417-4-1 V 1. 1.2:	SDH Path Layer Functions

ITU

ITU-T G.707	Network node interface for the synchronous digital hierarchy
ITU-T G.783	Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks
ITU-T G.803	Architecture of transport networks based on the synchronous digital hierarchy (SDH)
ITU-T G.805	Generic functional architecture of transport networks
ITU-T G.826	Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate
ITU-T G.841	Types and characteristics of synchronous digital hierarchy (SDH) 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

17.2.3 Synchronisation and Timing of Optical SDH Interfaces

The synchronisation and timing of optical SDH interfaces shall conform to the following recommendations:

ETS/EN

ETS 300 417-6-1 / EN 300 417-6-1 V 1. 1.2	Synchronisation Layer Functions
ETS 300 462-1 / EN 300 462-1-1 V 1. 1. 1	Transmission and Multiplexing (TM); Generic requirements for synchronisation networks; Part 1: Definitions and terminology for synchronisation networks.
EN 300 462-4-1 V1.1.1	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)

17.3 Abbreviations

ADM	Add-drop multiplexed
ALS	Automatic Laser Shutdown
BIP	Bit Interleaved Parity
CAP	Carrier-less Amplitude and Phase
CAS	Channel Associated Signalling

CRC	Cyclic Redundancy Check
DTMF	Dual Tone Multi-Frequency
EN	European Norm
EOW	Engineering Order Wire
ETS	European Telecommunications Standards
GPS	Global Positioning System
HDSL	High Density Subscriber Line
IEC	International Electrical Commission
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ITU	International Telecommunication Union
LAN	Local Area Network
MCMI	Multi Coded Mark Inversion
MS	Multiplex Section
NE	Network Element
NMS	Network Management System
OS	Optical Section
OSPF	Open Shortest Path First
PDH	Plesiochronous Digital Hierarchy
PPP	Point-to-Point Protocol
RS	Regenerator Section
SDH	Synchronous Digital Hierarchy
SNMP	Simple Network Management Protocol
SOH	Section Overhead
STM	Synchronous Transport Module
TCP	Transmission Control Protocol
TTI	Trail Trace Identifier
VC	Virtual Container
VF	Voice Frequency

17.4 General Requirements

The digital multiplex equipment shall be universal, software-controlled, and provide various interface cards to connect tributary interfaces signals such as voice, teleprotection and data to aggregate interfaces. On aggregate level 2Mbit/s and 8Mbit/s electrical interfaces complying with ITU-T recommendations G.703 / G.704 and 2Mbit/s HDSL interfaces shall be available. In addition, optical STM-1 aggregate interfaces on 155Mbit/s shall be available. All modules shall form an integrated part of a shelf.

The multiplexer shall provide means to drop and insert individual 64 kbit/s signals and allocate them to determined time slots in the 2Mbit/s streams. Path protection on 64 kbit/s and 2Mbit/s shall be 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
- X.24/V. 11 (RS-422), Nx 64kbit/s data interface
- V.24/V.28 (RS-232), data interface
- RS 232/485/422 dat interface
- Alarm collection interface
- Teleprotection command interface
- Binary signal (status and control) interface
- 2Mbit/s electrical interface for unframed signals acc. to ITU-T G.703 and framed signals acc. to G.703 and G.704.

Additionally, the equipment shall provide the following aggregate interfaces:

- STM-4 (622 Mbit/s) optical 1+1 interface for medium and long distances, with automatic laser shut down.
- STM-1 (155 Mbit/s) / STM-4 (622 Mbit/s) optical add-drop interface for medium and long distances, with automatic laser shut down
- 2 Mbit/s electrical interface /
- 2 Mbit/s HDSL interface

The equipment shall be equipped with a ringing generator for analogue subscriber interfaces.

17.5 General Conditions

The same equipment shall be used as a terminal, for through connections (transit, repeater) and as add-drop multiplexer (ADM) with integrated optical line modules.

First order multiplexing (2048 Mbit/s), second order multiplexing (8448 Mbit/s/s) and STM-1/STM-4 or STM-16 (for 400kV if any) multiplexer shall be integrated.

Conference for voice channels and point-multipoint function for data signals shall be possible.

The equipment shall be of fully modular design, based on a single cubicle.

17.5.1 Channel Capacity: Digital Cross Connection

The equipment shall be equipped with a redundant cross connection function with decentralised cross connection functions on each board.

The cross connect capacity shall be minimum 40x 2Mbit/s, or 200x 64kbit/s non-blocking.

17.5.2 Redundant Centralised Functions

The equipment shall be equipped with redundant circuits for all centralised functions.

17.5.3 Power Supply

The multiplex equipment shall operate at 48VDC +/- 15%. Redundant power-supply shall be supported.

17.5.4 ITU Compliance

The Equipment shall comply to the latest ITU-T recommendations for the plesiochronuous and synchronous hierarchies, such as:

G.702-704, G.706, G.711-714, G.732, G.735-737, G.742, G.826, G.823, Q-552

17.5.5 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.

17.5.6 Ambient Conditions

Storage and transport: -40... +70˚C; 98% (no condensation)

Operation: -5... +45˚C, humidity of max. 95% (no condensation)

17.5.7 Mechanical Construction

The equipment shall be of robust design. All tributary and aggregate units shall be integrated in the same shelf.

All connectors shall be accessible from the front.

17.5.8 Network Management System

The equipment shall be software programmable, by both a local craft terminal - preferably notebook and a centralised Network Management System (NMS).

Traffic through the multiplexer shall under no circumstances depend on Network Management System; i.e. the multiplexer has to operate without being connected to any management system.

The Network Management System shall be used to supervise & configure the tele-protection, PDH and SDH equipment.

17.5.9 1+1 Path Protection

The equipment shall protect communication channels. The protection shall be end to end from one interface (telephone or data) to the other. It shall switch automatically from the main

channel to the standby channel. It shall be configurable whether the system switches back to the main channel (reversible switching) or not (non-reversible).

If a path has switched to its standby route because the main route is disturbed this shall be indicated with an alarm.

The switching shall be done within the multiplexer without using the network management system.

17.5.10 1+1 Section Protection

The equipment shall provide multiplexing section protection. It shall be possible to use two independent links: one as the main and the other as the standby. The system shall automatically switch to the standby connection and generate an alarm if the main connection is disturbed.

The switching shall be done within the multiplexer without using the Network Management System.

17.5.11 Network Topology

It shall be possible to build point to point, linear, ring, T, and meshed networks.

17.5.12 Synchronisation

The equipment shall be synchronisable with an external centralised clock, with connected 2048 Mbit/s signals and/ or with internal oscillator. The synchronisation shall be configurable and it shall be possible to distribute the synchronisation to other equipment as well.

The system shall have means to switch to select the synchronisation source as well as means to prevent the system from switching synchronisation loops. The equipment shall be capable select the synchronisation source by means of the SSM (Synchronisation Status Messaging) feature according to ITU-T G.704 or priority based.

17.5.13 Alarms

Each module shall supervise its functions and shall have an alarm-indication LED on its front. All alarms shall be collected by the NMS.

Each node shall be capable to collect up to 50 external alarms.

17.5.14 Test Loops

The equipment shall provide means to loop signals on 64kBit/s level as well as on 2Mbit/s level. It shall indicate an alarm if a loop is activated. It shall have the possibility to determine the time after which an activated loop is switched back.

17.5.15 Maintenance Facilities

Every Network Element shall have a built-in Signal Generator and Analyser to analyse communication paths. It must be possible to cross connect the Generator and Analyser to transmission channels and terminate the signal in other Network Elements. The configuration must be possible locally with the craft access terminal and remotely with the NMS or the craft access terminal.

It must be possible to loop-back signals locally and remotely using the craft access terminal or the NMS.

17.6 Requirements for Transport Level

17.6.1 SDH Aggregate Units

The interface shall be designed for use on single mode fibre at 1310nm and 1550nm.

The following main functions shall be supported:

- Termination of the OS-, RS-, MS- and VC-4 layer
- Extraction and insertion of the SOH communications information through connections of VC-12 and VC-3

The following maintenance functions shall be supported:

- Status indications
- Loops
- Restart after ALS
- TTI monitoring
- BIP Error Insertion

The following SDH interfaces shall be available:

- STM-1/4 for 132kV & lower voltage level
- STM-4/16 for 230kV voltage level
- STM-16 for 400kV voltage level
- The number of optical port shall be as per field requirement

This interface shall provide Multiplex Section Protection (MSP): 1+1 Section Protection

- 2Mbit/s & 64kbit/s electrical interface
- The number of port shall be as per field requirement

17.6.2 HDSL Aggregate Units

2Mbit/s HDSL interface

The HDSL interface shall provide means to interconnect the multiplexer over two pairs of copper wire up to 12km using CAP modulation (Carrier-less Amplitude and Phase). It shall communicate either with another interface of the same type or with a remote desktop terminal.

2Mbit/s HDSL Desktop Terminal

This Terminal shall provide a HDSL interface to transmit 2Mbit/s over two pairs of copper over a distance up to 12 km. It shall be housed in a metallic indoor case. The following interfaces shall be available:

- G.703, 2Mbit/s, 75 ohm
- G.703, 2Mbit/s, 120 ohm
- X.21/V 11, Nx 64kbit/s (N = 1 .. 32)
- V.35, Nx 64kBit/s (N = l.. 32)
- V.36 / RS485, Nx 64kbit/s (N = l.. 32)

17.7 LAN Connection:

l/0 base ethernet connection for e.g. router supporting LAN protocols: IP, IPX; routing protocols: RIP; WAN protocols: HDLC, PPP, frame relay (including RFC 1490). It shall inter-operate with Cisco, Wellfleet, 3Com etc. and be manageable locally, remotely, and with Telnet and SNMP. Two such desktop terminals shall be connectable to provide a 2Mbit/s link over two pairs of copper.

17.8 HDSL Repeater:

An HDSL repeater solution for distances longer than 12km shall be offered including a remote powering solution.

17.8.1 HDSL Line Protection:

The HDSL equipment shall (where necessary) be protected against influences of induced voltages up to 10 kV.

17.9 Tributary Units

17.9.1 4-Wire Interface (VF Interface)

This interface shall provide 8 voice channels with a bandwidth of 300 Hz to 3.4 kHz and 2 signalling channels (M => E, M' => E') per voice channel.

Each interface shall be configurable to operate with or without CAS. With CAS it shall use the a and b bits for the two signalling channels.

The level shall be software adjustable within the following range:

- Input: +7.5 to -16 dBr
- Output:+7.0 to -16 dBr

Modules where each interface can be individually configured with 1+1 path protection shall be available.

17.9.2 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

17.9.3 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

17.9.4 Party Line Telephone System (Engineering Order Wire)

An engineering order wire (EOW) facility shall be provided at each multiplexer. The EOW shall be configured as a party line and use in band DTMF signalling to call another EOW-Terminal. The terminal shall have an integrated DTMF decoder allowing to program a subscriber call number (LA digits), and two group call numbers (LA digits each).

17.9.5 V. 24N.28 RS232 Interface

It shall support the following bit rates:

- 0... 0.3 kbit/s transp. (V. 110)
- 0.6... 38.4kbit/s synchronous / asynchronous (V. 110).

Modules where each interface can be individually configured with 1+1 path protection shall be available.

17.9.6 V.11/X.24 Interface

This interface shall comply to the ITU-T X.24 recommendation for signal definition and to V. 11 for electrical characteristics.

It shall support the following bit rates:

- 48, 56, Nx 64 kbit/s (N = 1... 30) synchronous
- 0.6... 38.4kbit/s synchronous / asynchronous (X.30)

Modules where each interface can be individually configured with 1+1 path protection shall be available.

17.9.7 V.35 Interface

~~This interface shall comply with the ITU-T V.35 and V. 110 recommendations. It shall support the following bitrates:~~

- ~~48, 56, Nx 64kbit/s (Nx = 1... 30) synchronous~~
- ~~0.6... 38.4kbit/s synchronous / asynchronous~~

Modules where each interface can be individually configured with 1+1 path protection shall be available.

17.9.8 V.36 / RS 485 Interface

~~This interface shall comply with the ITU-T V.36 and V. 110 recommendations. It shall support the following bit rates:~~

- ~~48, 56, Nx 64kbit/s (N = 1... 30) synchronous~~
- ~~0.6... 38.4kbit/s synchronous / asynchronous~~

Modules where each interface can be individually configured with 1+1 path protection shall be available.

17.9.9 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.

17.9.10 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.

17.9.11 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.

17.9.12 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.

17.9.13 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.

17.9.14 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.

17.9.15 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.

17.10 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.

17.11 Communications DC Power Supply Equipment

17.11.1 General

17.11.1.1 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 batteryshall 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.

17.11.1.2 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.

17.11.2 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.

17.11.3 Charger

17.11.3.1 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.

17.11.3.2 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.

17.11.3.3 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.

17.11.3.4 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.

17.11.3.5 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.

17.11.3.6 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.

17.11.4 Battery

17.11.4.1 Type

Nickel cadmium cells shall be of the pocket plate type in accordance with IEC 60623.

Cell containers shall be of the moulded plastic type, non-flame propagating and mechanically shock resistant. They shall provide for the electrolyte level to be viewed through the container material.

Cells shall be permanently marked with the following information:

- Sec-14: Fibre Optic Multiplexer
- Manufacturer's reference number and code
- year and month of manufacture
- voltage and nominal capacity at the 10 hour rate
- cell number.

17.11.4.2 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.

17.11.4.3 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.

17.11.4.4 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.

17.11.4.5 Capacity

The battery capacities shall be 200 ampere hours at the 10 hour rate.

17.11.5 D.C. Distribution and Instrumentation

17.11.5.1 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.

17.11.5.2 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.

17.11.6 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 theload.
- 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.

18. Power Line Carrier, Teleprotection And Communication Equipment

18.1 POWER LINE CARRIER EQUIPMENT [Not applicable]

18.1.1 General

Power Line Carrier equipment shall be installed on the 400 kV and 132 kV transmission networks associated with the project. The carrier frequency range available is between 50 to 500 kHz.

All materials and equipment offered shall be brand new, from the manufacturer's normal and standard construction, designed and manufactured according the latest technological methods.

Existing power line carrier (PLC) and communication equipment which are of has been supplied by ABB, Switzerland. For the purpose of standardisation of operating performance and facilities offered equipment shall be compatible with the existing ones.

Equipment providing increased signalling capacity, based on digital techniques shall be offered satisfying the following requirements:

- the high frequency bandwidth requirements are no greater than the SSB type.
- the digital equipment will not affect analogue equipment in service on the same line.
- an applicable schedule of technical particulars and guarantees is prepared and included with the Bid.
- full details of in service installations are included.

Should equipment manufactured by a different supplier be proposed, Bidders are to verify that the equipment shall be fully compatible with existing system and equipment and provide evidence that the equipment has been successfully interfaced with the existing type and is in continuous commercial operation.

18.1.2 Carrier Frequency Allocation

The Contractor shall submit a comprehensive carrier frequency allocation plan which shall be subject to the approval of the Employer. Before approval however, the Contractor shall agree all carrier frequency plans and power output with the governing radio frequency licencing authority to ensure non-interference with Air Traffic Control, and Marine Navigation Beacons, etc.

18.1.3 Line Coupling

(a) General

The high voltage transmission system is a three phase 50Hz system solidly earthed with the following design parameter detailed elsewhere in this specification:

Rated Voltage (kV)	420
Nominal Voltage (kV)	400
Symmetrical Short Circuit Current, 1 sec (kA)	63/ 50
Lightning Impulse Withstand Voltage (kVp)	1425
Continuous Switchgear Rating (A)	4000/3150

All current carrying equipment shall be capable of withstanding these conditions for a period of one second.

(b) Method of Coupling

Coupling of the carrier signals to the double circuit transmission lines shall be phase to phase by means of capacitor voltage transformers supplied under this contract.

The Contract shall include all line traps and mountings, coupling filters, conductor clamps, HF connections, matching transformers, HF cables and glands required to complete the HF installation at site.

(c) Line Traps

New line traps shall have at least the same continuous rating as the switchgear and shall be capable of withstanding the short circuit current for one second.

The preferred value of coil inductance is 1 millihenries although other values will be considered depending upon the Bidders frequency plan.

The line traps shall be broad band tuned by means of a tuning device, which shall preferably be arranged to permit interchange without removing the line trap. The ohmic resistance shall preferably be 600 ohms or greater.

The line trap shall have a protective device which utilises non-linear resistor type arrestors and the nominal discharge current shall be 10kA.

Bidders shall submit type test reports or be expected to demonstrate that their line traps satisfy the tests recommended in IEC publication 353 - Line Traps, with regard to temperature rise, short time current rating, protective discharge, and also the HF rejection bandwidth.

All line traps shall be provided with bird barriers and clearly visible rating plates which will include the following data:

i) Manufacturer’s name
ii) Type
iii) Serial number

iv) Rated continuous current
v) Rated short time current with respect to time
vi) Rated coil inductance
vii) Total mass (kg)

whilst the tuning device shall be similarly marked detailing:

i) Manufacturers's name
ii) Type
iii) Serial number
iv) Frequency band(s) etc., in kilohertz
v) Rated protective level of the tuning device.

Line traps are to be mounted on capacitor voltage transformers, supplied under this Contract and Bidders shall detail the type of mounting and connecting plates available for the line conductor and busbar connections.

18.1.4 Capacitor Voltage Transformers

New capacitor voltage transformers (CVT) and lattice steel structures shall be provided suitable for mounting line traps on them.

The capacitor shall have a rated capacitance of not less than 5000pF at the working voltage, an impulse withstand voltage as specified and meet the insulation level and test voltage equivalents of IEC recommendation for each device (IEC Publication 358 - Coupling Capacitors and Capacitor dividers).
Creepage distances will be 25mm/kV (based on maximum phase to earth voltage).

Full technical details of the capacitor voltage transformers shall be provided in the Schedules of Guarantees and Technical Particulars.

18.1.5 HF Coupling Units

The high frequency coupling units shall be assembled in a sheet steel box or similar and be suitable for mounting on the pedestal support for the capacitor voltage transformer, or coupling capacitor. The filters are to be suitable for outdoor use in a hot dusty/humid climate and are to have weatherproof door seals together with breather holes to avoid condensation. The units are to have an earthing switch which should preferably be interlocked with the box door/lid such that the latter cannot be opened unless the earth switch is closed to earth the device, and clear indication of the ON/OFF position of this switch should be indicated. The terminal of the filter which shall be connected directly to the substation earth shall be clearly designated.

The coupling device shall meet in full the safety and protection requirements of the IEC recommendation for such devices (IEC publication 481 - Coupling devices for power line carrier systems).

The tuning range of the coupling unit(s) shall be suitable for the HF carrier frequency allocations being provided on this Contract. Full details of the Bidder's proposals shall be submitted for approval by the Employer and appropriate Authority. The device shall be fitted with a rating plate clearly defining, but not limited to, the following data:

i) Manufacturer's name
ii) Type
iii) Serial number
iv) Peak envelope power
v) Available bandwidth or working range

Bidders shall be expected to demonstrate that their equipment complies with the following tests:

(a) Drain coil
- measurement of impedance at power frequency
- current carrying capacity at power frequency 1 amp RMS continuous and 50 amps RMS for 0.2 seconds.

(b) Power frequency voltage tests on the isolation transformer of 5 kV RMS for one minute between each coil and earth, and between each coil and screen.

(c) Composite loss at several frequencies within the working range of the filter.

(d) Return loss at several frequencies within the working range of the filter.

(e) Impulse voltage test on each phase to phase filter, in accordance with Section 6 of IEC Publication 60.

The coupling filters detailed above shall be mounted on the CVT or CC pedestals, unless a waterproof housing is provided in the base of the coupling capacitor or CVT, at a height such that the external HV (primary) terminal on the coupling filter shall be at a minimum height of 2440mm above ground level.

Full technical details of the HF coupling units shall be provided in the Schedule of Technical Particulars.

18.1.6 High Frequency Cable

Sufficient high frequency cable suitable to connect the coupling filters with the indoor PLC high frequency units shall be supplied. The cable shall preferably have a characteristic impedance of 75 ohms unbalanced or 150 ohms balanced depending upon the impedance of the coupling filters and the indoor equipment. The cable shall be PVC covered, steel wire armoured with a further outer sheath of PVC.

Bidders shall clearly show the make up of the cable, together with details of the cable mechanical and electrical characteristics. Bidders shall also state the "short" time and continuous test voltages with which their cable complies.

18.1.7 Power Line Carrier High Frequency Unit

(a) General

a The design and selection of equipment and components shall be based on achieving minimum lifetime of 20 years when operating under the specified service conditions.

The design and performance requirements of the digital power line carrier equipment shall be equivalent or better than IEC 495.

The equipment to be provided shall be of the digital transmission signalling type, constructed on a modular basis with modules plugging into 19" (480 mm) shelves. The equipment shall be composed completely of solid state integrated circuits with a minimum of discrete components.

Equipment providing increased signalling capacity, based on digital techniques shall be offered satisfying the following requirements.

* The high frequency bandwidth requirements are no greater than the SSB type

* The digital equipment will not affect analogue equipment in service on the same line.

* Full details of in service installations are included.

(b) Information to be Submitted with the Bid

The Bidder shall submit the following with the Bid:

i) a technical description, which shall include full details of the design, operation, construction, performance and maintenance aspects of the equipment.

ii) detail performance of the equipment .

iii) a proposed frequency plan.

(c) Deleted

(d) Digital Carrier Terminal Equipment

The equipment design shall be based on complete flexibility over the RF frequency spectrum and also in the selection of services to be transmitted. RF allocation shall be achieved with programmable synthesisers and easily tuned RF filters. The allocation of the frequency band and of the services to be transmitted shall be carried out by means of a laptop computer with suitable software installed, it shall be

interactive so that programming/reprogramming can be readily carried out at the factory and also at site.

The combined bit stream (containing speech/data etc.) shall be suitably digitally modulated (e.g. QAM, or PSK etc.) and converted to the selected nominal carrier frequency band for transmission over the power line.

The nominal impedance at the carrier frequency output shall be 75 ohms (un-balanced) or 150 ohms (balanced). Provision shall be made for terminating the output in an appropriate dummy load. The return loss within the nominal carrier frequency band in the transit direction shall be not less than 10dB.

Bidders shall provide calculations to justify operation of the PLC over the transmission line(s). This shall include allowance for line length/construction, coupling losses, adverse weather and fail margin - to obtain a suitable minimum BER (typically 10^{-6}).
There shall not be any limitations in parallelling the digital PLC with other similar digital PLC terminals on the same transmission line, or with analogue PLC equipment. Bidders shall show clearly the methods of transmission used, and identify the necessary RF frequency spacing between PLC equipment, also any interface equipment needed. The switching off/on of a PLC terminal connected with any other PLC terminals in parallel, shall not cause any interference with other still working PLC.

(1) Telephone Channels

To implement speech channels into the data stream the speech shall be sampled. Together with the associated signalling and error coding a bit rate derived from a basic sampling rate of 8 kbit/s shall be typically provided. The interface of each speech channel shall cover the required application and provide for both 4-wire and 2-wire termination. The telephone channel shall be suitable for 4-wire working at transit stations as determined by the requirements of the telephone scheme. Circuits terminating at a station shall be suitable for connection to a two-wire telephone exchange, 2/4 wire switching shall therefore, be available as a standard facility.

Bidders shall state the method of telephone signalling.

Bidders shall state the relative 4-wire levels used for speech transmission and reception.

All speech and VT signal input and output circuits shall be balanced and have a nominal impedance of 600 ohms. The return loss within the effectively transmitted frequency band shall be not less than 17 dB.

The interface of the speech channel shall include for inter PAX tie lines and “Long line” telephones. The speech channel interface shall manage the following types of interface:

- E&M
- MFC

- DTMF
- Decadic

(2) Data Transmission

Data channels shall be time multiplexed into the output bit stream. The interface for the data channels shall be RS 232 (V.24/V.28). The data channels shall be configured as any combination of synchronous or asynchronous channels.

Bidders shall state the capacity/number of data channels which can be equipped on a link.

Where an audio data channel interface is required to/from and FSK modem, a suitable 600 ohm FSK interface shall be provided. The centre frequency, shift frequencies, and modem levels which shall be managed shall be configurable.

(3) Receivers

To provide for level stability on the audio services, the receiver dynamic range shall be approximately 30 dB. Where PLC is required to signal over long transmission lines, proposals for maintaining adequate output capacity and suitable level stability on the audio services shall be included.

An alarm shall be raised in the event of the BER becoming degraded.

(e) Service Telephone

A service telephone shall be provided for the PLC terminal. The handset shall be located in the terminal cubicle. A means of telephone calling the equivalent telephone at the remote end of the link shall be included.

(f) Service Conditions

The noise generated within the terminals and the cross talk attenuation between speech and VF signalling channels shall comply with IEC recommendation 495.

The level of spurious emission shall be clearly stated in the schedules, together with the frequency response of the speech channel referred to 800Hz and the VFT signalling channels referred to 3.0 kHz.

The equipment shall operate to its stated performance with a variation in power supply voltage of +20% and -15% of the nominal value.

(g) Voltage Withstand Requirements

The equipment shall be designed to withstand satisfactorily the insulation tests defined in Section 7 of IEC recommendation 495.

The equipment shall not be subjected to interference by the presence of electrical noise generated by disconnector switching operations. The bandwidth of such noise

extends from 10 kHz to 1 MHz and can peak to 1200 volts at the coaxial termination. Limiting diodes of the avalanche type should be provided at the HF cubicle terminals in order to limit this voltage to 400 volts peak to peak.

(h) Test and Alarm Facilities

Clearly designated test points shall be provided on modules where adjustments are required or reference points are applicable. However, Bidders may offer alternative methods e.g. a hand held maintenance unit or laptop computer with appropriate software.

Supervisory facilities shall be provided for monitoring the HF output amplifier current, the BER and the cubicle supply voltage etc.

Alarm lamps or LEDs on the terminal shall as a minimum requirement show alarms for 'receiver fail', 'transmitter fail' and receive low BER. Bidders shall provide details of all alarms available on their equipment. An alarm lamp shall be provided on the cubicle, visible with the cubicle door closed.

In addition to the local annunciation on the PLC terminal, each alarm shall be provided with two sets of potential free contacts, for connection to external alarm monitoring systems.

18.2 TELEPROTECTION EQUIPMENT

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 and hence shall have inherent security against maloperation due to noise present in the bearer channel.

The Bid shall include a technical description of the equipment, which shall include a description of the design, operation, construction, performance and maintenance aspects of the equipment.

18.2.1 Technical Requirements

The teleprotection equipment shall be of modular construction and will preferably be mounted in the power line carrier units and work satisfactorily under the service conditions specified.

Manufacturers shall clearly state the precautions taken in the design of their receiver to safeguard the output against the presence of noise in the channel, and show the difference between their range of equipments used for "direct" and "permissive" signalling.

In the case of the "direct" tripping equipment it shall not be possible to cause a trip output under any of the following conditions:

(a) Removal or reinsertion of any printed circuit module in either transmitter or receiver of a link, including the PLC equipment.

(b) Switching on/off of the power supply to the teleprotection equipment.

(c) Switching on/off of the power line carrier equipment at either end of the 132 kV line.

(d) Shorting of the output of the teleprotection transmitter or shorting of the input to the teleprotection receive.

(e) Operation of disconnectors in the high voltage switchgear.

(f) When the level of the input signal to the receiver is below the receiver fail alarm threshold.

18.2.2 Signalling Conditions

Bidders shall state the precautions taken in the design of the receiver to safeguard the output against the presence of noise in the communications media. Under no circumstances shall a direct trip signal output occur due to:

- an equipment fault
- removal/restoration of power to the teleprotection or communications equipment
- shorting of the teleprotection transmitter/receiver
- operation of primary switchgear plant
- removal of reinsertion of any PCB in a teleprotection or communications media terminal.

Teleprotection signal outputs shall be inhibited when the level of the input signal to the receiver is below the fail alarm threshold.

Bidders shall provide the following performance graphs:

Transmission time: SNR versus operate time.

Security: SNR versus probability of an unwanted command output.

Dependability: SNR versus probability of failure of an output command.

Bit error rate/performance details

FSK modems shall be programmable with respect to both signalling speed and centre frequency. Bidders shall state the VF allocation required by the teleprotection equipment.

Equipment operating on a frequency shift principle, shall continuously transmit a low level (guard) signal to monitor the communications channel and as much of the terminal equipment as possible. The trip frequency shall be transmitted at an increased level output.

Similarly, equipment which transmit coded signal messages for tripping/signalling, shall also transmit guard codes.

18.2.3 Signal Transmission Times

The transmission times required from receipt of an input to the provision of a command output at the remote location, shall be less than

- 20 milliseconds for permissive tripping
- 40 milliseconds for direct tripping

Equipment capable of transmitting more than a single teleprotection signal is only acceptable provided the specified transmission times are met under all circumstances, including when more than one/all signal inputs are initiated simultaneously or part way through a code transmission.

Equipment used for direct tripping shall have the facility to hold on the output signal, so as to be suitable for applications with circuit breaker automatic reclose schemes, to prevent the remote circuit breaker reclosing until the faulted plant is disconnected from the HV system as detailed in a separate section of this Specification.

Direct tripping and permissive signals shall have a trip extension facility. The extension time shall be selectable, typically 200ms.

Bidders shall advise the minimum input pulse length (and the corresponding output), that is required to provide a guaranteed output. Also any limitation on the maximum output pulse length.

18.2.4 Interface

Data and control interfaces shall comply with CCITT RS232 and V24/V28 recommendations.

For digital communications media the interfaces shall comply with X21.

The transmitter signal command shall be initiated by means of the protection equipment switching both poles of the station dc supply to the teleprotection input.

The receiver command output shall be a semiconductor or relay arrangement providing two sets of “contacts”, with the “contacts” normally open (“contacts” shall be closed for a command output). These command output contacts shall be used for switching both poles of the station d.c. supply to the protection equipment.

The receiver shall also provide two sets of potential free command output auxiliary contacts, for connection to external alarm monitoring systems.

The rating of the above “contacts” shall be to the plant requirements.

The insulation requirements of the protection interface shall be 2 kV rms for one minute (IEC recommendation 255).

Individual counters shall be provided to show the number of teleprotection input and ouput commands which have been executed.

18.2.5 Service Conditions

The equipment shall operate to its stated performance with a variation in power supply voltage of +20% and -15% of the nominal value.

The equipment shall incorporate measures to ensure that signals are received and executed in the presence of noise on the communications channel. In the case of coded messages for example, transmission of a single “trip” code is a non preferred arrangement.

18.2.6 Voltage Withstand Requirements

Voice frequency, signalling and alarm circuits, when free from earth, shall be capable of withstanding without damage a voltage of 500 V d.c. applied for one minute between the terminals of the circuit connected together and earth.

The equipment shall not be subject to interference by the presence of electrical noise generated by disconnector switching operations. The bandwidth of such noise extends from 10 kHz to 1 MHz.

18.2.7 Test and Alarm Facilities

Clearly designated test points shall be provided on modules where adjustments are required or reference points are applicable. Supervisory facilities shall be provided for monitoring the teleprotection input and output at the interface to the communications media.

The alarm output shall be maintained for a minimum period of 100ms, and the operational output shall not be possible until the alarm output condition is removed.

A separate low level (or BER) shall be given, but not prevent operation, when the input signal level drops by typically 6dB from normal. Bidders shall detail the alarm facilities which are available from their equipment and state the level or BER at which the receiver will cease to function.

Alarm lamps or LEDs shall be provided on the equipment, together with two sets of potential free contacts, for connection to external alarm monitoring systems. A cubicle alarm lamp shall also be provided, visible with the cubicle door closed.

18.2.8 Housing

Terminal equipment shall be constructed on a modular basis, accommodated in a 19" or ETSI standard rack configuration, mounted in a cubicle. Equipment required to operate over PLC shall be mounted in the PLC equipment rack.

18.2.9 OPERATIONAL TELEPHONE SYSTEM

A new PAX operational telephone system and equipment (suitable for at least 50 percent spare capacity of the required trunk interfaces and 30 subscriber interfaces) shall be provided and installed at Rampura substation and shall interconnect with the existing network. Bidders shall be deemed to have investigated the existing system.

The trunk numbering plan shall be compatible with the present scheme in service in Bangladesh.

The telephone signalling (dialling) system shall be compatible with the present system.

An alarm system shall be provided to indicate traffic failure including blown fuses, loss of power supplies etc. In addition, contacts shall be provided to facilitate extension of the alarms to the telecontrol equipment.

18.3 COMMUNICATIONS DC POWER SUPPLY EQUIPMENT [Not Applicable]

18.3.1 General

(a) Basis of Design

The equipment shall comply with IEC 176 and 478.

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.

(b) 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.

18.3.2 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 20% spare for future use) for at least 10 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.

18.3.3 Charger

(a) 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.

(b) 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.

(c) Boost Charging

Manual boost charging shall be provided. A boost timer shall be included to prevent overcharging.

Operation of boost charging shall disconnect the charger and battery from the load. 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.

(d) Noise and Interference

To avoid unacceptable levels of electrical noise in the load equipment smoothing of the d.c. output is required. This shall achieve a psophometric noise level at the output, for loads between 0 and 100%, not exceeding the equivalent of 2 mV at a frequency of 800 Hz after weighting as specified by ITU-T (CCITT).

The relative harmonic content of the input current shall comply with the European Directive for EMC, the EN 60555-2 standard. In the case of SMPS chargers active power factor correction (i.e. boost for step up converter) shall be provided to control the power factor.The production of radio frequency interference voltages shall not exceed the values of suppression grade “N”, as defined in EN 55017/55015 - 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.

(e) 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.

(f) 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.

18.3.4 Battery

(a) Type

Nickel cadmium cells shall be of the pocket plate type in accordance with IEC 623.

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 the 5 hour rate
- cell number.

(b) 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.

(c) 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.

(d) Connections

The positive pole of each battery shall be connected to station earth via a single bolted link at the distribution cubicle. Low resistance intercell 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.

(e) Capacity

The battery capacities shall be 250 ampere hours at the 5 hour rate.

18.3.5 D.C. Distribution and Instrumentation

(a) 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.

(b) 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.

18.3.6 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.

19. Quality Assurance, Inspection, Testing, Commissioning and Warranty

19.1 Scope of Section

19.1.1 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.

19.1.2 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.

19.1.3 The Employer/Engineer or their designated representatives are entitled to attend the factory acceptance tests, which shall be performed at the Manufacturer's works/testing laboratories. The contractor is advised to go through schedule A of volume 03 for detail requirement of FAT.

19.1.4 The Contractor shall be responsible for bearing all costs for the mentioned training. All costs are deemed to be included in the contract price.

19.1.5 For notification of testing, four weeks shall be deemed as reasonable advance notice.

19.1.6 Within 45 days of the letter of acceptance for the contract the contractor shall submit a quality assurance programme and a work quality programme for the Engineer's approval.

19.1.7 The Contractor shall have an approved quality management system.

19.1.8 After the award of Contract, the Engineer shall have the right to carry out a review of the quality assurance procedures operated by

the Contractor. The Engineer's review may consider quality assurance in relation to the design and manufacture of plant items, but may equally investigate the Contractor's quality assurance procedures for the overall control of the wide range of design activities necessary for a complex project of this type, and the dissemination of paperwork, design drawings and data amongst the various design and manufacturing organisations within the Contract. The Contractor shall give all necessary help and assistance to the Engineer in carrying out such a quality assurance review. The Contractor shall consider and discuss the results of the review and make any reasonable improvements in his procedures.

19.1.9 Before any plant is packed or despatched from the Main or Sub-Contractors' works, all tests called for shall have been successfully carried out in the presence of the Engineer unless otherwise agreed.

19.1.10 30 days' notice shall be given when the plant is ready for inspection or tests and every facility shall be provided by the Contractor and his Subcontractors to enable the Engineer and Employer to carry out the necessary inspection and witnessing of tests.

19.1.11 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.

19.2 Subcontracts

19.2.1 Within two months of acceptance of the Bid and in order to facilitate the inspection of bought-out materials and plant, the Contractor shall submit to the Engineer for approval three copies of all sub-orders placed by him as soon as they are issued. One copy of any drawing or schedule referred to in the sub-order shall be submitted simultaneously unless agreed otherwise with the Engineer. Any reference to price may be deleted from the copies so submitted.

19.2.2 The sub-orders and drawings submitted to the Engineer shall cover all components which are subject to electrical and mechanical pressure or stress when the plant is in operation and also auxiliaries and spares which are to be despatched to Site direct from the Subcontractor's factory.

19.2.3 Sub-orders are to include a statement advising the Subcontractor that the items being ordered will be subject to inspection and test by the Engineer and Employer.

19.2.4 The Contractor shall advise his Subcontractors of all the pertinent clauses in the Specification when ordering bought out plant, equipment or materials.

19.2.5 Every sub-order or subcontract shall contain the following information:

- Main Contractor's name and sub-order or sub-contract number.
- Quantities and description of work.
- Delivery requirements.
- Delivery consignment instructions.
- Details of Employer and/or main Contractor's applicable drawing or schedule numbers.
- Name of the Engineer.
- A note advising that the plant or equipment which is the subject of the order shall comply in every respect with the Engineer's, Specification and shall be subject to inspection by the Engineer, Employer and the Contractor.
- A reference, particularised in the accompanying Specification, covering the following information:
  - Employer's name
  - Project title
  - Contract No.
  - Engineer's reference number

19.2.6 Subcontractors shall comply with all the applicable requirements of this Specification and the onus is upon the Contractor to ensure that Subcontractors comply with these requirements.

19.2.7 For the purposes of this clause, interworks orders shall be treated as sub-orders.

19.3 Guarantees

19.3.1 The Contractor shall state and guarantee the technical particulars listed in the Technical Schedules and other sections as specified by the Contract for testing procedures. These guarantees and particulars shall be binding and shall not be departed from without the written permission of the Engineer.

19.3.2 The Contractor shall further guarantee that all equipment supplied complies with the Contract Documents.

19.3.3 The tolerances permitted in the IEC and British Standards shall apply unless otherwise stated.

19.4 Quality Audit

19.4.1 The quality programme established by the Contractor shall be followed for all inspection and testing procedures.

19.4.2 The Engineer and Employer may, from time to time, visit the Manufacturer to carry out a quality audit of the Manufacturer's organisation.

19.5 Measuring and Testing Equipment

19.5.1 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.

19.5.2 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.

19.6 Design Review :

19.6.1 Design review for power Transformer

19.6.1.1 The transformer shall be designed, manufactured and tested in accordance with the best international engineering practices under strict quality control to meet the requirement stipulated in the technical specification. The manufacturer will be required to demonstrate the adequate safety margin w.r.t thermal, mechanical, dielectric and electrical stress etc. shall be maintained during design, selection of raw material, manufacturing process etc. in order to achieve long life of transformer with least maintenance and to take into account the uncertainties of his design and manufacturing processes. The scope of such design review shall include but not limited to the requirement as mentioned at 16.6.2.

19.6.1.2 Design reviews shall be conducted by Purchaser or an appointed consultant during the procurement process for transformers; however the entire responsibility of design shall be with the manufacturer. Purchaser may also visit the manufacturer's works to inspect design, manufacturing and test facilities at any time.

19.6.1.3 The design review will commence after placement of award and shall be finalised before commencement of manufacturing activity. These design reviews shall be carried out in detail to the specific design with reference of the transformer under the scope. It shall be conducted generally following the "Guidelines for conducting design reviews for transformers -Guidelines for conducting design reviews for power transformers.

19.6.1.4 The manufacturer shall provide all necessary information and calculations to demonstrate that the transformer meets the requirements for short circuit strength and durability. The latest recommendations of IEC and CIGRE SC 12 shall be applied for short circuit withstand evaluation.

19.6.1.5 The validity of Type tests (except dynamic short circuit test) of Transformer shall be 5 years as on the date of NOA, provided that offered transformer is of same design as that of type tested transformer and active materials like – CRGO, copper conductor and insulation material are of same or better grade with respect to type tested unit. Failing which, type testing of transformer shall be carried out by the contractor at his own cost. Further, type test report of Transformer from the same manufacturing plant shall only be acceptable.

19.6.1.6 The design review shall be carried out preferably at employer's country.

19.6.2 Design Review Document for power transformer

SL	Description
1.	Core and Magnetic Design
2.	Over-fluxing characteristics upto $1.7U_m$
3.	Inrush-current characteristics while charging from HV & IV respectively.
4.	Winding and tapping design
5.	Short-circuit withstand capability including thermal stress for min. 2 Sec.
6.	Thermal design including review of localised potentially hot area.
7.	Cooling design
8.	Overload capability
9.	Eddy current losses
10.	Seismic design, as applicable
11.	Insulation co-ordination
12.	Tank and accessories
13.	Bushings
14.	Tap changers
15.	Protective devices
16.	Fans, pumps and radiators
17.	Sensors and protective devices– its location, fitment, securing and level of redundancy
18.	Oil and oil preservation system
19.	Corrosion protection
20.	Electrical and physical Interfaces with substation
21.	Earthing (Internal & External)
22.	Processing and assembly
23.	Testing capabilities
24.	Inspection and test plan
25.	Transport and storage
26.	Sensitivity of design to specified parameters
27.	Acoustic Noise
28.	Spares, inter-changeability and standardization
29.	Maintainability
30.	PRD and SPR (number & locations)
31.	Conservator capacity calculation
32.	Winding Clamping arrangement details with provisions for taking it

SL	Description
	"in or out of tank"
33.	Conductor insulation paper details
34.	Location of Optical temperature sensors
35.	The design of all current connections
36.	Location & size of the Valves

Detailed Data to be provided for Design review shall be provided during execution stage.

19.6.3 Design review for GIS

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

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

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

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

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

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

SL	Description
1.	Dielectric Stress of Solid Insulation like Gas Barrier, support insulator etc.
2.	Dielectric stress of SF6 Gas Volume.
3.	Mechanical strength of enclosure, expansion joints etc.
4.	Criteria for providing expansion joint.
5.	Sealing system
6.	Insulation coordination

SL	Description
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.

16.6.3.7. 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

16.6.3.8. The design review shall be carried out preferably at employers country.

19.7 Inspection Plan and Procedure

19.7.1 The Inspection Plan, as submitted by the Contractor to the Engineer for approval, shall cover the following:

- Relevant International Standard. For each of the following stages of the work, the acceptance criteria shall be stated.
- The stages of inspection which shall include but not be limited to the following:
  - Tests to review or approve certification of material;
  - Review and approval of manufacturing procedures;
  - Witnessing tests or review and approval of certification of operator's qualification to carry out the work required;
  - Visual and dimensional examination of components;
  - Pressure tests on casings and vessels;
  - Non-destructive examination of materials in progress;
  - Functional tests on sub-assemblies, performance tests, type tests on complete units;
  - Examination of painting, packing and documentation for shipment.

19.7.2 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.

19.8 Test Certificates

19.8.1 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.

19.8.2 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

19.8.3 All test documentation shall be in the English language.

19.9 Material Tests

19.9.1 The Contractor shall provide test pieces as required by the Engineer to enable him to confirm the quality of the material supplied under the Contract. Such test pieces shall be prepared and supplied free of charge and any cost of the tests shall be borne by the Contractor.

19.9.2 If any test piece fails to comply with the requirements of the appropriate specifications for the material in question, the Engineer may reject the whole of the material represented by that test piece; the Contractor's or Subcontractor's designers and metallurgists will be consulted before any material is so rejected.

19.9.3 If the Engineer is furnished with certified particulars of tests which have been carried out for the Contractor by the suppliers of material, he may, at his own discretion, dispense with the previously mentioned tests.

19.10 General Requirements for Tests at Manufacturers' Works

19.10.1 Testing of Plant

19.10.1.1 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.

19.10.1.2 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.

19.10.1.3 Should the plant or any portion thereof fail under test to give the required performance, further tests which are considered necessary by the Engineer shall be carried out by the Contractor and the whole cost of the repeated tests borne by the Contractor. This also applies to tests carried out at the Subcontractors' works.

19.10.1.4 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.

19.10.1.5 If the plant, or any portion thereof, fails under test to give the required performance, such further tests which are considered necessary by the Engineer shall be carried out by the Contractor and the whole cost of the repeated tests shall be borne by the Contractor. This also applies to tests carried out at Subcontractors' works.

19.10.1.6 Tests shall be conducted in accordance with the specified standards. When no standards are specified, the test procedure shall be agreed between the Employer and the Contractor.

19.10.1.7 Specific details of tests to be carried out at the Manufacturers' works are defined elsewhere in this Specification.

19.10.2 Rejection of Plant

19.10.2.1 If any item fails to comply with the requirements of this Specification in any respect whatsoever at any stage of manufacture, test, erection or on completion at Site, the Engineer may reject the item, or defective component thereof, whichever he considers necessary, and after adjustment or modification as directed by the Engineer, the Contractor shall submit the item for further inspection and/or test.

19.10.2.2 In the event of a defect on any item being of such a nature that the requirements of this Specification cannot be fulfilled by adjustment or modification, such item is to be replaced by the Contractor, at his own expense, to the entire satisfaction of the Employer.

19.11 Specific Requirements for Tests at Manufacturers' Factories

19.11.1 Pressure Vessels

a) All pressure vessels shall be designed, fabricated, inspected and tested in accordance with an approved pressure vessel code or standard.
b) An approved method of radiographic or other non-destructive testing shall be used for proving all welding, at all positions of possible high stress concentration, such as large branch welds, and their vicinities after all heat treatment is completed. This shall be done whatever the programme of non-destructive testing before heat treatment.
c) Hydrostatic test shall be conducted in accordance with BS 5500.

19.11.2 Substation Automation System, Control, Relay Protection and Metering

19.11.2.1 **All** equipment for substation automation system, control, relay protection and metering shall be fully assembled at the Manufacturer's works and subject to the complete routine and functional test

19.11.2.2 For factory acceptance test all equipment for substation automation system, control, relay protection and metering, for each substation, shall be fully assembled at the Manufacturer's works and subjected to visual and functional tests

19.11.2.3 All control and relays and associated equipment shall be routine tested to prove the quality and accuracy. Routine tests shall be in accordance with relevant IEC Recommendations supplemented by additional tests as are considered necessary by the Employer. Routine test reports shall be submitted for each relay and piece of equipment. The reports shall record all measurements taken during the tests.

19.11.2.4 All relays shall be subjected to the appropriate routine tests as listed below, the individual tests being as detailed in IEC 60255 or as otherwise agreed with the Employer.

- Accuracy of calibrated pick-up and drop-off levels over the effective range of settings
- Insulation tests
- Accuracy of timing elements
- Correct operation of flag (or other) indicators
- Mechanical requirements, integrity/safety of draw-out units, check of contact pressure and alignment.

19.11.3 Wiring

19.11.3.1 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.

19.11.3.2 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.

19.11.3.3 For directional relays phase-shifting transformers shall be used to determine the maximum torque angle and the boundaries of operation/restraint.

19.11.3.4 Other relays shall be fully tested in accordance with the Manufacturer's recommendations.

19.11.3.5 All DC elements of protection relays shall be tested for operation at 70% rated voltage.

19.11.3.6 All DC supplies shall be checked for severity of current inrush when energised by switching on or inserting fuses or links.

19.11.4 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.

19.11.4.1 General

Sufficient tests shall be performed on the relays and protection schemes to:

- establish that the correct equipment has been supplied and installed.
- confirm that the various items of equipment have been correctly interconnected.
- confirm performance of schemes designed on the bases of calculation e.g. differential protection.
- to provide a set of figures for comparison with future maintenance values allowing the condition of the equipment to be determined.

19.11.4.2 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.

19.11.4.3 Primary Injection

All current operated relays shall be tested by injection of primary current to record the actual relay setting and as a final proof of the integrity of all secondary connections.

The stability of all differential schemes shall be checked by injection of primary current.

Primary current injection tests are to be carried out by the Contractor and the methods employed for a particular installation are to be agreed with the Engineer.

Tests are to be carried out as follows:

- Local primary injection to establish the ratio and polarity of current transformers as a group, care being taken to prove the identity of current transformers of similar ratio.
- Overall primary injection to prove correct interconnection between current transformer groups and associated relays.
- Fault setting tests, where possible, to establish the value of current necessary to produce operation of the relays.

19.11.4.4 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.

19.11.4.5 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 fool-proof operation and/or resetting. The functional and safety aspects of all shorting and/or isolation links, fuses and switches devices shall be proved.

The total burdens connected to all voltage transformer circuits shall be measured and recorded.

The total capacitance of all wiring and apparatus connected to the negative pole of each main tripping battery shall be measured and recorded; the value shall not exceed 10 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 circuit breaker (or other device) both open and closed.

19.11.5 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 supplemented by additional tests as are considered necessary by the Employer. Routine test reports shall be submitted for each relay and piece of equipment. The reports shall record all measurements taken during the tests.

All relays shall be subjected to the appropriate routine tests as listed below, the individual tests being as detailed in IEC 60255 or as otherwise agreed with the Employer.

- Accuracy of calibrated pick-up and drop-off levels over the effective range of settings
- Insulation tests
- Accuracy of timing elements
- Correct operation of flag (or other) indicators
- Mechanical requirements, integrity/safety of draw-out units, check of contact pressure and alignment.

19.11.6 Electrical Instruments and Meters

One instrument and meter of each type and rating shall be subjected to the tests as specified in IEC 60051.

19.11.7 AC Switchboards

Routine tests shall include general inspection and electrical operation tests.

19.11.8 Contactors

One contactor of each type and rating shall be subjected to type tests as specified in IEC 60292-1.

19.11.9 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.

19.11.10 Switchgear (Other than GIS)

All circuit breakers shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 62271-100.

For factory acceptance test one or at least 20% of the circuit breakers of each type, shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 62271-100.

19.11.11 Disconnectors and Earth Switches

All disconnectors and earthing switches shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 62271-102.

19.11.12 Current and Voltage Transformers

All current transformers and voltage transformers shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 61869.

19.11.13 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.

19.11.14 Surge Arresters

All surge arresters shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 60099-4.

For factory acceptance test three or at least 20 % of the surge arresters of each type, shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 60044.

19.11.15 Batteries and Battery Chargers

Battery:	The Contractor shall demonstrate that the battery will perform the duties specified.
Battery charger:	Routine tests according to IEC 60146 (BS 4417)
DC Switchboard:	Routine tests according to IEC 60439 (BS 5486:Part 1)

Complete charge and discharge tests on each of the combined batteries and chargers shall be conducted and results recorded so as to permit verification of the ampere-hour capacity of the battery.

During these tests the Engineer shall select at random reference cells and the voltage curves thereof shall be checked when the battery is discharged over three and ten hour periods. The alarm levels and the automatic voltage control feature of the charger shall be demonstrated over the specified load range. Where load changeover facilities are included, integrity of the changeover system without break or voltage variations during loading of the standby or test charger shall be demonstrated.

For factory acceptance test two or at least 20 % of the battery & charger, shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 60044.

19.11.16 Control Panels

Routine operation tests and insulation resistance tests shall be carried out.

19.11.17 Busbars

Routine tests including millivolt drop tests shall be carried out in accordance with the specified standard.

19.11.18 Instruments

Calibration tests shall be witnessed on all important pressure gauges and other instruments as required by the Engineer.

19.11.19 Neutral Earthing Resistor

Routine leakage and over voltage tests.
Bushing insulator wet flashover tests (internal and external).

19.11.20 Power Transformers

Inspection and testing during manufacture shall be in accordance with the General Conditions of Contract and this section of the Specification.

Works tests shall include all routine electrical, mechanical and hydraulic tests in accordance with the relevant IEC Standard, except where departures therefrom and modifications thereto are embodied in this Specification. For Plant not covered by any IEC Standard or specifically mentioned in this Specification, such tests as are relevant shall be agreed with the Engineer.

Should the Plant, or any portion thereof, fail under test to give the required performance, further tests which are considered necessary by the Engineer shall be carried out by the Contractor and the whole costs of the repeated tests borne by the Contractor. This also applies to tests carried out at the Subcontractors' works.

After satisfactory completion of the witnessed tests at the Works, the Plant shall be submitted for the Employer's approval during dismantling preparatory to shipment. No item of Plant is to be despatched to Site until the Employer has given his approval in writing.

All power transformers shall be fully assembled at the Manufacturer's works and subjected to routine testes and special tests

For factory acceptance test all power transformers shall be fully assembled at the Manufacturer's works and subjected to repetition of the all routine testes and special tests

19.11.20.1 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.

Following minimum test shall be performed as Routine test-

- Measurement of winding resistance on all tap positions and phases.
- Ratio, polarity and phase relationship.
- Impedance voltage.
- Load loss at normal, maximum and minimum taps.
- No load loss and no load current at normal voltage Un and at +5% Un and at +10% Un.
- Magnetising current at nominal voltage Un and at -5% Un and +5% Un and at +10% Un.
- Insulation resistance.
- Dielectric withstand tests:
  - On uniformly insulated windings with highest voltage Um = 36kV, tests shall comprise:
    - induced over voltage withstand.
    - short duration power frequency voltage withstand.
    - full wave lightning impulse withstand for line terminals.
    - lightning impulse chopped wave at 115% of the full wave level.
  - On non-uniformly insulated windings with highest voltage Um 145 W, tests shall comprise:
    - induced over voltage withstand combined with partial discharge.
    - short duration power frequency voltage withstand.
    - full wave lightning impulse withstand for line terminals.
    - lightning impulse chopped wave at 115% of the full wave level.
  - On non-uniformly insulated windings with highest voltage Um = 245kV, tests shall be carried out according to a combination of methods 1 and 2 and comprise:
    - short duration power frequency voltage withstand.
    - induced line to earth overvoltage withstand test at 460kV (method one routine test).
    - full wave lightning impulse withstand for line terminals.
    - lightning impulse chopped wave, at 115% of the full wave level.
    - induced power frequency overvoltage withstand test with partial discharge measurement.
- All other test as per section 04 of this specification

For detailed test procedure, please refer to section 04 of this specification

Type Tests

- Temperature rise test:

  As per section 04 of this specification

- Noise level tests:

  As per section 04 of this specification

Special Tests

- Measurement of Zero Phase - Sequence Impedance

  The test shall be in accordance with IEC 60076-1 Clause 8.7 and shall be carried out on one transformer of each type.

- All other test as per section 04 of this specification

19.11.20.2 Voltage Control Equipment

Routine Tests

Each finished tap changer shall be subjected to the routine tests specified in JEC.214 but in addition the mechanical test shall be carried out at rated voltage and no load.

Type Tests

Shall be carried out entirely in accordance with IEC 60214 except that evidence of the service duty type test shall be in excess of 100,000 operations.

19.11.20.3 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.

19.11.21 Outdoor Bushing Assemblies with Porcelain Insulators

Hollow insulators tested in accordance with IEC 60233
Complete bushings tested in accordance with IEC 60137

Routine Tests

Routine tests shall include:

- Oil leakage test
- 50Hz dry withstand test
- Power factor/voltage test
- Partial discharge test on all bushings of which the major insulation is either oil impregnated paper or resin impregnated paper.

19.11.22 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 to69 kN/m² or the normal pressure plus 34kN/m² whichever is the greater, for 24 hours during which time no leakage or oil ingress into normally oil free spaces shall occur.

19.11.23 Cooling Plant

Routine Tests

- Coolers: Pressure test to be as specified above.
- Motors and Control Gear: To the requirements as specified.

19.11.24 Gas and Oil-Actuated Relays

Routine Tests

- Oil leakage:When subject to an internal oil pressure of 207kN/m² for fifteen minutes.
- Gas collection
- Oil surge
- Performance test under service conditions. Voltage: 2kV for one minute between electrical circuits and casing.

19.11.25 Galvanizing

Routine Tests

To the requirements of BS 443 or BS 729 whichever is applicable

19.11.26 Earthing Transformers

Routine Tests

- Measurement of winding resistance
- Ratio, polarity and phase relationships
- Measurement of impedance voltage
- Measurement of loss
- Short duration power frequency voltage-withstand test
- Induced overvoltage withstand test
- Insulation resistance of each winding

Special Tests

- Measurement of zero-phase sequence impedance

19.11.27 GIS Equipment, when applicable

Clause reference of type tests and routine tests are listed below. Any other tests specified by the referred standard (current and future issues) but not listed shall be applicable as well.

Type tests shall have been carried out on the switchgear components in accordance with the relevant IEC Standards. Limiting values obtained during Type Test shall form basis for Factory Acceptance Tests. The limiting values shall be highlighted in the Routine Test Reports/Witness Tests.

Routine Tests

(a) One Complete Bay

IEC 62271-203 clause

7.1.1 Power-frequency voltage tests on the main circuit

7.1.2 Partial discharge measurement

7.2 Tests on auxiliary and control circuits

7.3 Measurement of the resistance of the main circuit

7.4 Tightness test

7.101 Pressure tests of enclosures

7.102 Mechanical operation tests

7.103 Tests of auxiliary circuits, equipment and interlocks in the control mechanism

7.104 Pressure test on partitions

19.11.28 Fibre Optic Multiplexer Equipment

Works tests shall be in accordance with the IEC standard.

19.11.29 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.

19.11.30 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.

19.11.31 Transducers

Transducers shall be tested in accordance with IEC 60688-1.

19.12 Dismantling Prior to Shipment

After the satisfactory completion of all tests at the factory, the plant shall be submitted for the Engineer's approval during dismantling preparatory to shipping. No item of plant shall be despatched to site until the Engineer has given approval in writing.

19.13 Inspection and Testing during Site Erection

19.13.1 General

The Contractor shall be responsible for the submission to the Engineer of all plant supplied under the Contract for inspection and testing during site erection, to ensure correct erection and compliance with the Specification.

During the course of erection, the Contractor shall provide access as required by the Engineer for inspecting the progress of the works and checking its accuracy to any extent that may be required.

The Contractor shall provide, at his own cost, all 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 Contractor in accordance with the General Conditions of Contract. The Contractor 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 Contractor shall submit a written programme of tests and checks according to this Clause for the approval of the Engineer.

A brief description of all tests and testing procedures shall be provided before tests commence and the method of testing, unless otherwise specified, shall be agreed with the Engineer.

The Contractor shall provide experienced test personnel and testing shall be carried out during normal working hours as far as is practicable. Tests which involve existing apparatus and outages may be carried out outside normal working hours. The Contractor shall give sufficient notice to allow for the necessary outage arrangements to be made in conformity with the testing programme.

The Contractor shall advise the Engineer in writing, at the time of commencement of site erection, of the site supplies which will be required for the operation of the test

equipment, to enable the Engineer to arrange accordingly or to agree alternative arrangements should this be necessary.

The Contractor 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 Contractor 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 Contractor's test equipment shall be of satisfactory quality and condition and, where necessary, shall be appropriately calibrated by an approved authority at the Contractor's expense. Details of the test equipment and instruments used shall be noted in the test sheets in cases where the instrument or equipment characteristics can have a beating on the test results.

The testing requirements detailed under this Specification may be subject to some variation upon the instruction or agreement of the Engineer where necessitated by changed conditions at Site or by differing design, manufacture, or construction techniques.

The Bidder is required to submit proposals for site dielectric tests and to include in his price the costs of such tests and of such equipment as deemed necessary.

19.13.2 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 Contractor.

b) Checking the alignment of rotating equipment to the Manufacturer's requirements.

c) Non-destructive 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 than 4.5 bar for a period of 2 hours, or at such other conditions as may be required by the pipework design code.

Air piping shall be subjected to an air pressure test rather than a hydrostatic test.

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 non-drainable sections shall be injected with an oxygen-absorbent 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 Contractor 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 Contractor shall state in the Schedule of Guarantees the fall in vacuum anticipated during this period but the rate of fall shall not exceed that which would occur due to the designed air leakage rate being attained.

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.

19.13.3 Electrical Equipment

19.13.3.1 General

A general check of all the main switchgear and ancillary equipment shall be made and shall include a check of the completeness, correctness and condition of earth connections, 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:

- Routine high voltage tests to the appropriate IEC Standard. Where no relevant standard exists, tests shall be agreed with the Engineer.
- Insulation resistance tests on all electrical equipment.
- Continuity and conductivity resistance tests.
- Test operation of alarm and tripping, devices to local and remote.
- Rotational tests on all motors.
- Polarity tests on CTs and VTs.
- Oil tests.
- Grounding system and electrode tests.
- Ratio, Vector Grouping and magnetising current tests on each transformer.
- Calibration of winding and oil temperature devices.
- Vector group and phasing tests on VT circuits.
- Magnetisation current/voltage tests and winding resistance tests on all current transformers.
- Primary and secondary injection tests on relays, protection devices and equipment.

19.13.3.2 Circuit breakers

Circuit breakers shall be visually inspected.In the case of gas type circuit breakers testing will be required on the gas system to prove the gas pressure, quantity, dryness and dielectric strength.

Contact resistance tests shall be carried out. In the case of multi-interrupter circuit breakers resistance tests will be required at each interrupter or pair of interrupters as well as through the series of interrupters on each pole.

Operational tests shall include local and remote trip/close. Timing tests shall be carried out on all circuit breakers, except those which are below 66kV and which are neither assembled at Site nor have mechanically ganged pole operation.

Local air components associated with 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.

19.13.3.3 Disconnectors and Earth Switches

Manual operation of disconnectors and earth switches shall be subject to operational tests to confirm contact pressures, contact resistances, simultaneous operation of all phases and the ease of operation.

Motorised operation of disconnectors, and earth switches shall be tested to prove the motor operation, including local and remote operation, and timing tests shall also be carried out. Motor protection shall be tested.

Checks shall be made on interlocks, local and remote indications and operation of auxiliary contacts.

Earth switches shall be tested to confirm the opening and closing sequences and checks shall be made on interlocks, indications and manual locking devices.

19.13.3.4 Busbars and Connections

Flexible busbars and connections shall be tested to ensure that the correct tensions, sags and clearances will be maintained over the range of environmental conditions and loads without stress to other equipment. If dynamometers are used to check the sags and tensions, they shall be checked both before and after use.

Rigid busbars and connections shall be tested to ensure that the busbars will not cause overloading of the supporting insulators under load conditions and under the range of climatic variations applicable to the site and that expansion and contraction of the equipment is fully accommodated by flexible connections.

Conductivity tests shall be carried out on all connections and joints which are made on site, without exception.

19.13.3.5 Earthing System

Tests shall be made on the effectiveness of the bonding and earthing which will include conductivity tests on selected joints, on the main earthing system, and at the connections to equipment and structures. Checks shall also be made on precautions taken to avoid corrosion. attack on the earthing system.

Test probes at approximately 300 and 600 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:

- of each earth rod after driving

- of the earth grid after completion and backfilling of the trenches
- of each group of earth rods or earth point after completion of the connection from the test link terminal
- of the completed installation without any connections outside the substation

The tests shall be carried out by a method and with equipment approved by the Engineer. All tests are to be witnessed and the equipment and method used recorded with the test results.

The Contractor may also be called upon to provide assistance in the measurement of earth resistance after earth connections to the system have been completed.

19.13.3.6 Control Relays and Metering Panels, Instruments and Protective Devices

a) Wiring

- After complete erection and cabling, all circuits shall be subjected to the high voltage test specified in the relevant IEC or approved standard.
- The insulation resistance of all circuits shall be measured before and after any high voltage tests.
- For AC secondary injection tests a substantially sinusoidal test supply shall be used.
- The operating and resetting level (current and/or voltage) and timing of all relays shall be measured over an agreed range of settings for all relays.
- For directional relays phase-shifting transformers shall be used to determine the maximum torque angle and the boundaries of operation/restraint.
- Other relays shall be fully tested in accordance with the Manufacturer's recommendations.
- All DC elements of protection relays shall be tested for operation at 70% rated voltage.
- All DC supplies shall be checked for 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:

- establish that the equipment has not suffered damage during transit.
- establish that the correct equipment has been supplied and installed.

- confirm that the various items of equipment have been correctly interconnected.
- confirm performance of schemes designed on the bases of calculation e.g. differential protection.
- to provide a set of figures for comparison with future maintenance values allowing the condition of the equipment to be determined.

d) Secondary Injection

- Secondary injection shall be carried out on all AC relays, using voltage and current of sinusoidal wave form and rated power frequency to confirm satisfactory operation and range adjustment.
- The polar characteristic of all distance protections shall be recorded at a minimum of 30 degree intervals.
- For circulating current protection employing high impedance voltage operated relays, the points of injection for relay voltage setting tests shall be across the relay and stabilizing resistance.
- The fault setting for the type of protection is to be established by secondary injection, where it is impracticable to ascertain this value by primary injection. Injection is to be made across the appropriate relay bus wires with all associated relays, setting resistors, and CT's connected.

e) Primary Injection

- All current operated relays shall be tested by injection of primary current to record the actual relay setting and as a final proof of the integrity of all secondary connections.
- The stability of all differential schemes shall be checked by injection of primary current.
- Primary current injection tests are to be carried out by the Contractor and the methods employed for a particular installation are to be agreed with the Engineer.
- Tests are to be carried out as follows:
  - Local primary injection to establish the ratio and polarity of current transformers as a group, care being taken to prove the identity of current transformers of similar ratio.
  - Overall primary injection to prove correct interconnection between current transformer groups and associated relays.
  - Fault setting tests, where possible, to establish the value of current necessary to produce operation of the relays.

f) DC Operations

Tests are to be carried out to prove the correctness of all DC polarities, the operating levels of DC relays and the correct functioning of DC relay schemes, selection and control switching, indications and alarms. The correct functioning of all isolation links and fuses shall also be checked.

g) Tests on Load

- Tests on load shall also be done to demonstrate stability and operation of protection relays as required by the Engineer.
- All tripping, control, alarm and interlocking circuits shall be functionally tested to prove satisfactory and fool-proof operation and/or resetting. The functional and safety aspects of all shorting and/or isolation links, fuses and switches devices shall be proved.
- The total burdens connected to all voltage transformer circuits shall be measured and recorded.
- The total capacitance of all wiring and apparatus connected to the negative pole of each main tripping battery shall be measured and recorded; the value shall not exceed 10 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 circuit breaker (or other device) both open and closed.

19.13.3.7 Batteries and Chargers

Tests shall be carried out on the batteries and chargers to confirm the charger ratings and adjustment, the battery and charger alarm systems and battery capacity.

The open-circuit cell voltages of the batteries when fully charged shall be recorded.

The insulation to earth of the complete DC installation shall be tested.

19.13.3.8 Power Cables

Each completed circuit shall be tested for continuity and insulation resistance.

19.13.3.9 Current Transformers

A magnetisation curve shall be obtained for each current transformer in order to:

- Detect damage in transit or installation
- Prove that the correct cores have been wired out to the relevant terminals
- For high impedance relay schemes, to confirm that correct relay settings have been calculated.

The DC resistance of each current transformer secondary winding shall be measured and also the 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.

19.13.3.10 Voltage Transformers

The transformer ratio and polarity shall be checked using a primary voltage high enough to give a clearly measurable secondary voltage or by using rated primary voltage and comparison with an already proven voltage transformer. The phasing and phase rotation shall be checked. For three phase voltage 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.

19.13.3.11 Control and Instrumentation Equipment

The following general tests shall be performed on control and instrumentation equipment at site:

- High voltage testing of all circuits, as specified in the relevant IEC or approved standard.
- Insulation resistance testing of all circuits.
- Functional tests of all tripping, control, alarm and interlocking circuits.
- The testing of all equipment in accordance with the Manufacturer's instructions or as advised by the Engineer.

19.13.3.12 Transformers and Ancillary Equipment

The following tests shall be performed:

- Insulation resistance tests on bushings.
- Insulation resistance test at 500V between core and core clamping structure.
- Voltage withstand tests on insulating oil to BS 148.
- Ratio.
- Phase relationship.
- Magnetisation characteristics of current transformers of winding temperature devices.
- Calibration of winding temperature devices.
- Tap Selector and Diverter Switch alignment.
- Calibration of automatic voltage control equipment.
- Proving tests as necessary on control schemes.

- Measurement of winding resistance on all taps and phases.

Where applicable the above tests shall also be carried out on earthing transformers.

19.13.3.13 FOX, Teleprotection and Communication

Tests shall be exhaustive and shall demonstrate that the overall performance satisfies every requirement specified.The following tests shall be carried out:

- Physical inspection unit testing and demonstration of diagnostic aids as appropriate of al equipment in stand-alone mode.
- System testing of 48V power supply equipment.
- System testing of FOX equipment for speech and teleprotection.
- System testing of telephone equipment.
- System testing of teleprotection equipment to plant.

19.14 Staffing

19.14.1 During pre-commissioning the Contractor shall provide all necessary supervisory and operating staff.

19.14.2 The only involvement of the Employer's staff will be in accordance with the training and instruction as in this specification.

19.14.3 During the commissioning phase, the Employer's operating staff will operate plant and equipment under the supervision of the Contractor's supervisors.

19.14.4 The Contractor shall have satisfied himself as to the capability of the Employer's operators to carry out such operations as he may direct and shall remain responsible for the successful performance of such operations. Throughout the whole of the Commissioning Period the Contractor shall provide suitably qualified and experienced operating staff, who shall instruct the Employer's staff in the correct operating procedures.

19.14.5 The Contractor shall provide a team of suitably qualified and experienced engineers and technicians to pre-commission and commission the overall plant. The Contractor shall also ensure that a suitably qualified commissioning engineer from the respective

Manufacturer's own service organisation shall visit the site to check the erection or installation of each significant plant item, and to supervise the commissioning of the plant item until the basic functioning of the item has been demonstrated to the Engineer's satisfaction.

19.14.6 At all times the Contractor shall ensure that his staff and any Subcontractor's or seconded staff, observe all prescribed safety rules and permit systems.

19.15 Taking Over

19.15.1 After satisfactory completion of the tests on completion, the Engineer will issue a Taking Over Certificate for the plant. The issue of any such certificate shall not however relieve the Contractor of any of his responsibilities in respect of proving that the performance of the plant meets the guaranteed values.

19.15.2 The Taking Over Certificate shall make reference to a schedule of outstanding minor defects and omissions which have been accepted by the Engineer as not affecting the full and safe operation of the plant. The Contractor shall rectify such defects and omissions not later than 3 months after Taking Over.

19.15.3 The date certified in the Taking Over Certificate shall be the date on which the tests on completion were completed.

19.16 Defects after Taking Over

19.16.1 In accordance with the General Conditions of Contract, the Contractor shall be responsible for making good defects or damage which may appear or occur during a 12-month guarantee period from the date certified in the Taking Over Certificate.

19.16.2 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.

19.16.3 Immediately prior to the completion of this period the Employer reserves the right to request the Contractor to open up for inspection the whole or any part of the Plant. The Employer will provide the labour to work under the direct supervision of the Contractor's representative for the purpose of such inspection.

19.16.4 The Contractor shall submit for approval the arrangements he intends making under this Contract for the making good of defects and for providing the supervisory service detailed above.

19.17 Final Acceptance Certificate

Application for the Final Certificate may be made to the Engineer after the Contractor has ceased to be under any obligation under the Contract. This shall include the submission of final contract record drawings and fully bound version of the Installation, Operation and Maintenance Manuals. If a Taking-Over Certificate has been issued in respect of any Section or Portion of the Works, only one Final Certificate will be issued after all the said obligation has ceased. Final Certificate will be issued after all the said obligation has ceased. Where the Contractor has carried out replacements or renewals to the Works, the Contractor's obligations shall continue, but the right of the Contractor to apply for a Final Certificate other than for the replacements or renewals shall not be affected by that fact.

20. DRAWINGS FORMING PART OF THE SPECIFICATION

Bid Drawings

20.1 General

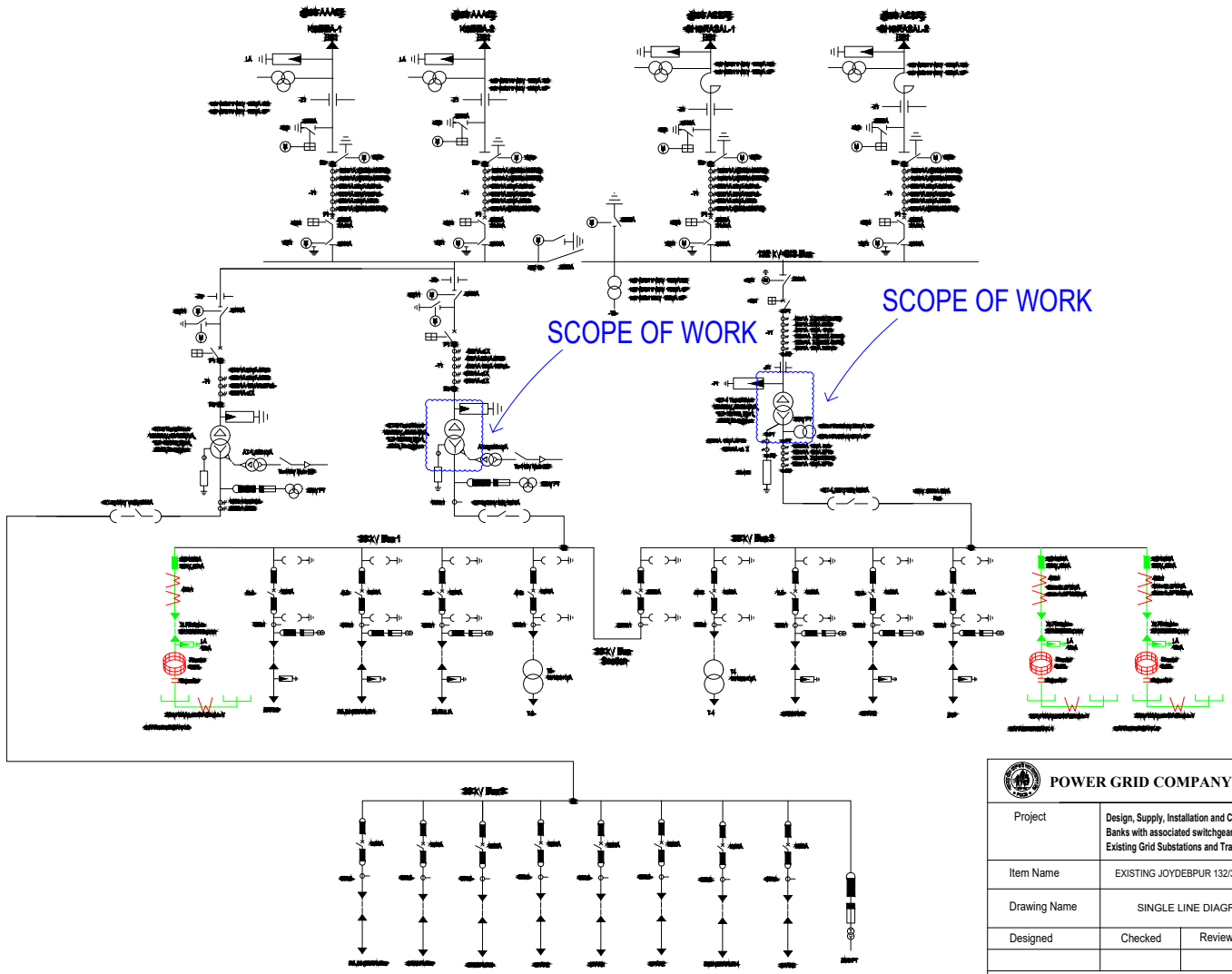
The drawings provided in this section are solely for the purpose of bid information and bid preparation. Therefore, the bid drawings shall not be considered for& as final design & costing accordingly .Final design shall be as per Employers approval during execution stage. Bidders are to consider such issues in their bids.

20.2 List of Bid Drawings

	Drawing No.	Drawing Title
1	PGCB_DESIGN_2021_CEEGSTL_P2L2_JOYDEBPUR_E 01	Single Line Diagram of Joydebpur 132/33kV Grid Substation
2	PGCB_DESIGN_2021_CEEGSTL_P2L2_JOYDEBPUR_E 02	Layout of Joydebpur 132/33kV Grid Substation (132kV side)
3	Deleted	
4	Deleted	
5	Deleted	
6	Deleted	
7	PGCB_DESIGN_2021_CEEGSTL_P2L2_LALMONIRHA T_E07	Single Line Diagram of Lalmonirhat 132/33kV Grid Substation
8	PGCB_DESIGN_2021_CEEGSTL_P2L2_LALMONIRHA T_E08	Layout of Lalmonirhat 132/33kV Grid Substation
9	PGCB_DESIGN_2021_CEEGSTL_P2L2_RAJENDRAPU R_E09	Single Line Diagram of Rajendrapur 132/33kV Grid Substation
10	PGCB_DESIGN_2021_CEEGSTL_P2L2_RAJENDRAPU R_E10	Layout of Rajendrapur 132/33kV Grid Substation
11	Deleted	
12	Deleted	
13	Deleted	
14	Deleted	
15	PGCB_DESIGN_2021_CEEGSTL_P2L2_JOYDEBPUR_E 15	Layout of Joydebpur 132/33kV Grid Substation (33kV side)

16	PGCB_DESIGN_2021_CEEGSTL_P2L2_PROTECTION_E16	Protection SLD for 132kV Line Feeder
17	PGCB_DESIGN_2021_CEEGSTL_P2L2_PROTECTION_E17	Protection SLD for 132kV Transformer Feeder
18	PGCB_DESIGN_2021_CEEGSTL_P2L2_PROTECTION_E18	Three Line Diagram of 33kV Capacitor Bank
19	PGCB_DESIGN_2021_CEEGSTL_P2L2_PROTECTION_E19	Protection SLD for 33kV Capacitor Bank
20	PGCB_DESIGN_2021_CEEGSTL_P2L2_C01	Switchyard Gravelling and Relative Levels of Different Structures
21	PGCB_DESIGN_2021_CEEGSTL_P2L2_C02	Typical Road sections
22	PGCB_DESIGN_2021_CEEGSTL_P2L2_C03	Typical Section of Chain linked fencing
23	PGCB_DESIGN_2021_CEEGSTL_P2L2_C04	Slpoe (1V:2H) protection with turfing
24	PGCB_DESIGN_2021_CEEGSTL_P2L2_C05	Typical Trench of 230kV/400kV Cables
25	PGCB_DESIGN_2021_CEEGSTL_P2L2_C06	Typical Road Crossing for 230kV/400kV Cables

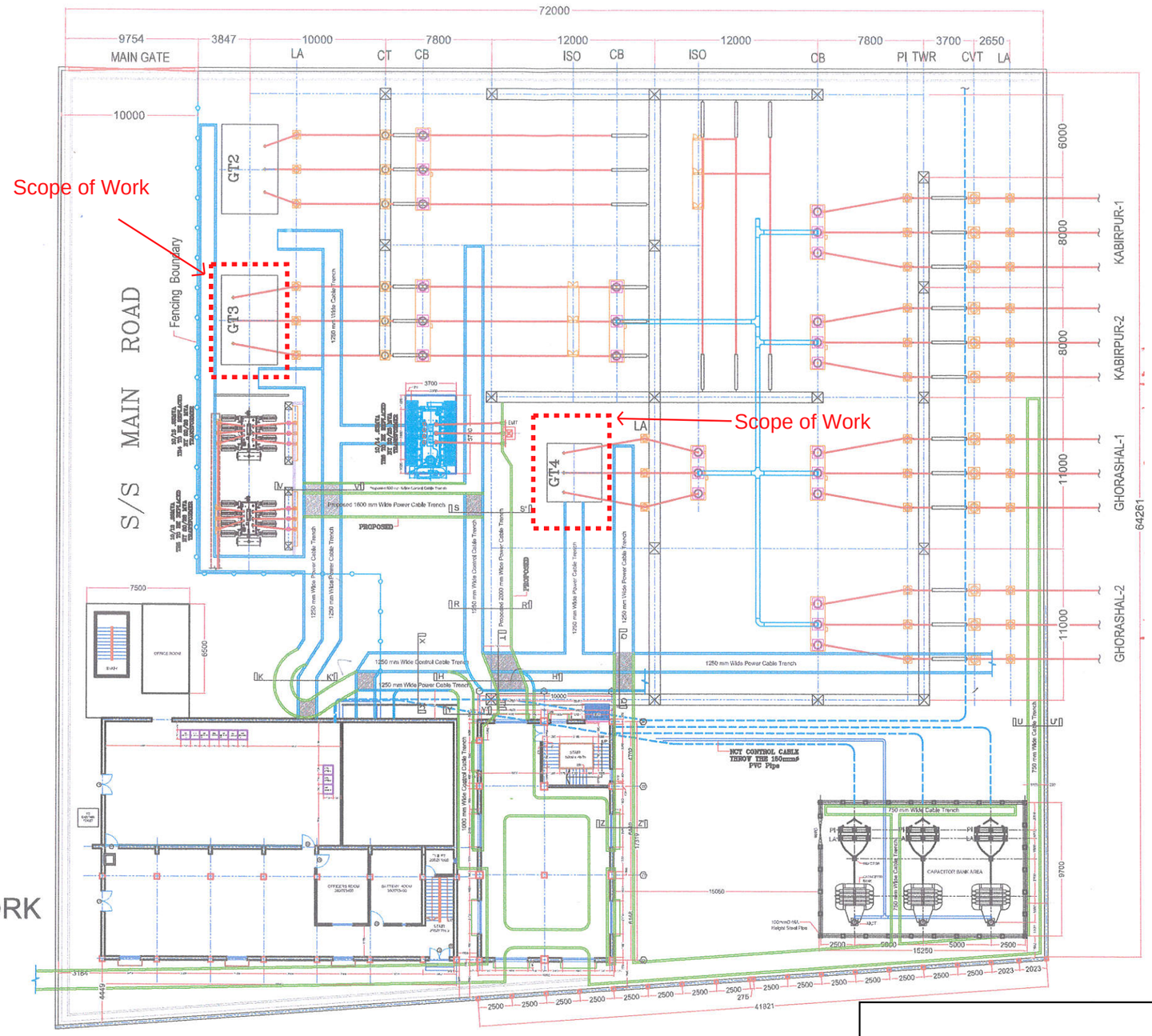
Single Line Diagram of Joydevpur 132/33 kV Grid Sub-Station (MD-Dhaka(North), PGCB



POWER GRID COMPANY OF BANGLADESH LIMITED

Project	Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package-2, Lot-2)				
Item Name	EXISTING JOYDEBPUR 132/33 kV AIS SUBSTATION				
Drawing Name	SINGLE LINE DIAGRAM				
Designed	Checked	Reviewed	Approved	Rev.	
				Date	
Drawing. No. PGCB/DESIGN/2021/CEEGSTL/P2L2/JOYDEBPUR/E01					

OPTION-02



LEGEND:

SCOPE OF WORK

EXISTING

N

Proposed Control Room Layout Plan of
Ground Floor at Joydebpur 132 /33 /11kv Sub-Station

Rev.	Date	Remarks	CAD By	Engineer
A	04.01.2022	Design Approval	M. A. SALAM	Md. Shahin Khan

Project:

Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package-2, Lot-2)

Title:

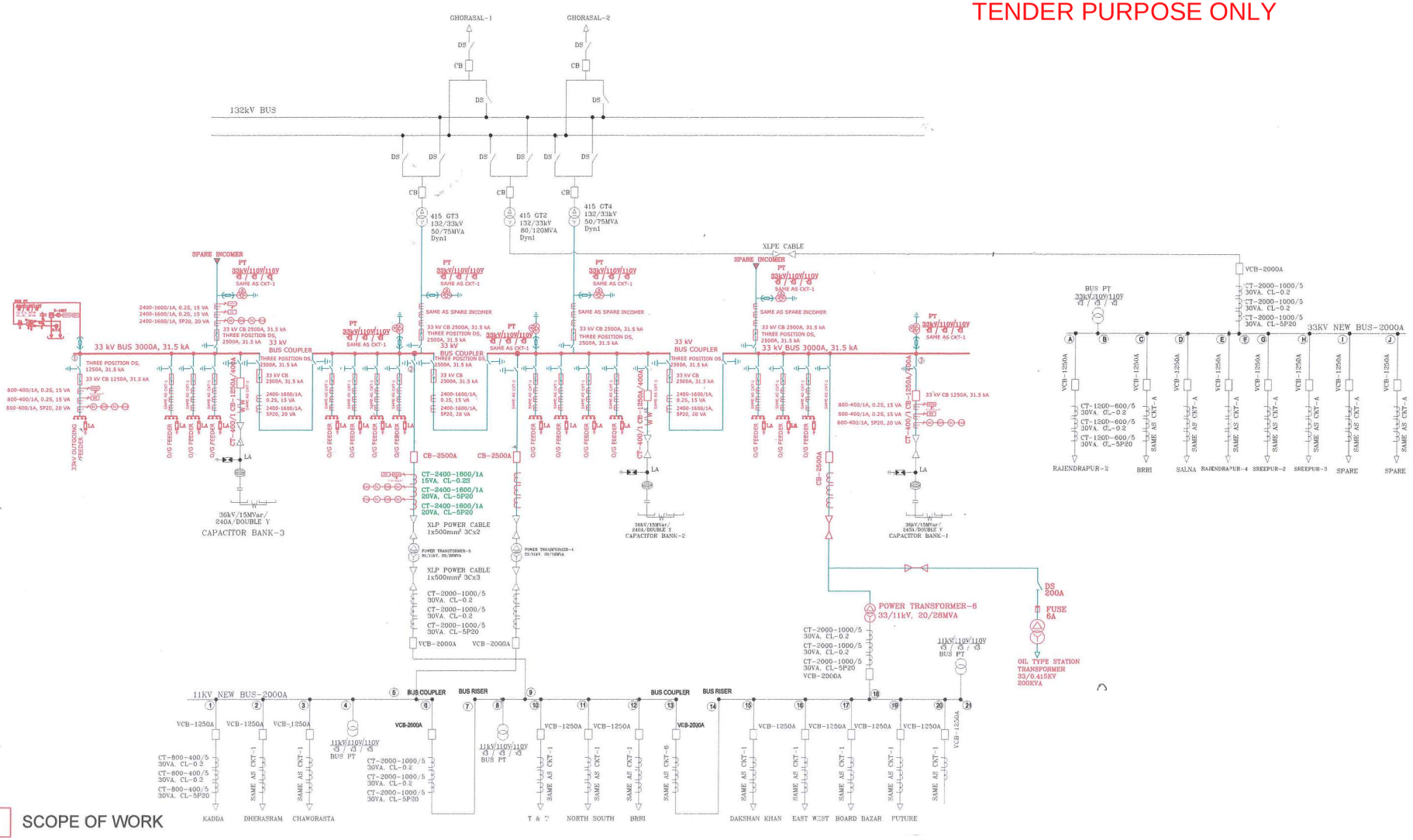
Electrical Layout of Joydebpur 132/33kV grid substation

Tender Ref. No:

PGCB/DESIGN/2021/CEEGSTL/P2L2/JOYDEBPUR/E02

Scale: None **Rev:** A Sheet No: **01**

TENDER PURPOSE ONLY



LEGEND:

SCOPE OF WORK

EXISTING

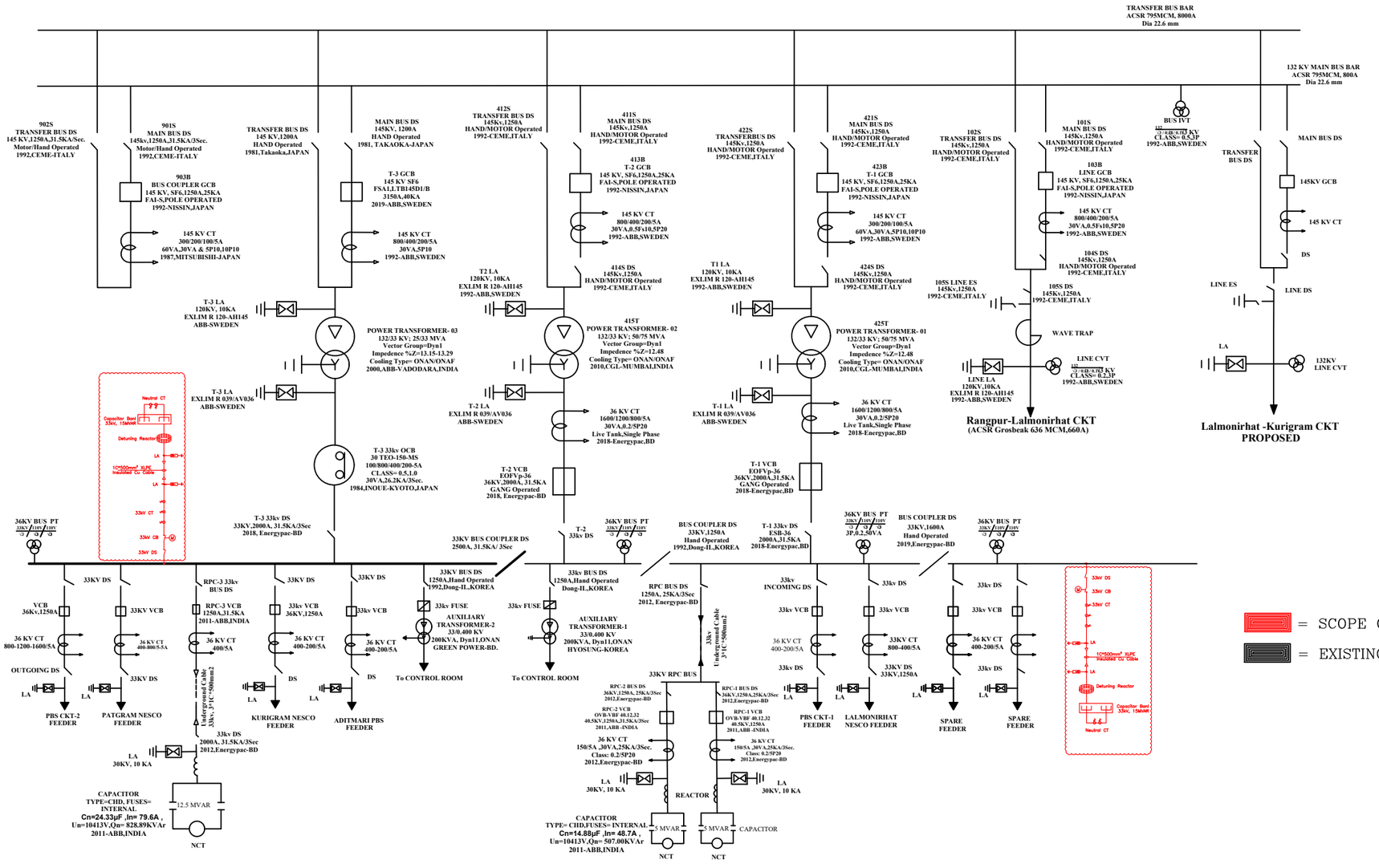
Rev.	Date	Remarks	CAD By	Engineer
A	25.02.2020	Design Approval	M.A. SALAM	Al Amin Hossain

ProjectL: Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package-2, Lot-2)

Drawing No.- PGCB/DESIGN/2021/CEEGSTL/P2L2/JOYDEBPUR/E15

Title: PROPOSED SINGLE LINE DIAGRAM OF JOYDEBPUR 132 /33 /11KV GIS SUB-STATION (33kV Part)

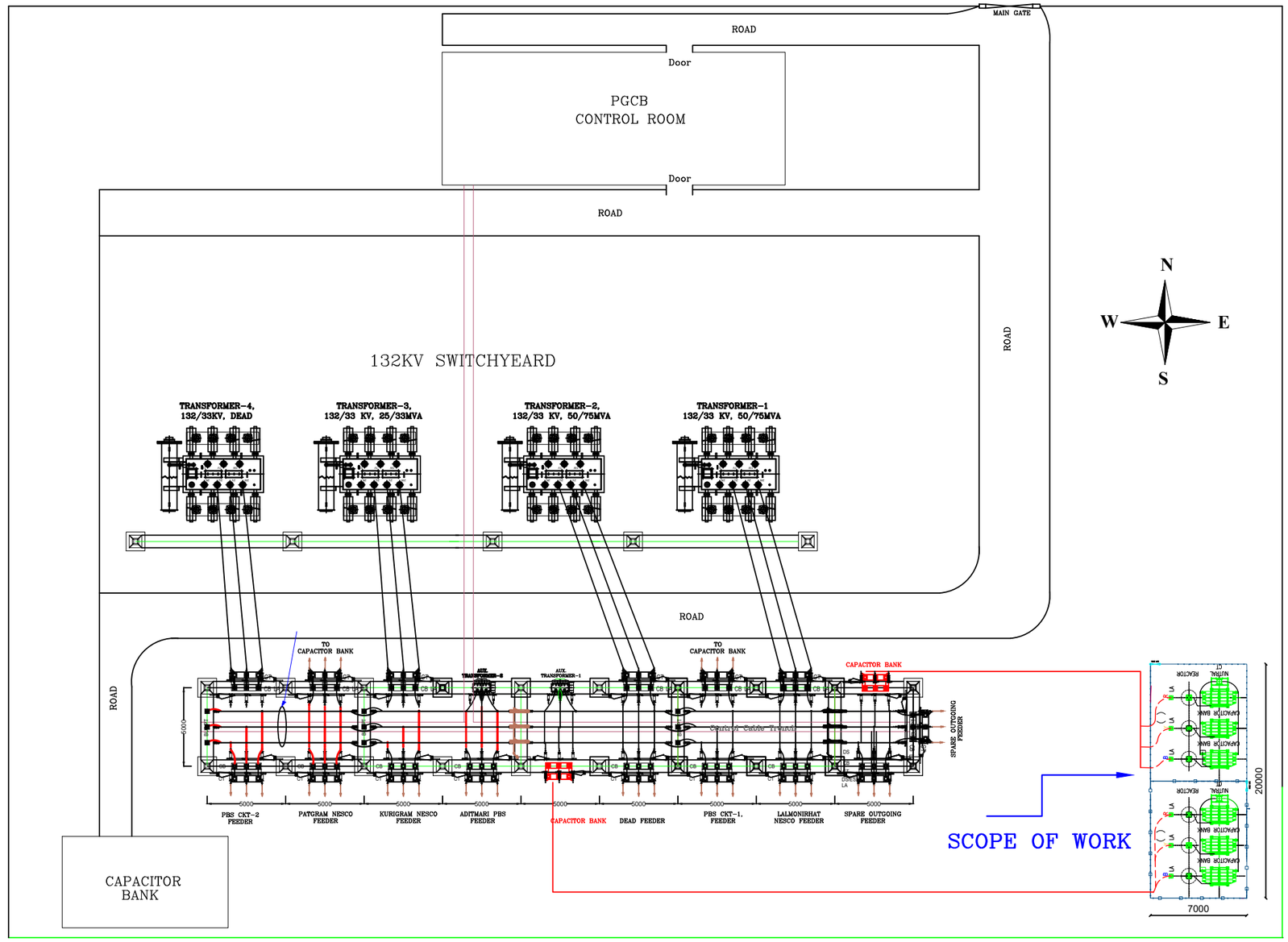
Scale: None | Rev: A | Sheet No: 01



TENDER PURPOSE ONLY

POWER GRID COMPANY OF BANGLADESH LIMITED

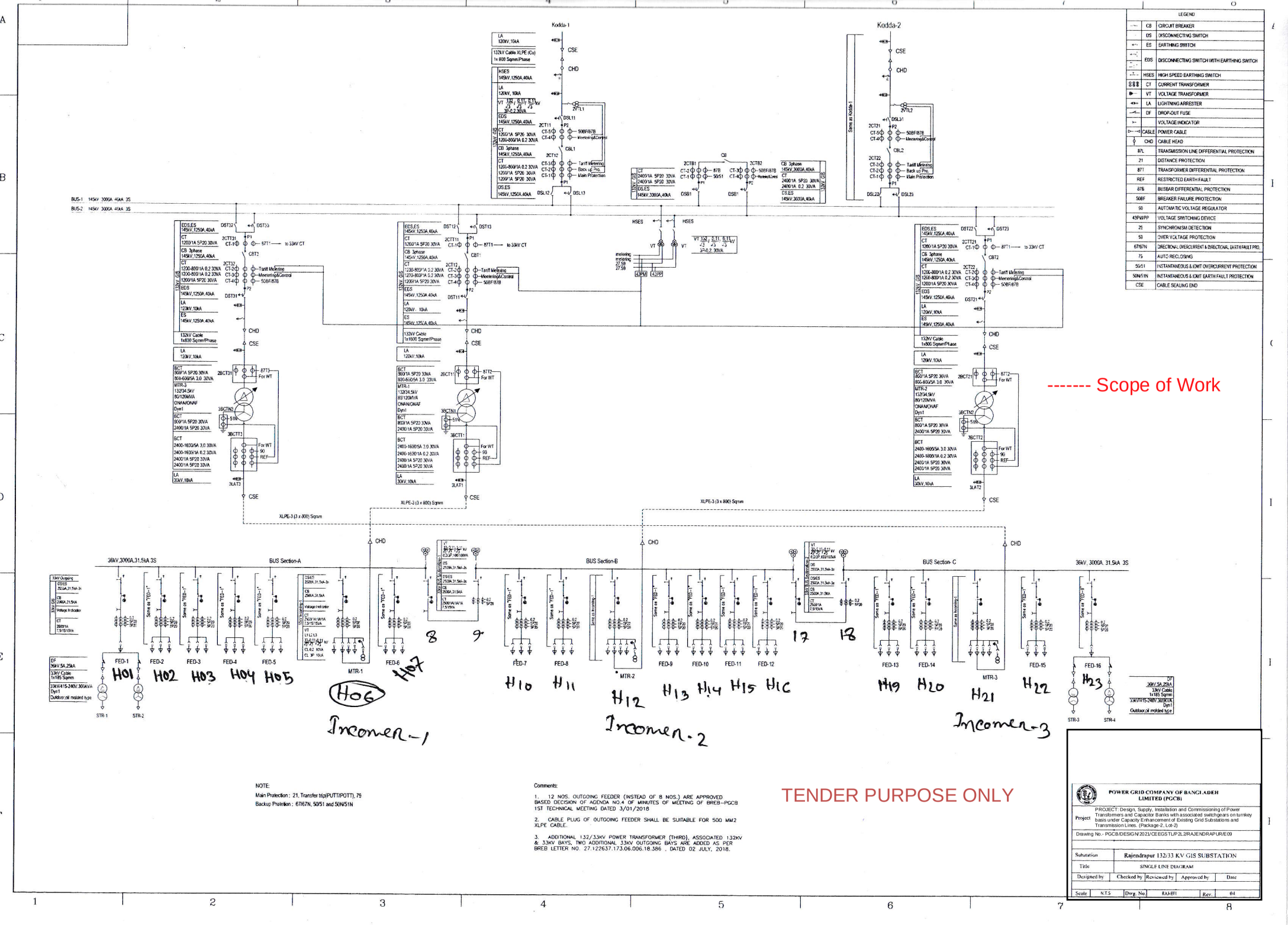
Project	Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package-2, Lot-2)				
Item Name	EXISTING LALMONIRHAT 132/33 kV AIS SUBSTATION				
Drawing Name	SINGLE LINE DIAGRAM				
Designed	Checked	Reviewed	Approved	Rev.	
				Date	
Drawing. No.	PGCB/DESIGN/2021/CEEGSTL/P2L2/LALMONIRHAT/E07				



TENDER PURPOSE ONLY

POWER GRID COMPANY OF BANGLADESH LIMITED

Project	Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package-2, Lot-2)				
Item Name	EXISTING LALMONIRHAT 132/33 kV AIS SUBSTATION				
Drawing Name	ELECTRICAL LAYOUT				
Designed	Checked	Reviewed	Approved	Rev.	
				Date	
Drawing. No.	PGCB/DESIGN/2021/CEEGSTL/P2L2/LALMONIRHAT/E08				



LEGEND		
	CB	CIRCUIT BREAKER
	DS	DISCONNECTING SWITCH
	ES	EARTHING SWITCH
	EDS	DISCONNECTING SWITCH WITH EARTHING SWITCH
	HSES	HIGH SPEED EARTHING SWITCH
	CT	CURRENT TRANSFORMER
	VT	VOLTAGE TRANSFORMER
	LA	LIGHTNING ARRESTER
	DF	DROP-OUT FUSE
		VOLTAGE INDICATOR
	CABLE	POWER CABLE
	CHD	CABLE HEAD
	87L	TRANSMISSION LINE DIFFERENTIAL PROTECTION
	21	DISTANCE PROTECTION
	87T	TRANSFORMER DIFFERENTIAL PROTECTION
	REF	RESTRICTED EARTH FAULT
	87B	BUSBAR DIFFERENTIAL PROTECTION
	50BF	BREAKER FAILURE PROTECTION
	90	AUTOMATIC VOLTAGE REGULATOR
	43PM/PP	VOLTAGE SWITCHING DEVICE
	25	SYNCHRONISM DETECTION
	59	OVER VOLTAGE PROTECTION
	67/67N	DIRECTIONAL OVERCURRENT & DIRECTIONAL EARTH FAULT PRO.
	79	AUTO RECLOSING
	50/51	INSTANTANEOUS & IDMT OVERCURRENT PROTECTION
	50N/51N	INSTANTANEOUS & IDMT EARTH FAULT PROTECTION
	CSE	CABLE SEALING END

NOTE:
Main Protection : 21, Transfer trip(PUTT/POTT), 79
Backup Protetion : 67/67N, 50/51 and 50N/51N

Comments:

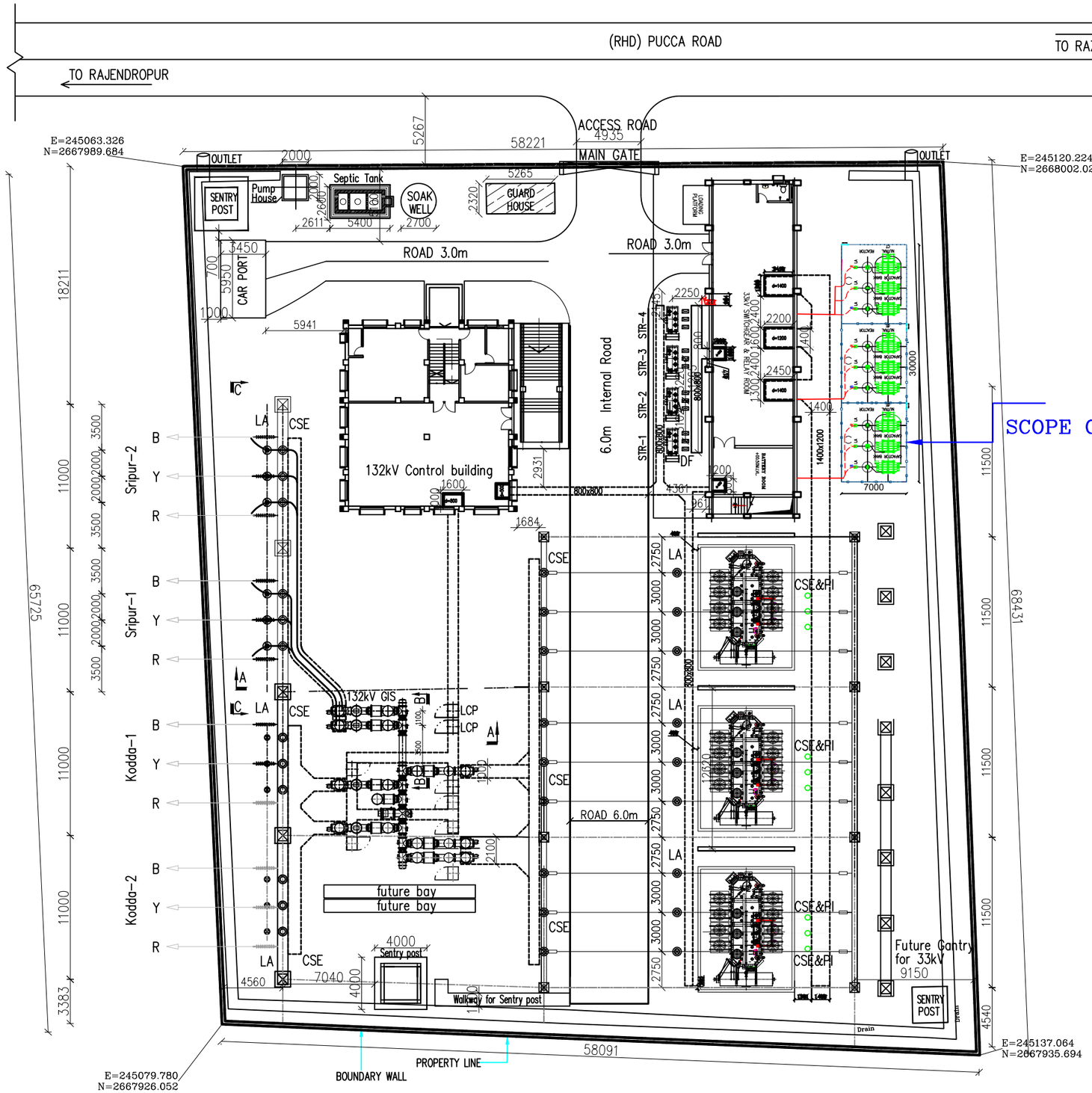
1. 12 NOS. OUTGOING FEEDER (INSTEAD OF 8 NOS.) ARE APPROVED BASED DECISION OF AGENDA NO.4 OF MINUTES OF MEETING OF BREB-PGCB 1ST TECHNICAL MEETING DATED 3/01/2018
2. CABLE PLUG OF OUTGOING FEEDER SHALL BE SUITABLE FOR 500 MM2 XLPE CABLE.
3. ADDITIONAL 132/33KV POWER TRANSFORMER (THIRD), ASSOCIATED 132KV & 33KV BAYS, TWO ADDITIONAL 33KV OUTGOING BAYS ARE ADDED AS PER BREB LETTER NO. 27.122637.173.06.006.18.386 , DATED 02 JULY, 2018.

POWER GRID COMPANY OF BANGLADEH LIMITED (PGCB)

Project	PROJECT: Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package-2, Lot-2)
Drawing No.- PGCB/DESIGN/2021/CEEGSTL/P2L2/RAJENDRAPUR/E09	
Substation	Rajendrapur 132/33 KV GIS SUBSTATION
Title	SINGLE LINE DIAGRAM
Designed by / Checked by / Reviewed by / Approved by / Date	
Scale: N.T.S	Dwg. No: RAJ-E01 Rev: 04

THIS DRAWING IS CONFIDENTIAL IT MUST NOT BE COPIED OR PASSED TO A THIRD PARTY WITHOUT WRITTEN CONSENT WE RESERVE ALL THE RIGHTS ON NEW IDEAS/CHARACTERISTICS ESPECIALLY FOR PATENT PURPOSES.

RAJENDRAPUR



N

W E

S

TENDER PURPOSE ONLY

EQUIPMENT (OUTDOOR)

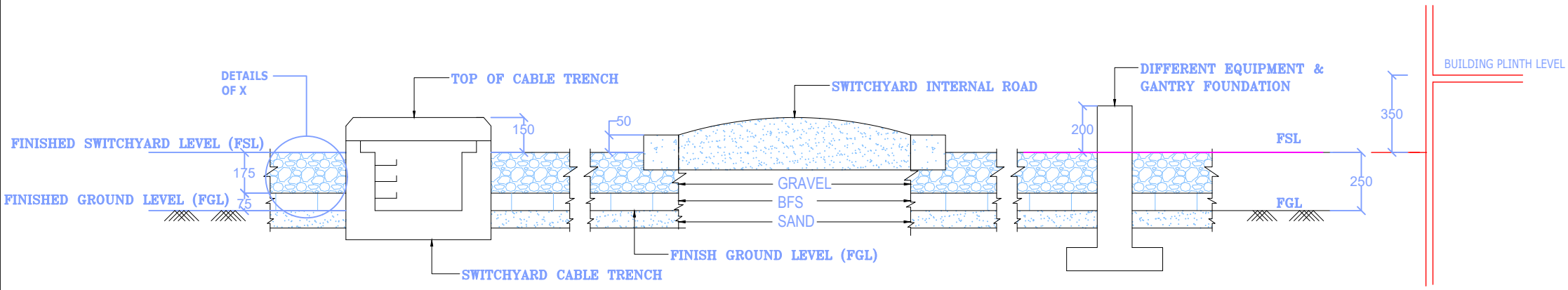
DESIGNATION		DESCRIPTION	UNIT	QTY
132kV	GIS	UNDER GROUND CABLE CIRCUIT BAY	sets	2
	CSE	OUTDOOR CABLE SEALING END	NOS.	6
	LA	OUTDOOR LIGHTNING ARRESTER	NOS.	6

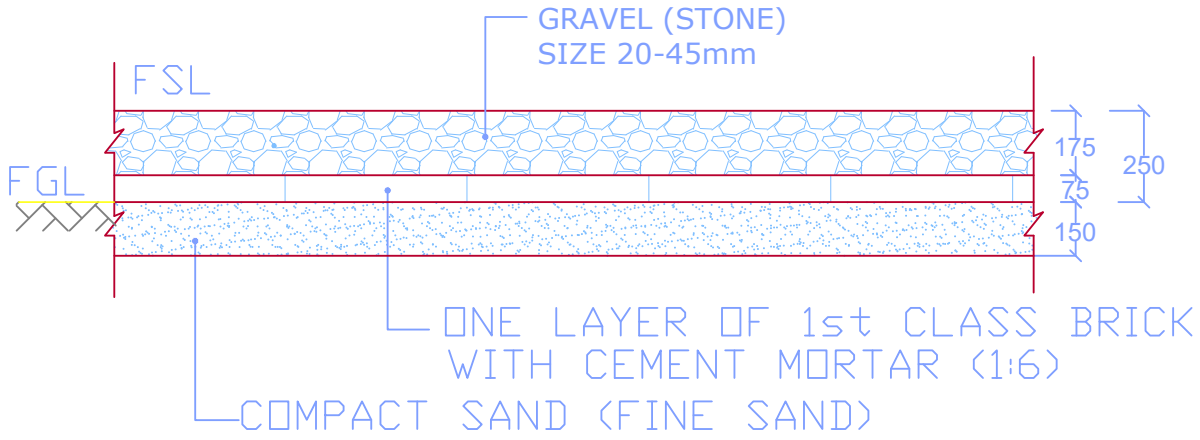
PROJECT: Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package-2, Lot-2)

EMPLOYER : POWER GRID COMPANY OF BANGLADESH LIMITED (PGCB)

SUBSTATION NAME : RAJENDRAPUR 132/33kV EXISTING GIS SUBSTATION.

SCALE		TITLE : LAYOUT PLAN OF RAJENDRAPUR 132/33kV GIS GRID SUB-STATION
DRAWN		
CHECKED		
APPROVED		
DATE		DRAWING NO. : PGCB/DESIGN/2021/CEEGSTLP2L2/RAJENDRAPUR/E10 REV : △





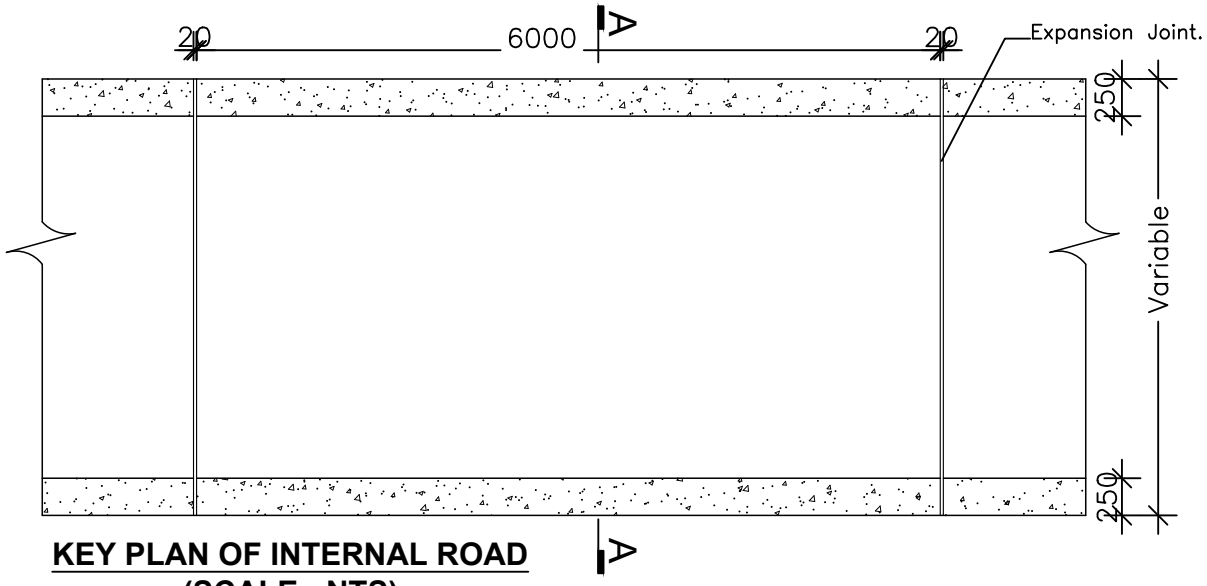
DETAIL OF X

NOTE:

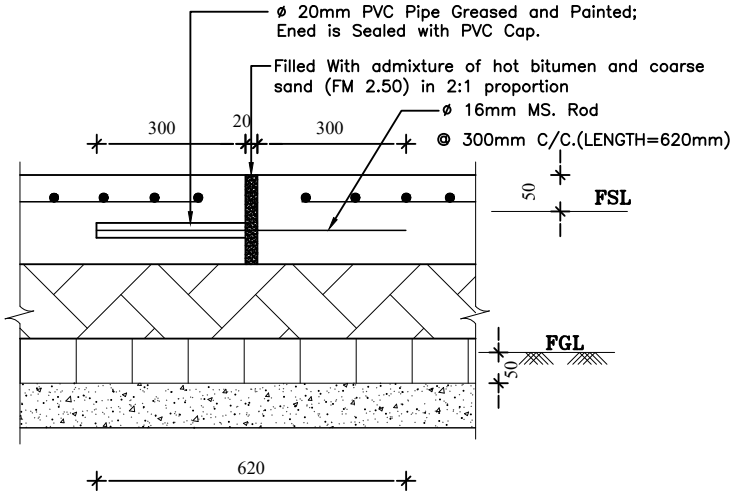
After determination of Finished Ground Level (FGL) with respect to MSL/PWD, the contractor should prepare and submit the relative RLs of all the structures for approval for each site.

Tender Drawing

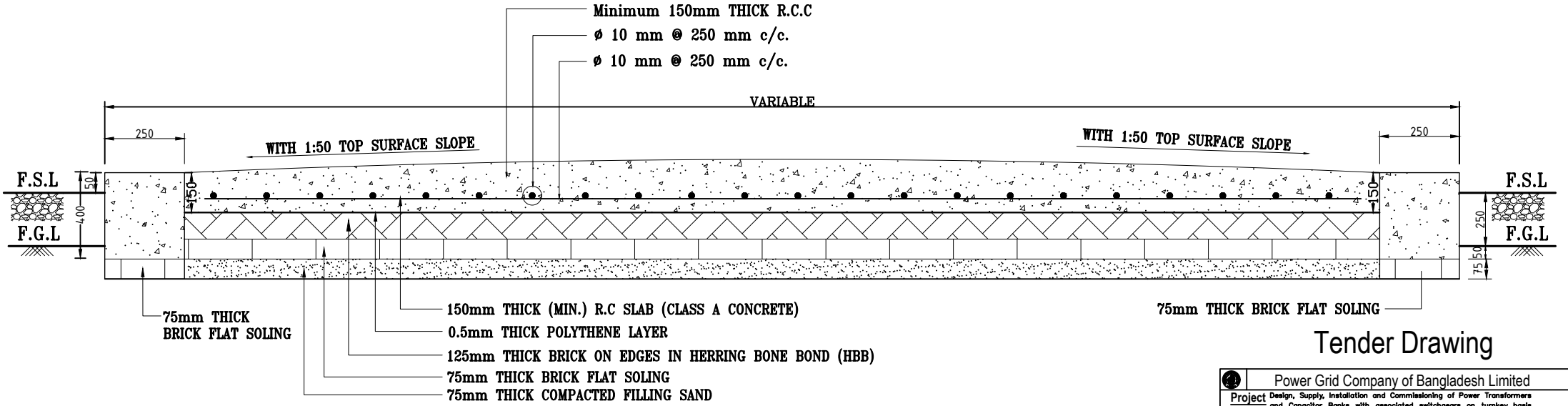
Power Grid Company of Bangladesh Limited	
Project	Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package–2, Lot–2)
Drawing Title	Switchyard Gravelling and Relative Levels of Different Structures
Drawing No.	PGCB_DESIGN_2021_CEEGSTL_P2L2_C01
Drawn:	Checked: Approved:



KEY PLAN OF INTERNAL ROAD
(SCALE - NTS)



DETAIL OF EXPANSION JOINT
(SCALE - NTS)



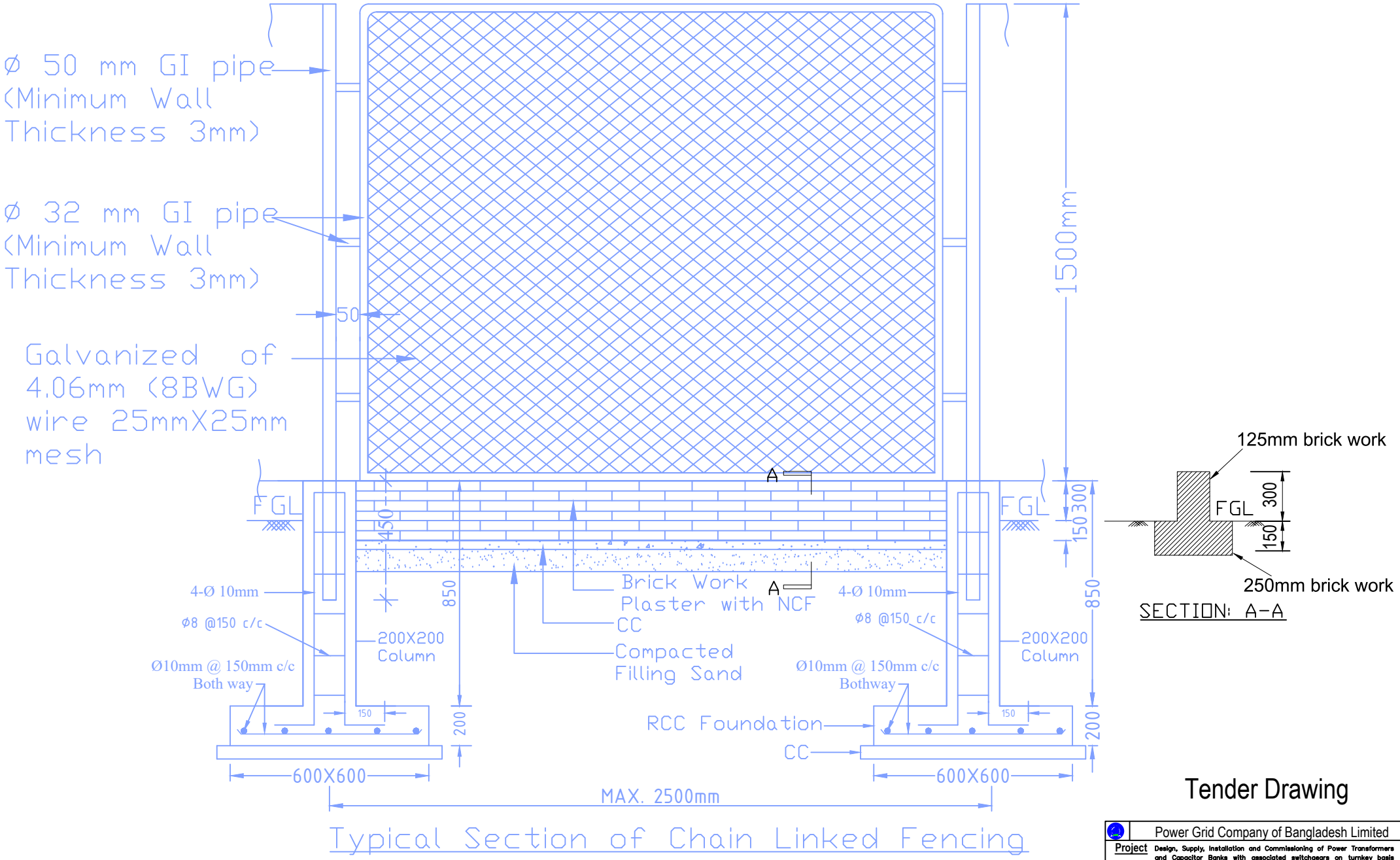
ROAD CROSS SECTION : A-A
(SCALE - NTS)

Tender Drawing

Power Grid Company of Bangladesh Limited

Project Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package-2, Lot-2)

Drawing Title	Typical Road sections
Drawing No.	PGCB_DESIGN_2021_CEEGSTL_P2L2_C02
Drawn:	Checked: Approved:

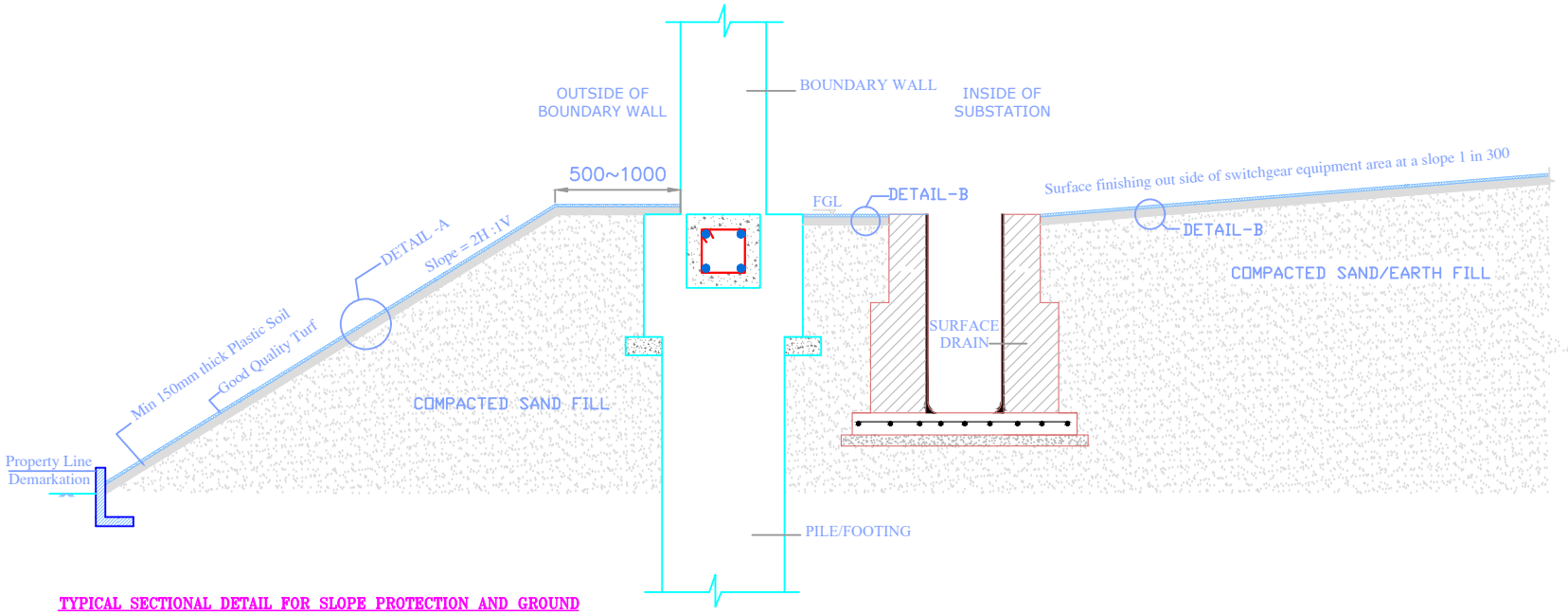


Typical Section of Chain Linked Fencing

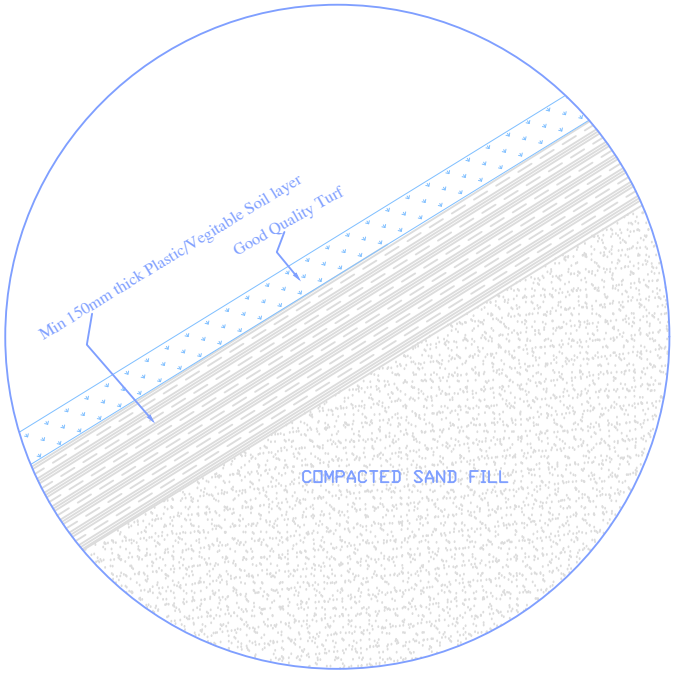
SECTION: A-A

Tender Drawing

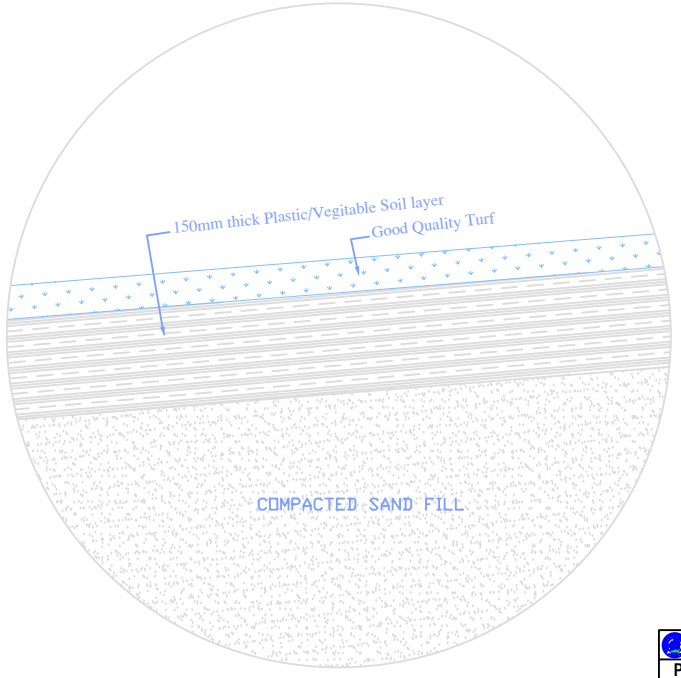
Power Grid Company of Bangladesh Limited	
Project	Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package-2, Lot-2)
Drawing Title	Typical Section of Chain linked fencing
Drawing No.	PGCB_DESIGN_2021_CEEGSTL_P2L2_C03
Drawn:	Checked: Approved:



TYPICAL SECTIONAL DETAIL FOR SLOPE PROTECTION AND GROUND SURFACE FINISHING AROUND THE SURFACE DRAIN



DETAIL-A



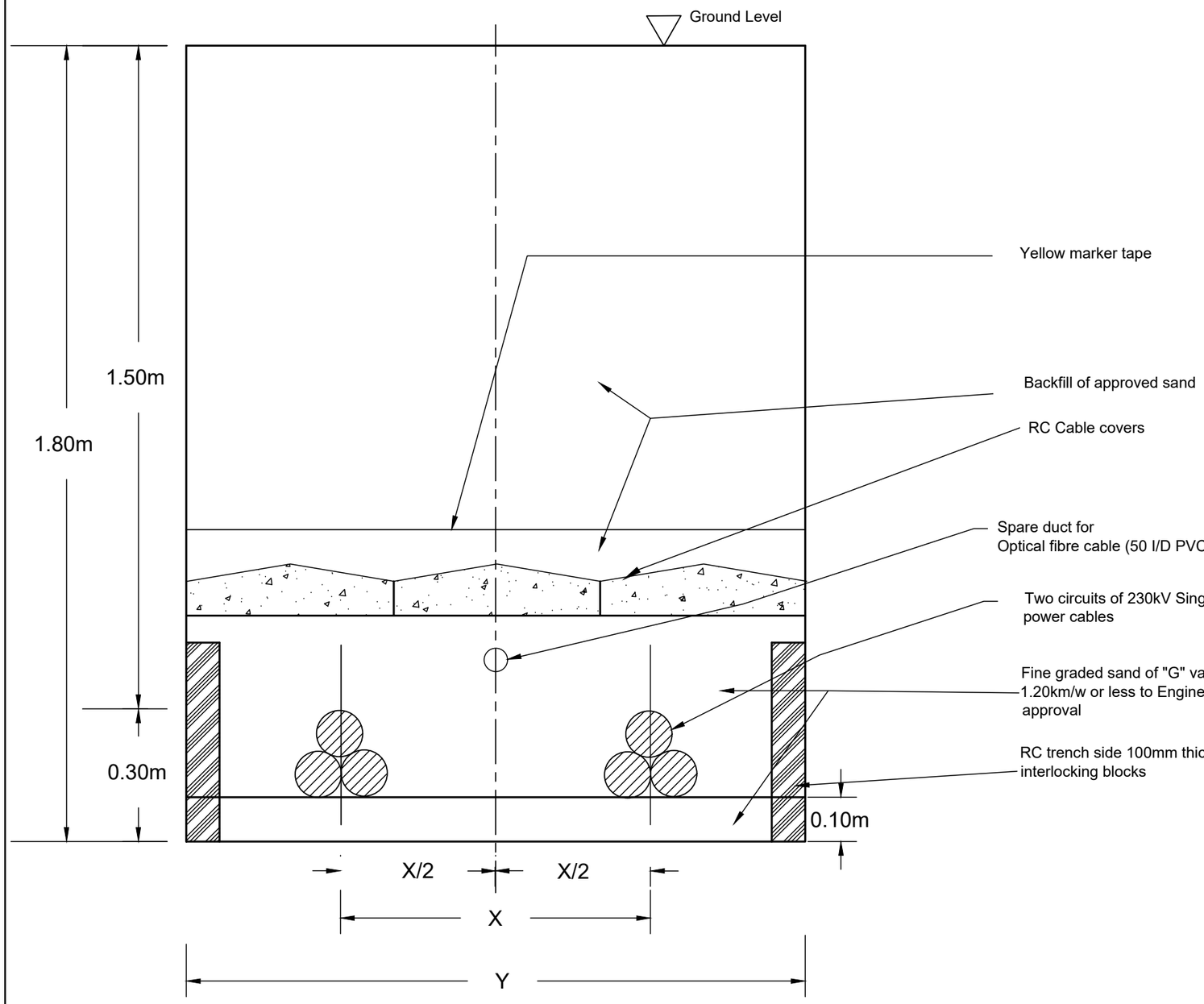
DETAIL-B

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

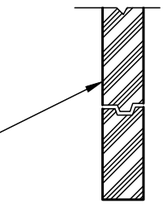
Power Grid Company of Bangladesh Limited	
Project	Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package-2, Lot-2)
Drawing Title	Slpoe (1V:2H) protection with turfing
Drawing No.	PGCB_DESIGN_2021_CEEGSTL_P2L2_C04
Drawn:	Checked: Approved:



Voltage Level	X(m)	Y(m)
230kV	0.7	1.4
400kV	1.0	1.7

Notes:

1. Backfill to be compacted in layers not greater than 250mm.



PLAN
(Typical interlocking blocks)

Tender Drawing

Power Grid Company of Bangladesh Limited

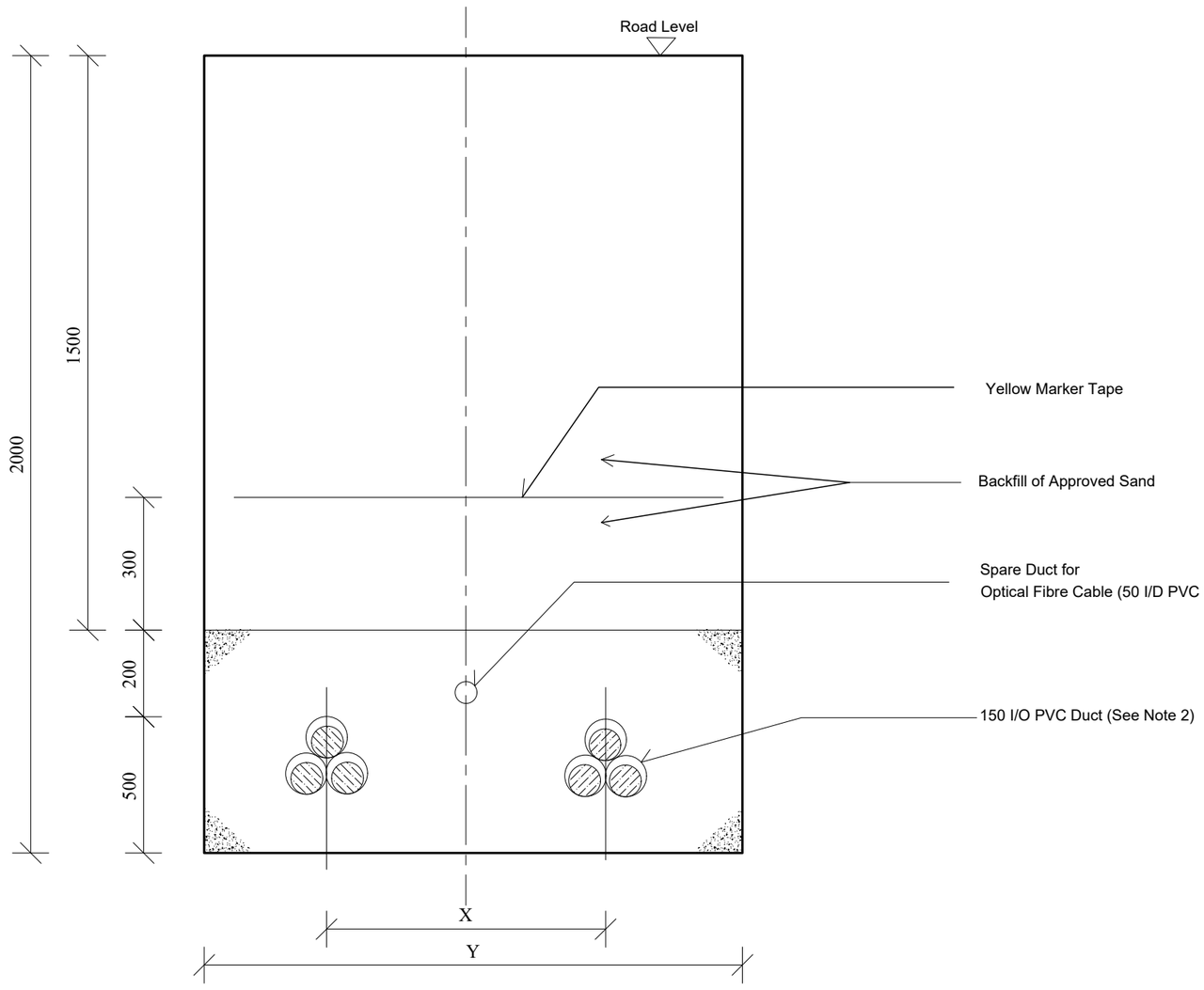
Project:

Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package–2, Lot–2)

Drawing No. PGCB_DESIGN_2021_CEEGSTL_P2L2_C05

Title

Typical Trench of 230kV/400kV Cables



Voltage Level	X (m)	Y (m)
230kV	0.7	1.35
400kV	1.0	1.65

Notes:

1. Spacing and buried depth of cables may vary to suit site conditions.
2. Ducts to be high impact PVC 6 thk nominal gray male and female sections and to extend at least 1.0m beyond edge of road.
3. Duct to have 150 minimum cover of concrete.
4. All unused ducts shall be supplied with a galvanized draw wire inside and fitted with suitable plugs both ends.
5. Backfill to be compacted in layers not greater than 250.00mm.

Tender Drawing

Power Grid Company of Bangladesh Limited

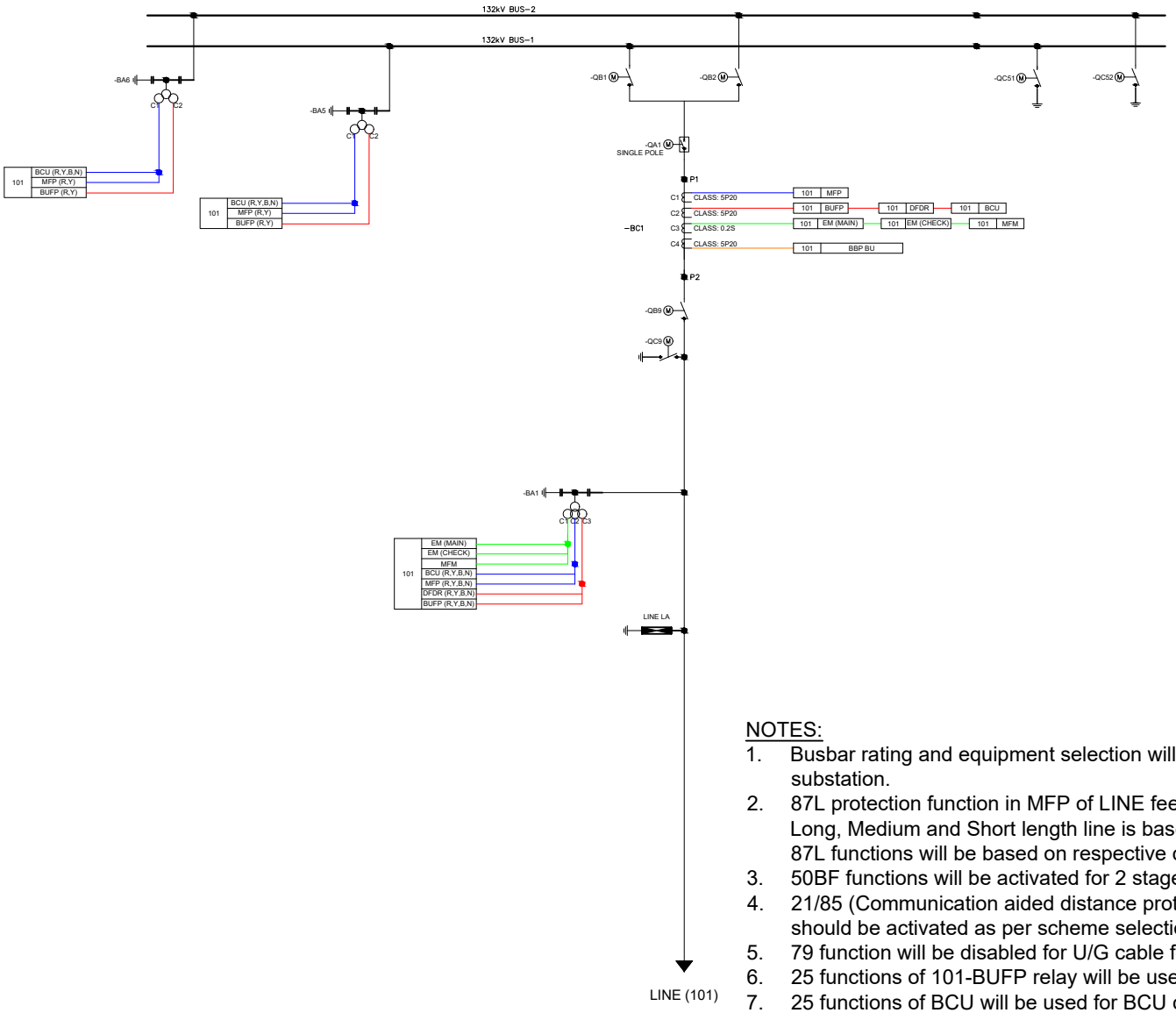
Project:

Design, Supply, Installation and Commissioning of Power Transformers and Capacitor Banks with associated switchgears on turnkey basis under Capacity Enhancement of Existing Grid Substations and Transmission Lines. (Package–2, Lot–2)

Drawing No. PGCB_DESIGN_2021_CEEGSTL_P2L2_C06

Title

Typical Road Crossing for 230kV/400kV Cables



101	MFP	
	MAIN FEEDER PROTECTION	
	87L	67/67N
	21	51/51N
	21/85	50/50N
	67N/85	46BC
	SOTF	50STUB
	68	79 (QA1)
	VTFF	25 (QA1)
	21FL	DDR

101	EM (MAIN)	
	ENERGY METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

101	EM (CHECK)	
	ENERGY METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

101	BUFP	
	BACK UP FEEDER PROTECTION	
	67/67N	59
	51/51N	25 (QA1)
	50/50N	DDR
	27	

101	MFM	
	MULTIFUNCTION METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

101	BCU	
	BAY CONTROL UNIT	
	kV	25 (QA1)
	A	CONTROL
	MW	INTERLOCK
	MVAR	

101	BBP BU	
	BUSBAR PROTECTION BAY UNIT	
	87B	50BF
	EFP	

NOTES:

1. Busbar rating and equipment selection will be followed by Fault Level and Load Flow study for the specific substation.
2. 87L protection function in MFP of LINE feeder is optional for Long and Medium length lines; Definition of Long, Medium and Short length line is based on Clause 5.2 of IEEE Std. C37.113™-2015. Availability of 87L functions will be based on respective clause mentioned in the Tender document and Scope of Work.
3. 50BF functions will be activated for 2 stages: Re-trip to the same CB and Remote trip to the other sources.
4. 21/85 (Communication aided distance protection) and 67N/85 (Communication aided DEF protection) should be activated as per scheme selection in the particular relay.
5. 79 function will be disabled for U/G cable feeders.
6. 25 functions of 101-BUFP relay will be used for MIMIC controls of the CB.
7. 25 functions of BCU will be used for BCU controls of the CB.
8. DTT from remote end of the LINE feeder will be received by MFP to provide tripping to the CB.
9. Busbar Protections should be decentralized in principle.
10. For 50BF Remote Trip of Bus CBs, tripping will be issued to all CBs connected to the respective Busbar; the trip logic will be implemented internally with BBP Central Unit.
11. Optical Multiplexer based communication should be established between both end substations of the LINE feeder.
12. Any aspect mentioned in the Standard Document may be superseded by the Tender document and Scope of Work depending on specific application.

TENDER PURPOSE ONLY

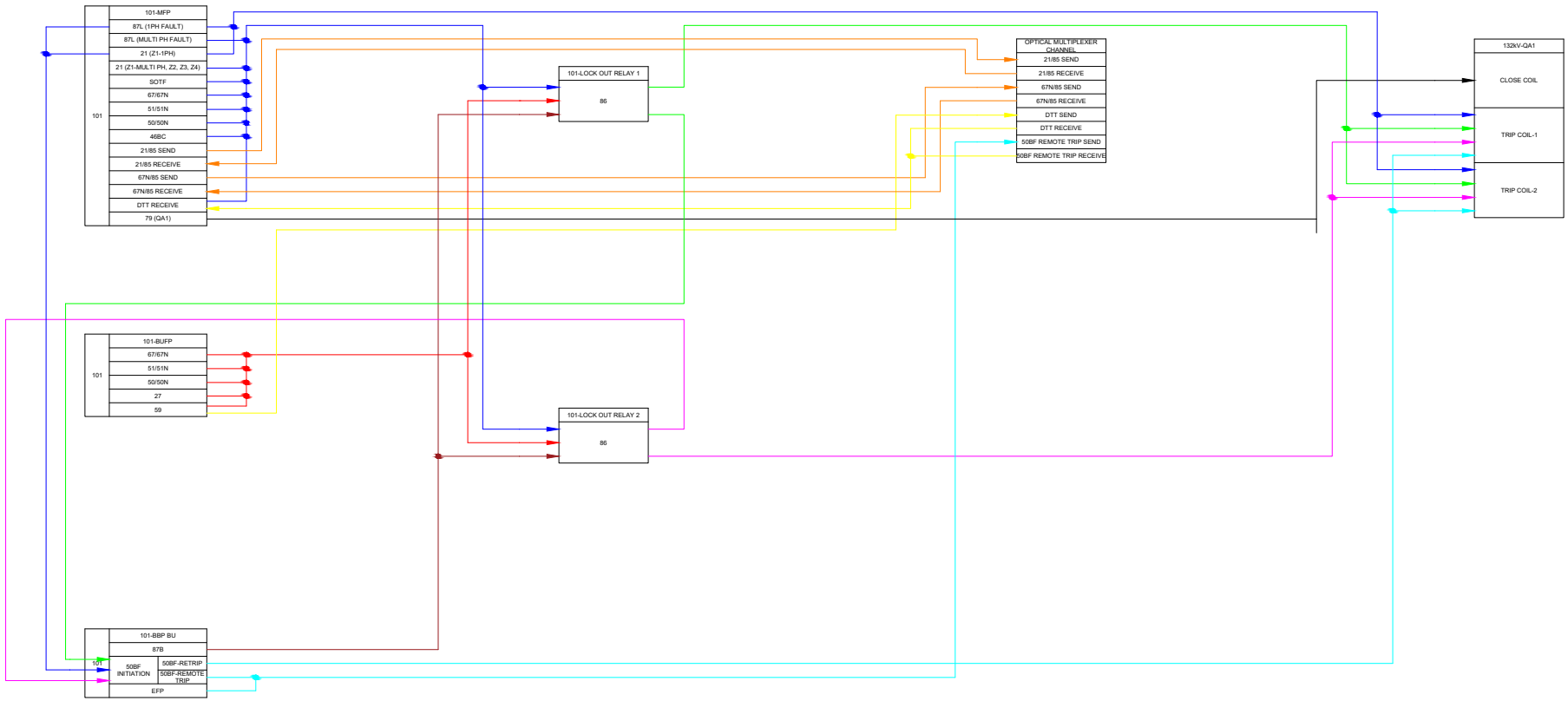
REVISION	DATE	REMARKS
1	11.06.2020	AS PER SSD'S COMMENTS
0	08.04.2020	FIRST PREPARATION

STANDARD DOCUMENT NUMBER: 02

POWER GRID COMPANY OF BANGLADESH LTD.

TITLE: PROTECTION SLD & TRIP LOGIC OF 132kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR LINE FEEDER

Document No.- PGCB_DESIGN_2021_CEEGSTL_P2L2_PROTECTION_E16



TENDER PURPOSE ONLY

REVISION	DATE	REMARKS
1	11.06.2020	AS PER SSD'S COMMENTS
0	08.04.2020	FIRST PREPARATION

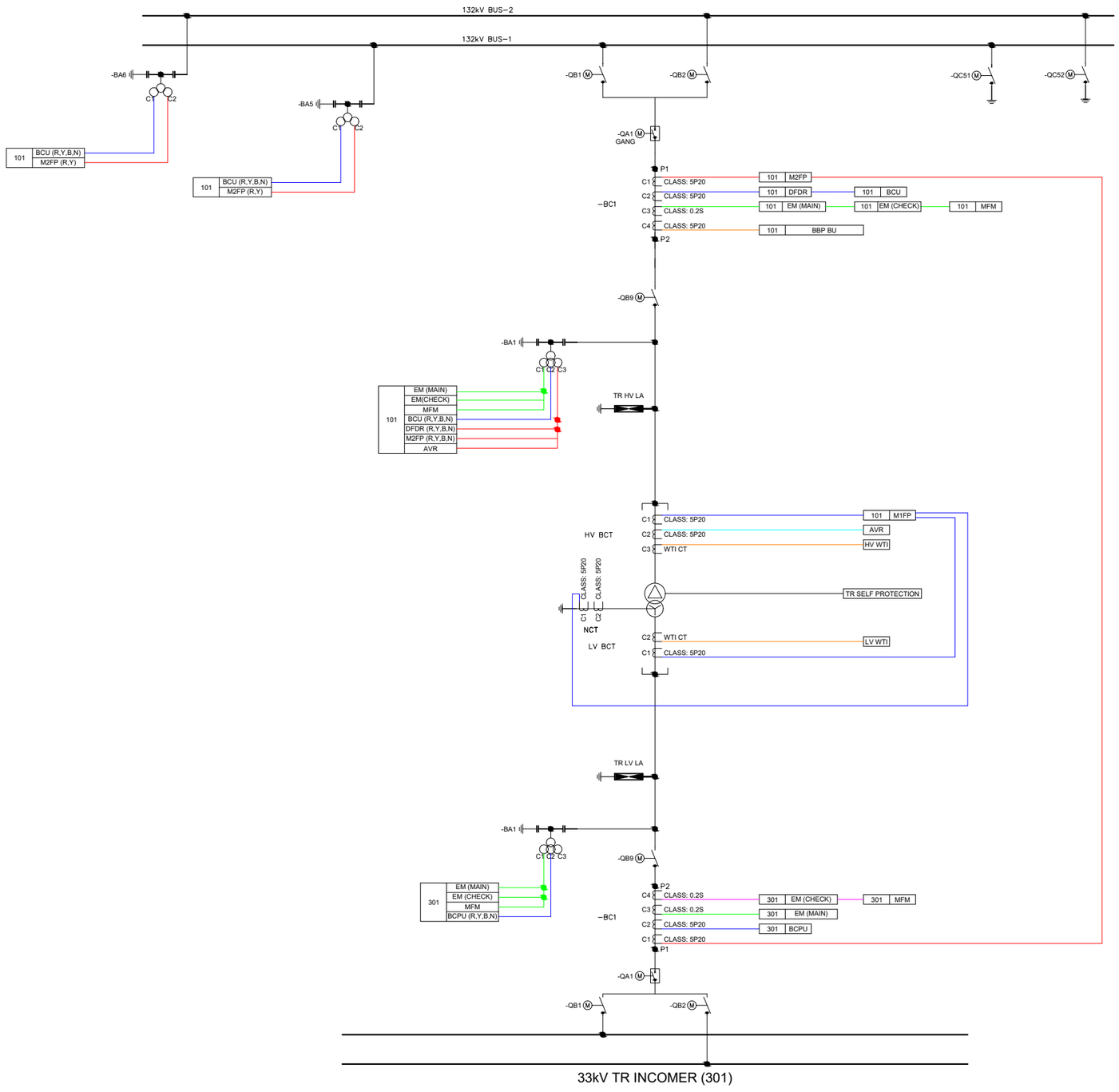
STANDARD DOCUMENT NUMBER: 02

POWER GRID COMPANY OF BANGLADESH LTD.

TITLE: PROTECTION SLD & TRIP LOGIC OF 132kV GIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR LINE FEEDER

Document No.- PGCB_DESIGN_2021_CEEGSTL_P2L2_PROTECTION_E16

SHEET	2 of 2
NEXT SHT	N\A



101	M1FP	
	MAIN-1 FEEDER PROTECTION	
	87T1	50/50N (HV)
	87N (LOW IMP)	24
	51/51N (HV)	DDR

101	M2FP	
	MAIN-2 FEEDER PROTECTION	
	87T2	24
	51/51N (HV)	27
	50/50N (HV)	59
	25 (QA1)	DDR

101	BCU	
	BAY CONTROL UNIT	
	kV	25 (QA1)
	A	CONTROL
	MW	INTERLOCK
	MVAR	

101	EM	
	ENERGY METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

101	MFM	
	MULTIFUNCTION METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

101	BBP BU	
	BUSBAR PROTECTION BAY UNIT	
	87B	50BF
	EFP	

101	TR SELF PROTECTION	
	ALARM	TRIP
	HV-WTI	HV-WTI
	LV-WTI	LV-WTI
	OTI	OTI
	BUCHHOLZ (MAIN)	BUCHHOLZ (MAIN)
	BUCHHOLZ (OLTC)	BUCHHOLZ (OLTC)
	OIL LEVEL	PRD
		OSR

301	BCPU	
	BAY CONTROL & PROTECTION UNIT	
	67/67N (LV)	A
	51/51N (LV)	kW
	50/50N (LV)	kVAR
	27	CONTROL
	59	INTERLOCK
	81O, 81U, 81R	DDR
	kV	

301	EM (MAIN)	
	ENERGY METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

301	EM (CHECK)	
	ENERGY METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

301	MFM	
	MULTIFUNCTION METER	
	kV	FREQ
	A	PF
	MW	kWh
	MVAR	kVARh

NOTES:

1. Busbar rating and equipment selection will be followed by Fault Level and Load Flow study for the specific substation.
2. 50BF functions will be activated for 2 stages: Re-trip to the same CB and Remote trip to the other sources.
3. 25 function of 101-M2FP relays will be used for MIMIC controls of the respective CBs.
4. 25 functions of BCU will be used for BCU controls of the respective CBs.
5. Busbar Protections should be decentralized in principle.
6. For 50BF Remote Trip of Bus CBs, tripping will be issued to all CBs connected to the respective Busbar; the trip logic will be implemented internally with BBP Central Unit.
7. Main-1 and Main-2 Transformer protection relays, BBP relays and BFP relays should preferably of different manufacturer. Alternatively, different model of the same manufacturer.
8. Any aspect mentioned in the Standard Document may be superseded by the Tender document and Scope of Work depending on specific application.

TENDER PURPOSE ONLY

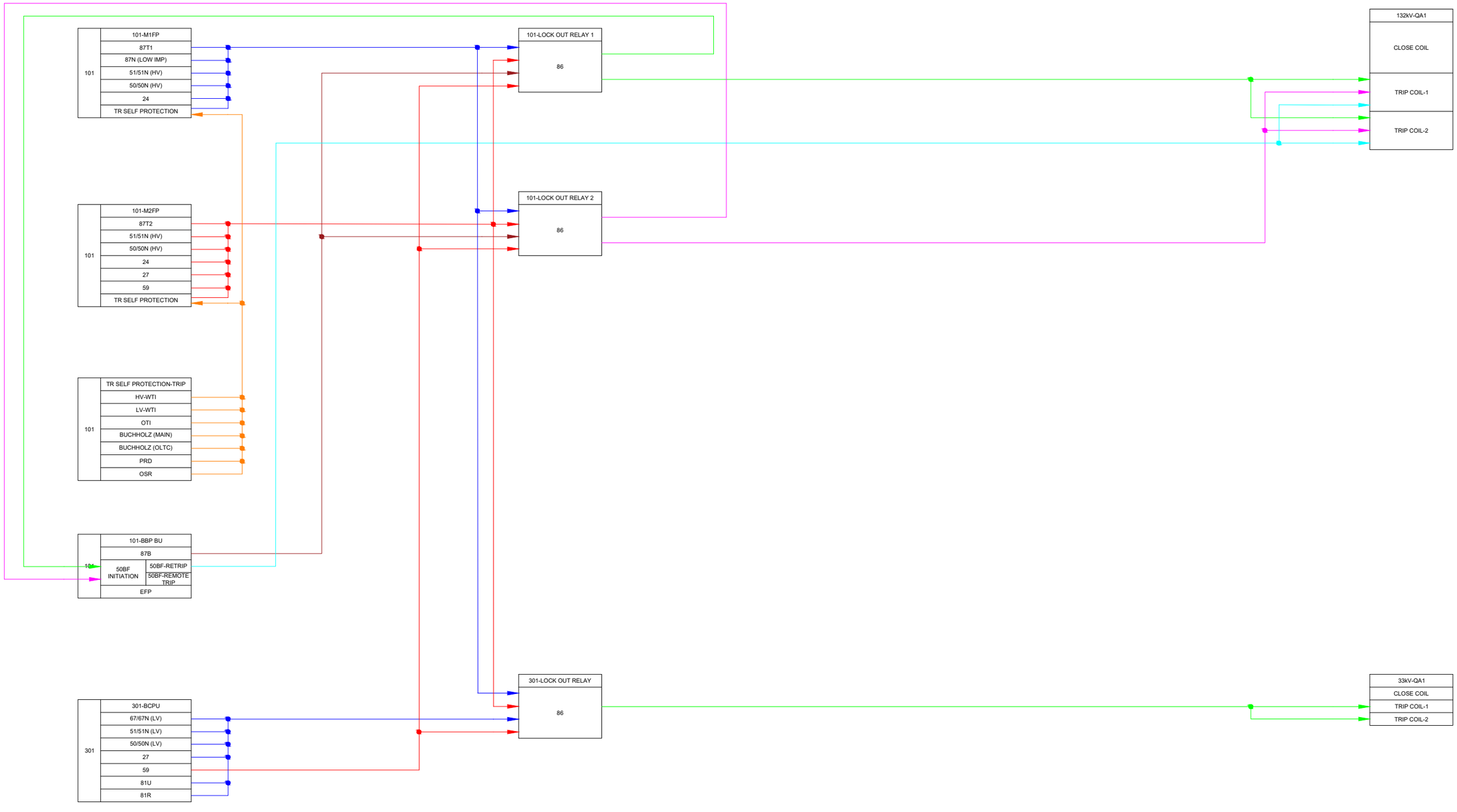
REVISION	DATE	REMARKS
1	11.06.2020	AS PER SSD'S COMMENTS
0	08.04.2020	FIRST PREPARATION

STANDARD DOCUMENT NUMBER: 02

POWER GRID COMPANY OF BANGLADESH LTD.

TITLE: PROTECTION SLD & TRIP LOGIC OF 132kV AIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR TRANSFORMER FEEDER

Document No.- PGCB_DESIGN_2021_CEEGSTL_P2L2_PROTECTION_E17



TENDER PURPOSE ONLY

REVISION	DATE	REMARKS
1	11.06.2020	AS PER SSD'S COMMENTS
0	08.04.2020	FIRST PREPARATION

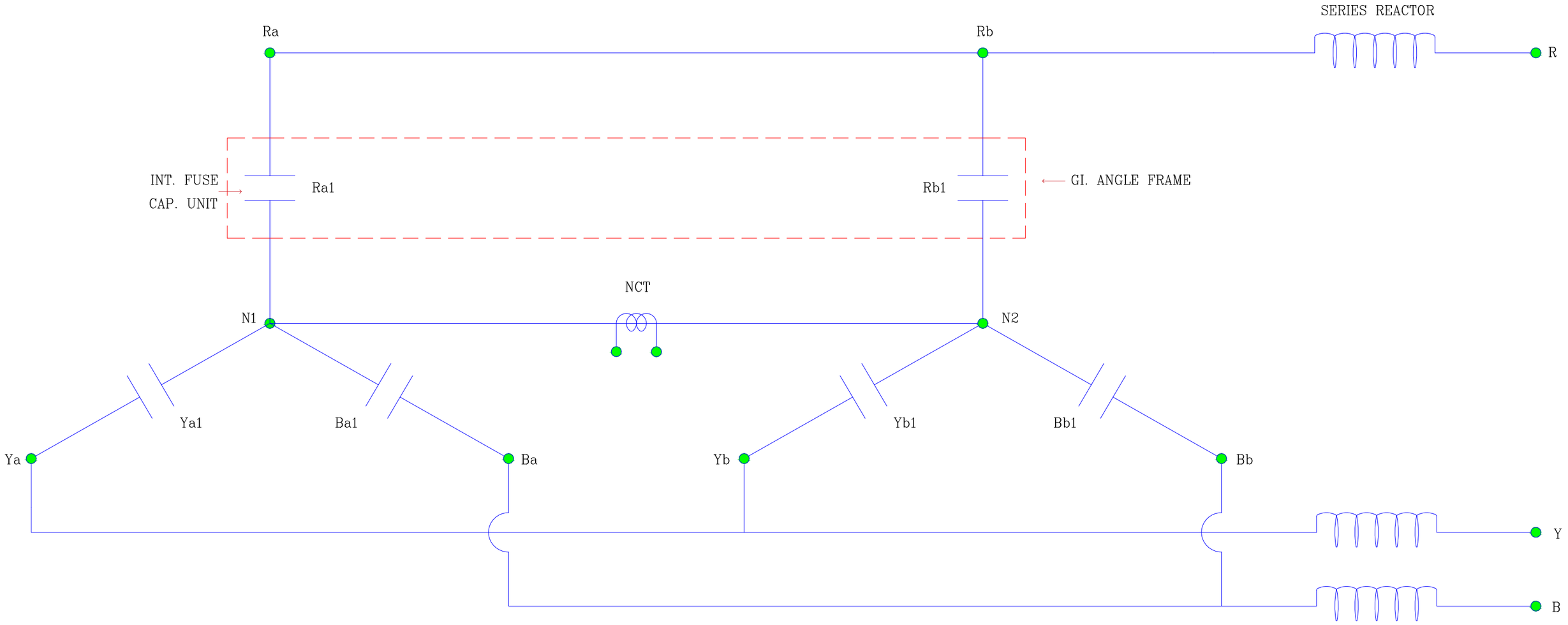
STANDARD DOCUMENT NUMBER: 02

POWER GRID COMPANY OF BANGLADESH LTD.

TITLE: PROTECTION SLD & TRIP LOGIC OF 132kV AIS SUBSTATION WITH DOUBLE BUS ARRANGEMENT FOR TRANSFORMER FEEDER

Document No.- PGCB_DESIGN_2021_CEEGSTL_P2L2_PROTECTION_E17

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TENDER PURPOSE ONLY

L E G E N D		
SL.NO.	FIGURE	FIGURE NAME
01		CAP. UNIT
02		SERIES REACTOR
03		NCT

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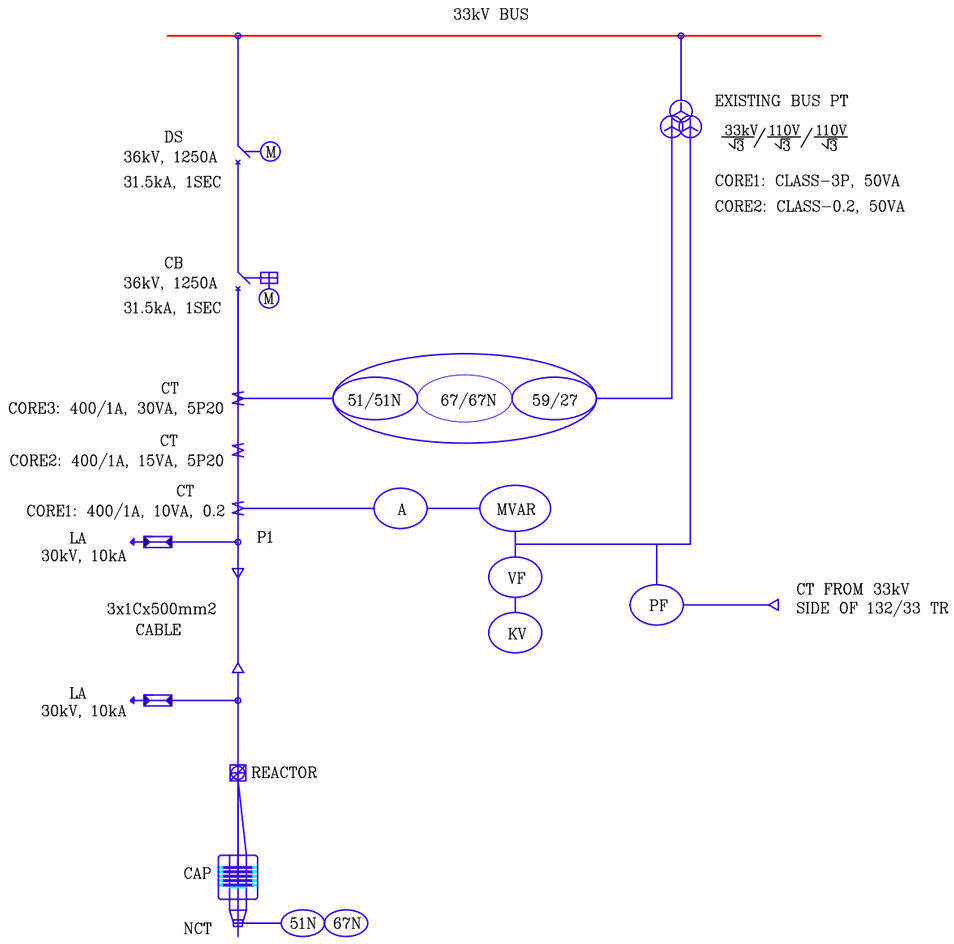
PROJECT:

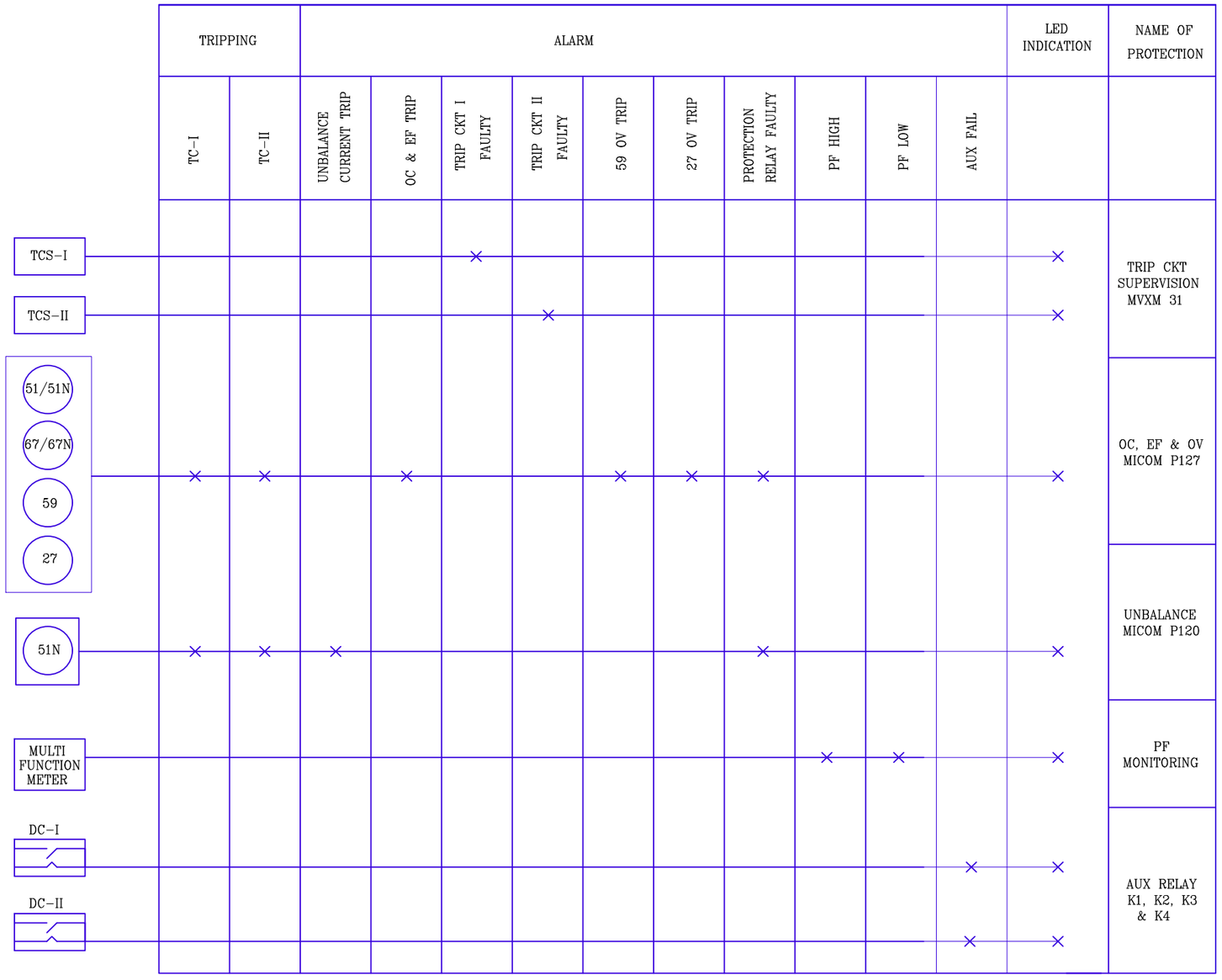
33kV CAPACITOR BANK

SCALE	NTS	TITLE : THREE LINE DIAGRAM OF 33kV CAPACITOR BANK
DRAWN		
CHECKED		
DATE		

DRAWING NO. : PGCB_DESIGN_2021_CEEGSTL_P2L2_PROTECTION_E18 | REV : 0

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NOTE:

** Timer based lockout relay has to be provided in CB for safe discharge of capacitor bank.

LEGEND			
SL.NO.	FIGURE	FIGURE NAME	RATING
01		LIGHTNING ARRESTOR (LA)	30kV, 10kA
02		DISCONNECTING SWITCH (DS)	1250A, 31,5kA
03		CIRCUIT BREAKER (GCB)	1250A, 31.5kA
04		POTENTIAL TRANSFORMER (PT)	$\frac{33kV}{\sqrt{3}} / \frac{110V}{\sqrt{3}}$
05		CURRENT TRANSFORMER (CT)	400A/1A

POWER GRID COMPANY OF BANGLADESH LTD.

PROJECT:

33kV CAPACITOR BANK

SCALE	NTS	TITLE : 33kV CAPACITOR BANK PROTECTION
DRAWN		
CHECKED		
DATE		

DRAWING NO. :PGCB_DESIGN_2021_CEEGSTL_P2L2_PROTECTION_E19 REV : 0