BANGLADESH-CHINA POWER COMPANY (PVT.) LIMITED

Bidding Documents

for

Design, Supply, Installation, Testing & Commissioning of Payra – Gopalganj – Aminbazar 400kV Double Circuit Transmission Line (2nd phase) on Turnkey Basis

Volume 2

Scope of Works
Technical Specifications
Drawings forming Part of the Specification

Section II

Switchyard and Substations

Memo No.	:	**1258/BCPCL/Payra/2020**
Date	:	**December 14, 2020**
Deadline for Tender Submission	:	**February 04, 2021 @ 12.00 hours Local Time (GMT +6 hours)**

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Section II – Switchyard and Substations

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1. Scope of Works

1.1 General

The salient features of the work covered by this Section is outlined below for 400kV rated voltage outdoor type Air Insulated Switchgear (AIS) substation plant and civil works.

The Works shall include the design, manufacture, quality assurance, new packing for export, insurance and shipment to site, complete construction and installation, jointing, terminating, bonding, earthing, painting, setting to work, site testing and commissioning, warranty for a period of one (1) year for all equipment, including all civil works.

The detailed requirements are listed in Volume 3, Schedule-A (Schedule of Requirements). In addition to the scope described in Volume 2, Section I for Transmission Lines, the following two (2) Switchyard and Substations extensions will be constructed under the Contract:

i) Extension of Gopalganj 400 kV AIS Substation

The scope of extension works under this Contract shall include design, supply, delivery, installation, testing, and commissioning of outdoor type AIS substation. The extension works are for two (2) 400kV complete diameter of one and half breaker system in order to connect two (2) double circuit lines. One double circuit line is from Payra Power Plant and other double circuit line from Aminbazar Substation each opposite of other in the same diameter;

ii) Extension of Aminbazar 400kV AIS Substation

The scope of extension works under this Contract shall include design, supply, delivery, installation, testing, and commissioning of outdoor type AIS substation. The extension works are for two (2) line bays to connect two (2) 400kV double circuit line from Gopalganj including two (2) 400kV bus tie breakers and associated equipment to connect with 400kV busbar 1 and 2.

The scope of works for Gopalganj Substation shall include associated control, protection, fibre optic multiplexer equipment for communication & protection, substation automation, digital fault & disturbance recorder (DFDR), station power facilities, and associated civil works for extension of existing Local Control Houses (also known as Switchyard Panel Rooms (SPR)) to accommodate for the additional 400 kV protection and control IED, associated equipment, outdoor switchyards, cable trenches, and internal roads, etc.

The scope of works for Aminbazar Substation shall include associated control, protection, fibre optic multiplexer equipment for communication & protection, substation automation, digital fault & disturbance recorder (DFDR), station power facilities, and associated civil works for one (1) Local Control House to accommodate for the additional 400 kV protection and control IED, associated equipment, outdoor switchyards, cable trenches, and internal roads, etc.

The "Schedule of Requirements" for equipment, materials and services and the detailed technical specifications of equipment and materials of the Bidding Document shall be read in conjunction with the scope of work described herein. The drawings provided in the Bidding Documents are indicative only and hence the entire scope of works is not fully reflected in those drawings.

The Contractor is responsible for ensuring that all and any items of work required for the safe, efficient and satisfactory completion and functioning of the works, are included in the Bid price whether they be described or not.

As the substation works are extension of existing substation, all equipment for the proposed bay extension shall fulfil the requirements of existing substation.

1.2 System Electrical Parameters

1.2.1 System Conditions

Equipment supplied under this Contract shall be suitable for the following system conditions.

Nominal system voltage between phases	kV	400
System frequency	Hz	50
Rated voltage between phases	kV	420
Lightning Impulse withstand Level	kVp	1550 for Bus PI 1425 for other equipment
Switching Impulse withstand Level	kVp	1175 (Ph-E) for Bus PI 1050 (Ph-E) for other equipment
50Hz withstand 1 minute	kV	650
Symmetrical short-circuit current (1 sec)	kA	63

1.2.2 System Earthing

The existing 400/135/33 kV auto transformers are solidly earthed.

1.2.3 Minimum Substation Clearances

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

Nominal system voltage between phases	kV	400
Minimum clearance between live metal and earth	mm	3500
Minimum clearance between live metal	mm	4000
Minimum safety clearance between ground and the nearest point not at earth potential of an insulator	mm	2500
Minimum safety clearance between ground and the nearest live unscreened conductor (BS 7354 'Safety Working Clearance')	mm	6400
Minimum insulator creepage distance (at rated voltage between phases)	mm/kV	25

1.2.4 Low Voltage AC System

Rated service voltage (3 phase, 4 wire 50 Hz)	415 volts
Tolerance on rated voltage	±5%
Switchgear symmetrical breaking capacity	10 kA / 6kA / 4kA, 3 sec
System earthing	Solid

1.2.5 D.C. System

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

Normal battery voltage	110 V nominal
Tolerance on rated voltage	±5%
For telecommunication & SCADA	
Normal battery voltage	48 V nominal
Tolerance on rated voltage	±5%

1.3 Climatic Conditions

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

The project area and vicinity is close to sea level and is in a tropical climate. The ambient shade temperature variation is between 4°C and 45°C with periods of high humidity.

Between May and November low lying areas are subject to flooding.

The flooding can be taken advantage of at certain Sites in that the heavy loads may be floated on barges to close proximity to the Sites.

The project area is designated a zone of moderate intensity for earthquakes. The seismic factor is 0.2 g.

Atmospheric pollution is moderate and special insulator design or washing is not required. The area is subject to high winds of typhoon strength.

Maximum ambient shade temperature	45°C
Minimum ambient shade temperature	4°C
Maximum daily average temperature	35°C
Maximum annual average temperature	25°C
Maximum wind velocity	160 Km/h
Minimum wind velocity for line rating purposes	3.2 Km/h
Solar radiation	100 mW/sq.cm
Rainfall	2.5 m/annum
Relative humidity, maximum	100%
Relative humidity, average	80%
Altitude	less than 150 m
Atmospheric Pollution	light
(No ice or snow expected)	
Soil type	alluvial
Soil temperature (at 1.1 m)	30°C
Soil thermal resistivity	1.5°Cm/W
Isokeraunic Level (Thunderstorm days/year)	80

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

2. Ancillary Mechanical and Electrical Apparatus

2.1 Scope

This technical specification describes the general requirements for mechanical and electrical designs of all the plant being supplied under the Contract for both Gopalganj and Aminbazar Substations. It shall be read in conjunction with the Drawings provided in this Section and the Schedules in Volume 3 covering particular aspects of the plant.

2.2 References

2.2.1 ISO Standards

ISO68-1	General Purpose Screw Threads
ISO261	General Purpose Metric Screw Threads
ISO262	Selected sizes for screws, bolts & nuts
ISO272	Fasteners - hexagon products – widths across flats
ISO885	General purpose bolts and screws - metric series
ISO888	Bolts, screws and studs - nominal lengths & thread lengths for general purpose bolts
ISO965/1,2,3	General purpose Metric screw threads
ISO4759-1	Tolerances for fasteners
ISO9000	Quality management and quality assurance standards
ISO9001	Quality management systems – Requirements

2.2.2 IEC Standards

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
60034	Rotating Electrical Machines
60038	IEC Standard Voltages
60044 1	Instrument transformers - Part 1: Current transformers
60044 2	Instrument transformers - Part 2: Inductive voltage transformers
60044 5	Instrument transformers - Part 5: Capacitor voltage transformers
60051	Direct acting indicating analogue electrical measuring instruments and their accessories
60055	Paper insulated metal sheathed cables to 18/30 kV
60059	IEC Standard Current Ratings
60228A	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

60383-2	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(14)	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
62052-11	Electricity metering equipment - General requirements
62053-11	Electricity metering equipment - Particular requirements
60529	Degrees of protection provided by enclosures (IP Codes)
60587	Test methods for evaluating resistance to tracking
60614	Conduits for electrical installations Specification
60621	Electrical installations for outdoor sites under heavy conditions
60644	Specification for high voltage fuse links for motor circuit applications
60660	Tests on indoor post insulators of organic mats. between 1 300 kV
60672	Specification for ceramic & glass insulating mats.
60898	Circuit Breakers for overcurrent protection for households etc.
60947-1	Low-voltage switchgear and controlgear - Part 1: General rules
60947 2	Low-voltage switchgear and controlgear - Part 2: Circuit-breakers
60947 3	Low-voltage switchgear and controlgear - Part 3: Switches, disconnectors, switch disconnectors and fuse-combination units
60947 5 1	Low-voltage switchgear and controlgear - Part 5-1: Control circuit devices and witching elements
60981	Extra heavy-duty steel conduits for electrical installations
61035	Specification for conduit fittings for electrical installations
61084	Cable trunking & ducting systems for electrical installations
62271-1	High-voltage switchgear & controlgear - Part 1: Common specifications
62271-100	High-voltage switchgear & controlgear - Part 100: High -voltage alternating-current circuit breakers
62271-102	High-voltage switchgear & controlgear - Part 102: Alternating current disconnectors and earthing switches
62271-105	High-voltage switchgear & controlgear - Part 105: Alternating current switch-fuse combinations
62271-200	AC metal enclosed switchgear & control gear for 1 kV and above

2.2.3 British Standards

BS29	Specification for Carbon steel forgings
BS 182	Specification for galvanised line wire for telephone & telegraphic purposes
BS 443	Specification for testing zinc coatings on steel wire
BS499	Welding terms & Symbols
BS709	Method & testing fusion welded joints
BS 729	Specification for hot dip galvanised coatings on iron & steel articles
BS970	Specification for wrought steels for mechanical & allied engineering
BS CP 1014	Tropicalisation
BS 1224	Specification for electroplate coatings of nickel and chromium
BS1710	Specification for identification of pipelines & services
BS 1780	Specification for Bordon tube pressure and vacuum gauges

BS 1858	Specification for bitumen based filling compounds
BS 2011	Environmental Testing
BS 2569 Pt 2	Protection of iron & steel against corrosion at elevated temp.
BS 2600 Pt 1	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
BS3923 Pt 1 & Pt 2	Methods of examination of fused welds and butt joints.
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
BS4479 Pt 1-9	Recommendations for coatings.
BS 4592 Pt 1-4	Industrial type flooring, walkways and stair treads
BS4604 Pt 1-2	Specification for high strength friction bolts
BS4670	Specification for alloy steel forgings.
BS 4800	Schedule of Paint Colours for building
BS 4675 Pt 2	(ISO 2954) 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
BS6072	Method for penetrant flaw detection
BS 6121-1	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
BS6443	Method of penetrant flaw detection.
BS7079	Preparation of steel substrates before application of paints

2.2.4 BS European Standards

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

2.3 Definition of Terms

The definition of terms shall be as set out in the General Conditions of Contract in Volume 1 of the Bidding Documents.

2.4 Statutory Regulations

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

2.5 Design Standards and Codes

2.5.1 General Compliance with International Standards and Codes

The 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 (which ensure equivalent or higher quality than specified standard) or other approved standards shall apply.

2.5.2 Standards Named in Specification

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

2.5.3 Hierarchy of Standards

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

i) Statutory regulations of Bangladesh
ii) Standards named in the Specification
iii) International Standards
iv) Other standards approved by the Engineer

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

2.5.4 Substitution of Standards and Design Codes

The Bidder may offer Works which comply with international standards, or internationally recognized national codes or standards, which differ from those specified. However, the Bidder may offer Works which comply with the different standards or codes only if, he is able to demonstrate to the Employer / 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 organization in question has extensive experience with the alternative code or standard offered.

Any Bidder offering the Works or part of those Works to standards and codes which differ from those specified shall declare the fact to the Employer / Engineer. If requested to do so by the Employer / Engineer, the Bidder shall supply to the Employer / Engineer, at his own cost, two copies in English of the relevant code or standard which he proposes to substitute for that specified.

2.6 Erection Marks

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

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

2.7 Cleaning and Painting

2.7.1 General

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 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 authorized representative of the paint manufacturer.

The painting of the plant shall be carried out in accordance with the appropriate schedule later in this Section. The work is generally covered by the relevant schedules in sub-clause 2.7.2 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 Employer.

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 which occurs during transport shall be made good at Site.

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

Steel sections and plate shall be free from surface flaws and laminations prior to blast cleaning and shall not be in worse condition than ISO 8501-1.

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.

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.

The Employer / 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 relevant schedules in sub-clause 2.7.2.

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

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

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

Where lapped or butted joints from part of an assembly which 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.

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 Employer / Engineer.

Priming coats of paint shall not be applied until the surfaces have been inspected and preparatory work has been approved by the Employer / Engineer.

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 Employer / Engineer.

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

The schedules differentiate between "Treatment at Maker's Works" 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 Employer / Engineer and the painting is finished or made good at Site to the Employer / Engineer's satisfaction.

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

All paint film thicknesses given are minima and refer to the dry film condition. All thicknesses shall be determined by the correct use of approved commercial paint film thickness measuring meters.

All 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.

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.

2.7.2 Schedules of Finishes

2.7.2.1 Schedules for Indoor Surfaces

2.7.2.1.1 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).

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
Blast clean to BS 7079 2nd quality (SA 2.5) profile amplitude 40-75 microns. Then apply within 4 hours one coat (13 microns) weldable holding primer for 12 months xmatch 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.

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
Galvanize to BS 729	Thoroughly clean to remove oil, grease and dirt. Where galvanizing is damaged wire brush to BS 7079 3rd quality (SA2) and apply 1 coat zinc rich epoxy primer (50 microns). Then apply: 1st coat etch primer 2nd coat epoxy zinc chromate 3rd coat 2 pack epoxy micaceous iron oxide (50 microns) On galleries and stairways top surfaces apply 4th coat non-skid epoxy deck paint (30 microns)

c) Galvanized iron and steel requiring paint finish

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
Galvanize 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 nonferrous alloys requiring paint finish.

TREATMENT AT MAKERS WORKS	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

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
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)

2.7.2.1.2 Battery Rooms (open top batteries), Chlorination Plant Rooms, Electrolytic Cell Rooms (If Applicable)

a) Steelwork

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
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)

2.7.2.1.3 Bright Parts

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
Coat with a mixture of oil, grease or approved proprietary inhibitor.	Clean and polish

2.7.2.1.4 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

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
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 3rd coat alkyd undercoat (30 microns) Rub down with fine abrasive paper Then apply: 4th coat alkyd matt (25 microns) 5th coat alkyd matt (25 microns) 6th coat alkyd matt (25 microns) Total film thickness (125 microns)	Touch up if necessary and burnish

2.7.2.2 Schedules for Outdoor Surfaces

2.7.2.2.1 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).

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
Blast clean to BS 7079 2nd quality (SA2.5) profile amplitude 40-75 microns. Then apply within 4 hours one coat (13 microns) weldable 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

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
Galvanized to BS 729	Thoroughly clean to remove oil, grease and dirt. Where galvanizing is damaged wire brush to BS 7079 3rd quality (SA2) and apply I coat zinc rich epoxy primer (50 microns). Then apply: 1st coat epoxy etch primer 2nd coat epoxy zinc chromate (30microns) 3rd coat two pack epoxy micaceous iron oxide (100 microns) On galleries and stairways top surfaces apply 4th coat nonskid epoxy deck paint (30 microns)

c) Galvanized iron and steel requiring paint finish

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
Galvanized to BS 729	Thoroughly clean to remove oil, grease and dirt. Then apply: 1st coat etch primer 2nd coat zinc chromate primer (30microns) 3rd coat alkyd undercoat (30 microns) 4th coat alkyd gloss (25 microns)

d) Stainless steel, aluminium alloys and nonferrous alloys requiring paint finish

TREATMENT AT MAKERS WORKS	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

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
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)

2.7.2.2.2 Bright Parts

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
Coat with a mixture of oil, grease or approved proprietary inhibitor.	Clean and polish

2.7.2.2.3 Instrument Panels, Control Panels, Marshalling Kiosks, Lighting and Small Power Distribution Boxes and Junction Boxes etc.

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
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

2.7.2.2.4 Water and Oil Storage Tanks - Internal Surfaces (If Applicable)

The epoxy paint formulation shall be to the approval of the Employer / Engineer. The finished coating shall be capable of being tested with a high voltages spark tester for absence of pinholes and porosity.

For oil storage tanks, solvent free epoxy paint formulation shall be used.

TREATMENT AT MAKERS WORKS	TREATMENT AT SITE AFTER COMPLETION OF ERECTION
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	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)	Touch up damaged areas as necessary.

2.7.2.3 Radiators (If Applicable)

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 above. Radiators which are hot dip galvanised to BS 729, Part 1, shall be artificially weathered and given one coat of zinc chromate primer followed by the same number and type of paint coatings specified in Clause. Radiators shall be painted with Munsell colour No. 5Y-7/1.

2.8 Rating Plates, Nameplates and Labels

2.8.1 General

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

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. 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.

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

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

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

All equipment within panels and desks shall be individually identified.

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

2.8.2 Rating Plates

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

2.8.3 Circuit Labels

Each main item of Plant shall be provided with an identification plate. The inscriptions shall be approved by the Employer / Engineer.

In addition, the device number allocated by the Employer 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 Employer.

2.8.4 Pipe Service Identification (If Applicable)

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

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

Valve labels shall be circular and fitted under the handwheel captive nut. For check valves and small valves the Bidder may provide rectangular labels fitted to the valve or secured close by the valve.

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

Where the direction of flow through a valve or other device is an important requirement for correct functioning, the body of the valve or device shall be legibly marked with a cast on or a properly secured arrow, showing the direction of flow.

Pipework shall be provided with plentiful large painted arrows or other secure and durable arrow markings to allow the flows of fluids around the plant to be readily understood.

2.9 Environmental Protection and Tropicalisation

2.9.1 General

All equipment shall be designed to operate in the environmental conditions specified. Outdoor equipment shall be designed so that water cannot collect at any point. The undersides of all tanks (if applicable) shall be ventilated in an approved manner to prevent corrosion.

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

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.

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

Sunshades need not be provided on outdoor plant or equipment provided the manufacturer can satisfy the Employer / Engineer that the materials employed will not be adversely affected or the temperature rise due to internal heat generation plus that due to solar radiation will not exceed the equipment design temperature. However, equipment requiring manual operation shall be provided with sunshades to ensure that surface temperatures will not exceed 50°C.

Sunshades shall protect plant and personnel when the sun is more than 45°C above the horizon. They shall not impede the operation or maintenance of the plant or the movement of ventilating air and shall include adequate artificial light as necessary.

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

2.9.2 Tropicalisation

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

Metals: Iron and steel are generally to be painted or galvanized as appropriate. Indoor parts may alternatively have chromium or copper nickel plating or other approved protective finish. Small iron and steel parts (other than stainless steel) of all instruments and electrical equipment, the cores of electromagnets and the metal parts of relays and mechanisms shall be treated in an approved manner to prevent rusting.

Screws, Nuts, Springs, etc.: The use of iron and steel shall be avoided in instruments and electrical relays wherever possible. Steel screws shall be zinc, cadmium or chromium plated, or when plating is not possible owing to tolerance limitations, shall be of corrosion resisting steel. Instrument screws (except those forming part of a magnetic circuit) shall be of brass or bronze. Springs shall be of non-rusting material, e.g., phosphor bronze or nickel silver, as far as possible.

Rubbers: Neoprene and similar synthetic compounds, not subject to deterioration due to the climatic conditions, shall be used for gaskets, sealing rings, diaphragms, etc.

2.10 Platforms, Stairways, Ladders and Hand-Railing

2.10.1 General

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

Galleries, platforms and stairways shall be designed generally for a load of 7.5 kN/m^2 but where loads in excess of this are likely to be imposed during operation or maintenance, the Contractor shall make due allowance for the increased loads in the design. Particular care shall be given to their rigidity. All the necessary supports from the floors, buildings and foundations shall be supplied under this Contract.

Galleries and platforms around 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.

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.

Ladders will only be permitted where stairways are impractical, and access is required for maintenance.

All platforms, stairways, ladders and other accessways, 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 Works.

2.10.2 Flooring

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

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

The open grid flooring and stair treads shall be from an approved manufacturer and generally in accordance with BS 4592.

The pattern of open grid flooring and chequer plate shall be uniform and laid with the pattern in one direction.

Open grid floor panels shall be not less than 25 mm in depth and shall be fitted neatly between 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 to approval and only minimal protrusion above the floor level will be permitted.

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.

2.10.3 Hand-Railing and Protective Barriers

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

Double hand-railing shall be provided unless otherwise specified. Each length shall be joined by internal ferrules and all joints shall be neatly finished by the removal of all burrs. The top rail shall be not less than 30 mm diameter and mounted at a height of not less than 1100 mm from the gallery or platform level. The intermediate rail shall be not less than 25 mm diameter and mounted at a height of not less than 535 mm from the gallery or platform level. Handrails for stairways shall have the top rail at a height of not less than 900 mm and lower rail at not less than 420 mm above the stairway pitch line.

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

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

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

2.10.4 Stairways

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 standardized. Angles exceeding 42° to the horizontal shall not be used.

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

2.10.5 Fixed Access Ladders

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

2.11 Nuts, Bolts, Studs and Washers

The threads and other details of fasteners shall comply with the relevant ISO Standards for metric series fasteners.

Nuts and bolts for pressure parts shall be of the best quality steel.

Nuts, bolts, studs and washers shall be of materials most suitable for the service operating conditions and designed to ensure the stresses arising in normal operation shall not exceed those necessary to ensure that the specified plant life is achieved.

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

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

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

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

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

On outdoor equipment all bolts, nuts and washers shall be of non-rusting material where they are in contact with nonferrous parts in conductor clamps and fittings.

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

2.12 Forgings

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

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

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

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

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

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

2.13 Castings

2.13.1 General

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

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

2.13.2 Steel Castings

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

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

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

Only welders who have passed an appropriate qualification test shall be employed on the repair of castings. All repairs shall be carried out by the metal arc process.

Ultrasonic inspection shall be applied to all important castings to locate the extent of sub surface defects and to check the wall thickness.

All castings shall be identified by stamped or cast on reference marks, which shall be entered on all relevant documents and test certificates.

The Employer / Engineer may require that certain castings be examined using radiographic techniques. The Contractor shall include for this eventuality and shall comply with the Employer / Engineer's instructions when issued.

2.13.3 Iron Castings

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

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

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

Test blocks shall be integrally cast on all medium and large castings.

The Employer / Engineer may require that certain castings be checked using radiographic techniques. The Contractor shall include for this eventuality and shall comply with the Employer / Engineer's instructions when issued.

2.13.4 Aluminium Bronze Castings

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

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

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

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

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

2.14 General Welding Requirements

2.14.1 General

All welding shall conform to the relevant British Standards, or other British or National Standard Specification as agreed by the Employer / Engineer.

Where there is a conflict between Codes and/or Standards the Employer / Engineer's decision will prevail.

2.14.2 General Fabrication

The Employer / 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.

2.14.3 Weld Procedure Documents

Complete and fully detailed weld procedure documents shall be kept by the Contractor and these shall be made available to the Employer / Engineer on request.

Prior to commencement of welding, the Contractor shall submit to the Employer / 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 to G.

2.14.4 Weld Procedure Qualification Tests

Weld procedure qualification tests shall be carried out in accordance with the requirements of BS EN 288, or agreed National Standard for the item of Plant under consideration.

Provided that the Contractor confirms that the basic parameters of the procedure have not been changed since approval, the results of weld procedure qualification tests previously carried out under the supervision of an internationally recognised inspecting authority may be accepted by the Employer / Engineer.

The Contractor shall inform the Employer / Engineer of any proposed changes to the welding procedures before such changes are implemented. If in the opinion of the Employer / 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 Employer / Engineer, if required.

2.14.5 Welder's Qualification Tests

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

All welders' tests shall be witnessed and/or approved by the Employer / Engineer before the welder or operator is permitted to work. The decision of the Employer / 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 Employer / Engineer.

2.14.6 Storage of Welding Consumables

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

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

2.14.7 Welding Equipment

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

2.14.8 Visual Weld Inspection

Each weld shall be subjected to a stringent visual inspection and shall be free from undercut, excessive spatter, craters, cracks, porosity and other surface imperfections. Welds shall be of regular contour, even weld ripple and indicative of good workmanship.

Fillet welds shall be checked for dimensional tolerance and form using a fillet weld gauge. Fillet welds should be slightly concave in form and each leg of the weld shall have equal length.

2.14.9 Internal Examination

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

2.14.10 Non-destructive Examination

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

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

2.14.11 Ultrasonic Examination

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

2.14.12 Magnetic Crack Detection

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

2.14.13 Dye Penetrant Tests

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

2.14.14 Quality Requirements for Welds

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

2.14.15 Weld Repairs

The Employer / Engineer's approval shall be obtained prior to commencement of any repair or rectification work.

Weld repairs shall be made to the same procedure as for the original weld. All tests shall be repeated after the repair has been completed and reports on radiographic and ultrasonic tests shall be marked to indicate that the report refers to a repaired weld.

2.14.16 Mandatory Inspections

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

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

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

2.15 Galvanized Work

All materials to be galvanized 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 galvanizing process commences.

All galvanizing shall be done by the hot dip process with spelter, 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 Employer / Engineer. Bolts shall be completely galvanized 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.

Galvanized 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 Employer / Engineer may select for test as many components to be weighed after pickling and before and after galvanizing as he may think fit.

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

All galvanized 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 Employer / Engineer, the extent of the damage found on Site to a galvanized 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 Employer / Engineer to accept the repaired part when this is re offered for inspection.

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

2.16 Chromium Plating

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

2.17 Pumps

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

Preventive and routine maintenance time should be minimized by the selection of appropriate designs of pump, preferably those that leave casing to piping joints intact, i.e. horizontal split casing types for large centrifugal pumps and horizontal, back pull out types for smaller units. Where a significant saving in floor space or improvement of layout can be shown, a vertical pump may be acceptable.

Pumps shall be capable of continuous operation with minimum maintenance.

2.18 Pipework

2.18.1 General

During the contract engineering, the Contractor shall supply to the Employer / 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 allowances, the pipework design code, insulation proposals, pipe supports and any other data relevant to the mechanical design of the pipework system or part of a pipework system.

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

2.18.2 Internal cleaning of pipes

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

The procedure adopted by the Contractor is to include the following:

i) 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.

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

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

2.18.3 Pipe Supports and Anchors

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 Employer / Engineer.

2.19 Valves

2.19.1 General

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.

2.19.2 Hand Operation Requirements

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 handwheel or other point of application of manual action shall not need to exceed 400 N (normally 200 N pull plus 200 N push) to exercise any valve. Special attention shall be given to the operating mechanism for large size valves with a view to ensuring that a minimum of maintenance is required and to obtaining quick and easy operation.

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

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

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

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

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

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

2.20 Pressure Vessels (If Applicable)

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:

(a) 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.

(b) hot water storage vessels heated by steam or any other indirect means when none of the following limitations is exceeded:

i) a heat input of 58 kW
ii) a water temperature of 93°C
iii) a nominal water containment capacity of 454 litre.

(c) 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.

(d) vessels having an internal diameter not exceeding 150 mm.

(e) vessels and equipment covered more appropriately by boiler or pipework design codes.

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

Notwithstanding the foregoing exclusions (a) to (e), if it is stated elsewhere in this specification that a particular vessel shall comply with a pressure vessel design code, then a vessel complying with a suitable design code shall be provided.

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

2.21 Lubrication

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

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

The Contractor is to 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 is to be supplied and permanently labelled.

2.22 Oil Level Indicators

Oil level indicators of approved design are to be fitted to all oil containers such as reactor tanks, etc.

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

2.23 Pressure Gauges

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

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

Gauges shall be calibrated to read pressure at the tapping point and a sealed pressure transmitting system shall be used.

All pressure gauges are to be clearly identified by means of labels of approved type and lettering.

All pressure gauge piping is to be of corrosion resistant steel or copper tube.

2.24 Thermometer Pockets

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

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

2.25 Gauge Cubicles and Panels

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

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

2.26 Locking Facilities

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

(a) Control position selector switches in all positions provided.

(b) Marshalling, operating and terminal kiosks or cubicle access doors and panels.

(c) Isolating valves in open or closed positions.

Locking facilities shall be of an approved dead latch type. Three keys shall be supplied for each lock and all locks and keys shall be non-interchangeable.

Where a set of locks is provided under a particular section of the Plant, a group master key shall be supplied in addition.

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

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

Where a group of locks is supplied under any part of the Contract, a rack or cabinet of approved design shall be supplied for the accommodation of all padlocks and/or keys while not in use. The padlocks and

keys shall be engraved with an agreed identifying code or inscription and this shall be repeated on the racks or cabinets on engraved labels.

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

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

2.27 Electrical Equipment

2.27.1 General

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

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

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

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 Employer and Engineer's satisfaction.

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

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

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

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

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

2.27.2 Electrical Equipment Enclosures

Equipment enclosures for electrical equipment shall comply with IEC 60079, IEC 60529 and IEC 60947-1 as applicable. Equipment enclosures for use in hazardous areas other than explosive gas atmosphere shall comply with National and Local Regulations relating to this application.

Unless otherwise specified, minimum equipment enclosure classifications for non-rotating electrical equipment shall be as follows:

(a) Indoors only in totally enclosed rooms with provision for limiting ingress of dust: IP 31

(b) Indoors, except as noted otherwise: IP 54

(c) Outdoors, and indoors in areas subject to water spray, or heavy condensation: IP55W

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

2.28 Current Ratings

2.28.1 Normal Current Ratings

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

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

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

2.28.2 Temperature Rise

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

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

To allow for high ambient site temperatures, the allowable temperature rise for transformers shall be reduced by a maximum of 10°C.

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 subject to the Employer / Engineer's approval.

The maximum temperature attained by components under the most onerous service conditions shall not cause damage or deterioration to the equipment or to any associated or adjacent components.

The Contractor shall submit his calculations to the Employer / Engineer to prove that all plant has been sufficiently derated to suit the site conditions and any changes required by the Employer / Engineer shall be made at no extra cost.

2.28.3 Short-time Current Ratings

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

Equipment shall be constructed as to withstand the specified maximum short circuit currents for the time specified in the Schedule A of Volume 3 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.

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

2.29 Voltage Ratings

2.29.1 Normal Voltage Ratings

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

All electrical equipment shall, except where otherwise specified, be capable of continuous operation at a voltage in the range of ±15% of the nominal voltage and at a frequency in the range of 47 to 51 Hz coincidentally without deterioration.

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

2.29.2 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.

2.30 Electrical Insulation

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.

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.

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

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

Linseed oil and untreated materials of fibre, leatheroid, 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.

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

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

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

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

2.31 Insulating Oil

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

2.32 Control and Selector Switches

Control switches shall be of the three-position type with a spring return action to a central neutral position and without a locking feature.

Circuit breakers shall have control switches which shall be labelled open/N/close or (O/N/I) and arranged to operate clockwise when closing the circuit breakers and anti-clockwise when opening them.

Control switches of the discrepancy type shall be provided where specified. Such discrepancy control switches shall be arranged in the lines of the mimic diagram. Such switches shall include lamps and be of the manually operated pattern, spring loaded such that it is necessary to push and twist the switch past its indicating position for operation. The lamp shall be incorporated in the switch base and shall flash whenever the position of the controlled device is at variance with the position indicated by the control switch. Hand dressing of the control switch to the correct position shall cause the lamp to extinguish.

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

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

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

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

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

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

2.33 Panels, Desks and Cubicles

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

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

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

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

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

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

For outdoor equipment, metal to metal joints shall not be permitted and all external bolts or screws shall be provided with blind tapped holes where a through hole would permit the ingress of moisture. For harsh environments, all nuts, bolts and washers shall be tropicalised as appropriate in accordance with sub-clause 2.10.2.

Door sealing materials shall be provided suitable for the specified site conditions. Doors shall be fitted with handles and locks. Where walk in type panels are supplied the door shall be capable of being opened from inside the panel without the aid of a key after they have been locked from the outside. Hinges shall be of the lift off type, and shall permit the doors when open, to lie back flat so as not to restrict access. Means shall be provided for securing the doors in the open position.

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

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

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

Each panel shall include rear access doors internal power sockets and door operated internal lighting and be clearly labelled with the circuit title at front and rear, with an additional label inside the panel. Panel sections accommodating equipment at voltages higher than 125 V (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.

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

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

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

All panels, whether individually mounted or forming part of a suite, shall incorporate a common internal copper earthing bar onto which all panel earth connections shall be made. Suitable studs or holes to the Engineer's approval shall be left at each end of the bar for connection to the main station earthing system and possible future extension.

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

Where intrinsically safe circuitry is routed from a hazardous area to a safe area instrument panel, it shall be connected through Zener Barriers located in the safe area (instrument panel) of suitable rating and mounted on an insulated earthing busbar having facilities for connection of a separate dedicated outgoing cable to a "clean earth" system.

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

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

All cubicles, desks and panels shall be painted externally with a high gloss paint of Munsell 5Y-7/1 colour. The interiors of all cubicles, desks and panels shall be painted matt white.

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

2.34 Instruments and Meters

2.34.1 Indicating Instruments

All indicating instruments shall be of the flush mounted pattern with dust and moisture proof cases complying with BS 2011, Classification 00/50/04, and shall comply with IEC 51-1.

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

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

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

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

2.34.2 Electrical Meters

All electrical meters shall comply with IEC 521 and, unless otherwise specified, shall be of accuracy Class 0.2. Three phase power measuring instruments shall be of the three-phase unbalanced load pattern wherever the current and voltage references permit.

Where precision grade metering is specified meters shall be calibrated to precision grade accuracy to IEC 521. Due allowance shall be made for the errors of current and voltage transformers with which they shall work and whose accuracy class shall be Class 0.2.

Where commercial grade metering is specified the meters shall be calibrated to commercial grade accuracy to IEC 521.

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.

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

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

Each feeder shall be provided Main 1 and Main 2 energy meters. The energy meter shall be 3 element, 4 wire arrangement of programmable digital type and shall have proven performance and shall consist of different types, either from the same manufacturer or different manufacturers. The accuracy class of the energy meter shall be 0.2.

2.35 Indicating Lamps and Fittings

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

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

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

The variety of indicating lamps provided shall be rationalized to reduce maintenance and spares requirements. The lamps shall be clear and shall fit into a lamp holder. The rated lamp voltage shall be at least 20% in excess of nominal supply voltage, whether A.C. or D.C. The lamps shall have an operating life of at least 10,000 hours, under site conditions. In the event that other indicating devices, such as light emitting diodes, are used in place of lamps then these shall have the same life expectancy and performance capability as the lamps they replace.

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

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

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

Red: energised or operative position

Green: de-energised or inoperative position

Amber: fault or abnormal condition

White: healthy or normal condition

Blue: other purposes, to be used with descriptive label

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

Indication circuits shall be fused.

2.36 Anti-Condensation Heaters

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

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

Motor anti condensation heaters where fitted shall be fed from an LV single phase and neutral supply buswired 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.

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

2.37.1 General

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

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

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

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

(a) Class 1 conductors up to a maximum of 0.9 mm diameter where necessary for wire wrapped terminations and similar techniques,

(b) Class 2 conductors except where specified otherwise,

(c) Class 5 and Class 6 conductors between points subject to relative movement.

The following minimum conductor sizes shall be used:

(a) 2.5 mm^2 for current transformer secondary circuits with a rated secondary current of not exceeding 1A.

(b) 1.5 mm^2 except where specified otherwise,

(c) 0.5 mm^2 for alarm and indication circuits with a continuous or intermittent load current not exceeding 1A.

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

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

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

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

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

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

2.37.2 Identification of Wires

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

When a wire numbering system is used, it should be in accordance with 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.

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

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

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

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

2.37.3 Terminals and Terminal Blocks

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

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

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

Where clamp type terminals are used, Class 1 and Class 2 conductors may be terminated without lugs. Crimp lugs shall be used for Class 5 and Class 6 conductors. Means shall be provided for retaining the identifying ferrules of the wire end when it is disconnected. Pinch screw type terminals shall not be permitted.

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

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

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

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

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

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

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

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

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

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

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

2.38 Cable Boxes and Glands

2.38.1 General

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

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

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

Clearance and creepage distances shall be adequate to withstand the specified alternating current voltages and impulse voltages for service under the prevailing site conditions. Means shall be provided for preventing accumulation of dirt, dust, moisture, vermin or insects such as to maintain the anticipated life of the equipment.

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

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

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

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

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

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

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

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

Removable 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.

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

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

2.38.2 Additional Requirements for Compound-filled Cable Boxes

Cable boxes for paper insulated cables shall be complete with universal tapered brass glands, insulated from the box in an approved manner and including an island layer for testing purposes, together with removable shorting links.

Filling and venting plugs, where required, shall be positioned so as to avoid the possibility of air being trapped internally and adequate arrangements shall be made for expansion of compound, etc.

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

2.38.3 Cable Glands

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

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

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

mm nominal size, the earthing connection shall have a short circuit rating of at least 25 kA for 1 second, and of at least 40 kA for 1 second on larger sizes.

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

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

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

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

2.39 Box-Filling Compounds

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

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

The Contractor shall take particular care to adhere to the recommended topping up procedures and to ensure that no leakage or migration of the filling compound occurs. Should leakages occur during the maintenance period, the Employer will require the joint to be re-made at the Bidder's expense.

2.40 Oil or Compound-Filled Chambers

All joints of oil or compound filled fabricated chambers, other than those which 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 Employer / Engineer.

Insulating compound shall comply with BS 1858.

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

2.41 Joints and Gaskets

All joint faces are to be flat and parallel to the approval of the Employer / Engineer and arranged to prevent the ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of oil or air.

Oil resisting synthetic rubber gaskets are not permissible, unless the degree of compression is accurately controlled. For gaskets of cork or similar, oil resisting synthetic rubber may be used as a bonding medium.

2.42 Valves on Electrical Equipment Fluid Lines and Vessels

Valves shall comply with the requirements of sub-clause 2.19.

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

2.43 Junction and Marshalling Boxes

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

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

All outdoor kiosks, cubicles and panels shall be provided with sun/rain shades. All kiosks, cubicles and panels not in air-conditioned rooms shall be provided with thermostat controlled anti condensation heaters.

All kiosks, and cubicles shall be fitted with door operated internal illumination lamps.

All necessary gland plates shall be provided undrilled.

Boxes shall be complete with suitably inscribed identification labels.

Boxes for use in hazardous areas shall have all entries factory pre-drilled. Every unused screwed entry shall be sealed by means of a tamperproof screwed plug in accordance with IEC 60079.

Hazardous area boxes with bolted or screwed lids shall require the use of special keys or spanners, for lid removal.

Where weatherproof types of hazardous area boxes are not available, the gaps should be protected against the ingress of moisture, by an approved means, compliant with local standards.

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

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

2.44 Conduit and Accessories

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

All conduit and conduit fittings shall comply with IEC 60423. Unless otherwise approved, all conduit and conduit fittings shall be threadable steel conduit with minimum enclosure classification IP55, heavy mechanical protection and high resistance to corrosion inside and outside. No conduit smaller than 20 mm diameter shall be used.

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

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

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

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

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

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

All conduits run in any circuit are to be completed before any cables are pulled in. Flexible metallic conduit shall be used where relative movement is required between the conduit and connected apparatus, and a separate earth continuity conductor shall be provided.

2.45 Trunking

Steel trunking may be used for running numbers of insulated cables or wires in certain positions to the approval of the Engineer. The trunking thickness shall not be less than 1.2 mm.

Connection of conduit to trunking shall be with socket and male bush. All trunking shall be manufactured from hot dip zinc coated steel sheet and conform to IEC 1084.

2.46 Electric Motors

2.46.1 General

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

2.46.2 Type and Rating

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

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

Three phase A.C. motors shall be rated for the voltages specified elsewhere in this specification. The minimum rated output of HV motors shall comply with IEC 34 1. The maximum rated output of LV motors shall not exceed 150 kW, except where approved by the Employer / Engineer.

2.46.3 Insulation

Motors shall be insulated with materials complying with IEC 85. All motors shall have Class F insulation but the temperature rise shall not exceed the limits applicable to Class B.

2.46.4 Conditions of Operation

A.C. motors shall be capable of continuous operation under the service conditions within the Zone A voltage and frequency variations specified in IEC 34-1, Figure 13 or as covered in sub-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.

2.46.5 Starting Performance

Unless otherwise specified or required, cage induction motors up to and including 40 kW shall have a starting performance better than or equal to Design N in accordance with IEC 34 (External inertias for 50 and 60 Hz motors shall be in accordance with BS 4999 Part 112). Cage induction motors above 40 kW shall have a starting performance better or equal to Design D in accordance with BS 4999 Part 112. The starting current at full voltage shall not exceed 6 times full load current.

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

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

Electric motors shall be suitable for two successive starts with the motor already at full load working temperature, subject to the motor being permitted to decelerate to rest under operating conditions between successive starts.

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

2.46.6 Bearings

The type of bearings used in the motor shall be fully compatible with those used in the driven equipment.

The type of bearing, bearing numbers and regressing interval shall be stamped on each motor rating plate.

Bearings shall comply with the applicable ISO standards.

Bearings shall be designed to exclude the ingress of dust and water and sealed to prevent leakage of lubricant along the shaft.

2.46.7 Enclosures and Methods of Cooling

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

- IP54 for indoor locations not subject to hosing.

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

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

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

Aluminium and its alloys shall only be used when the manufacturer can demonstrate that such materials are entirely suitable for the particular application at its installation location.

Fans of identical motors shall be interchangeable without affecting motor balance.

2.46.8 Anti-condensation Heaters

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

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

2.46.9 Terminals and Terminal Boxes

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

(a) Main (line) connections.

(b) Star point connections.

(c) Anti condensation heater connections.

(d) Instrumentation and alarm devices.

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

All HV terminal boxes shall be provided with a desiccant indicator, externally sealed.

Terminals and terminal leads shall be to approval and shall be substantially designed for connection to a system having the symmetrical short circuit rating of the source switchboard, as limited by fuses, where applicable.

The clearances and creepage distances shall apply also to insulated terminals and connectors.

Porcelain terminal bushings and insulators shall not be used.

Main and star point terminal boxes of HV motors shall be of steel. Cast iron may only be used for LV motor terminal boxes and auxiliary terminal boxes.

Star point terminal boxes shall only be provided where required to accommodate neutral end current transformers and shall be positioned opposite the main terminal box.

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

Provision shall be made for earthing the cable armour and the cable insulation screens, where applicable, in accordance with the cable termination method being used.

In auxiliary cable boxes either stud terminals or clamp terminals shall be provided.

The anti-condensation heater terminal box shall have a warning label adjacent to it, stating "Motor heater terminals live".

2.46.10 Earth Terminal

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

2.46.11 D.C. Motors

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

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

All D.C. motors shall be provided with brushgear which does not require to be moved to suit load conditions.

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

2.47 Motor Starters and Contactors for Separate Mounting

In special cases for motors below 30 kW, and non-essential non plant auxiliaries, such as roller shutter doors, and where approved by the Employer / 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 online 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 Employer / Engineer.

Contactors shall be of robust design and shall comply with IEC 60947.

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

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

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

2.48 Pushbuttons and Separately Mounted Pushbutton Stations

Pushbuttons, which may be of the illuminated or non-illuminated type, shall be shrouded or well recessed in their housings in such a way as to minimize the risk of inadvertent operation.

In instances where "enable" pushbuttons are required they shall be electrically interlocked with the normal control such that deliberate operation of the "enable" push button is required before the normal control can take place.

The colour of pushbuttons shall be as follows:

- When mounted on pushbutton stations adjacent to running plant the stop button shall be coloured red and the start button coloured green.

- When mounted on the front of the contactor panel the stop button shall be coloured red and the start button coloured green.

- When mounted on panels or desks with adjacent indication lights both buttons shall be coloured black, unless required otherwise by the Employer / Engineer.

Loose pushbutton stations, unless supplied as weatherproof free-standing enclosures, shall be of the metalclad weatherproof type suitable for wall or bracket mounting with a minimum enclosure classification of IP55. All outdoor mounted pushbutton stations shall incorporate a protective cover or guard (e.g. toughened glass door) to prevent inadvertent operation.

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

Pushbuttons used on covered desks, panels etc. may of necessity require to be of special types (e.g. miniature, illuminated). The specifications and requirements for these special pushbuttons shall be agreed with the Employer / Engineer.

Emergency stop pushbuttons shall be provided adjacent to all motors and machinery with exposed moving parts, couplings etc. to prevent danger, and on main and local control panels. These 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.

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

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

2.49 Miniature Circuit Breakers, Fuses and Links

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

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

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

All fuses shall incorporate HRC cartridges to BS 88 or IEC 60269. Fuse holders shall be designed to lock the cartridges firmly into position without the use of screw clamping devices.

Miniature circuit breakers (MCB's) shall comply with IEC 60898. Where MCB's are used on control, protection and alarm supplies, tripping shall cause an alarm to be displayed.

2.50 Earthing and Bonding

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

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

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

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

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

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

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

The size of the copper earth bar in control panels, control desks or similar enclosures containing low voltage apparatus shall be such as to comply with the specified requirements for withstanding prospective short circuit currents. The size of this bar shall be a minimum of 100 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.

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.

If the plant contains electronic equipment which 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 Neutral Earthing Equipment

3.1 Scope

These clauses describe the General Technical Requirements for the extension of 400kV outdoor, open terminal circuit breakers & general switchyard equipment, and shall be read in conjunction with the Drawings in this Section and relevant Schedules in Volume 3.

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.

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

The requirement for switchgear spares, tools and appliances, including test, maintenance and handling equipment shall be as stated in the Bidding Documents. All devices necessary for operation and earthing shall be provided within the Contract Price.

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

3.2 References

3.2.1 IEC Standards

IEC 60060	High Voltage test techniques
IEC 60071	Insulation Co ordination
IEC 60099	Surge arresters
IEC 60044-1	Instrument Transformer - Part 1: Current transformers
IEC 60044-2	Instrument Transformer - Part 2: Voltage transformers
IEC 60044-5	Instrument Transformer - Part 5: Capacitive Voltage transformers
IEC 60273	Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000 V.
IEC 60305	Insulators for overhead lines with a nominal voltage above 1000 V - Ceramic or glass insulator units for ac systems - Characteristics of insulator units of the cap and pin type
IEC 60376	Specification of technical grade sulfur hexafluoride (SF6) for use in electrical equipment
IEC 60383	Insulators for overhead lines with a nominal voltage above 1000 V
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 62271-102	HV switchgear and controlgear – part 102: AC disconnectors and earthing switches
IEC 62271-200	A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV

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 1000 V.

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

3.3.1.1 General Requirement

The normal operations will be affected from the National Load Dispatching Centre (NLDC) at Rampura. The Contractor shall take into consideration the unmanned operation of the substation in his design (no operators are necessary in the existing substation control rooms).

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

The following provisions shall be made for control and indications:

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

Remote panel in the control room of each Substations - control of circuit breakers, disconnectors and line side earthing switches where power operated with position indication in each instance.

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

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

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.

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

In the event of leakage from any compartment, equipment shall withstand rated voltage with SF6 at atmospheric pressure. The insulation levels shall be able to withstand basic test voltages in accordance with the relevant standards for Synchronising Operation for Breakers.

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

3.3.2 Availability for Maintenance, Repair, Extensions, Testing

Maintenance, Repair or Extension (MRE) and HV Testing on one busbar with directly connected apparatus shall be possible with the other busbar in normal operation.

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

MRE Testing on/of buscoupler bay shall be possible with one busbar at the time in normal operation and all switchgear bays in normal operation.

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

3.4 Outdoor HV Switchgear

3.4.1 Switchgear - Design and Performance

The switchgear shall be suitable for outdoor location and capable of continuous operation under the existing site climatic conditions. It shall be designed to comply with this specification and relevant IEC and British Standards, where applicable. Deviations from this specification and Standards shall be stated in Schedule F "Departures from the Specification" in Volume 3.

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

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.

The layout and design of plant and equipment on substation sites shall provide for ready access for operation, maintenance and extension whilst the remaining sections of equipment are alive. Electrical clearances provided between isolated equipment and nearest live metal work shall not be less than the distance data as mentioned in sub-clause 1.2.3 of this Section. Insulation creepage distances shall not be less than 25 mm per kV rated voltage between phases.

The Contractor shall be responsible for ensuring that insulation coordination in accordance with recommendation of IEC 60071 is achieved. Dynamic and temporary over voltages shall be assumed to be in accordance with normally accepted IEC levels and subject to approval of the Engineer.

3.4.2 Current Ratings

Every current carrying part of the switchgear including 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.

Every part of the switchgear shall also withstand, without mechanical or thermal damage, the instantaneous peak currents and rated short time current pertaining to the rated breaking capacity of the circuit breaker.

3.4.3 Corona

Equipment shall be designed so as to minimize corona or other electrical discharge and radio interference. The Contractor is to confirm and ensure adequacy of design in terms of corona performance. Ion current density shall be less than 20 na/sqm at ground level. The Contractor shall furnish all calculations and documents in support of the above during detailed engineering. Tests for corona and radio interference shall be carried out by the Contractor as required by the Employer / Engineer. 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 in the scope of works.

3.4.4 Local, Remote and Supervisory Control

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

For supervisory telecontrol, the interface between the telecontrol control equipment and the control equipment being provided under this Contract and shall be as specified in clause 10 in this Section.

3.4.5 HV Circuit-Breakers

3.4.5.1 General

The circuit breakers and accessories shall conform to relevant IEC: 62271-100, IEC: 60694 and other relevant IEC standards except to the extent explicitly modified in the specification.

The circuit breakers shall be sulphur hexafluoride (SF6) type only.

The circuit breaker shall be complete with terminal connectors, operating mechanism, control cabinets, piping, interpole cable, cable accessories like glands, terminal blocks, marking ferrules, lugs, pressure gauges, density monitors (with graduated scale), galvanised support structure for CB and control cabinets, their foundation bolts and all other circuit breakers accessories required for carrying out all the functions the CB is required to perform. All necessary parts to provide a complete and operable circuit breaker installation such as main equipment, terminals, control parts, connectors and other devices whether specifically called for herein or not shall be provided. The support structure of circuit breaker as well as that of control cabinet shall be hot dip galvanised. All other parts shall be painted as per approved shade.

3.4.5.2 Operating Duty and Performance

a) The circuit breaker shall be rated for the switching, interrupting and current carrying duty imposed upon them in their intended application.

b) The total interrupting time shall be 2 cycles or less from energization of trip circuit of the circuit breaker to the extinction of the arc. The total closing time shall be less than 150 msec from energization of closing circuit of the circuit breaker to closing of the breaker contacts. The operating duty cycle shall be 0 - 0.3 sec - CO - 3 min - CO, with no de-rating for the first re-closure between operations over the voltage range from nominal to rated maximum voltage and from zero to the maximum rated interrupting current without the necessity of intermediate maintenance. The circuit breakers shall be capable of withstanding the transient recovery voltage as per IEC-62271 (values to be determined by the Contractor).

c) The circuit breaker shall be designed for M2C2 class as per IEC 62271 under all duty conditions.

d) The circuit breaker shall meet the duty requirements for any type of fault or fault location and for line switching when used on a 420 kV effectively grounded system and perform make and break operations as per the stipulated duty cycles satisfactorily.

e) The circuit breaker shall be capable of performing their required duty as per application including
   i) Interrupting steady and transient magnetizing current of transformers of specified ratings or as the case may be.
   ii) Interrupting line charging current as per IEC.
   iii) Clearing short line faults (Kilometric faults) with source impedance behind the bus equivalent to symmetrical fault current specified.
   iv) Clearing bus faults on 400 kV AC switchyard.
   v) Clearing faults as second-in-line breaker in the event of failure of main breaker.
   vi) Breaking small inductive currents of 0.5 A to 10 A without switching over voltage exceeding 2.3 p.u.
   vii) Breaking 25% of the rated fault current at twice rated voltage under phase opposition condition.
   viii) Breaking large capacitive currents considering the largest bank/sub-bank of filters under most onerous condition causing maximum stress to the breaker. The breakers shall satisfactorily withstand the high stresses imposed on them during fault clearing, load rejection and re-energization with trapped charges. The breakers shall also withstand the voltages specified.

f) The total break time as specified shall not be exceeded under any of the following duties:
   i) Test duties 1,2,3,4,5 (TRV as per IEC:62271-100)
   ii) Short line fault L75, L90 (TRV as per IEC:62271-100)

g) The total break time of the breaker shall not be exceeded under any duty conditions specified.

3.4.5.3 Constructional Features

The features and constructional details of the circuit breaker shall be in accordance with requirements stated hereunder:

a) The gap between the open contacts shall be such that it can withstand at least the rated phase to ground voltage for 8 hours at zero-gauge pressure of SF6 gas due to leakage. The breaker should be able to withstand all dielectric stresses imposed on it in open condition at lockout pressure continuously (i.e. 2 p.u. across the breaker continuously).

b) If multi break interrupters are used, these shall be so designed and augmented that a uniform voltage distribution is developed across them. Calculations/test reports in support of the same shall be furnished by the Contractor. The thermal and voltage withstand capabilities of the grading elements shall be adequate for the service conditions and duty specified.

c) The SF6 circuit breaker shall meet the following additional requirements:
   i) The circuit breakers shall be of single pressure buffer type. The design and construction of the circuit breaker shall be such that neither SF6 gas shall leak to atmosphere and nor moisture shall enter in the breaker. There shall not be any condensation of SF6 gas on the internal insulating surface of the circuit breakers.

   ii) All gasket surfaces shall be smooth, straight and reinforced, if necessary, to minimize distortion and to make a tight seal. The operation rod connecting the operating mechanism to the arc chamber shall have adequate seals. The SF6 gas leakage should not exceed 1% per year. In case the leakage under specified conditions is more than 1% after one year of commissioning of the circuit breaker, the manufacturer shall have to supply free of cost, the total make up gas requirement for subsequent ten (10) years based on actual leakage observed during first year

of operation after commissioning. In the interrupter assembly there shall be an absorbing product box to minimize the effects of SF6 decomposition products and moisture. The material used in the construction of the circuit breakers shall be such as to be fully compatible with SF6 gas as well as its decomposition products.

iii) Each pole shall form an enclosure filled with SF6 gas independent of two other poles and the SF6 density of each pole shall be monitored. The SF6 gas density monitor shall be provided on each of the individual poles.

iv) The gas density in the SF6 circuit breaker shall never be less than the minimum required insulating density of SF6. Gas density monitoring equipment with two level alarms shall be provided.

v) The dial type SF6 gas density monitor shall be adequately temperature compensated to model the density changes due to variations in ambient temperature within the body of the circuit breaker as a whole. The density monitor shall meet the following requirements:

It shall be possible to dismantle the density monitor for checking/replacement without draining the SF6 gas by using suitable interlocked non-return valve coupling.

It shall damp the pressure pulsation while filling the gas so that the flickering of the pressure switch contacts does not take place. Filling of SF6 gas shall not be performed in the closed position of breaker.

vi) Suitable means for pressure relief shall be provided in the gas chamber of circuit breaker to avoid the damages or distortion during the occurrence of abnormal pressure increase or shock waves generated by internal electric fault arcs. The position of vents, diaphragms and pressure relief devices shall be so arranged to minimize danger to the operators in the event of gas or vapour escaping under pressure.

vii) Each circuit breaker shall be capable of withstanding a vacuum of 8 mill bars without distortion or failure of any parts.

viii) Sufficient SF6 gas including that required for gas analysis during filling shall be provided to fill all the circuit breakers installed. In addition, 20% of total gas requirement shall be supplied at respective station, in separate cylinders as spare requirement for Employer's later use.

d) Provision shall be made for attaching an operational analyser after installation at site to record contact travel, and making measurement of operating timing, synchronization of contacts in one pole and dynamic contact resistance measurement.

3.4.5.4 Sulphur Hexafluoride Gas (SF6 Gas)

a) The SF6 gas shall comply with IEC-60376, 376A and 376B and shall be suitable in all respects for use in the switchgear under the operating conditions.

b) The high-pressure cylinders in which the SF6 gas shall be shipped and stored at site shall comply with requirements of relevant IEC / British standards and regulations.

c) SF6 gas shall be tested for purity, dew point, break down voltage, air, hydrolysable fluorides and water content as per IEC-60376, 376A and 376B and test certificates shall be furnished to Employer indicating all the tests as per IEC-60376 for each lot of SF6 gas. Gas bottles shall be tested for leakage after receipt at site.

3.4.5.5 Insulators

a) The porcelain of the insulators shall conform to the requirements stipulated under sub-clause 3.4.11 of this Section.

b) The mechanical characteristics of insulators shall match with the requirements specified.

c) All insulators shall conform to IEC-61264 (for pressurised hollow column insulators) and IEC-233 (for others). All routine and sample tests shall be conducted on the hollow column insulators as per these standards with requirements and procedures modified as under:
   i) Pressure test as a routine test
   ii) Bending load test as a routine test
   iii) Bending load test as a sample test on each lot.
   iv) Burst pressure test as a sample test on each lot.
   v) In addition to the above, ultrasonic test shall be carried out as additional routine test.

d) Jointed porcelain shall not be accepted.

3.4.5.6 Mandatory Maintenance Equipment

The Contractor shall supply the following mandatory maintenance equipment.

a) SF6 gas filtering, drying, storage, filling and evacuation plant **(one each for Gopalganj and Aminbazar sub-stations)**. This shall include all the necessary devices for measurement of purity, moisture content, etc. of SF6 gas. The plant shall be complete with accessories and fittings so that SF6 gas from the breaker can be directly filled in the plant storage reservoir. The SF6 gas handling plants shall comply with the following requirements:
   i) The plant shall be complete with all the necessary pipes, couplings, flexible tubes and valves for filling or evacuating SF6 gas.
   ii) The design and construction of the plant shall be such that leakage of SF6 gas is minimum.
   iii) Instruments for dew point measurement and air content measurement shall be provided.
   iv) Equipment shall have built in calibration facility.

b) SF6 gas leak detector (one each for Gopalganj and Aminbazar sub-stations):
   The detector shall be free from induced voltage effects. The sensing probe shall be such that it can reach all the points on the breaker where leakage may be required to be sensed.

c) Operational analyzer (one each for Gopalganj and Aminbazar sub-stations):
   The operational analyzer shall meet the following requirements:
   i) The analyzer shall be suitable for outdoor operation and shielded against induced charges.
   ii) Operational analyzer shall be one complete system which once installed should record all the parameters as laid down in subsequent clauses.
   iii) The analyzer should be able to record breaker contact movement during opening, closing, auto reclosing and make break operation as well as the speed of contacts at various stages of operation, travel of contacts, opening time, closing time, make break time, dynamic contact resistance measurements etc.
   iv) The analyzer shall have provisions for recording simultaneously at least 12 different functions of the circuit breaker. All necessary transducers, cables, and attachments required for the breaker shall be supplied with the analyzer.

3.4.5.7 Operating Mechanism and Control

General Requirements

a) Circuit breaker shall be operated by spring charged mechanism, or a combination of hydraulic and spring mechanism. The mechanism shall be housed in a weatherproof and dust proof control cabinet. Circuit Breakers with Hydraulic mechanism only is not acceptable.

b) The operating mechanism shall be strong, rigid, not subject to rebound and shall be readily accessible for maintenance for a man standing on ground.

c) The operating mechanism shall be suitable for high speed reclosing and other duties specified. During re-closing operation, the breaker operating mechanism and control shall have capability to close fully and re-open if required. The mechanism shall be anti-pumping and trip free (as per IEC definition) under every method of closing.

d) The mechanism shall be such that the failure of any auxiliary spring shall not revent tripping and shall not cause trip or closing operation of the power operating devices.

e) A mechanical indicator shall be provided to show open and close position of the breaker. It shall be located in a position where it shall be visible to a man standing on the ground level with the mechanism housing closed. An operation counter shall also be provided in the central control cabinet.

f) Working parts of the mechanism shall be of corrosion resisting material. Bearings which require grease shall be equipped with pressure type grease fittings. Bearing pins, bolts, nuts and other parts shall be adequately pinned or locked to prevent loosening or changing adjustment with repeated operation of the breaker.

g) The Contractor shall provide software-based condition-based monitoring for life assessment and maintenance of the Circuit Breaker.

Control

a) The close and trip circuits shall be designed to permit use of momentary contact switches and push buttons.

b) Each breaker pole shall be provided with two (2) independent tripping circuits and coils each being connected to different set of protective relays.

c) The breaker shall normally be operated by remote electrical control. Electrical tripping shall be performed by shunt trip coils. However, provisions shall be made for local electrical control. For this purpose, a local/remote selector switches and close and trip push buttons shall be provided in the breaker central control cabinet.

d) The trip coils shall be suitable for trip circuit supervision. During both open and close position of breaker. The trip circuit supervision relay would be provided.

e) Closing coil and associated circuits shall operate correctly at all values of voltages between 85% and 110 % of rated voltage. Shunt trip coil shall operate correctly under all operating conditions of the circuit breaker up to the rated breaking capacity of the circuit breaker and at all values of supply voltage between 70% and 110% of rated voltage.

f) Density meter contacts and pressure switch contacts shall be suitable for direct use as permissive in closing and tripping circuits. Separate contacts have to be used for tripping and closing circuits. If contacts are not suitably rated and multiplying relays/contactors are used for density, monitor and pressure switch contact multiplication then fail-safe logic/schemes shall be employed. DC supplies for all auxiliary circuits shall be monitored and provision shall be made for remote annunciation and operation lockout in case of failures. Density monitors are to be so mounted that the contacts do not change on vibration during operation of circuit breaker.

g) The auxiliary switch of the breaker shall be positively driven by the breaker operating rod.

Spring Operated Mechanism

a) Spring operated mechanism shall be complete with motor, opening spring and closing spring with limit switch for automatic charging and other necessary accessories to make the mechanism a complete operating unit.

b) As long as power is available to the motor, a continuous sequence of the closing and opening operations shall be possible. The motor shall have adequate thermal rating for this duty.

c) After failure of power supply to the motor OCO operation shall be possible with the energy contained in the operating mechanism.

d) Breaker operation shall be independent of the motor which shall be used solely for compressing the closing spring. Facility for manual charging of the closing spring shall also be provided. The motor rating shall be such that it requires not more than 30 seconds for full charging of the closing spring.

e) Closing action of circuit breaker shall compress the opening spring ready for tripping.

f) When closing springs are discharged after closing the breaker they shall be automatically charged for the next operation and an indication of this shall be provided in the local control cabinet.

g) Provisions shall be made to prevent a closing operation of the breaker when the spring is in partial charged condition. Mechanical interlocks shall be provided in the operating mechanism to prevent discharging of closing springs when the breaker is already in the closed position.

h) The spring operating mechanism shall have adequate energy stored in the operating spring to close and latch the circuit breaker against the rated making current and also to provide the required energy for the tripping mechanism in case the tripping energy is derived from the operating mechanism.

3.4.5.8 Support Structures

a) The structure design shall be such that during operation of circuit breaker vibrations are reduced to a minimum.

b) If required, the Contractor shall provide suitable platform with steps on both sides of the circuit breaker for easy accessibility for monitoring the density/pressure of gas.

3.4.5.9 Terminal Pads

The circuit breaker terminal pads shall be made up of high-quality electrolytic copper or aluminium. The terminal pad shall have protective covers which shall be removed before interconnections.

3.4.5.10 Fittings and Accessories

Following is a partial list of some of the major fittings and accessories to be furnished by Bidder in the central control cabinet. Number and exact location of these parts shall be indicated in the drawing.

a) Cable glands, lugs, ferrules, etc.
b) Local/Remote changeover Switch
c) Open/Close buttons and Operation counter
d) Pressure gauges
e) Control switches to cut off control power supply
f) MCBs/MCCBs as required
g) Anti-pumping relay
h) DC auxiliary power supervision relay.
i) Pole discrepancy relay
j) Rating and diagram plate in accordance with IEC
k) The number of terminals provided shall be adequate to wire out all contacts and control circuits after leaving 24 terminals as spare for future use.

3.4.5.11 Tests

Type Tests

Each type of circuit breaker along with its operating mechanism shall conform to the type tests as per IEC: 62271-100.

Routine Tests

Routine tests as per IEC: 62271-100 shall be performed on all circuit breakers.

Site Tests

All routine tests except dielectrics shall be repeated on the completely assembled breaker at site.

3.4.5.12 Technical Parameters

The Bidder shall determine the technical parameters of breakers to be provided. Refer to Appendix A1 of Schedule A of Volume 3 for the technical parameters of the circuit breakers generally used by the Employer and are given for the information of the Bidder.

3.4.6 Disconnectors and Earth Switches

3.4.6.1 General

The disconnectors (isolators), earth (ground) switches and accessories shall conform in general to IEC-62271-102 except to the extent explicitly modified in the specification.

The isolators shall be electrically ganged only. Earth switch(es) shall be provided on isolators wherever possible, otherwise free-standing earth switch shall be provided.

Complete isolator with all the necessary items for successful operation shall be supplied including, but not limited to, one central (common) control cabinet for each 3 phase isolator/earth switch and one control cabinet for each pole with all the required electrical devices mounted therein, complete with base frame, linkages, complete operating mechanism etc.

3.4.6.2 Operating Duty and Performance

Isolators and earth switches shall be capable of withstanding the dynamic and thermal effects of the maximum possible short circuit current of the systems in their closed position. They shall be constructed such that they do not open under influence of short circuit current.

The earth switch shall be capable of discharging trapped charges.

The isolators shall be capable of making/breaking normal currents when no significant change in voltage occurs across the terminals of each pole of isolator on account of make/break operation.

The isolator shall be capable of making/breaking magnetizing current of at least 0.7A at 0.15 power factor and capacitive current of at least 0.7A at 0.15 power factor.

The terminals of the isolator and earth switch(es) shall be able to withstand the total forces including wind loading and electrodynamics forces on the attached conductor without impairing reliability or current carrying capacity in accordance with IEC-62271-102.

The earth switch should be able to carry the same fault current as the main blades of the isolator and shall withstand dynamic stresses.

3.4.6.3 Constructional Features

The main features and constructional details of isolators with earth switches and other accessories shall be in accordance with requirements stated hereunder:

General

Design of the isolator shall be such as to permit addition of earth switches at a future date. It shall be possible to interchange position of earth switch to either side of pole even at site.

Contacts

a) The isolator shall be provided with high pressure current carrying contacts made of copper on the hinge and jaw ends and all contact surfaces shall be silver plated. The thickness of silver plating shall not be less than 25 microns. The contacts shall be accurately machined and self-aligned.

b) The contacts shall be of sufficient pressure to ensure effective contact and low contact resistance throughout the life of the switch. The contact pressure shall not exceed a safe working value for the materials in contact and shall cause no abrasion or scarring of the contacts.

c) The contacts shall be of self-aligning and self- cleaning type and shall be so designed that binding cannot occur after remaining closed for prolonged periods.

d) No undue wear or scuffing shall be evident during the mechanical endurance tests. Contacts and springs shall be designed so that readjustments in contact pressure shall not be necessary throughout the life of the isolator/earth switch. Each contact or pair of contacts shall be independently sprung so that full pressure is maintained on all contacts at all times. Provision shall be made to adjust the contact pressure.

e) Contact springs shall not carry any current and shall not lose their characteristics due to heating effects.

f) The isolator shall be so designed that when operated within their specified rating, the temperature of each part shall be limited to values consistent with a long life for the material used. The temperatures shall not exceed the permissible limits given in IEC-62271-102 under specified ambient conditions.

Base

a) Each single pole of the isolator/earth switch shall be provided with a completely galvanized steel base. The base shall be rigid and self-supporting and shall require no guying or cross bracing between phases.

b) The frame of each isolator and earthing switch shall be provided with two ground terminals for connection to the ground mat.

Blades

a) All metal parts shall be of non-rusting and non-corroding material. All current carrying parts shall be made from high conductivity electrolytic copper/aluminium. Bolts, screws and pins shall be provided with lock washers. Keys or equivalent locking facilities when provided on current carrying parts shall be made of copper silicon alloy or equivalent. The bolts or pins used in current carrying parts shall be made of nonferrous and non- corroding material. All castings except current carrying parts shall be made of malleable cast iron or cast-steel. No grey iron shall be used in the manufacture of any part of the isolator.

b) The live parts shall be designed to eliminate sharp joints, edges and other corona producing surfaces. Where this is impracticable adequate corona shields shall be provided. Corona shields/rings etc. shall be made up of aluminium/aluminium alloy.

c) The isolator/earth switch shall be so constructed that the switch blade shall be locked in the open/close position and shall not fall to the closed/opened position in case the operating shaft gets disconnected.

d) The isolator/earth switch including their operating parts shall be such that they cannot be dislodged from their open or closed positions by short circuit forces, gravity, wind pressure, vibrations, shocks, or accidental touching of the connecting rods of the operating mechanism.

e) The isolator/earth switch shall be designed such that no lubrication of any part is required except at very infrequent intervals.

f) The switch blade contact shall enter into the counter contact even if it is misaligned by 45 mm in any direction.

Insulator

a) The insulator shall conform to IEC-60168. The porcelain of the insulator shall have minimum cantilever strength of 800 kg, however, the final strength shall be as per short circuit force calculation during detail Engineering. The insulators shall be of solid core type.

b) Pressure due to the contact shall not be transferred to the insulators after the main blades are fully closed.

c) The insulators shall be so arranged that leakage current shall pass to earth and not between terminals of same pole or between phases.

Earth Switches

a) Wherever earth switch(es) are specified these shall include the complete operating mechanism and auxiliary contacts.

b) The earth switch shall form an integral part of the isolator and shall be mounted on the base frame of the isolator, whenever possible.

c) The earth switch shall be only locally (motor) operated.

d) The earth switch(es) shall be constructionally interlocked, wherever provided with the isolator, so that the earth switch(es) can be operated only when the isolator is open and vice versa. The constructional interlocks shall be a built-in feature in construction of isolator and shall be in addition to the electrical and mechanical interlock provided in the operating mechanism.

e) In addition to the constructional interlock, isolator and earth switch(es) shall have provision to prevent their electrical and manual operation unless the interlocking conditions are met. All these interlocks shall be of fail-safe type. Suitable individual interlocking coil arrangements shall be provided. The interlocking coil shall be suitable for continuous operation from dc supply and within a variation range as stipulated.

f) Each earth switch shall be provided with flexible copper/aluminium braids for connection to earth terminal. These braids shall have the same short time current carrying capacity as the earth blade. The transfer of fault current through switch connection shall not be accepted.

g) The plane of movement and final position of the earth blades shall be such that adequate electrical clearances are obtained from adjacent live parts including in the course of its movement between Close and Open position.

Operating Mechanism

a) The isolators and earth switches shall be ac motor operated.

b) Limit switch for control shall be fitted on the isolator/earth switch shaft, within the cabinet to sense and ensure the open and close positions of the isolator and earth switch.

c) After final adjustment has been made it shall not be possible for any part of the mechanism to be displaced at any point in the travel sufficient enough to allow improper functioning of the isolator/earth switch whenever it is opened or closed at any speed. All holes in cranks, linkage etc. having moving pins shall be drilled to accurately fit so as to maintain the minimum of slack and loose motion in the entire mechanism.

d) A "Local/Remote" selector switch and a set of "Open/Close" push buttons shall be provided in the control cabinet of the isolator to permit its operation. A "Local/Remote" selector switch and "Open/Close" push buttons shall also be provided in central control cabinet to permit simultaneous operation of all three phase.

e) Provision shall be made in the control cabinet to disconnect power supply to prevent local/remote power operation.

f) Suitable reduction gearing shall be provided between the motor and the drive shaft of the isolator. The mechanism shall stop rapidly when motor supplies are switched off.

g) Each motor operated mechanism shall be subjected to blocked rotor test.

3.4.6.4 Operation

a) Isolator and earthing switch shall have one drive for main blade and one drive for earthing switch. The operating mechanism of the three poles shall be well synchronized and interlocked.

b) The design shall be such as to provide maximum reliability under all service conditions. All operating linkages carrying mechanical loads shall be designed for negligible deflection. The length of operating rods shall be capable of adjustments, by means of screw thread which can be locked with a lock nut after an adjustment has been made. The isolator and earth switches shall be provided with "over centre" device in the operating mechanism to prevent accidental opening by wind or vibration or short circuit forces or movement of the support structures.

c) Each isolator and earth switch shall be provided with a manual operating handle enabling one man to open or close the isolator or earth switch with ease in one movement while standing at ground level. The manual operating handle shall have provision for padlocking. The operating handle shall be located at 1000 mm from the base of isolator support structure.

d) The isolator/earth switch shall be provided with positive continuous control throughout the entire cycle of operation. The operating rods shall be sufficiently rigid to maintain positive control under the most adverse conditions and when operated in tension or compression for closing. They shall also be capable of withstanding all torsional and bending stresses due to operation of the isolator/earth switch. Wherever supported the operating rods shall be provided with bearings on either ends. The operating rods shall be provided with suitable universal couplings to account for any angular misalignment.

e) The transmission of motion from the electrical operating mechanism shall be by rigid members. It is required that, in the event of over torque of the switch mechanism, no part of the main switch mechanism shall bend, twist or shear and so allow the auxiliary switch contacts to operate erroneously.

f) All rotating parts shall be provided with grease packed roller or ball bearings in sealed housings designed to prevent the ingress of moisture, dirt or other foreign matter. Bearings pressure shall be kept low to ensure long life and ease of operation. Locking pins wherever used shall be rustproof.

g) The position of movable contact system (main blades) of each of the isolators and earth switches shall be indicated by a mechanical indicator at the lower end of the vertical rod of shaft for the isolators and earth switch. The indicator shall be of metal and shall be visible from operating level.

h) Signalling of closed position shall not take place unless it is certain that the movable contacts shall reach a position in which rated normal current, peak withstand current and short time withstand current can be carried safely. Signalling of open position shall not take place unless movable contacts have reached a position such that clearance between contacts is at least 80% of the isolating distance.

i) Counterbalance spring if required shall be provided for counterbalancing the isolator and earth switch to prevent impact at the end of the travel both on opening and closing. The spring shall be made of non-rusting type alloy.

3.4.6.5 Tests

Each type of isolator and earth switch along with their operating mechanism shall be subjected to the type tests and routine tests in accordance with IEC-62271-102. The radio interference voltage and corona extinction voltage test shall also be conducted as type test.

3.4.6.6 Technical Parameters

The Bidder shall determine the technical parameters of the isolators/earth switches. Refer to Appendix A1 of Schedule A of Volume 3 for the technical parameters of the isolators/earthing switch generally used by the Employer and are given for the information of the Bidder.

3.4.7 Instrument Transformers

3.4.7.1 General

The AC Instrument Transformers and accessories shall conform to the latest version of IEC 60044. The instrument transformers provided for control, metering and protective relaying functions shall have accuracy ratings and burden capabilities adequate to provide their designated functions within the overall accuracy requirements of the systems.

3.4.7.2 Technical and Constructional Requirements

The following requirements shall apply.

3.4.7.2.1 Common for All Instrument Transformers

Bushing Insulators

a) The instrument transformers shall be oil filled with porcelain/silicone rubber housing bushings suitable for outdoor service and upright mounting on steel structures.

b) Bushing/Insulators shall conform to requirements of sub-clause 3.4.11.

c) Bushings shall be provided with oil filling and drain plugs, oil sight glass for CT and for electromagnetic unit of CVT etc.

d) Instrument transformers shall be hermetically sealed units. The Bidder shall furnish details of the arrangements made for the sealing of instrument transformers.

e) Polarity shall be marked on each instrument transformer and at the lead terminals at the associated terminal block.

Box

Each single phase instrument transformers shall be complete with its terminal box. The terminal box shall meet the requirements of IP 55 relevant IEC Standard. A marshalling box for a set of 3 instrument transformers shall be provided, wherever required.

Tank

The Instrument transformer tank alongwith top metallics shall be hot dip galvanised or painted.

Lifting Arrangements

Instrument transformer shall be provided with suitable lifting arrangement, to lift the entire unit. The lifting arrangement shall be clearly shown in the general arrangement drawing.

3.4.7.2.2 Current Transformers (CT)

a) Current transformers shall have single primary either ring type, or bar type (live tank), or hair pin type (dead tank) and suitably designed for bringing out the secondary terminals in a weatherproof terminal box at the bottom. These secondary terminals shall be terminated to stud type non disconnecting terminal blocks inside the terminal box.

b) Different ratios, as specified/required shall be achieved by secondary taps only and primary reconnection shall not be acceptable.

c) Core lamination shall be of cold rolled grain oriented silicon steel or other equivalent alloys.

d) The expansion chamber at the top of the insulators shall be suitable for expansion of oil.

e) Facilities shall be provided at terminal blocks for star/delta formation, short circuiting and grounding of CT secondary terminals.

f) The guaranteed burdens and accuracy class are to be simultaneous for all cores. The accuracy class for measuring cores shall be met up to the rated extended primary current.

g) For 420 kV class CT, the rated extended primary current of the CT shall be 200% of rated primary on all except (one) highest tap ratio. On the highest tap ratio, the rated extended primary current shall be 120% for line bays.

h) The current transformer shall be suitable for horizontal transportation.

i) The instrument security factor of metering core at all ratios shall be less than 5. If any auxiliary CTs/reactor are used in the current transformers than all parameters specified/required shall have to be met treating auxiliary CTs as an integral part of the current transformer. The auxiliary CTs/reactor shall preferably be inbuilt construction of the CT. In case these are to be mounted separately these shall be mounted in the central marshalling box suitably wired up to the terminal blocks.

j) The current transformers shall be suitable for high speed auto-re-closing, if required.

k) Special Technical Requirements

Through Fault Capability - The CTs shall be capable of withstanding with the secondary short circuited, a fully offset primary current having an ac (i.e. symmetrical) component with a rms value equal to the specified short-circuit capacity of the system. The CT's shall withstand the discharges of filter banks after ground fault.

Transient Performance (if applicable) - The CTs shall meet the requirements for transient performance and tests shall be conducted accordingly.

3.4.7.2.3 Voltage Transformers

a) Voltage transformers shall be capacitor voltage divider type with electromagnetic units and shall be suitable for carrier coupling.

b) The electromagnetic unit consisting of compensating reactor, intermediate transformer, protective and damping devices etc. shall also be mounted in a hermetically sealed metal enclosure, which shall also be used as a mechanical support for the capacitor voltage divider. The terminals of the secondary windings of the electromagnetic units shall be brought out in a separate, weatherproof terminal box, which shall be properly mounted on the wall of the metal enclosure of the electromagnetic unit. Suitable quantity of silica gel shall also be provided in a suitable porous container.

c) The capacitor voltage divider shall be capable of being used over a wide carrier frequency bandwidth. The value of capacitance shall be suitably chosen for reliable wide band carrier coupling and shall not be less than the value specified in the Appendix A1 of Schedule A of Volume 3. The reactance of the teed branch of the CVT shall be adjusted to minimize carrier loss. With carrier frequency coupling device connected to the earth lead of the intermediate coupling capacitor, the accuracy of the electromagnetic voltage transformer unit shall remain within the specified limits.

d) Each core of secondary winding to be used for protection purpose shall be protected by MCB's of suitable rating. NO and NC contacts shall be provided on the MCB for monitoring purposes. The secondary terminals of the CVT's shall be terminated to the stud type non-disconnecting terminal blocks in the individual phase secondary boxes via the MCB's.

e) The accuracy of metering winding shall be maintained throughout the entire burden range up to total burden simultaneously on all the three windings without any adjustments during operation.

f) It shall be ensured that access to secondary terminals is without any danger of access to high voltage circuit.

g) A protective surge arrester shall be provided to prevent breakdown of insulation by incoming surges and to limit abnormal rise of terminal voltage of shunt capacitor, tuning reactor/RF choke etc. due to short circuit in transformer secondaries.

h) Special Technical Requirements

i) Transient Response

The transient response (at rated frequency and beyond) shall be such that, after sudden removal of the primary voltage, the transient secondary voltage in the capacitor voltage transformer shall not exceed 10 (ten) percent of the peak value of the secondary voltage existing before the collapse of the primary voltage to zero nor it shall exceed value required to meet the performance. This value shall be measured (oscillograms) following the primary short circuit when the capacitor voltage transformer is loaded with 25% and 100% of rated burden at 0.8 power factor lagging.

ii) Ferro-resonance

The Ferro-resonance requirement shall be met as per the relevant standards.

iii) Protective Device

A protective device shall be incorporated in the capacitor voltage transformer for the purpose of limiting over voltages which may appear across one or more of its components. The device shall include a heavy-duty class spark gap with adjustable setting and drain coil. The setting of the protective device shall be determined by the Bidder, however, it shall be adjustable and shall not introduce distortion in the secondary voltage wave shape at rated frequency and at an applied voltage up to 1.2 per unit of nominal voltage. Should the protective device operate on switch surge or atmospheric over voltages, the secondary voltage shall recover to its correct wave shape within 4 ms when the applied voltage is 1.2 per unit of nominal voltage.

iv) Power Line Carrier

Coupling Application If required, the capacitor voltage transformers shall be equipped with power line carrier coupling components, and the capacitance value shall be that required for PLCC coupling purposes.

v) Reproduction of Harmonics

Harmonics with frequency 100 Hz to 650 Hz superimposed on the fundamental frequency shall be reproduced within an accuracy of amplitude error of 10% & phase angle error (for each separate harmonic) of 10-degree elect.

vi) Reproduction of Transients

A step of 10% of rated voltage (rms) superimposed on the primary voltage shall be reproduced at maximum burden with a delay (time constant) of less than 100 microsecond and within +10% of correct value within 400 microsecond.

3.4.7.3 Type Tests

The current transformers shall be type tested as per the requirements of IEC: 60044-1 and the voltage transformers shall be type tested as per IEC-60044-5.

3.4.7.4 Routine Tests

The current transformers shall be subject to routine tests as per IEC: 60044-1 and the voltage transformers shall be routine tested as per IEC- 60044-5. Additional routine tests as specified below shall also be conducted on each unit:

Current Transformers

a) Measurement of capacitance

b) Measurement of tan delta at 0.3, 0.7, 1.0 and 1.1 $Um/\sqrt{3}$

c) Oil leakage test

Voltage Transformers

a) Capacitance and loss angle measurement before and after dielectric tests as per IEC

b) Sealing test as per IEC

3.4.7.5 Technical Parameters

The technical parameters shall be determined by the Bidder. Refer to Appendix A1 of Schedule A of Volume 3 for the technical parameters for Instrument Transformers generally used by the Employer and are furnished for the information of the Bidder.

3.4.8 Surge Arresters

3.4.8.1 General

Surge arresters shall be of the type employing non-linear metal oxide resistors without spark gaps. The Contractor shall demonstrate by calculations that the surge arresters will adequately protect the switchgear arrangement proposed.

3.4.8.2 Operating Duty and Performance

The protective characteristics and discharge duties shall be determined by the Contractor. The arresters shall give consistent protection to their associated equipment against over voltages produced by lightning, switching, station internal or external faults, and other system disturbances.

The arresters shall be rated and tested such that they are able to discharge a specified maximum energy due to the application of temporary voltages of form and magnitude which can occur in service as determined by insulation coordination studies to be carried out by the Contractor, without coming into the temperature region where thermal runaway could result upon subsequent application of maximum transient and steady state voltage conditions.

Particular attention shall be given to the high discharge currents which some of the arresters may experience in service due to the requirements to discharge the energy of the, shunt capacitors and reactive compensating equipment or in other circumstances.

The design of the arresters shall take into account and shall maximize the degree of current sharing between complete arresters. Similarly, the design shall also take into account and shall maximize the degree of current sharing between parallel columns of the same arrester.

420 kV class AC arrester shall be capable of discharging energy equivalent to at least class 3 of IEC on two successive operations followed immediately by 50 Hz energization with a sequential voltage profile at least as specified below:

- 705 kVp for 3 peaks
- 580 kVp for 0.1 sec
- 565 kVp for 1sec
- 550 kVp for 10 sec.

The reference current of the arresters shall be high enough to eliminate the influence of grading and stray capacitance on the measured reference voltage. The Bidder shall furnish the values and supporting calculations along with the Bid. The arresters shall be fully stable thermally under site conditions and shall take care of the effect of direct solar radiation.

3.4.8.3 Constructional Features

Surge arresters shall be housed in porcelain insulators designed to withstand extremes of the environment described. The insulation shall have a minimum creepage distance of 25 mm/kV rated system phase to phase voltage. The method of sealing against the ingress of moisture shall be of a type well proven in service and the manufacturing procedures shall include an effective leak test which can be demonstrated to the inspecting engineer if required.

The internal components of arresters shall be arranged to minimise radial voltage stresses, internal corona and to ensure minimal capacitive coupling with any conducting layer of pollutant on the outside of the porcelain housing. Except where approved, organic materials are not permitted.

Good electrical contact shall be maintained between resistor blocks taking account of any thermal expansion and contraction of the block or mechanical shock during transport and erection, by installing a well proven clamping system.

Metal oxide arresters installed outdoors shall be able to dissipate, when new, twice the energy generated in the resistor blocks when energised at their maximum continuous operating voltage immediately having been subjected to the discharge duties specified in IEC 60099 4 and assuming that the porcelain housing and the surrounding air is at least 5°C higher than the maximum ambient air temperature specified.

Good quality control of the manufacturing process of the resistors shall be ensured by rigorous testing procedures. The procedures shall ensure that the characteristics of the blocks are, and will remain, within the specified limits when new and throughout the anticipated life of the arresters. Samples may be selected at random by the Employer / Engineer for special tests to be agreed with the manufacturer.

All surge arresters shall be fitted with a pressure relief diaphragm which shall prevent explosive shattering of the porcelain housing in the event of an arrester failure and the arrester shall have been tested according to the high and low current tests specified in IEC 60099 1.

3.4.8.4 Fittings and Accessories

Arresters shall be supplied complete for installation in an outdoor switchyard, including insulating bases and surge counters, one per phase, and, if applicable, grading rings. The material used for terminals shall be compatible with that of the conductors to which they are to be connected.

Each arrester shall be identified by a rating plate in accordance with the requirements of IEC 60099-4. In addition, an identification mark shall be permanently inscribed on each separately housed unit of a

multi-unit arrester so that units can be replaced in the correct position in the event of them being dismantled.

Surge counters shall have an internal assembly which is matched to the line discharge capability of the arrester and shall include a leakage current meter with a bi linear scale for ease of reading. Auxiliary contacts are to be provided to signal remote indication of counter operation.

3.4.8.5 Tests

Arresters shall be designed and tested in accordance with the requirements of IEC 60099-4. Any departure shall be the subject of agreement between the Employer / Engineer and the Contractor. Routine tests shall be carried out in accordance with the requirements of clause 15 of this specification.

3.4.8.6 Technical Parameters

The technical parameters shall be determined by the Bidder. Refer to Appendix A1 of Schedule A of Volume 3 for the technical parameters for surge arrestor generally used by the Employer and are furnished for the information of the Bidder.

3.4.9 Neutral Grounding Resistors

The earthing resistors shall be of the metal grid type with enclosure having degree of protection IP 33 and suitable for outdoor service on the neutral earthing system as specified. The framework and enclosure shall be of galvanised steel. The grids shall be adequately supported on steel rods and porcelain insulators and be designed to withstand the currents flowing under fault conditions. Adequate insulating barriers shall be provided to prevent internal flashover.

The resistor shall be complete with lifting and jacking lugs, access panels, holding down bolts or clamps, earth terminals, connectors and connections.

The bushing shall have a minimum creepage distance of 25 mm/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 A of Volume 3.

3.4.10 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 clause 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 the Engineer.

Materials used for busbars and connections shall be stressed to not more than two fifths of their elastic limit. Provision shall be made for expansion and contraction with variation in conductor temperature and busbars shall be arranged so they may be readily extended in length with a minimum of disturbance to existing equipment.

Tubular bus conductor shall be used for 400kV busbar and supported by station post insulator.

3.4.10.1 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 shall be determined by the Bidder.

Tests

The tests shall be conducted on tubular bus conductors as per relevant IEC Standard. Also, the wall thickness and ovality of the tube shall be measured by ultrasonic method. In addition to the above tests, 0.2% proof test on both parent metal and aluminium to be after welding shall be conducted.

3.4.10.2 Flexible Busbars and Earthwire

General

The conductors shall conform to relevant IEC/BS Standard. The number and diameters of the individual wires forming the finished conductor shall be subject to approval of the Engineer.

Constructional Features

Workmanship:

All the aluminium strands shall be smooth, uniform and free from all imperfections, such as spills and splits, die marks, scratches, abrasions and kinks after drawing and also after stranding. The finished conductor shall have a smooth surface without any surface cuts, abrasions, scuff marks and shall be free from dirt, grit, etc.

Joints in Wires:

No joints shall be permitted in the individual wires in the outermost layer of the finished conductor. However, joints in the inner layers of the conductor shall be allowed but these joints shall be made by cold pressure butt-welding and shall be such that no two such joints are within 15 metres of each other in the complete stranded conductor.

Materials:

The aluminium strands shall be hard drawn from electrolytic aluminium rods having purity not less than 99.5% and a copper content not exceeding 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.

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 °C as per relevant IEC Standard.

Acceptance Test:

i) Visual and Dimensions check on Drums
ii) Visual Check for Joints, Scratches etc.
iii) Dimensional check on Aluminium Strands
iv) Check for lay-ratios of various Layers The following tests shall be conducted once on sample/samples of conductor.
    - Breaking load test on aluminium strands
    - Wrap load test on aluminium strands
    - DC resistance tests on aluminium strands

All the above tests shall be carried out on aluminium strands after stranding only.

Routine Tests:

i) Check to ensure that the joints are as per specification.
ii) Check that there are no cuts, fins, etc. on the strands.
iii) Check that drums are as per specification.
iv) All acceptance tests as mentioned above are to be carried out on each coil

Tests During Manufacture:

Chemical Analysis of Aluminium used for making aluminium strands Samples taken from the aluminium ingots/coils/ strands shall be chemically/spectrographically analyzed. The same shall be in conformity to the specified requirements.

Packing:

The conductor shall be supplied in strong wooden drums constructed to protect the conductor against all damage and displacement during transit, storage and subsequent handling and stringing operations in the field. The drums shall generally conform relevant IEC/Standard. Only one length of conductor shall be wound on each drum.

3.4.10.3 Clamps 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 2 mm thick Bimetallic liner
    - For connecting G.I. Shield wire: Galvanised mild steel

- Bolts, nuts and 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 2 mm 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 class clamps shall not be less than 320 kV.

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

3.4.10.4 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.

3.4.11 Insulators, Bushings, Buses and Hardware

3.4.11.1 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 airtight. 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 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 cannot be damaged easily.

o) Each porcelain insulator shall have marked upon it the manufacturer's name or identification mark and year of manufacture. These marks shall be clearly legible after assembly of fittings and shall be imprinted before firing, not impressed. Each complete bushing shall be marked with the manufacturer's name or identification mark, year of manufacture, serial number, electrical and mechanical characteristics in accordance with IEC 60137:1973.

Parameters

The parameters shall be determined by the Bidder, however the minimum performance parameters for the 420 kV class post insulator shall be as per the stipulation in Schedule A of Volume 3.

Tests

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

3.4.11.2 String Insulators 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.

Constructional Features

a) Requirements specified in sub-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 sub-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 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.

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

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

f) 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

g) Routine Test on Disc Insulator/Long Rod Insulator:
   i) Visual Inspection
   ii) Mechanical Routine Test
   iii) Electrical Routine Test

h) Routine Test of Hardware Fittings:
   i) Visual examination
   ii) Mechanical strength test

i) 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

j) 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 energized 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 along with 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.

3.4.12 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 integration with the existing substation arrangement. The items of plant supplied under this Contract shall be complete with all interlocking facilities needed for the integration with the existing 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.

3.4.13 Auxiliary Switches and Contactors

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

Auxiliary contactors shall be provided only where the circuit requirement cannot be met by the auxiliary switch arrangements and multiple contactors and relays will not be accepted in lieu of the auxiliary switches except as specifically approved by the Engineer. Auxiliary switches and contactors shall comply with the requirements of this specification and in particular shall be capable of operation within the same voltage limits as specified for the associated circuit breaker close and trip coils.

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

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

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

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

For Circuit Breakers

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

For Busbar Disconnectors

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

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

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

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

For Line Disconnectors

As for Busbar disconnector auxiliary switches.

For Earthing Switches

As for Busbar disconnector auxiliary switches. Any deviation from the above should be stated in Schedule G of Volume 3.

3.5 Interference with Existing Equipment

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

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

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

Permission for access to existing substations to execute the Works shall be obtained in writing from the Employer. The 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 Schedule A of Volume 3, equipment for existing substations shall be of the same type and manufacture as that already in service.

4. Power Transformers

Not used.

5. Substation Automation (Protection, Metering and Control)

5.1 Requirement and Extension Scope of Substation Automation

This specification covers the extension of the existing Substation Automation System which includes design, extension and commissioning as described in the following sub-clauses, to control and operate the extension of 400 kV grid substation.

This describes the facilities required to provide the control of plant and system within a substation and outlines the facilities to be provided on site, interface requirements and performance criteria.

The extension of existing Substation Automation System (SAS) shall comprise full station and bay protection as well as control, monitoring and communication functions, and provides 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 perform the necessary system control and data acquisition functions. It shall include the necessary modification on the existing system for communication gateway to NLDC, inter-bay-bus, intelligent electronic devices (IED) for bay control and protection as shown in the enclosed general system architecture drawing.

The modification on the existing communication gateway shall secure control from and information flow to remote network control centers. The modification on the existing 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.

For the extension works, the Contractor shall adopt the same communication network as the existing system for bay level and process level based on IEC 61850. Network topology and access mode shall be clearly indicated. The physical medium of those shall be glass fibre optics.

The IED's 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 IED's shall be directly connected to the IEC 61850 bus and shall use only IEC 61850 protocol for communication. No proprietary protocols shall be used.

The system design life shall be not less than 20 years.

Modifications, testing and commissioning of the existing SAS along with protection relay shall be undertaken by the existing SAS manufacturer(s) engaged by the Contractor.

The SAS manufacturer(s) shall demonstrate that the modification carried out on the existing system has been modified, installed and commissioned in accordance with IEC 61850 standards.

All the auxiliary relays (Contactor, TCS, Tripping relays, thermostat, humidity controllers, etc.) used for protection scheme shall be of Europe/USA origin.

5.2 Arrangement of Facilities

The existing Substation Automation System and associated protection and automation equipment are installed in the Main Control Building and Local Control Houses. The automation server, HMI, ethernet switches, substation gateways and communication facilities are installed in Main Control Building. Communication between Local Control Houses and Main Control Facilities is based on communication protocol of IEC 61850 standards. The architectures and system configurations are shown in the attached Drawing and modification on existing design shall be approved by Engineers during the design approval stage.

5.3 Compliance with Standards

For design and type testing of the protection and control equipment, the following standards shall be applicable.

5.3.1 General List of Standards

IEC 60255: Electrical Relays
IEC 60038: IEC Standard voltages
IEC 68068: Environmental testing
IEC 60664: Insulation co-ordination for equipment within low-voltage systems
IEC 61850: Standard for Substation integrated protection and control data communication

5.3.2 Detailed List of Standards

IEC 255-6:	Measuring relays and protection equipment
IEC 255-7:	Test and measurement procedures for electromechanical all-or-nothing relays
IEC 68-2-3:	Test Ca: Damp heat steady state
IEC 68-2-30:	Test Db and guidance: Damp heat, cyclic
IEC 255-5:	Insulation tests for electrical relays
IEC 255-22:	Electrical disturbance tests for measuring relays and protection equipment:
IEC 255-22-1:	1 MHz burst disturbance test
IEC 255-22-2:	Electrostatic discharge test
IEC 255-22-3:	Radiated electromagnetic field disturbance test
IEC 255-22-4:	Fast transient disturbance test
IEC 255-11:	Interruptions to and alternating component (ripple) in D.C. auxiliary energizing quantity to measuring relays
IEC 255-6:	Measuring relays and protection equipment
IEC 255-21:	Vibration, shock, bump and seismic tests on measuring relays and protection equipment
IEC 255-21-1:	Vibration tests (sinusoidal)
IEC 255-21-2:	Shock and bump tests
IEC 255-21-3:	Seismic tests
IEC 255-0-20:	Contact performance of electrical relays
IEC 870-3/class 2:	Digital I/O, Analogue I/O dielectric tests
IEC 801-5/class 3:	Digital I/O Surge withstand test
IEC 870-3/class2:	Radio interference test
IEC 801-4/4:	Transient fast burst test
IEC 801-2/4:	Static discharge
IEC 801-3/3:	Electromagnetic fields

5.4 Design and Operating Requirements

5.4.1 General

The SA shall be extended (both hardware and software) for operation and monitoring of the bay extensions under this Contract.

As shown in the SA system structure, protection is an integral part of the SA system and protective relays shall be directly connected to the inter-bay bus in order to provide unrestricted access to all data and information stored in the relays and for changing protection parameters from the remote control location.

Failure behavior of the hardware and software functions shall be addressed and related diagnostic and rectification working instructions shall be provided. The system performance, if failure of communication to NLDC, main and redundant computer-based workstations, central functions, data model, control and protection IED's, station and bay level communication shall also be clearly addressed.

5.4.2 Modes of Operation

The existing operator stations and remote users have following operational modes, each password protected.

Monitoring:

Ability to select graphic displays and lists for viewing only. No capability to acknowledge alarms, complete controls or select items for inclusion in program functions.

Control:

Selection of graphic display and lists. Able to acknowledge station and SA alarms, complete controls, dressing, etc. associate with normal real time of the control of the substation.

SA Engineering:

Provides the entire SA monitoring functions, together with online facilities for program/database/format modifications and checking without the possibility of executing power system controls.

System Manager:

Provides access to all system functions, including assignment of passwords and system maintenance activities.

In addition, a facility to provide access to the numerical Protection relays including AVR, change/modify relay settings & AVR parameters and fault and disturbance data has been provided.

A series of passwords has been personally assigned to operators in each of the above categories.

It is possible for substation operators to log on either of the substation workstation and to be allocated the appropriate mode of operation relevant to the password. SA System Engineering work and access to the protection relays and fault and disturbance recording information are generally be carried out at the Engineering workstation or remote master station.

All the workstation and the system database function as a system. It is not necessary for example to acknowledge an alarm at more than one workstation.

Similarly, an operator manual entry applied at a workstation is immediately displayed at other workstations where this data is presented.

5.4.3 Project Specifications

Specific functions and boundary conditions of the SA are detailed elsewhere in this specification. The following drawings are attached in this Section:

- Overall single line diagram
- General system architecture
- Location of substation buildings

- Control and operation principles
- Protection schemes

5.4.4 Vendor's Experience and Local Support

Not used

5.4.5 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 Bid Proposal.

5.4.6 General System Design

System control from the substation control room is operated with the help of Industrial Computers (PCs). Modification on the Human Machine Interface (HMI) shall be carried out for the extended bays with the following HMI functions:

- Acquisition and plausibility/monitoring check of switchgear status including Bus PT & ES
- Control of switchgear excluding all ES
- Remote checking of device parameters and activation of alternative parameter sets in the connected protective relays
- Display of actual measured values (U, I, P, Q, f)
- Display of events
- Display of alarms
- Display of trends
- Sequence control functions
- Dynamic busbar coloring
- Disturbance records and fault location
- System self-supervision
- Hard copy printing

The existing SA supports remote control and monitoring from NLDC centre via an industrial grade gateway with redundant CPU as well as redundant DC/DC converters. The gateway provided for communication to/from remote control centers via IEC60870-5-101 protocol. Even if the Station PC is not available, it is possible to control the station from NLDC center as well as from the backup control panel in the individual bays with all interlocks. Interlocking in case of emergency (i.e. if bay controller fails) shall be waived locally by means of a switch with key lock by the maintenance engineer for all the switchgear.

Maintenance, modification or extension of components will not require a shutdown of the whole station automation system. Self-monitoring of single components, modules and communication has been incorporated in the existing system to increase the availability of the equipment while minimizing maintenance time to repair.

As shown in the system drawing, the SA has been 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 as per IEC 61850 standards. The entire station is controlled and supervised from the station level PC. It is 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 should fail. Clear control priorities is in place to 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 is with the lowest enabled control level.

Each bay control and protection unit is independent of each other and its functioning shall not be affected by any fault occurring in any of the other bay control and protection units of the station.

The SA contain the following main functional parts:

- Human Machine Interface (HMI) with process database
- Gateway function for remote control via an industrial grade hardware
- Dial in facility / laptop workstation for protection relay parameterization, disturbance analysis and SA system fault analysis.
- Data exchange between the different system components via high speed bus
- Bay level devices for control, monitoring and protection
- Bay oriented local control and protection panels with mimic inserts
- Facility for emergency operation of all the switchgear, if bay controller fails. (Key / master key system)

The main process information of the station is stored in distributed databases. The existing system is based on a de-centralized concept with bay oriented distributed intelligence for safety and availability reasons. Functions are decentralized, object oriented and located close to the process.

The substation monitoring/protection system supplies data for maintenance, repair and remote parameter setting of protection and control devices in the switchyard.

In the event of a fault in the electrical network, the substation monitoring will provide a quick means for collecting the relevant and critical data of the fault.

The monitoring system supervises and monitors of all the secondary (IED) and primary devices in a substation including the bay extensions under this Contract.

Maintenance, modification or extension of components will not cause a shut-off of the whole station monitoring system. Self-monitoring of single components, modules and communication has been incorporated to the existing system to increase the availability and the reliability of the equipment and minimize maintenance.

It is possible to access all protection and control devices for reading the terminal parameters (settings). The setting of parameters or activation of parameter sets is restricted by password to the protection engineer.

One remote computer for the bay extension under this Contract shall be provided with the access to SMS with different access levels. The required SMS software and application specific firmware (for relay parameterization) shall be provided with associated tools and equipment. The required engineering tools analyzing software also shall be provided/installed both in the station PC and the remote Master Analysis station. A backup copy of all the software shall be provided in CDs.

5.5 Flexibility and Scalability

The existing SA system is flexible and permits extensions to be realized easily as per IEC 61850 standards. Preference will be given to the same manufacturer(s) of the existing system who are in a position to provide protection and control devices which can be freely adapted to the existing application functions required.

5.6 System Hardware

5.6.1 Operator Station

The existing main operator station is based on an industrial PC hardware and high-resolution full-graphics screen with manufacturers' standard type tested software operating under Windows environment. An Event printer and a Hard Copy printer is connected via a printer server and LAN to the operator station. A black & white printer and a Hard Copy colour printer is connected via LAN to the operator station.

Dual station computers are controlling the SA system and drive the work stations and other peripherals. One of the station computers operates the system in the "on line" state while the other acts as a "redundant hot standby". The standby computer is continuously updated and immediately takes over the SA system duties without interruption or transfer mechanism should the on-line operator workstation fail. The Industrial computers are housed in cubicles with protection class IP55 or better along with the GPS clock & switches as required.

Disturbance event data is being analyzed using the installed Disturbance Record Analysis program. The Disturbance Records are collected from the connected IED's by the system software. All necessary facilities are provided to allow the system to perform spontaneous upload of Disturbance data or upload them in a pre-programmed manner. The Event printer prints events spontaneously as they arrive in the main operator station.

Each uploaded data report file are being reported on one line that contains:

- The event date and time
- The name of the event object
- A descriptive text
- The state or value of the object

Additionally, the Disturbance Record Analysis program system has disturbance and fault recording and graphical analysis function showing fault behavior of before trigger, during faults and post fault. The system has the following features:

- Event: trip, alarm, change of binary input signal, etc.
- Fault / disturbance record: magnitude of voltage, current, wave and phases,
- Recording storage capacity: minimum 4 time of 1sec fault
- Time synchronized with GPS time synchronized software

All fault and disturbance records are being stored as a file format. In alliance with the functioning, the IEDs also generate and provide the COMTRADE file format (IEEE C37.111) for fault simulation functions.

The information fields above are structured in columns for maximum readability.

The hard copy printer permits printing of any picture (or part thereof) from the station level PC's using easily accessible commands from the window menus.

The main Station PC's is supplied by the station DC battery and a UPS/Inverter system with a supply duration of more than 30 minutes for the monitor and the printers.

A 32 window annunciator unit is directly connected to the main Station PC`s to monitor the same and also to annunciate common station abnormal/fault conditions.

5.6.2 Station Inter-bay Bus

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 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 ensure a certain level of quality, performance and availability at least the following described criteria's have to be fulfilled concerning the Ethernet switches and topology.

Industrial grade Ethernet switches that fulfill the hardened requirements concerning temperature, EMC (Electromagnetic capability) 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 future system extension, utility has not to rely on one switch supplier only. External switches shall be supplied as they have the advantage that there is no interruption or reconfiguration of the Ethernet ring if one or several bay devices are taken out of service. To increase reliability the Ethernet Switches shall have redundant power supply & shall be powered from two different station batteries.

5.6.3 Protection and Control IED and Local Back-up Control Mimic

The bay control IED 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 measures for operation via the HMI. They shall perform all bay related functions, such as protection, commands/controls, 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. Also, they shall be connected to the substation Ethernet in dual.

The numerical bay control IED shall be provided with a minimum of nine (9) configurable (current or voltage) analogue input channels and adequate number of binary input & output channels which are galvanically isolated from the SA system. The channels shall also be individually separated from each other. HV switchgear and instrument transformers shall be directly connected to the bay level IED without any interposing equipment.

The devices shall meet the requirements for withstanding electromagnetic interference according to relevant parts of IEC 255 to conform to the high requirements for operation on the secondary system of HV switchgear.

The 400kV bay control and protection IED shall have the following features:

- A minimum of 9 configurable analogue channels
- At least 32 binary inputs, 24 signal relays and 2 command relays
- 16 nos. LED's on the front of the unit for indication
- Synchro-check function
- Power function which can be configured to measure forward or reverse, active or reactive power
- Four (4) independently settable parameter setting groups, settable/selectable locally or remotely via the HMI programme
- Four (4) line Local Display Unit (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.
- High speed bus serial communication port as per IEC 61850 standards
- Sequence of Events Recorder with a buffer for 256 events and a resolution of 1 msec. The events that are to be recorded should be freely programmable. These could be alarm/trip

signals, external signals connected to coupler inputs, internal signals, etc. Once events are defined, they are recorded in chronological order as they occur.

- Disturbance recorder function which can record 9 analogue values, 16 binary signals, and 12 analogue channels for internal measurement values. It shall be possible for the Disturbance Recorder function to be triggered by any internal or external binary signal or internal protective function.
- Comprehensive self-supervision
- Battery-free memory back-up of Event and Disturbance Records
- Logic functions (AND, OR, bistable flip flop, etc.)
- Delay/Integrator function

The numerical bay control IED shall be mounted together with all the relevant bay protective relays in cubicles of Protection Class IP55 or better. Distributed back-up control mimics with associated switches meters and Indicating LED's shall also be provided on these cubicles. These cubicles shall be installed in an air-conditioned room in the substation, i.e. either in Main Control room or in switchyard panel room as mentioned in other parts of this bidding document. The room temperature shall be monitored and controlled via the SA system.

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, synchro-check, interlock override user guidance, etc. as the station HMI. Local bay control shall be key-locked and the control either from local control panel or station HMI or from remote shall be disabled if the local/remote selector switch on the back-up control mimic is in the 'local' position.

The electronic system (of IED) has to be provided with functions for self-supervision and testing. Each circuit board shall contain circuits for automatic testing of its own function.

Faults in the bay control IED shall be indicated on a front HMI and a message shall be sent to the station level HMI. The time for fault tracing and replacement of a faulty unit shall be reduced to a minimum. The supervision shall also cover the power supply system, the internal system bus and the ability of the central processing module to communicate with different printed circuit boards.

Failure of any single component within the equipment shall neither cause unwanted operation nor lead to a complete system shutdown. The n-1 criteria 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.

Only the backup protection can be incorporated in the bay control unit and not the main protections. Main protection shall be provided separately.

All IED shall have at least 5 years of successful proven experience in HV applications.

5.7 Software Structure

The existing software package is structured according to the SA architecture and is divided in various levels. It is possible to extend the station with the minimum possible effort. Maintenance, modification or extension of components of any feeder may not force a shut-down of the parts of the system which are not affected by the system adaptation.

5.7.1 Station Level Software

Not used.

5.7.2 Bay Level Software

5.7.2.1 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 modifications. The system shall support the generation of typical control macros and a process database for user specific data storage.

5.7.2.2 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.

5.8 System Testing

The Contractor shall submit applicable Type Test certificate for individual bay level IEDs.

The manufacturing phase of the SA shall be concluded by a Factory Acceptance Test (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, the FAT shall be limited to sub-system tests. In such cases, the complete system test shall be performed at site together with the Site Acceptance Test (SAT).

5.9 System Functions

5.9.1 Control Unit Functions

5.9.1.1 Control

The different high voltage apparatuses within the substation shall either be operated manually by the operator or automatically by programmed switching sequences.

The control function shall comprise:

- Commands from different operator places, e.g. from the associated control centre (NLDC), station HMI, or local control panel according to the operating principle
- Select-before execute commands
- Operation from only one operator place at a time
- Operation depending on conditions from other functions, such as interlocking, synchro-check, operator mode, or external status conditions.

The control function shall also include:

- Prevention of double operation
- Command supervision

- Selection of operator place
- Block/unblock of operation
- Block/unblock of updating of position indications
- Manual setting of position indications
- Overriding of the interlocking function (Second key switch)
- Switchgear run time supervision

5.9.1.2 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, recorded in the event list, and a hard copy printout shall be produced. Alarms shall be initiated in cases when spontaneous position changes have taken place.

Each position of an apparatus shall be indicated using two binary auxiliary normally closed (NC) and normally open (NO) contacts. An alarm shall be initiated if these position indications are inconsistent or indicate an excessive running time of the operating mechanism to change position.

5.9.1.3 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 decentralized so that it does not depend on a central control device. Communication between the various bays for the station interlocking shall be hard wired/take place via interbay bus.

An override function shall be provided, which can be enabled to by-pass the interlocking function via a key/password, in cases of maintenance or emergency situations.

5.9.1.4 Measurements

Analogue inputs for voltage and current measurements shall be connected directly to the voltage transformers (VT) and the current transformers (CT) without intermediate transducers. The correlated values of active power (W), reactive power (VAr), frequency (Hz), and the rms values for voltage (U) and current (I) shall be calculated.

5.9.1.5 Event and Alarm Handling

Events and alarms shall be generated either by the switchgear, by the control devices and by the station level unit. Additionally for the purpose of smooth and easy monitoring & maintenance, alarms shall also be generated from LV switching devices, i.e. ACBs / MCCBs / MCBs, used in LVAC & DC systems where applicable, located in switchyard panel rooms, PT junction box, marshaling box, CB / DS / reactor control cubicle, etc. remote from the operator room. However, for simplicity, instead of individual status, status of LV switching devices in a single location may be grouped together for the purpose of fail status display in SA system. They shall be recorded in an event list in the station HMI. Alarms shall be recorded in a separate alarm list and appear on the screen. All or a freely selectable group of events and alarms shall also be printed out on an event printer. The alarms and events shall be time tagged with a time resolution of 1 ms. The time tagging shall be done at the lowest level where the event occurs, and the information shall be distributed with the time tagging.

5.9.1.6 Time Synchronization

The time within the SA is set via a GPS Clock Receiver connected directly to the Bay Level LAN. The time is then be distributed to the control/protective devices via the high-speed optic fibre bus. An accuracy of ±1 ms within the station is required.

5.9.1.7 Synchronism and Energizing Check

The synchronism and energizing check functions shall be distributed to the control and/or protective devices and shall have the following features:

- Adjustable voltage, phase angle, and frequency difference.
- Energizing for dead line - live bus, or live line - dead bus.
- Settings for manual close command shall be adaptable to the specific switchgear.

5.9.1.8 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.

5.9.2 HMI Functions

5.9.2.1 General

The operator station HMI provides basic functions for supervision and control of the whole substation. The operator gives commands to the switchgear via the station monitor with the help of mouse clicks on soft keys.

The HMI provides the operator with access to alarms and events displayed on the screen. Besides these lists on the screen, there is facility to print out of hard copies of alarms or events in an event log. The Alarm List indicates persisting and fleeting alarms separately.

Acoustic alarm indicates abnormalities, and all unacknowledged alarms are accessible from any screen selected by the operator.

Following standard pictures are available from the HMI:

- Single line diagram showing the switching status and measured values
- Control dialogues
- Measurement dialogues
- Blocking dialogues
- Alarm list, station / bay oriented
- Event list, station / bay oriented
- System status
- Checking of parameter setting

5.9.2.2 HMI Design Principles

The labels, colours, dialogues and fonts has been established in the existing HMI, the same shall be adopted for the extension works. Non-valid selections shall be dimmed out.

Object status are indicated using different status colours for:

- Selected object under command
- Selected on the screen
- Not updated, obsolete value, not in use or not sampled

- Alarm or faulty state
- Warning or blocked
- Update blocked or manually updated
- Control blocked
- Normal state
- Busbar colouring to show live & dead bus. Busbar colour shall as follows:
    - 400 kV: Dark Violet
    - 230 kV: Red
    - 132 kV: Blue
    - 33k V: Dark Yellow
    - Ground: Green + White

5.9.2.3 Process Status Displays and Command Procedures

The process status of the substation in terms of actual values of currents, voltages, frequency, active and reactive powers as well as the positions of circuit breakers, isolators and transformer tap changers are displayed in the station single line diagram.

In order to ensure a high degree of security against unwanted operation, a special "select – before - execute" command procedure is provided. After the "selection" of a switch, the operator is able to recognize the selected device on the screen and all other switchgear are blocked. After the "execution" of the command, the operated switch symbol will blink until the switch has reached its final new position.

The system permits the operator to execute a command only if the selected object is not blocked and if no interlocking condition is going to be violated. The interlocking conditions shall be checked by the interlocking scheme which is implemented on bay level.

After command execution, the operator will 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.

5.9.2.4 System Supervision Display

The SA system features 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 covers the status of the entire substation including all switchgear, IED's, communication links, and printers at the station level, etc.

5.9.2.5 Reports

The SA generates reports that provide time related information on measured values and calculated values. The data displayed comprise:

Trend reports:

- Day (mean, peak)
- Month (mean, peak)
- Semi-annual (mean, peak)
- Year (mean, peak)

Historical reports:

- Day
- Week

- Month
- Year

It is possible to select displayed values from the database on-line in the process display. Scrolling between e.g. days is also possible. Unsure values are indicated. It is possible to select the time period for which the specific data are kept in the memory.

This report is printed automatically at pre-selected times. It is also possible to print this report on request.

5.9.2.6 Trend Display (Historical Data)

A trend is a time-related follow-up of process data. The analogue channels of all the connected bay level devices on the 400 kV level are illustrated as trends. The trends are displayed in graphical form as columns or curve diagrams with 10 trends per screen as maximum.

It is possible to change the type of value logging (direct, mean, sum, or difference) on-line in the window. It is also possible to change the update intervals on-line in the picture as well as the selection of threshold values for alarming purposes.

5.9.2.7 Event List

The event list contains events, which are important for the control and monitoring of the substation. The time has to be displayed for each event.

The operator is able to call up the chronological event list on the monitor at any time for the whole substation or sections of it.

A printout of each display is possible on the hard copy printer.

The events are registered in a chronological event list in which the type of event and its time of occurrence are specified. It is possible to store all events in the computer. The information is obtainable also from printed event log.

The chronological event list contain:

- Position changes of circuit breakers, isolators and earthing devices.
- Indication of protective relay operations
- Fault signals from the switchgear
- Violation of upper and lower limits of analogue measured value.
- Loss of communication

Filters for selection of a certain type or group of events is available. The filters are designed to enable viewing of events grouped per:

- Date and time
- Bay
- Device
- Function
- Alarm class

5.9.2.8 Alarm List

Faults and errors occurring in the substation is listed in an alarm list and immediately transmitted to the control centre. The alarm list substitutes a conventional alarm tableau and constitute an evaluation of all station alarms. It contains unacknowledged alarms and persisting faults. Date and time of occurrence is indicated.

The alarm list consists of a summary display of the present alarm situation. Each alarm is reported on one line that contains:

- The alarm date and time
- The name of the alarming object
- A descriptive text
- The acknowledgement state

The operator is able to acknowledge alarms, which is either audible or only displayed on the monitor. Acknowledged alarms are marked at the list.

Faults that appear and disappear without being acknowledged especially presented in a separate list for fleeting alarms. For example, due to bad contacts or intermittent operation.

Filters for selection of a certain type or group of alarms are available as for events.

5.9.2.9 Object Picture

When selecting an object such as a circuit breaker or isolator in the single line diagram, first the associated bay picture will be presented. In the selected object picture, all attributes such as

- type of blocking
- authority
- local / remote control
- NLDC / SA control
- errors

are be displayed.

5.9.2.10 Control Dialogues

The operator will be able to give commands to the system by means of soft keys located on the single line diagram. It is also possible to use the keyboard for soft key activation. Data entry is performed with the keyboard.

5.9.2.11 User Authority Levels

The activation of the process pictures of each object (bays, apparatus, etc.) are restricted to a certain user authorization group. Each user is given access rights to each group of objects, e.g.:

- Display only
- Normal operation (e.g. open/close apparatus)
- Restricted operation (e.g. by-passed interlock)
- System administrator

For maintenance and engineering purposes of the station HMI, the following authorization levels are available:

- No engineering allowed
- Engineering/configuration allowed
- Entire system management allowed

The access rights are defined by passwords assigned during the log-in procedure. Only the system administrator is able to add/remove users and change access rights.

5.9.3 System Performance

The refresh/update times on the operator station PC under normal and calm conditions in the substation is according to the levels specified below:

Function	Typical values
Exchange of display (first reaction)	< 1 s
Presentation of a binary change in the process display	< 0.5 s
Presentation of an analogue change in the process display	< 1 s
From order to process output	< 0.5 s
From order to update of display	< 1.5 s

5.9.4 System Reliability

The SA system is designed to satisfy very high demands for reliability and availability concerning:

- Solid mechanical and electrical design
- Security against electrical interference (EMI)
- High quality components and boards
- Modular, well-tested hardware
- Thoroughly developed and tested modular software
- Easy-to-understand programming language for application programming
- Detailed graphical documentation, according to IEC 1131-3, of the application software
- Built-in supervision and diagnostic functions
- After sales service
- Security
- Experience of security requirements
- Process know-how
- Select before execute at operation
- Process status representation as double indications
- Distributed solution
- Independent units connected to the local area network
- Back-up functions
- Panel design appropriate to the harsh electrical environment and ambient conditions
- Panel grounding to provide immunity against transient ground potential rise

5.9.5 Configuration Tools

The configuration of the station HMI shall be made using the operator station working in Windows NT environment. The various functions can be customized by easy to use interactive configuration tools. Configuration include the visual presentation of the object, adaptations needed in process database and adaptations of the communication configuration data.

A portable Personal Computer (PC) as a service unit shall be foreseen for on-site modifications of the control and protection devices. The service unit shall be used for documentation, test and commissioning.

The PC based service and support system shall be used for the following purposes:

- System configuration
- System testing
- Help functions
- Program documentation
- Down- and up-loading of programs
- System commissioning
- Data base management
- Changing peripheral parameters

The service and support system shall be able to monitor data in the running substation control system and to present changing variables on the display screen in graphic representation.

5.9.6 Documentation

The following documentation shall be provided for the system during the course of the Project and they shall be consistent, CAD supported, and of similar look/feel:

- List of Protection Drawings
- Control Room Lay-out
- Assembly Drawing
- Protection Single Line Diagram including detail CRP drawing
- Block Diagram
- Circuit Diagram
- List of Apparatus
- List of Labels
- Functional Design Specification (FDS)
- Test Specification for Factory Acceptance Test (FAT)
- Logic Diagram
- List of Signals
- Operator's Manual
- Product Manuals
- Calculation for uninterrupted power supply (UPS) dimensioning (if applicable)
- High quality SCD file

5.9.7 Indicating Meters in Local Back-up Control Panels

Each circuit shall be equipped with indicating meter for measurement of three phase currents, voltages, frequency, power factor, active and reactive power. Repeat pulse outputs are to be provided from all energy meters, where specified.

5.9.8 Trip Circuit and Power Supply Supervision

Trip circuit supervision relays shall be provided to monitor each of the trip circuits of circuit breakers in the relay panel and each relay shall have sufficient contacts for visual/audible alarm and indication purposes.

The trip circuit supervision scheme shall provide continuous supervision of the trip circuits of the circuit breaker in either the open or closed position and independent of Local or Remote selection at the local operating position. It shall be suitable for use in single and three pole tripping schemes as appropriate.

Relay elements shall be delayed on drop off to prevent false alarms during faults on D.C. wiring on adjacent circuits, or due to operation of a trip relay contact.

Series resistances shall be provided in trip circuit supervision circuits to prevent mal-tripping of a circuit breaker if a relay element is short circuited.

Relay alarm elements should be equipped with self-resetting flag indicators.

Where specified, time delayed power supply supervision relays shall be provided to monitor the duplicated D.C. power supplies for tripping, closing, CB fail, busbar protection etc. within a relay panel. An alarm shall be given if either supply voltage falls below 70% of nominal voltage for a period in excess of 3 secs. The relay shall be equipped with a self-resetting flag indicator and shall be suitable for continuous operation at 125% of nominal D.C. voltage.

5.9.9 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.

5.9.10 Availability Calculations

Not used.

5.10 Diagrams

The Contractor shall submit schematic protection diagrams for consideration of the Employer / 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 protection drawings for each substation (if not already provided in this Bidding Documents) 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, cable schedules, etc.).

5.11 Current Transformer Calculations

The Contractor shall submit to the Employer / Engineer detailed calculations substantiating the parameters of the current transformers he proposes to provide. They shall be presented within six weeks of the Contract commencement date.

5.12 Requirement of Protection

5.12.1 General

The protection and control facilities shall be suitable for the power system arrangement as shown in the Drawings enclosed in this Section.

For standardization of operation, performance, reliability facilities and spare requirements, the main protective relays and control system including complete panels to be supplied under this project shall comprise GE (former Alstom), ABB, SEL and Siemens. The protection relays should match with existing protection system.

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 of 63 kA for 400kV system. All current transformer design shall be based on these fault levels.

All relays shall operate correctly within system frequency limits of 47 Hz to 51 Hz.

5.12.2 Fault Clearance Times

400 kV system overall fault clearance times (i.e. from fault initiation to arc extinction) shall not exceed the following:

Type of Fault	Unit	Maximum Fault Clearance Time for 400 kV
Substation and Transformer fault	msec	80
Line fault		
a) 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
b) 72% to 100% of the line length plus protection signalling time.	msec	100

These requirements must be fulfilled under all system conditions including maximum D.C. current offset and any time delay. Clearance within these times shall be achieved for all types of faults except high resistance earth faults detected by DEF protection or under circuit breaker failure conditions.

5.12.3 Arrangement of Facilities

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.

Control panels shall incorporate all necessary control and indication facilities for the operation of the plant and equipment at the associated substation. In addition, the plant may be remotely controlled and supervised from the National Load Dispatch Centre (NLDC) in Dhaka.

Extension of 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. and shall be from the same manufacturer / model. Where specified for the mounting of, and connection to, interposing relays and transducers, links shall be provided to enable transducers to be isolated for test purpose and shortening facilities shall be provided where transducers are used in the secondary of the current transformers. All circuits provided under this Contract whether or not they are subject to the system control requirements at the present time, shall be designed and constructed so that the standard facilities specified can be readily provided as required in the future.

The Contractor shall be responsible for ensuring the correct operation of the protective equipment and shall submit for approval recommended relay settings supported by design calculations for all protective equipment been supplied. The Employer 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 Employer.

5.12.4 Multi Core Cable Diagrams

This Contract includes the preparation of cabling schematic diagrams, showing the approved routing of cores in the various cables, and detailed cable schedules and connection diagrams for all the cables associated with each item of equipment.

5.12.5 Test and Earthing Facilities

Each control or relay panels shall be provided with a copper earth bar of not less than 150 mm^2 Cross-section and arranged so that the bars of adjacent panels can be joined together to form a common bus.

The common earthing busbar of control and relay panels shall be connected to the main station earthing system via a copper earthing connection of not less than 150 mm^2.

Software for testing the protection and control devices shall be included in the scope of supply. In addition, for secondary injection testing of the protection and control devices, provision shall be made in the panel for current and 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 Employer.

5.12.6 Protection Devices

Simplified arrangements of the main connections and protection for the various items of plant are shown in the Drawings of this Section.

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.

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 Section.

5.12.7 Relays

5.12.7.1 General

Relays shall conform to IEC 61850 standards, be of approved types complying with IEC 60255 or BS 142 and 5992, Part 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 Employer will reject any design he considers unsatisfactory or having insufficient field experience. All the protective relays shall be numerical type. Numerical relays shall be configured in such a way that at least 2 nos relays shall be provided for each feeder.

The protection relays shall be located in conventional panels and shall be flush mounted in dust and moisture proof cases and of the draw out type with rear connections.

Relays shall be of approved construction and shall be arranged so that adjustments, testing and replacement can be affected with the minimum time and labour. Relays of the hand reset type shall be capable of being reset without opening the case.

Electrically reset tripping relays shall be provided where necessitated by the system of control, such as for those circuits subject to remote supervisory control.

Relay contacts shall be suitable for making and breaking the maximum currents which they may be required to control in normal service but where contacts of the protective relays are unable to deal directly with the tripping currents, approved auxiliary contacts, relays or auxiliary switches shall be 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.

Relays, where appropriate, shall be provided with LCD, LED or flag indicators, phase coloured where applicable. LCD, LED or Flag indicators shall be of the hand reset pattern and shall be capable of being reset without opening the case. Where two or more phase elements are included in one case, separate indicators shall be provided for each element.

All relay settings shall be visible and readable without having to remove the relay front cover. It shall not be possible to amend relay settings with the front cover in place; other than over a serial link, if provided.

If a connector for local use is provided, this shall be accessible only after removing the front cover. Where a port is provided for permanent connection to a modem or other peripheral equipment, remote access shall be password protected.

Relays which rely for their operation on an external DC supply shall utilize for this purpose the trip supply of the associated circuit-breaker trip coil. This supply shall be monitored, and an alarm provided in the event of failure.

Any auxiliary supplies needed shall be drawn from the main station batteries and not from separate internal batteries in the protection equipment.

Relays, whether mounted in panels or not, shall be provided with clearly inscribed labels describing their function and designation in addition to the general purpose labels.

Attention is practically drawn to the tropical climate and relay designs should be entirely suitable for duty under full tropical conditions.

To minimize the effect of electrolysis, relay coils operating on DC shall be so connected that the coils are not continuously energized from the positive pole of the battery.

Relay shall be suitable for operation on 110 V nominal, 121 V float DC systems without the use of voltage dropping resistors or diodes.

Numerical protection shall be designed in such a way that in case of a failure of DC auxiliary infeed, the full information needs to be maintained at least 24 hrs. After a recovery of DC auxiliary infeed, the last information and alarms will be displayed and the alarm "failure of DC auxiliary infeed" released. The relay reset shall not erase the relay memory.

The numerical protection functions shall be in the form of software such that additional or different functions, application specific logic, etc. can be readily implemented without changes to the existing hardware. It shall be possible to 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.

All numerical relays shall be adequately protected against damage from incoming surge and shall meet relevant IEC, BS and ANSI SWC test standards. Relays shall utilize a DC-DC converter type regulated power supply to provide transient surge isolation between the station battery and protection equipment. Each DC supply shall be designed to protect it from high voltage and surge and provide electrically isolated contacts for annunciation.

In addition to all equipment and components, the Contractor shall supply documents and calculations to prove the correct functioning of the equipment and he shall ensure and demonstrate that the setting range of relays and the operating limits of all equipment are suitable for the intended applications.

5.12.7.2 Electromagnetic Compatibility

In certain cases, e.g. distance protection, current differential etc., electronic relays, or devices utilizing microprocessors are specified and electromagnetic devices will not be accepted.

Where such devices are required, they and the ancillary circuits connected to them, such as power supplies, current and voltage transformer secondaries, status, 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.

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.

All relays offered must therefore have been type tested to meet the current requirements of IEC 60255 with respect to High Frequency Disturbance, Fast Transients, Electrostatic Discharge, Radio Frequency Interference testing, etc.

5.12.8 Transmission Line Protection

5.12.8.1 400 kV Overhead Line Protection

The adopted 400 kV transmission line protection scheme specified as below, however, the Contractor shall prove the applicability of the protection scheme, especially considering line distance. If it is not applicable in the system, then the Contractor shall propose an option and it shall be approved by Employer.

	Main Scheme		Back up Scheme	Reclosing	Details
	Relay	Comm. Ch			
Main 1	Transfer Trip (PUTT/POT)	Optical & PLC	Distance (21) 67/67N 68, VTF 50 Stub 50 SOTF		Full scope of Distance and Multiple OC Function
Main 2	Transfer Trip (PUTT/POT)	Optical & PLC	Distance (21) 67/67N 68, VTF 50 Stub 50 SOTF	Multiple 1 phase, 3 phase, 1 + 3 phase	Full scope of Distance and Multiple OC Function

The 400 kV overhead transmission lines shall be protected by a full scheme of Distance relay with PUTT/POTT scheme as a Main 1 and another full scheme of Distance relay with PUTT/POTT scheme as a Main 2.

Two stages overvoltage protection are provided for 400 kV Lines. The overvoltage protection relays shall have a high drop-off to pickup ratio with adjustable setting range for voltage and time. The low set stage shall monitor any one phase to phase voltage and shall have associated timer. The high set stage shall monitor all three phase to phase voltages and shall have associated timer. This shall be connected to trip concerned line Breakers, start local breaker backup, block auto-reclosure and send direct trip command.

Both Main 1 and Main 2 relay shall have auto reclose function. Both Main 1 and Main 2 relays shall be from different manufacturers.

5.12.8.2 Distance and Directional Earth Fault Protection

Distance protection shall comprise at least duplicate three zone distance relays capable of detecting all types of phase and earth fault.

The Zone 1 elements will normally be set to approximately 80 per cent of the line impedance. They shall trip the local line circuit breaker.

The Zone 2 elements will be set to over reach the remote substation with tele-protection signaling channels to form a permissive over reaching scheme. They shall also act as a backup time delayed zone which trips the local circuit breaker.

The Zone 3 elements shall provide a further time delayed back up zone.

Distance protection back up zones shall also trip the remote end circuit breaker(s) via a direct inter-tripping channel.

Partially cross polarized mho or polygonal impedance characteristics relays are preferred for Zones 1, and 2 for 3 phase and 2 phase faults but other characteristics will be considered. Quadrilateral characteristics with adaptive reactance measurement to avoid overreach or 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. Details of methods used for polarizing the

relays to deal with faults close to the relaying point shall be provided. Zone 3 shall be capable of being set as either directional or non-directional and shall be capable of being independently off set in both directions.

The reach of each zone and reverse element shall be individually adjustable by means of a multi tap voltage transformer or other approved method. The characteristic angle shall be adjustable between approximately 40 and 80 degrees.

Where used in a permissive overreach transfer tripping scheme with weak infeed tripping the Zone 3 unit may be set looking in the reverse direction. The reverse looking impedance/directional elements shall detect all reverse faults capable of being detected by the Zone 2 relay at the remote substation. The Contractor shall explain how this is achieved.

The protection sensitivity shall be shown to be adequate for the minimum fault level conditions. These will be advised to the Contractor at a later stage.

Where fault resistance may be significant, the Contractor shall illustrate that the distance protection can cover such values taking fault current distribution and load conditions into account.

The operating time of each distance protection zone shall be substantially independent of fault current magnitude. The operating times shall be stated, and curves shall be provided showing the effect of line and source impedance, fault position and operating current.

Under no circumstances shall any line protection operate because of normal system switching including de energization of the line.

A feature shall be incorporated to ensure instantaneous tripping in the event that the circuit breaker is closed onto a fault on a previously de energized line.

Distance protection backup Zone 2 and Zone 3 time delay setting ranges shall be 0.2 to 1.0 seconds and 0.5 to 3.0 seconds respectively.

A monitoring system shall be provided to supervise the voltage transformer supply to distance protection. In the event of loss of one, two or three phases, the monitoring system shall inhibit relay operation and initiate an alarm. The VT supervision unit associated with the distance relay shall also inhibit the DEF protection in the event of VT fuse failure.

All relays shall incorporate indicators to show the relay tripped, zone indication and the phase or phases faulted. Indication must not be lost in the event of a supply failure.

Directional earth fault protection operating in a permissive overreach scheme shall be provided to cater for high resistance faults which cannot be detected by the distance protection. The same tele-protection signaling channel shall be used for the directional earth fault scheme and the distance protection scheme. An echo feature shall be included with the DEF Scheme and shall be subject to approval by the Engineer.

The directional relays shall be dual polarized i.e. polarized with zero sequence voltage and current. The relay sensitivity shall be adjustable between approximately 5 and 10% of rated current. A relay characteristic angle of 60 degrees is preferred but alternative angles will be considered. It is appreciated that because the 400kV system zero sequence source is an auto transformer with a delta tertiary winding, that current polarizing of a dual polarized relay is unreliable without careful analysis. The Contractor shall be responsible for determining whether such a current signal can be taken from the

auto transformer neutral and safely used for polarizing the relay within three months of being advised of all transformer impedance parameters.

Directional earth fault relays shall incorporate a backup stage. The time delay range shall be 0.2 to 5.0 seconds or inverse time delayed with a characteristic to IEC 60255.

Neither the distance protection scheme nor the directional earth fault scheme shall mal operate due to fault current reversal during sequential clearance of a fault on the parallel circuit.

The effect of zero sequence mutual coupling between the double circuit lines on the protection shall be described, together with any measures considered necessary to overcome this effect.

The distance protection time delayed back up Zones 2 and 3 and the directional earth fault backup stage shall inter-trip the remote station circuit breakers over direct inter-tripping channels.

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.

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 to reverse looking, the power swing blocking characteristic shall be set such that it encompasses the forward looking Zone 2 characteristic.

Facilities shall be provided to block Zones 1, 2 and 3 of the distance relay from the power swing blocking logic as required.

Blocking logic shall be derived by determining the time taken for the apparent impedance of the power swing locus to pass from the characteristic of the power swing relay to the appropriate distance relay characteristic. Blocking shall not take place until the apparent impedance has passed through the two power swing characteristics and the set time delay has expired.

The associated time delay relay shall have a setting range of 50-250 ms.

If the associated VT supplies are lost due to VT fuse failure the power swing blocking relay shall not operate.

Where protection is supplied from multi ratio current transformers, the lowest ratio will be used for the initial system configuration, when fault levels are low. The working ratio will be increased when the system expands and the fault levels and load transfers increase.

5.12.8.3 Overcurrent and Earth Fault Protection

The overcurrent and earth fault relays shall be fully numerical and have multi characteristics (inverse, very inverse, extremely inverse) to IEC 60255.

Overcurrent relays shall have a current setting range from at least 50%-200% in 25% setting steps.

Earth fault relays shall have a current setting range from at least 20%-80% in 10% setting steps.

Time multiplier settings shall be continuously adjustable from 0 to 1 or, as an alternative in steps of 0.025 from 0.05 to 1.0.

In the case of transformer circuits, relays shall be provided with high set instantaneous units which can be set to 1.25 times the fault current in the HV winding for a fault on the LV terminals computed using the transformer minimum impedance and assuming negligible source impedance. The instantaneous unit shall have a low transient overreach (less than 5% for system X/R ratio of 10) and an operating time of less than 40 msec at two times the current setting.

In the case of 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 msecs.

Overcurrent and earth fault relays shall trip via the CB duplicate trip coils and initiate duplicated direct inter-tripping to the remote line end CB.

Relays shall be thermally rated such that the operating time of the relay at the highest practical current levels on any combination of current and time multiplier settings shall not exceed the thermal withstand time of the relay. The Contractor shall provide copies of type test reports to show that this requirement has been met.

Where directional back up overcurrent and earth fault devices are specified directional elements shall be voltage polarized.

Directional units for directional overcurrent protection shall be quadrature connected with a relay characteristic angle setting of 30° or 45° current leading voltage.

Directional units for directional earth fault back up protection shall employ residual voltage quantities and the relay characteristic angle be variable 0°, 45° and 60°, current lag.

The nominal operating boundary shall be ±90° from the relay characteristic angle and the operating time of the directional unit shall not exceed 20 ms at the relay characteristic angle.

The relay shall be capable of operating correctly when both the operating current and polarizing voltage quantities are 1% of rated values at an angle equal to the relay characteristic angle.

The residual polarizing voltage for earth faults may reach 190.5 volts and therefore it should withstand this value continuously. The continuous withstand current should be no less than twice rated current.

5.12.9 Busbar Protection

5.12.9.1 General

The busbar protection for 400kV (1 & ½ Breaker scheme) 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.

The busbar protection shall meet the fault clearance time of 80 ms for 400kV under all conditions and have the following features:

(a) In case of 400 kV busbar protection, two independent measurement, protection, and tripping criteria shall be applied.

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.

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.

Each trip relay shall trip the circuit breaker via both trip coils. Both relays on the transformer circuits shall trip the associated circuit breakers.

(b) The operating time of the measuring relays shall not exceed 30 msecs at five times the relay current setting.

The busbar protection will be supplied from multi ratio current transformers. The working ratio will be selected on the basis of maximum load transfer in the same manner as the line current transformer ratios.

The overall fault setting shall be between 10% and 30% of the minimum fault current available for any type of fault, unless otherwise specified. The minimum fault current for busbar faults will be advised at a later stage.

The rated stability limit of the protection shall not be less than the switchgear short circuit rating.

Automatic and continuous supervision of current transformer circuits shall be provided to give an alarm when the out of balance current reaches an undesirable value. Operation of current transformer supervision equipment should take the defective protection zone out of service by short-circuiting current transformer bus wiring.

The Contract shall include for all necessary current transformers, relay panels, marshalling boxes, isolating and shorting links, etc. A lockable Busbar protection ON/OFF switch shall be provided.

Current transformer secondary bus wiring should be suitably dimensioned to reduce current transformer burdens to a minimum.

Suitable voltage limiting devices shall be provided as necessary, including across the unused part of the CT secondary when tapings are employed.

Full details of the existing scheme, together with performance figures for stability and sensitivity shall be provided in accordance with sub-clause 5.12. 9.2

The numerical busbar protection shall be multi-processor in structure, with extensive self-supervision, 16 bit analogue to digital converters, together with appropriate algorithms to provide phase segregated measuring principles and multi criteria evaluations before initialization of trip commands. The busbar protection shall be of decentralized with redundant DC/DC supplies type and the bay units shall be fixed as close to the CTs as possible reducing the copper wiring to a bare minimum and thereby also reducing the CT burden and CT dimension.

If the intercommunication between the bay unit and central unit by fibre optic cables, the required fibre optic cable and all necessary items shall be supplied, connected and commissioned by the Contractor.

5.12.9.2 Conditions of Acceptance of Busbar Protection Systems Submitted on the Basis of Calculated Performance

The Employer is prepared to accept 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 Class X or 5P, low reactance type. Split core type current transformers will not be accepted.
vi) The Contractor shall submit for the Employers approval a design report detailing the protected equipment, design parameters of associated current transformers, details of connections and burdens between current transformers and relays, details of the relay circuits and performance calculations.

5.12.10 Circuit Breaker Failure Protection

Breaker failure protection shall be fitted to all 400 kV circuit breakers. 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 fiber optic links at 400 kV.

In the case of circuit breaker failure protections, the position and fault current of every circuit breaker shall be monitored by independent current check relays (50BFs) fed from each protection current transformer as shown on the drawings in this Section.

The relays shall be capable of remaining in the operated position continuously and of carrying twice the circuit rated current continuously.

The scheme provided shall be suitable for use in a single pole and three pole tripping as appropriate.

The operating time from initiation to back tripping output shall be selected by means of duplicated timers with a setting range of 50-500 msecs. The two timers shall also be connected in series in a two-out-two basis and energize both trip coils of all adjacent circuit breakers but via a single trip relay.

The timers shall be of a modern design to minimize overtravel. Busbar protection trip circuits may be employed for circuit breaker fail back tripping.

In the event that a circuit breaker is unable to trip due to low gas pressure, low hydraulic oil pressure etc. the associated alarm shall be arranged to by-pass the breaker fail time delay. The breaker fail relay/scheme shall be designed to accept this input.

Operation of the breaker fail protection shall block manual and automatic reclosure of the associated circuit breaker. Breaker failure protections inbuilt in distance/transformer relays will not be accepted.

5.12.11 Coupling Bay Protection

The coupler bay shall be provided with overcurrent instantaneous trip relay protection (50 BF) and over current time delay relay protection (51, 51N). Relays shall comply with the requirements of sub-clause 5.11.

All trip signal of line and transformer feeder protection shall be transferred to the coupling breaker in case the feeder breaker is bypassed, and the feeder is protected by the coupling bay circuit breaker. This shall be provided by auxiliary relay, not by auxiliary contacts of the circuit breaker by pass isolator.

5.12.12 Transformer and Shunt Reactor Protection

Not used.

5.12.13 Tripping Relays

All tripping relays, where specified shall be of the heavy-duty type suitable for panel mounting. The trip relays of the offered numerical protections shall be directly capable of tripping the breaker coils. It shall not be required to add additional trip relays.

Trip relay contacts shall be suitably rated to satisfactorily perform their required duty and relay operating time shall not exceed 10 ms from initiation of trip relay operating coil to contact close.

Where specified latching type relays shall have hand or electrically reset contacts and hand reset flag indicators. Resetting of the flag indicator and the contacts shall be possible without having to open the relay case.

Tripping relays shall operate when the supply voltage is reduced to not higher than 30% of nominal battery voltage. It shall not operate for wiring leakage currents and discharge of wiring capacitance

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.

All tripping relays, where specified shall be of the high speed, (less than 10 ms), high burden, heavy duty (greater than 150 W) type suitable for panel mounting.

Relays shall comply with the requirements of sub-clause 5.13.7.

5.12.14 DC Auxiliary Voltage Operating Range

DC operated relays, coils, elements, etc. will be operated from a 110 V rated D.C. battery, which under float charging conditions operates at about 125 V D.C. operated relays coils elements etc. shall be suitable for operation over a voltage range of 66 V to 143 V; i.e. 110 - 40% to + 20%.

5.12.15 Tele-protection Signaling

Details of protection initiation and various permissive and direct inter-tripping signals are indicated in the "Fiber Optic Multiplexer Equipment" drawing enclosed in this Section.

5.12.16 Protection Setting

Relay settings with calculation for all unit type protective schemes and shall be submitted to the Employer / Engineer prior to commissioning of any plant for approval. Settings shall also be provided for those relays and other equipment provided under this Section 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.

5.13 Digital Fault and Disturbance Recorder (DFDR)

This specification states the requirements for supply, installation and commissioning, of a Digital Fault and Disturbance Recorder [DFDR] at the substation control buildings. Installation, testing and commissioning of DFDR shall be performed by the DFDR manufacturer(s) appointed by the Contractor.

For the purpose of standardization, the DFDR to be supplied under this project shall be from Qualitrol or Siemens and shall be from the same manufacturer / model.

The DFDR have the following features:

a) The equipment is an independent standalone system to monitor analogs and digital signals from all 400 kV feeders including transformer and bus-coupler bays that requires to be monitored.

b) The DFDR system is modular in design for easy expansion, upgrade and easy maintenance.

c) The acquisition system or it's storage unit is not be based on a PC platform.

d) An Independent DFDR System shall be equipped with a minimum of :
   - **128 for 400 kV ANALOG INPUT** and suitable for AC/DC measurement without any hardware changes
   - **384 for 400 kV Digital / Events inputs [Dry / Wet contact]**

e) The system is 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.

f) All input signals is able to scan and record simultaneously at least 2 or 3 user programmable sampling rates from 500 Hz to 6 kHz for Fast (Short terms) transient monitoring and from 1 Hz to 500 Hz for Slow phenomena (Long terms) monitoring in order to detect and record Fast (short terms) and Slow phenomena (Long terms) events.

g) 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 is provided in addition to the auto maintained inbuilt Hard Disk unit which is installed for data storage. The inbuilt Hard Disk Unit is managed and operated by the identical industrially proven operating system of the DFDR.

h) The graphical data records all feeders simultaneously (snap shot image). The recording contains the data prior to the event, post event including the dynamic length of the event / fault without any alterations.

i) The system possesses a library of sensors (triggering criteria), which is selected by the user and able to detect and record various type of incidents. The system is able to detect incidents by the selected starting criteria and should be able to produce a record.

j) The recordings 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.

k) The DFDR is able to communicate with Local and / or Remote Master Station using Master communication and Analysis software. This software permits the user either locally or remotely to down load the recorded data, to ascertain the system operational status, change parameters etc.

l) Master communication is able to communicate via RS 232 (Direct connection), through modem (dial up telephone line) and LAN [Ethernet (TCP / IP) – IEEE 802.3] networking.

m) Among the functions performed by the DFDR are 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.

n) The system is equipped for time synchronization by the external GPS clock receiver for real time synchronizing (including Antenna).

o) Local printing facility is provided with the system.

p) Provision for Power Quality monitoring or continuous monitoring (periodical recording) shall be made available for at least 4 feeders.

6. Auxiliary Power and Control Cables

6.1 Scope

A complete cabling system for the bay extension works including 415/230 V auxiliary power requirements and the control and protection multicore cabling shall be designed, provided, installed and commissioned by the Contractor. 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.

6.2 General Description of Installation

The complete cabling installation, including that associated with control and instrumentation, shall be managed by the Contractor, who shall be responsible for design, procurement, installation and works/site testing of the whole installation.

The Contractor shall employ a cabling computer program to facilitate the above and the Bidder shall describe in his Bid the cabling management procedures he will adopt. A cable scheduling system will be imposed by the Employer.

The Contractor shall provide an installation in accordance with the best modern practice and complete in every detail for continuous operation.

Cabling areas will include those which have natural ventilation. Cabling shall therefore be designed for the maximum ambient temperatures expected.

To cater for future requirements, adequate provision shall be made for the associated cables in respect of trench sizes, space for future racks or trays and numbers of cables permitted in areas or spaces required for future equipment.

The Contractor shall submit to the Employer drawings for approval showing the proposed cable routes, cross sections of the trenches and arrangements of the cable racks and trays.

The Contractor shall prepare and provide all necessary cable schedules. The cable numbering system to be used shall be advised to the Contractor and this system shall be followed.

The Contractor shall provide all necessary power, multicore and communications cables required as required.

6.3 Standards

The cables shall comply with British Standards or International Electrotechnical Commission (IEC) Standards and Recommendations, or any other internationally recognized standards, subject to the approval and acceptance of the Employer.

6.4 Cable Installation

6.4.1 General

The cabling system shall be designed to incorporate maximum practical security, to ensure that an incident such as fire causing loss of cable circuits in any one route would at worst result in the interruption in operation of one unit only. Cables with reduced fire propagation characteristics shall be provided.

Cables shall be satisfactory for operation under the atmospheric and climatic conditions prevailing at the site and under such variations of current, voltage and frequency as may be met under fault and surge conditions on the system.

Cables shall be derated to allow for the likely number of cables following a given route.

The methods of installation shall be as follows:

(a) In concrete trenches
(c) In ducts
(d) On cable racks, trays or ladders

Control and instrumentation cables shall be screened/shielded to minimize interference, where necessary.

6.4.2 Installation Criteria

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 600 mm apart from the cables of the other of the pair with an airspace, but not necessarily a physical barrier, between them.

In general, to minimise interference, control cables and instrumentation cables shall be separated from power cables.

The following group classifications will be allocated for each cable:

i) Group A: Single core power cables,
ii) Group B: Multicore power cables,
iii) Group C: Multicore control cables and protection cables,
iv) Group D: multipair control and instrumentation or indication cables.

In general, single core (Group A) and multicore (Group B) power cables shall be allocated to separate racks. In a similar manner, multicore control (Group C) and multipair (Group D) instrumentation cables shall generally be allocated to separate trays.

There shall generally be a minimum separation of 600 mm between instrumentation cables (Group D) and power cables (Groups A and B), and a minimum separation of 300 mm between control cables (Group C) and power cables (Groups A and B). However, both these separation distances may be reduced where the two types of cable only run in parallel for a limited distance, provided the Contractor demonstrates that the level of interference resulting will not be detrimental to the operation of the equipment concerned.

6.4.3 Reduced Fire Propagation

A cable installation with reduced fire propagation characteristics shall be provided, utilising cables with organic compounds which are capable of extinguishing or considerably reducing the spread of flame along the cable.

Consideration shall also be given to ensuring that the minimum toxic or corrosive products are given off on combustion of any organic component used in cable construction.

6.4.4 Type Approval

Cables and accessories for use at all voltages shall have satisfactorily passed type approval tests equal to those required by the International Electrotechnical Commission or equivalent, and details for the cable designs offered shall be given in Volume 3, Schedule E, Particulars and Guarantees.

The Contractor is to certify that the cables and/or accessories offered will be identical in all essential particulars in respect of design, materials and workmanship with the cables and/or accessories for which type approval certificates are offered in support of his tender. The Contractor shall also ensure that all materials used will be subjected to and shall have satisfactorily withstood such tests as are customary in the manufacture of the types of cables specified. Records of such tests shall be available for inspection, if required by the Employer.

6.4.5 Cable Sizing and Routing

The Contractor shall be responsible for all cable sizing and routing design, procurement, installation and testing.

Proposals for the following aspects of cable design shall be submitted for approval:

- Routing cables along the shortest route compatible with segregation / separation and capacity limitations
- Sizing cables in accordance with length grouping, ambient temperature and current rating
- Recording estimated lengths and later measured lengths for each cable
- Progressing the cable installation
- Producing and progressing cable schedules, cable termination schedules, and support steelwork schedules and drawings

All necessary de-rating factors shall be applied when sizing cables, to allow for maximum ambient temperatures, soil temperatures, values of thermal resistivity of soil, and grouping as necessary.

Due allowance shall be made for the method of installation, depth of laying, spacing and grouping factors.

All power cables shall be adequately rated to withstand the thermal and magnetic effects of short circuit fault currents equivalent to the short circuit fault rating of the associated switchgear, except when 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.

The short time rating of all transformer and interconnector feeders shall correspond to the maximum short circuit conditions and be based on the previous maximum continuous rating operating temperature, followed by the initial asymmetric peak current, followed by the thermal steady state r.m.s. fault current for the total duration required for the associated main and back up protection to operate and isolate the circuit. When protected by a circuit breaker which is not of the current limiting type, the cable shall withstand the maximum fault current, including asymmetric peak, for at least 3 seconds without damage.

For 415 V motor supply cables, the rating shall be based upon the duration of the let through current of the associated main circuit breaker or fuse protection. The fault currents considered shall not include for the reduction due to the impedance of the cables concerned.

Maximum conductor temperatures permissible during the passage of short circuit current shall be in accordance with cable manufacturer's recommendations and joints and terminations shall be designed to match the cable characteristics.

For all alarm, control, indication, instrumentation, metering and protection cables, the Contractor shall determine the impedances, load burdens and other requirements of the cabling and associated equipment and shall provide cabling for satisfactory operation. Particular attention shall be given to protection circuits and the Contractor shall ensure that satisfactory operation will be achieved under overload or short circuit conditions on the system.

The Contractor shall furnish copies of calculations and other details to show how the ratings and cross section areas of all cables have been obtained and the de rating factors for which allowance has been made. Where a cable is routed through differing types of installation conditions, the condition giving the lowest cable rating shall determine the cable size.

The sizes of all cables shall be submitted to the Employer / Engineer for approval and the Employer / Engineer may require the Contractor to increase the cross sectional area of the conductor to ensure that the required current carrying capacity and performance is obtained. All such changes shall be made by the Contractor without extra cost.

6.5 Cable Construction

6.5.1 Oversheaths

All cables shall have a black flame-retardant low smoke PVC oversheath material, to meet the fire retardant characteristics of BS 4066 and IEC 60332.

PVC sheathing shall have flame retardant properties such that the Oxygen Index is not less than 30 when tested in accordance with A.S.T.M. D2863-77. Test certificates stating measurement values for sample drum lengths of cable shall be provided.

The external surface of the oversheath shall be embossed along two or more lines approximately equally spaced around the circumference with the words 'ELECTRIC CABLE' in English. Figures for the relevant voltage grade, together with manufacturer's name, shall be embossed on the oversheath.

The letters and figures shall be raised and shall consist of upright block characters. The maximum size of the character shall be 13 mm and the minimum size 15% of the approximate overall diameter of the cable. The gap between the end of one set of embossed characters and the beginning of the next shall not be greater than 150 mm.

The minimum thickness of oversheath shall not fall below the manufacturer's stated value by more than 0.2 mm plus 20 percent.

A means of identifying the manufacturer shall be provided throughout the length of the cable.

6.5.2 Armouring

All multicore cables shall be provided with galvanised steel wire armour. Single core cables shall have copper or aluminium wire or tape armouring.

The armour shall be protected by an overall PVC or plastic sheath.

6.5.3 Laying up

The cores of multicore cables shall be laid up with a right-hand direction of lay. Where necessary, non-hygroscopic fillers, which may be applied integrally with the bedding, shall be used to form a compact and circular cable.

6.5.4 Cable Drums

Cable drums shall be non-returnable and shall be made of timber, pressure impregnated against fungal and insect attack, or made of steel suitably protected against corrosion. They shall be lagged with closely fitting battens.

Each cable drum shall bear a distinguishing number on the outside of one flange. Particulars of the cable, i.e. voltage, conductor size and material, number of cores, type, length, gross and net weights shall also be clearly shown on one flange. The direction of rolling shall be indicated by an arrow on both flanges. The method of drum marking shall be to the Employer / Engineer's approval.

Cable spare lengths shall be wound on to steel drums before they are handed over to the Employer's stores.

6.5.5 Sealing and Drumming

Immediately after the Works, both ends of each cable length shall be sealed by means of a shrinkable cap and the end projecting from the drum shall be adequately protected against mechanical damage during handling. The ends of each drum length of multicore cables shall be masked red and green in accordance with BS 6346 or BS 5467.

6.5.6 Spare Cable

Spare cable and accessories, as detailed in the schedules, are required to be included in the Contract.

6.5.7 Jointing Accessories

Cables shall be installed in continuous lengths and straight through jointing between shorter lengths will not be permitted.

Jointing accessories shall include all necessary internal and external fittings, insulating materials, soldering metal, glands, filling and drain plugs, armour clamps, earth bonding terminals and filling compounds as appropriate.

Mechanical glands for the termination of elastomeric or thermoplastic insulated cables into straight through joints and termination accessories shall meet the requirements of BS 6121 and shall be correctly designed for the termination of the armouring. The gland shall not only adequately secure the armour to provide efficient electrical continuity but shall also provide a watertight seal between the oversheath and the inner extruded or taped bedding to prevent the ingress of moisture. All glands shall be fitted with a substantial earth bond terminal.

The armour clamping device shall be capable of clamping the cable armour so that the clamp withstands any short circuit current from the armour wires, through the gland body to the integral bonding connector.

Sealing end porcelains shall be free from defects and thoroughly vitrified so that the glaze is not depended upon for insulation. The glaze shall be smooth and hard, completely cover all exposed parts of the porcelain and for outdoor types shall be a uniform shade of brown.

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

Sealing ends and fittings shall be unaffected by atmospheric conditions, proximity to the coast, fumes, ozone, acids, alkalis, dust or rapid changes of air temperature between 15°C and 65°C under working conditions.

6.6 Types of Cable

6.6.1 Low Voltage Cables

These cables shall be in accordance with IEC 60502 with a voltage rating of 0.6/1 kV.

These cables shall have stranded copper conductors.

Insulation shall be XLPE with an operating temperature of 90°C.

6.6.2 Control Cables and Instrumentation Cables

6.6.2.1 General

Two types of cable shall be provided for the control and instrumentation cabling. The first is multicore cable with stranded (7/0.67 mm wires) copper conductors of 2.5 sq.mm which is suitable for voltages up to 300 V to ground A.C. or D.C. and currents up to 5 A. 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.

The second type designated "signal cable" is defined as those cables carrying milliamp, analogue or digital signals at low voltage levels (50 V D.C. maximum) used on instrument and Logic Transmission Systems. These cables shall be multiple twisted pairs, screened and PVC covered with conductors sized 0.5 mm^2 minimum (1/0.8 mm or 1/0.9 mm diameter). 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.

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 600 mm from power cables.

6.6.2.2 Multicore Control Cables

Cables shall comply with the construction here above and shall have cross linked polyethylene (XLPE) insulation.

All cables shall be provided with a low smoke PVC oversheath.

Multicore control cables shall be generally in accordance with IEC 60502 with voltage rating 0.6/1 kV, except that 2.5 mm^2 copper conductors shall be stranded (7/0.67 mm wires). Standard designs shall be for cables with 2, 3, 4, 7, 12, 19, 27 and 37 cores, and single strand conductors will be accepted at 1.5 mm^2.

All these cables shall have galvanised steel wire armouring.

These cables shall be used where a low impedance is essential, e.g. for the secondary wiring of current and voltage transformers and for circuit breaker and contactor control circuits.

6.6.2.3 Multipair Instrumentation Cables

Multipair instrumentation cables shall be provided in accordance with industry standards.

These cables shall have solid copper conductors, typically of 0.9 mm diameter laid in twisted pairs, triplets or quads. The cables shall be polyethylene or XLPE insulated. They shall have galvanised steel wire armouring.

Cables shall be provided with either an overall metallic tape screen or individual tape screens round each conductor bundle to reduce interference from adjacent circuits.

These cables shall be used for circuits with a voltage rating not exceeding 125 V to earth and a current rating not exceeding 20 mA, where considerations of interference and cross talk are of great importance. Typical applications include communications, computer signals, transducer circuits and alarms.

6.6.2.4 Oversheaths

All the cable types above shall have a black flame-retardant low smoke PVC oversheath. In normally manned locations, especially the control building, cables shall have a low smoke, zero halogen oversheath, so as to minimise the generation of smoke and corrosive acid gases in the event of a fire.

6.6.2.5 Telephone Type Cables (TWPVC)

Construction

Multipair cables with 1/0.9 mm tinned copper conductors complying with IEC 60228, PVC insulation, individual twisted pairs, PVC bedding, single wire armoured and low smoke PVC sheathed overall.

Insulation

PVC insulation shall be "Hard Grade" to BS 6746 with a radial thickness of 0.7 mm nominal 0.57 mm minimum. Minimum insulation resistance per 1000 metres of conductor at 20°C shall be 10,000 Megohms.

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 150 mm 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.

Core Identification

The insulation of the cores shall be colour coded in accordance with IEC 60189 2 for 20 unique cabling elements (pairs) as described in Appendix A of IEC 60189 2.

6.6.2.6 Pilot Cable

Telephone type cable laid in the ground alongside HV power cables shall take into account the effects of induced voltages.

6.7 Straight Through Joints

Each cable shall be run in one continuous length. Straight-through joints will not be permitted.

6.8 General Methods of Cable Installation

The arrangement of cables and the methods of laying shall be approved by the Employer / Engineer. Cables shall be installed by the following methods only:

- In concrete trenches
- In ducts
- On cable racks, trays or ladders

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.

All cables routed under roads and access ways usable by vehicular traffic shall be installed in ducts.

At all such crossings spare ducts shall be installed; the number of spare ducts shall be two, or 20% of the total number of ducts installed at each crossing, whichever is greater.

Mechanical protection to the Employer / 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.

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 Employer / Engineer.

Sunshields shall be provided in all locations where the cable would otherwise be subjected to direct sunlight.

6.9 Cables Drawn into Ducts

Ducts and pipes 35 mm minimum in excess of cable diameter, shall be supplied and installed by the Contractor in accordance with Clause 12 of this Section.

Ducts shall be of rigid PVC and shall be surrounded by 150 mm minimum thickness of concrete.

Before pulling cables through ducts, the Contractor shall remove any loose material from the ducts and prove them by drawing through a mandrel of slightly less diameter than the duct. Any lubricant used shall have no deleterious effect on the cables.

Any ducts or pipes not used shall be sealed by plugs (detail subject to approval) supplied by the Contractor before back filling.

The ducts shall be water and vermin proof sealed, after completion of cable installation.

6.10 Cables Installed in Concrete Trenches

The cable trench system shall be designed by the Contractor to the approval of the Employer / Engineer. It shall be complete with removable covers and shall comply with Clause 12 of this Section.

All cables routed in concrete trenches shall be suitably supported by means of cleats or racks and raised from the trench floor by means of suitable spacers. All cables shall be run in a neat and orderly

manner and the crossing of cables within the trench shall not be acceptable without the prior approval of the Employer / Engineer.

The Contractor shall be responsible for removing and replacing the trench covers free of charge during the execution of his work as directed by the Employer / Engineer.

6.11 Cables Supported on Racks, Trays and Ladders

6.11.1 General

All single core and multicore main power cables shall be installed in cleats or saddles fixed at intervals. Multicore power cables shall be installed on trays, racks or ladders but segregated from other cables on the same tray by a space of 300 mm.

All control cables shall be installed on racks or trays with adequate clamps, cleats or ties to avoid excessive sagging. The Contractor shall include for the preparation and provision of single line cable routing drawings and detailed cable supporting steelwork drawings, necessary to enable the Employer / Engineer to give his approval for all main and subsidiary routes before installation commences.

Ample allowance shall be made in the design for additional cabling for future extensions.

Racks and trays shall be secured to channel or similar inserts installed in accordance with Clause 12 of this Section.

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.

Trays and supporting steelwork shall be securely bonded and grounded to the main earthing/grounding system. Bonding and grounding connections shall be adequate to carry prospective fault currents without exceeding thermal or voltage limits.

6.11.2 Supporting Steelwork

All supporting steelwork shall be hot dip galvanised after manufacture and shall be to the approval of the Employer / Engineer.

Steelwork section shall not be less than 50 x 50 x 6 mm for steel channels and 50 x 50 x 5 mm for angles.

On all main cable runs, supporting structures shall be designed and drilled to accommodate additional cable racks or cleats to the extent of 20% of cables installed under the Contract and those required for known future extensions. The spacing between supporting structures shall be not greater than 1 m unless otherwise approved by the Employer / Engineer.

In cases where cables or their supports must be fixed to structural metal work, care shall be taken to avoid eccentric load transfer to beams or other structural metal. Also, local overloading or deformation of structures shall be avoided. The Contractor shall, if required, demonstrate that the loading resulting from the attachment of cabling steelwork has been taken into account in the steelwork design.

6.11.3 Cable Clamps, Cleats, Saddles and Ties

For single core cables carrying three phase alternating current, non-magnetic trefoil cleats shall be used and for other single core and three core cables claw type single or multicore unit cleats shall be used. The cleating arrangements for single core cables shall be adequate to withstand all short circuit forces

Cable clamps shall be used at any change of direction of cable laying, but at agreed intervals on straight runs cable ties of approved design may be used.

Every non-flexible type cable shall be securely supported at a point not more than 1 m from its terminal gland to prevent stressing the termination, and on vertical runs passing through floors, immediately above the floor.

6.11.4 Trays, Racks and Ladders

The Contractor shall provide all necessary trays, racks or ladders which shall be fixed at not more than 1 m centres. On all main runs trays, racks or ladders shall be installed to accommodate additional cables to the extent of 50% of those installed under the Contract or known future requirements.

Cables shall be installed on trays, in general as follows:

(a) Up to 16 mm^2 - double layer touching
(b) 25 mm^2 to 70 mm^2 - single layer touching
(c) Above 70 mm^2 - single layer with 25mm (minimum) spacing

All cable trays shall be perforated.

All trays, racks and ladders 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, racks or ladders shall not proceed until the Employer / Engineer's approval for such has been obtained.

Where cables are run on trays, racks or ladders, they shall be tied to the tray at 1 m intervals using materials approved by the Employer.

The cable tray system shall have minimum of 20% spare cable capacity throughout.

6.12 Terminations

6.12.1 General

The Contractor shall be responsible for making all terminations, checking and setting to work the completed installation. All cables provided as part of the Contract shall be terminated at both ends.

For control wiring, the cable tails shall be so bound that each wire may be traced back to its associated cable without difficulty. Cores in twisted pairs or groups shall be kept together. Any spare cores shall be numbered and terminated in the spare terminals furthest away from the cable gland. All cables shall be long enough to permit a second termination if necessary, at a future date to the remotest termination location in the panel.

Cable glands shall be used at all equipment to support the weight of cable from the terminations and to seal the cable to the equipment, unless otherwise approved by the Employer / Engineer.

PVC, XLPE, silicone rubber and PTFE insulated cables shall be terminated via glands to BS 6121. Glands where water may impinge on cables shall be type EIU, with inner and outer seals and armour clamp. Unarmoured single core cables in these areas shall have type A2 glands.

Glands in indoor locations with the exceptions as noted above shall be type C for armoured cables and type A2 for unarmoured single core cables.

PVC shrouds shall be supplied and installed over each gland.

6.12.2 Power Cables

The Contractor shall ensure that the correct phase rotation and connections are achieved. Particular care shall be taken in the case of heavy cables, where subsequent correction may be difficult. Phase tests will be witnessed by the Employer / Engineer and, if found necessary, the Contractor shall carry out the reversal of phase connections. Connections to electric motors shall be made as specified. Where motors have tails rather than bushings, a heat shrink or equivalent PVC tube for insulation of the crimp joint shall be provided.

Where insulated glands are provided, the Contractor shall ensure that the insulation is maintained after jointing the cable and shall, if required, demonstrate this to the satisfaction of the Employer / Engineer.

The tails of two or three or four core cables in air insulated terminations shall be identified by a band of approved tape of appropriate colour over the self-sealing tape.

Single core cables shall be similarly identified by coloured tape over the cable beneath the gland.

6.12.3 Mineral Insulated Cables

The MICS cables shall be terminated with pot type seals in Universal ring type glands utilising cold plastic compound of an approved type. Accessories and methods of anchoring the extension sleeving shall be to the approval of the Employer / Engineer. All MICS cable terminations shall be complete with high temperature neoprene sleeves of sufficient length over conductors and sundries. All MICS seals shall be tested not less than twenty-four hours after completion with a 1000V insulation resistance tester and a reading of greater than 10 Mohms must be obtained before conductors are connected at any apparatus.

The Contractor shall provide the necessary compound of approved grade and necessary MICS cable glands. Where the ambient temperature is expected to exceed 50°C, special seals shall be used, details of which shall be approved by the Employer / Engineer.

6.13 Terminating and Jointing Conductors

Compression (indentation) type cable lugs and ferrules shall be provided and all necessary tools, including dies and other materials for making compression joints, shall be provided by the Contractor, who shall comply with the recommendations of the supplier of cables and lugs in the preparation and execution of each termination.

For stud type terminals approved crimping lugs shall be used.

Where clamp type terminals are used, the conductor shall be terminated without lugs with the exception of flexible conductors having wires 0.3 mm or smaller which shall be fitted with crimps. Not more than one conductor shall be terminated in each clamp.

6.14 Core Identification

The core identification system shall adopt the existing system used in the substations. The following clauses outline the broad requirements, but the exact implementation shall be agreed with the Employer Engineer.

Approved numbered ferrules shall be supplied and fitted to every cable core of control and instrument cables at each termination. The ferrules or sleeves shall be of interlocking ring insulating materials such

as plastic which shall be black engraved on yellow background and have a glossy finish. The ferrules or sleeves shall be unaffected by oil or damp. Identification marks on self - sticking cloth shall not be used. The ferrules shall be of "O" or "D" cross section. Ferrules of "C" type cross section shall not be used.

Single D.C. wires shall be identified by a red or blue coloured ring (positive or negative polarity) followed by the identification of the polarity concerned (instrumentation, klaxon, alarm, etc.).

Direct A.C. circuits shall be identified by a yellow end piece followed by an identification of the phase concerned.

Wiring for secondary circuits of voltage transformers shall be identified by a grey end piece and wires in current transformer secondary circuits shall be identified by a green end piece. This identification shall be completed by a terminal index.

All markings for terminal blocks, cables, cable conductors and wiring shall be located on the corresponding fault-finding drawing.

Characters suitably marked 'TRIP' in white shall be fitted on all wires associated with trip circuits.

A common system of ferrule numbering shall be adopted such that ferrule numbers at terminations shall agree with ferrule numbers on the internal wiring of equipment.

6.15 Cable Identification and Schedules

The Contractor shall prepare and submit computerized cable schedules, the content and style of which shall be to the general approval of the Employer / Engineer. These shall include cable identification numbers for all cables except those provided for lighting and small power circuits and those which are connected to the load side of distribution boards for lighting and small power circuits.

The cable identification number system shall be such as to give a brief general indication of the type and function of individual cables and shall be approved by the Employer / Engineer.

The Contractor may use a fully computerized system for rating, and routing of cables, but shall provide a system that readily permits the cables to be scheduled on the following basis in sequence of cable identification number:

(a) By cable identification number only
(b) By type and size of cables
(c) By function of cable
(d) By main LV AC and DC Switchboard, actuator boards
(e) By agreed electrical and mechanical plant functional groups.

The Contractor shall provide copies of the cable schedule in an approved format. The schedules shall be accessed by simple interactive dialogue using 'menu selection' or other approved procedure.

In addition, at agreed intervals the Bidder shall provide selected copies of the above schedules in a computer printout form.

Each end of every cable, except those provided for lighting and small power circuits and which are connected to the load sides of distribution fuse boards, shall be identified with a separate cable

reference number fitted in a suitable position under the cable termination. Where cables enter and leave ducts or pipes, suitable identification markers shall be fitted.

The materials of the markers and fastenings shall be such as to avoid corrosion or deterioration due to incompatibility of materials and shall ensure permanent legibility.

6.16 Inspection and Testing

Inspection and testing during manufacture and after installation on site shall be in accordance with Clause 15 of this Section.

7. Earthing Systems, Electrodes Connections

7.1 Scope

These clauses describe the general requirements for the Earthing and Lightning Protection.

7.2 References

7.2.1 American Standards

ANSI / IEEE / Std. 80	IEEE Guide for Safety in AC Substation Grounding
ANSI / IEEE / Std. 81	IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potential of a Grounding System

7.2.2 German Standards

DIN VDE 0141	Earthing Systems for Power Installations with Rated Voltages above 1 kV

7.2.3 British Standards

BS 1432	Specification for copper for electrical purposes: High conductivity copper rectangular conductors withdrawn or rolled edges
BS 1433	Specification for copper for electrical purposes: Rod and bars
BS 2871	Specification for copper and copper alloys: Tubes
BS 2874	Specification for copper and copper alloy rods and sections (other than forging stock)
BS 4360	Specification for weldable structural steel
BS 6360	Specification for conductors in insulated cables and cords
BS 6651	Protection of Structures against Lightning
BS 6746	Specification for PVC insulation and sheath of electric cables
BS 7430	Code of Practice for Earthing

7.2.4 International Standards

ISO 427	Wrought copper-tin-alloys - chemical composition and form of wrought productions
ISO 428	Wrought copper-aluminium alloys - chemical composition and forms of wrought production
ISO 1187	Special wrought copper alloys - chemical composition and forms of wrought products
ISO 1137	Wrought coppers (having minimum copper contents of 99.85%) - chemical composition and forms of wrought products

7.3 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.

7.4 Extent of Work

The Works under this Section comprises the site testing, design, supply and installation, including excavation, backfilling and temporary reinstatement, of earthing systems and connections to electrical apparatus at each substation. The scope of work also includes earthing of substation building.

The Contractor shall be required to undertake all necessary earth resistivity tests at the substation sites and, from these tests, to undertake the design of the earthing systems. These designs, as well as providing safe passage to earth for the stated earth fault currents, shall also include calculation of step, touch and mesh potentials, which shall be within the allowable limits of the standards quoted in this specification.

The design calculations of step, touch and mesh potentials, accompanied by full installation drawings and material requirement schedules, shall be submitted to, and receive the approval of the Engineer before materials procurement or installation commences.

7.5 Soil Survey

The preliminary Bid design shall be based on a value of 1623 ohm-m soil resistivity for Aminbazar substation and 223 ohm-m soil resistivity for Gopalganj substation.

Not later than one month after the site has been handed over for access, the Contractor shall carry out an earth resistivity survey of the sites and report in writing to the Engineer in accordance with the approved programme. The report shall detail the methods and instruments used and the results of the surveys. Based on the results the Contractor shall include in the report his proposals for the resistivities to be used in the design of the earthing system.

The surveys shall show the variation of resistivity across the site and with the depth below the site. The Contractor shall consider if there is a need to model the resistivity in two layers and if there is any advantage in the use of deep rod electrodes.

The surveys shall also determine the depth and nature of any underlying rock, which may limit the depth for driving earth rods or if boring will be necessary for installing earth rods.

The weather conditions prior to and at the time of the surveys shall be recorded in the report and an assessment made of the seasonal variations in resistivity based on meteorological data for the area. The programme for the project should, as far as possible, time the resistivity surveys to take place during a dry season.

The report should also state if there are any indications that the ground is corrosive to bare copper.

The report shall be approved by the Engineer before proceeding with the design of the earthing system.

7.6 Fault Current and Duration

Each site shall be provided with an earth grid of buried conductors designed for an earth fault current of 63 kA for 400 kV. The preliminary earthing design shall be such that the potential rise shall not exceed 5 kV.

7.7 Earth Electrode System Design

7.7.1 Design Calculations

The design of the earth electrode systems shall be based on the approved earth resistivity data and the system fault currents and their duration.

The design calculations shall be to the approval of the Engineer and shall be based on the methods given in the standards listed. The calculations shall include the following parameters:

(a) earth resistance of the whole system and of its components
(b) earth potential rise
(c) step, touch and mesh potentials inside and outside the perimeter fence
(d) requirements for a high resistance surface layer
(e) conductor ratings

Earthing points shall be provided such that the combined resistance of the earth grid and all other earthing points does not exceed 0.5 ohm during the dry season.

The earth potential rises shall not exceed the CCITT limits appropriate to the classification of the system unless special precautions are taken to cater for transferred potentials.

Step, touch and mesh potentials shall be within the permitted limits calculated in accordance with the standards given in IEEE 80 for the proposed surface layer.

For calculating the conductor size of main mesh a current distribution of 30% - 70% may be considered, In case direct current is allowed to pass through mat in any mode of operation, allowance for the same shall be made in design.

7.7.2 Earth Electrode

The earth electrode shall comprise a system of bare conductors forming a mesh buried near the surface of the ground and supplemented, if required, by one or more of the following electrodes:

(a) a system of interconnected rods driven into the ground
(b) a mesh system of bare conductors buried in the ground
(c) structural metalwork in direct contact with the ground
(d) reinforcing steel in buried concrete
(e) a system of bare conductors buried near the surface of the ground outside the perimeter fence

7.7.3 Mesh System

The mesh system shall be designed 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.

The rating of the mesh conductors shall be compatible with the fault currents after allowing for parallel paths of hard drawn high conductivity copper strip with a minimum conductor size of 150 mm^2.

The conductor shall be installed in trenches excavated by the Contractor to a depth of 500 mm. The system will be installed after all foundations have been laid and the site filled to 100 mm below finished level. When the earthing grid has been laid and backfilled, bricks will be laid up to finished site level. Where the excavated material is rocky or may be difficult to consolidate, the backfilling shall be carried out using other material to the approval of the Engineer. The cost of such material shall be deemed to be included in the Contract.

7.7.4 Interconnected Rods

If the design calculations show that a mesh alone is unable to limit the potentials to the required values, then the mesh shall be supplemented by the use of interconnected earthing rods driven into the ground or installed in bored holes.

Rods shall be installed inside the perimeter fence to enclose the maximum possible area compatible with the earthing of any metallic fence. The spacing between rods shall not be less than their length, unless rating considerations determine otherwise. The copper rod electrodes of 15 mm diameter shall be interconnected in groups of four to eight rods by insulated copper conductors and non-ferrous clamps to form a ring. Each group shall be connected to the mesh by duplicate insulated copper conductor via disconnecting test links.

Individual rods may be connected directly to the mesh, provided the rod can be disconnected for testing.

Rods installed in bored holes may be used to reach lower resistivity ground strata at depths beyond the reach of driven rods or where rock is encountered and it is not possible to drive rods. After installing the rod, the bored hole shall be back filled with a low resistivity liquid mixture, which shall not shrink after pouring, to ensure good contact between the rod and the ground for the life of the installation.

The resistance and rating of individual rods and the combined resistance of the groups of rods in the proposed design shall be calculated and the rating of the interconnecting conductors shall not be less than that of the group of rods with a minimum conductor size of 70 mm^2.

The calculation of potentials in the design of the complete installation shall be made without the group of rods with the lowest estimated resistance to simulate the condition with the group disconnected for testing.

7.7.5 Other Conductors

As an alternative to rods to supplement a mesh, additional bare copper conductors with a cross section area of not less than 150 mm^2 may be used. They shall be buried in the ground within the perimeter fence to enclose the maximum possible area compatible with the earthing of any metallic fence. Such conductors may be laid below the mesh, below foundations or in areas where there is no plant. It shall be shown by calculation that the step potentials are low in such areas.

The conductor shall be in a ring, or a part of a ring, with at least two widely separated connections to the mesh or other parts of the earthing system.

7.7.6 Reinforcing Steel

The reinforcing steel in the foundations of buildings containing the primary electrical equipment may be used as auxiliary electrodes, subject to the approval of the Engineer. The Contractor shall show in the design calculations that the fault currents and D.C. stray currents will not damage the structure.

Steel reinforcing mesh in the floors of the building may also be used for the control of step and touch potentials within the building, subject to the approval of the Engineer.

7.7.7 Conductors Outside Perimeter Fence

If the design calculations show that the step and touch potentials outside the perimeter fence or wall exceed the limits, then additional bare conductors shall be buried in the ground outside the fence in the form of rings encircling the whole site.

The distance of the conductors from the fence and the depth shall be determined in the design to ensure that step and touch potentials are within the limits.

The minimum conductor size shall be 75 mm^2 copper and shall be connected to the fence or the mesh with 75 mm2 conductors at each corner of the site and at intervals of not more than 100 m. These conductors shall not be included in the calculations called for above.

7.8 Design of Earth System

7.8.1 Earth System

An earth system shall comprise the following components:

(a) the conductors between the earth electrode system and the main earth bar

(b) the main earth bar

(c) the conductors between the main earth bar and the metallic frames, enclosures or supports of electrical equipment

(d) the conductors between structural metalwork and non-electrical equipment and the main earth bar

The rating of earth system conductors connected between an item of electrical plant and the earth electrode system shall be sufficient to withstand the fault currents and duration, after allowing for the parallel paths through the earth system conductors, with any one conductor disconnected.

The design of earth system shall take into account the corrosiveness of the soil based on the soil survey.

The design comprising all the above-mentioned items shall be submitted to the Engineer for approval within four months of the award of Contract.

7.8.2 Connection of System Neutrals and Earth

The system neutral points within a substation shall have duplicate connections to the closest link chamber of an earthing point.

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 mm^2 from each test link to the earth grid. The duplicate connection may be in the form of a ring.

Neutral earthing connections between the substation system (transformer) neutral and the test links shall be of bare copper tape, secured and supported on stand-off insulators so that there is no contact between copper tape and transformer tank.

Neutral earthing conductors shall normally be buried directly in the ground but where necessary, they may be cleated to walls, fixed to cable racks or laid in the cable trenches.

7.8.3 Main Earth Bar

The main earth bar shall be in the form of a ring or rings of bare conductors surrounding, or within, an area in which items to be earthed are located. Where two or more rings are installed, they shall be interconnected by at least two conductors which shall be widely separated.

The main earth bar, or parts thereof, may also form part of the earth electrode system, providing this is bare conductor.

Each main earth bar shall be connected by at least two widely separated conductors to the earth electrode system.

The minimum conductor size for the main earth and interconnections between earth bars and the earth electrode system shall not be less than 150 mm^2.

7.8.4 Electrical Equipment Structure Connections to Earth

Connections between: (a) all HV electrical equipment and (b) LV electrical equipment comprising substantial multi cubicle switchboards and the main earth bar shall be duplicated. The bare copper conductor size shall have a minimum cross section area of 150 mm^2.

All substation equipment, including disconnectors, earth switches, current and voltage transformer tanks, switchgear and electrical supporting steelwork, etc. shall all be connected with the earth grid.

An earth 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 mm^2.

Galvanized structures comprising bolted lattice components shall not be used as the sole earth connection path to post and strain insulators.

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 switchgears, 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.

Connections between other LV electrical equipment and the earth bar need not be duplicated. The single conductor shall be rated to withstand the fault rating of the equipment.

7.8.5 Connections to Non-Electrical Structural Metalwork and Equipment

All metalwork within the project area which does not form part of the electrical equipment shall be bonded to the main earth bar except where otherwise specified. The bonding conductor size shall be not less than 150 mm^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.

Small electrically isolated metallic components mounted on non-conducting building fabric need not be bonded to the main earth bar.

7.9 Materials and Installation

The technical data sheet of Earthing material used in the design and the methodology of earthing system installation shall be submitted to the Employer / Engineer for approval.

7.9.1 Conductors

Conductors shall be of high conductivity copper in the form of circular conductors stranded to IEC 60228 or solid rods or bars to BS1433.

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.

Buried conductors which are not part of the earth electrode system shall be PVC sheathed circular stranded cable.

Bare strip conductors only shall be used for earth electrodes or voltage control meshes.

Conductors buried in the ground shall normally be laid at a depth of 500 mm in an excavated trench. The backfill in the vicinity of the conductor shall be free of stones and the whole backfill shall be well consolidated. 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 PVC sheathed conductor, at the same depth as any auxiliary power or control cables following the same route.

All conductors not buried in the ground shall be straightened immediately prior to installation and supported clear of the adjacent surface.

7.9.2 Earth Rods

Earth rods shall be driven to a depth below the ground water table level, to be determined by the Contractor during soil investigation and survey of site.

The earth rods shall be of hard drawn high conductivity copper with a diameter of not less than 15 mm with hardened steel driving caps and tips. The rods should be as long as possible, but couplings may be used to obtain the overall depth of driving required by the design.

The rods shall be installed by driving into the ground with a power hammer of suitable design to ensure the minimum of distortion to the rod. Where it is not possible to drive rods to the full depth required due to the presence of a strata of rock, then holes shall be drilled or blasted in the rock. The holes shall be filled with bentonite or other approved material prior to inserting the rod.

If difficult driving conditions arising from hard or rocky ground are encountered or are anticipated or there is a need for deep rods, then high tensile steel rods shall be used. High tensile steel rods shall have a molecularly bonded high conductivity copper coating with a minimum radial thickness of not less than 0.25 mm. The overall diameter shall be not less than 12 mm. Rolled external screw threads shall be used on the rods for coupling and after rolling the thickness of the copper coating on the threaded portion shall be not less than 0.05 mm.

Rods, driving caps and tips shall abut at couplings to ensure that the couplings and screw threads are not subject to driving forces. All screw threads shall be fully shrouded at the couplings. Alternatively, conical couplings may be used to the approval of the Engineer.

High conductivity copper for earth rods shall have a minimum copper content (including silver) of 99.90% to ISO 1337, Cu ETP or Cu FRHS (BS 2894 Grade C101 or C102) for copper earth rods and to ISO 1337 Grade Cu ETP (BS 28734 Grade C101) for the molecular bonded copper coating of steel rods.

The steel for copper clad steel rods shall be low carbon steel with a tensile strength of not less than 570 N/mm^2 to ISO 630, Grade Fe 430A (BS 4360, Grade 43A) or better.

Couplings for copper rods shall be of 5% phosphor bronze (copper tin phosphorous) to ISO 427, CU Sn4 (BS 2874, Grade PB 102M) and for copper bonded steel rods of 3% silicon or 7% aluminum bronze to BS 2874, Grade CS 101 and BS 2871, Grade CA 102.

7.9.3 Fittings

Clips for supporting strip conductors not buried in the ground shall be of the direct contact type and clips for circular conductors shall be of the cable saddle type. The clips shall support the conductors clear of the structure.

Conductors shall be connected to earth rods by a bolted clamp to facilitate removal of the conductor for testing the rod.

Disconnecting links shall comprise a high conductivity copper link supported on two insulators mounted on a galvanised steel base for bolting to the supporting structure. The two conductors shall be in direct contact with the link and shall not be disturbed by the removal of the link. Links for mounting at ground level shall be mounted on bolts embedded in a concrete base.

Disconnecting links mounted at ground level and the connections at the earth rods shall be enclosed in concrete inspection pits, with concrete lids, installed flush with the ground level.

All conductor fittings shall be manufactured from high strength copper alloys with phosphor bronze nuts, bolts, washers and screws. Binary brass copper alloys will not be acceptable. All fittings shall be designed for the specific application and shall not be permanently deformed when correctly installed.

Sheathed conductor support fittings may be of silicon aluminium, glass filled nylon or other tough non hygroscopic material for indoor installations.

Fittings not in direct contact with bare or sheathed conductors may be of hot-dip galvanised steel. Bi metallic connectors shall be used between conductors of dissimilar materials and insulating material shall be interposed between metallic fittings and structures of dissimilar materials to prevent corrosion.

7.9.4 Joints

Permanent joints shall be made by exothermic welding below ground or crimping for above ground connections.

Detachable joints shall be bolted and stranded conductors at bolted joints shall be terminated in exothermically welded lugs or a crimped cable socket. The diameter of any holes drilled in strip conductors shall not be greater than half the width of the strip.

Connections to electrical equipment shall be detachable and made at the earthing studs or bolts provided on the equipment by the manufacturer. When an earthing point is not provided, the point and method of connection shall be agreed with the Engineer.

Connections to metallic structures for earthing conductors and bonding conductors between electrically separate parts of a structure shall be either by direct exothermic welding or by bolting using a stud welded to the structure. Drilling of a structural member for a directly bolted connection shall only be carried out to the approval of the Engineer.

Bolted joints in metallic structures, including pipework and which do not provide direct metallic contact, shall either be bridged by a bonding conductor or both sides of the joint shall be separately bonded to earth, unless the joint is intended to be an insulated joint for cathodic protection or other purposes.

When the reinforcing in concrete is used as a part of the earthing system, the fittings used to provide a connection point at the surface of the concrete shall be exothermically welded to a reinforcing bar. This fitting shall be provided with a bolted connection for an earthing conductor. The main bars in the reinforcing shall be welded together at intervals to ensure electrical continuity throughout the reinforcing.

No connections shall be made to reinforcing bars and other steelwork which do not form part of the earthing system and are completely encased in concrete.

7.10 Earthing of Fences

7.10.1 Method

Metallic fences shall be separately earthed unless they come within 1.8 m of any equipment or structure above the surface of the ground and which is connected to the main earthing system. If the separation of 1.8 m cannot be obtained, the fence shall be bonded to the main earthing system.

7.10.2 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 3.0 m. 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 corner post, below the outer phase conductors of overhead line connections passing over the fence, at each gate and at intervals of not more than 100 m.

7.10.3 Bonded Fences

Fences which need to be bonded to the main earthing system of the installation shall be connected by copper conductors to the nearest accessible point on the main earthing system at each point where the fence comes within 1.8 m of any electrical equipment. Bonds shall also be made to each corner post, below the outer phase conductors of overhead line connections passing over the fence, at each gate and at intervals of not more than 100 m.

7.10.4 Bonding of Fence Components

Fences made up of bolted steel or other metallic components do not require bonding between components. Where such fences have non-metallic components, bonds shall be installed to maintain continuity between metallic components. Reinforced concrete components shall be treated as being non-metallic.

Longitudinal wires for supporting other fence components, or for anti-climbing guards and the wires of chain link shall be directly bonded to each fence earth electrode or to each bond to the main earthing system.

Metallic components on masonry, brick, concrete or similar boundary wall shall be treated in the same manner as metallic fences.

Wire fence components coated for anti-corrosion protection shall be earthed in accordance with this Clause.

7.10.5 Gates

The fixed metallic components on both sides of the gate shall be directly bonded together by a copper conductor installed under the surface of the access way. Flexible conductors shall be installed to bond the moving parts of the gates to the metallic fixed parts. An earth rod or a bond to the main earthing system shall be installed at each gate.

7.10.6 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 corner, 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 corner of the site and at intervals of not more than 100 m. Any metallic components on such boundary fences or walls shall be bonded to the earthing system in accordance with this specification.

If the boundary fence is metallic and is not within 1.8 m of any part of the main earthing system or equipment bonded thereto, the fence and outer conductor rings shall not be connected to the main earthing system unless the approved design calculations show otherwise.

Any meshes formed by bonding the outer conductors to the main earthing system shall be sub divided by additional conductors, if required, to give acceptable touch, step and mesh potentials.

7.10.7 Conductors

All conductors used for earthing and bonding the fences and components and for outer rings shall have a cross sectional area of not less than 70 mm^2.

7.11 Direct Stroke Lightning Protection

The Contractor shall provide adequate overhead shielding to effectively prevent direct lightning strikes to any equipment or energized bus within the switchyard areas. The system shall also be designed to provide "effective shielding" to ensure that no insulation flashover can result from atmospheric discharges striking the overhead shielding. The screens shall be of aluminium clad steel wires of not less than 50 sq.mm total section and connected to provide low impedance paths to earth.

The lightning protection scheme shall be designed by the Contractor using the latest version of the electro geometric model (EGM) or Razevig method. Detailed calculations demonstrating the adequacy of the proposed shielding shall be submitted to the Employer / Engineer for approval prior to the overhead shielding design being finalized.

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 and shall not lead to a fault, if broken. Conductor sag shall be considered when designing the overhead shielding system; however, conductor swing need not be considered.

The overhead earthwire shall be suitable for extension to protect the substation equipment to be installed in future stages of development.

8. Batteries, Chargers and DC Distribution Switchgear

8.1 Scope

These clauses describe the general technical requirements for Batteries, Chargers and DC distribution switchgear for use in substations for 110 V DC power for switchgear operations, protection, control, alarms, indications and emergency lighting.

Based on the existing Drawings attached in this Section, the Bidder shall assess the need for expansion of the existing DC Distribution System to cater for the bay extension works as appropriate.

The equipment shall be supplied, installed and commissioned as per the specification in this Section.

8.2 References

8.2.1 IEC Standards

IEC 60051	Direct acting indicating analogue electrical measuring instruments and their accessories
IEC 60146	Semiconductor converters
IEC 60146-1-1	Basic requirements of electrical power converters
IEC 60146-1-3	Transformers and reactors
IEC 6060529	Degree of protection provided by enclosures
IEC 60439	Low voltage switchgear and control gear assemblies (BS EN 60439)
IEC 60623	Vented nickel cadmium prismatic rechargeable single cells

8.2.2 British Standards

BS 88	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 controlgear wiring

8.3 Design Requirements

8.3.1 General

Batteries shall be located in with separate mechanical ventilation and provided with sinks and water supplies. Storage facilities shall be provided for electrolyte, distilled water and maintenance equipment.

The voltage measured at the main distribution switchgear shall not vary by more than plus 10 percent or minus 20 percent of the nominal voltage under all charging conditions when operating in accordance with the requirements of this Section.

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.

8.4 Batteries

8.4.1 Type of Battery

The battery shall be of high-performance Nickel Cadmium pocket plate type complying with IEC 60623 and shall be designed for a life expectancy of 25 years.

Battery cases shall be of high impact translucent plastic or annealed glass and shall be indelibly marked with maximum and minimum electrolyte levels. The design of the battery shall permit the free discharge of the gases produced during the normal operating cycle, whilst excluding dust. Spray arresters shall be included.

The electrolyte shall be free from impurities and the Potassium Hydroxide used shall comply with BS 5634. Dilution of the alkaline electrolyte and topping up of cells shall be carried out using distilled water only.

A complete set of test and maintenance accessories, suitably boxed, shall be provided for each battery. A syringe hydrometer and a durable instruction card shall be included in each set.

Cells shall be numbered consecutively and terminal cells marked to indicate polarity.

Cells shall be permanently marked with the following information:

- Manufacturer's reference number and code
- Year and month of manufacture
- Voltage and nominal capacity at the 5 hour discharge rate

The electrolyte capacity and general design of the cells shall be such that inspection and maintenance, including topping up of the electrolyte, shall be at intervals of not less than twelve (12) months.

8.4.2 Initial Charge and Test Discharge

The initial charge, test discharge and subsequent re-charge of the battery must be carried out under continuous supervision. Resistors, instruments, leads, and the other apparatus will be necessary for the initial charge, test discharge and subsequent recharge of the battery.

8.4.3 Battery Duty

The battery shall have sufficient capacity to supply the following continuous and intermittent loads for the periods specified, with the chargers out of service.

The battery shall supply standing DC load for protection, control, indications and alarms for 5 hours. This loading shall be determined from all equipment to be supplied on this Contract. In addition, the future circuit requirements estimated on the same basis as the present requirements.

At the end of 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 90 percent of the nominal voltage with the standing loads, specified above, connected.

1. Two closing operations on all circuit breakers (for the bay extension) supplied by the battery.

2. Two tripping operations on all circuit breakers (for the bay extension) supplied by the battery. Where busbar protection is provided, it shall be assumed that all circuit breakers in any one busbar protection zone trip simultaneously.

3. Charging of DC motor wound circuit breaker closing springs (where applicable) to enable the closing operations to be carried out.

4. At the end of these duties, the battery voltage shall not have dropped such that the voltage at the battery terminals falls below 90% of the nominal system voltage when supplying the standing load.

5. In addition, the voltages at the terminals of all components in the system (e.g. relays, trip and closing coils) shall not be outside of the individual voltage limits applying to them.

6. A margin of 10 % shall be allowed for derating of this battery over its life time.

All quantities derived in this manner shall be quoted in the Bid but shall not be used for ordering materials until specifically approved by the Employer / Engineer. Detailed calculations, and loading characteristics on which these are based, shall be submitted to the Engineer for approval during the basic design stage of the Project.

8.4.4 Location of Batteries

The batteries shall be housed in a ventilated battery room. The charging equipment and distribution switchboards shall be housed in a separate room.

The floor of the battery room shall be coated with a suitable electrolyte resistant protective coating. The floor shall be fitted with a drain and shall have sufficient slope to prevent any major electrolyte spillages from entering into other areas.

No ducts or any other items shall penetrate the floor or create a means whereby spillage can drain away apart from the drain provided for this purpose.

The ventilation fans and lamps in battery room shall be an explosion proof type.

8.4.5 Battery Mounting Connections and Accessories

Batteries shall be placed on timber boards mounted in double tiers on steel stands of robust construction and treated with acid resisting enamel or gloss paint to BS 381C No. 361. The cells shall be arranged so that each cell is readily accessible for inspection and maintenance and it shall be possible to remove any one cell without disturbing the remaining cells. The stands shall be mounted on insulators and be so dimensioned that the bottom of the lower tier is not less than 300 mm above the floor.

Alternatively, batteries may be mounted in a similar manner on treated hardwood stands.

Batteries shall be supplied and erected complete with all necessary connections and cabling. Connections between tiers, between end cells and between porcelain wall bushings shall be by PVC cables arranged on suitable racking or supports. Before jointing, joint faces shall be bright metal, free from dirt, and shall be protected by a coating of petroleum jelly. Terminal and intercell connections shall be of high conductivity corrosion free material.

Cartridge fuses shall be provided in both positive and negative leads, positioned as close to the battery as possible and shall be rated for at least three times the maximum battery discharge current at the highest operating voltage. The two fuses shall be mounted on opposite ends of the battery stand or rack in an approved manner. These fuse links shall comply with BS 88 Clause DC. 40 and shall be bolted in position without carriers.

Warning labels shall be fitted to warn personnel of the danger of removing or replacing a fuse whilst the load is connected and that fuses should not be removed immediately following boost charge due to the possible ignition of hydrogen gas.

Fuses between the battery and charger shall be located adjacent to the battery in a similar manner to that described above. A warning label shall be placed on the charging equipment indicating the location of these fuses and the fact that they should be removed to isolate the charger from the battery.

It shall not be possible to leave the battery disconnected (by means of switches or removal or operation of fuses) without some local and remote indication that such a state exists.

One set of miscellaneous equipment, including two syringe hydrometers, one cell testing voltmeter, two cell bridging connectors, two electrolyte pouring funnels, two electrolyte thermometers, battery instruction card for wall mounting, electrolyte airtight containers, labels, tools and other items necessary for the erection and correct functioning and maintenance of the equipment, shall be provided for each substation.

8.5 Control and Charging Equipment

Each battery charging equipment shall comply with the requirements of BS 4417 (IEC 146), 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. Generally, all equipment shall be naturally ventilated; however, forced cooling shall be provided when required, specially to, main transformer, rectifier module etc.

All the equipment for each charger shall be contained in a separate ventilated steel cubicle. The charger cubicles shall normally be mounted immediately adjacent to the DC distribution panel to form a board and shall be of matching design colour and appearance.

Where their ratings permit, chargers shall preferably be designed for operation from a single-phase AC auxiliary supply with a nominal voltage of 230 V. Otherwise a three phase 400 V supply may be utilized. Chargers shall maintain the float charge automatically for all DC loads between 0 and 100%, irrespective of variations in the voltage of the ac supply within the following limits:

Frequency variation: 47 to 51 Hz.
Voltage variation: ± 15%

The mains transformer shall be of a suitable rating and design. Clearly marked off circuit tappings shall be provided on the primary windings and change of tapping shall be by means of easily accessible links. The transformer shall be of the natural air-cooled type capable of operating continuously at full load on any tapping with the maximum specified ambient temperature.

All rectifiers and semi-conducting devices employed in the charger shall be of the silicon type. They shall be adequately rated, with due regard to air temperature within the charger enclosure, for the maximum ambient temperature.

The rating of the charger on float charge shall be equal to the normal battery standing load plus the recommended finishing charge rate for the battery.

Each charger shall also incorporate a boost charge feature which shall, after having been started, provide an automatically controlled high charge rate sufficient to restore a fully discharged battery to the fully charged state within the shortest possible time without excessive gassing or any form of damage to the battery. The boost charge shall be initiated manually or automatically upon detection of a significant battery discharge. An adjustable timer shall be provided to automatically switch the charger to the float condition after the correct recharge period. Load shall be kept connected to the charger during boast charge.

Should the AC supply fail while a battery is on boost charge, the switching arrangements shall automatically revert the charger to float charge status.

The output voltage regulator shall be adjustable for both float and boost charge modes, within limits approved by the Engineer, by means of clearly marked controls located inside the cubicle.

Although it is not intended that the charger be operated with the battery disconnected, the design of the charger shall be such that with the battery disconnected the charger will maintain the system voltage without any damage to itself and with a ripple voltage no greater than 2.0% rms of the nominal output voltage.

The charger shall automatically adjust the charging current from boost to float charging current when required. The charging circuitry shall be so designed that the failure of any component will not give a situation which will cause permanent damage to the battery by overcharging.

Each charger shall have a float charge maximum current rating sufficient to meet the total standing load current on the dc distribution board plus a battery charging current equal numerically to 1 - 2 mA of the battery capacity at the 5-hour rate. However, the battery manufacturer recommendation shall always be preferred in this case.

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 & frequency, the output voltage shall not vary by more than plus 3% to minus 2% with any combination of input supply voltage and frequency variation as stipulated in this Specification and output current variation from 0 - 100% of rating.

Each charger shall be suitable for operating alone or in parallel with the other charger. When operating with both chargers, one charger shall be arranged to supply the standing load with the second charger in the quiescent standby mode.

Each charger shall also have a taper characteristic boost charging facility which shall be selectable by a float/boost charge selection switch and which will give boost charging of 1.60 - 1.75 volts per cell.

Each charger shall be designed with a performance on boost charge such that with rated input voltage and frequency the charger output shall not be less than its rating in Watts at 1.3 V and 1.65 V per cell, and also the output voltage shall be 1.60 - 1.75 V per cell over an output range of 0 - 100% of rating.

The boost charging equipment shall be capable of recharging the battery within six hours following a one-hour discharge period.

In the event of the battery becoming discharged during an AC supply failure, the rate at which recharging commences shall be as high as possible consistent with maintaining the automatic charging constant voltage feature and with the connections remaining undisturbed as for normal service.

The charger shall have an automatic boost/quick charge feature, which shall operate upon detection of a significant battery discharge. When, after a mains failure, the AC supply voltage returns and the battery have 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 / boost charge shall be activated.

An override selector switch shall be provided inside the charger unit to enable a first conditioning charge to be made, in line with the battery manufacturer's recommendations, for batteries which are shipped dry and require forming at site.

A voltage dropper diode unit (typically called DVR module) shall be incorporated in the output circuit of each charger to limit the load voltage during boost charging of the battery. These diodes shall be continuously rated to carry the maximum possible load current during boost charging. The diode unit shall not be in service in the normal float charging mode. Should the voltage stabilizer / DVR unit fail in the boost charging mode, the charger shall automatically revert to the float mode.

An anti-paralleling diode shall be provided in each positive feed to the DC distribution board to prevent faults on one supply affecting the other. These diodes shall be continuously rated to carry the maximum possible discharge current likely to occur in service and a safety factor of 4 shall be used to determine the repetitive peak reverse voltage rating. The I^2t, i.e. energy handling capacity for short time, rating of the diodes shall be such that in the event of a DC short circuit, no damage to the diodes shall result.

Each charger shall be capable of sustaining, without damage to itself, a continuous permanent short circuit across its output terminals. The use of fuses, MCBs or other similar devices will not be acceptable in meeting this requirement.

Suitable relays shall be provided for each charger to detect failure of the incoming supply and failure of the DC output when in float charge mode. These relays shall operate appropriate indicating lamps on the respective charger front panel and shall have additional voltage free contacts for operating remote and supervisory alarms. These alarms shall be immune from normal supply fluctuations and shall not be initiated when any one charger is taken out of service.

The charger shall also be fitted with a device to de-energize the charger in the event of a DC output float over voltage.

Each charger shall be provided, as a minimum, with the following instrumentation, indication and alarm facilities:

- Indicating lamps for the AC supply to the rectifier and DC supply from the rectifier
- Indicating lamps for float and boost charging operations
- Voltmeter - Input voltage
- Voltmeter - Output voltage
- Ammeter - Output current
- Alarm - Charger failure
- Alarm - Charger Main transformer failure
- Alarm - Charger Rectifier Diode Module failure
- Alarm - Charger DVR module failure
- Alarm - Mains failure

The following battery alarms shall also be provided:

- Battery fuse failure
- Diode assembly failure
- Battery circuit faulty
- Low DC volts
- High AC volts

- Earth fault +ve
- Earth fault -ve

Lamp test facilities shall be included.

A "charger faulty" alarm for each charger and a "battery faulty" alarm shall be provided in the substation control room and to the SCADA system where applicable.

Each battery charger shall be equipped with charge fail detection equipment to give local indication and remote alarm if the voltage from the charger falls below a preset level which will be lower than the nominal float charge voltage. Suitable blocking diodes shall be provided to prevent the battery voltage being supplied to the equipment and so prevent charge fail detection.

The device shall not operate on switching surges or transient loss of voltage due to faults on the AC system. The voltage at which the alarm operates shall be adjustable for operation over a range to be approved by the Engineer.

Each charger shall be equipped with a switch fuse for the incoming AC supply and an off-load isolator for the DC output.

Bidders shall include particulars with their bid on the method of adjustment included to compensate for ageing rectifier elements. The construction of the charger shall be such that access to all components is readily available for maintenance removal or replacement. Internal panels used for mounting equipment shall be on swing frames to allow for access to the charger interior.

8.6 Distribution Switchboards

The switchboard shall comply with the requirements of BS 5468 (IEC 60439)

The distribution switchboard shall be of the cubicle type placed separate from battery charger. Double pole switches and fuses or switch fuses (miniature circuit breakers to BS 4752 or IEC 60127 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.

Distribution panels shall be mounted adjacent to the charger control panel and shall be of the cubicle type complying with the general requirements of cubicle type control panels. No equipment associated with the chargers shall be installed in the distribution board.

Distribution panels shall incorporate double pole switches and fuses for each of the outgoing DC circuits and double pole isolators for the incoming DC supplies. The panel shall be provided with a voltmeter and centre zero ammeter on each incoming circuit.

A switching device, MCB / MCCB or contactor shall be provided for the purpose of sectionalizing the busbar.

A battery earth fault detecting relay, which will centre tap the system via a high resistance, shall be incorporated in the distribution panel.

A low voltage detecting device for the system shall be incorporated in the distribution panel. No volt relays will not be accepted for these devices. The voltage setting shall be adjustable over an approved range.

In addition to any other requirements specified elsewhere, the battery earth fault detecting relays and low voltage detecting devices shall each have three alarm contacts, one for local visual annunciation, one for the station control panel alarm indication and one for potential free contact for external supervisory alarms. A lamp test facility shall be provided.

Connections between the battery and the distribution cubicle shall be made in PVC insulated cable as required. Cable laid in runs where it may be subject to damage shall be protected by wire armouring, be sheathed overall and be cleated to walls as required.

Cable boxes or glands shall be provided as appropriate for all incoming and outgoing circuits of the distribution switchboard and associated battery chargers. Each circuit shall be suitably labelled at the front of the panel and at the cable termination where the terminals shall be additionally identified.

Charging and distribution switchboards shall be provided with an earthing bar of hard drawn high conductivity copper which shall be sized to carry the prospective earth fault current without damage or danger.

The cubicles for the chargers and distribution boards shall be of rigid, formed sheet metal construction, insect and vermin proof, having front facing doors allowing maximum access to the working parts, when open. The design of the cubicles for the chargers shall be such as to prevent the ingress of dust and minimize the spread of flames or ionized 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 minimized, satisfy relevant standards, and not limit the life of the equipment. The frame shall allow the fixing of lifting and so that the equipment remains properly mechanically supported whilst being transported, lifted and installed.

8.7 Labelling

All relays, instruments and control devices, and each unit of the equipment, shall be provided with a label. All labels and lettering shall be of sufficient size to provide easy reading from the normal operating or maintenance positions and shall consist of black lettering on a white background. All warning and danger labels shall have white lettering on a red background. Labels shall be of the non-corrodible type and lettering shall be of motorway script or similar. If plastic labels are used, these shall be laminated to avoid warping.

8.8 Special Tools

The Contractor shall provide a complete set of all special tools and services necessary for the erection and maintenance of the complete equipment.

8.9 Inspection and Testing

Inspection and testing during manufacture and after installation on site shall be in accordance with Clause 15 of this Section.

9. LVAC Distribution System and Switchgear

9.1 Scope and LVAC System Design

These clauses describe the general technical requirements for LVAC system and switchboards for additional supplies to the existing "Substation Services" including lighting and control building services, as required for the bay extension works.

Based on the existing Drawings attached in this Section, the Bidder shall assess the need for expansion of the existing LVAC System to cater for the bay extension works as appropriate.

The existing LVAC system comprised of two independent station power sources; from two 400 / 135 / 33kV auto transformers.

Station power transformers are installed in designated location in the switchyard as shown in the drawing attached in this Section. The connection from station power transformers to main distribution board is made with LV cables.

VCBs (33kV, 25kA, 630A / as per drawing) are used for the primary circuit breaker for station power transformer and ACBs/MCCBs/MCBs (as per drawing) are applied for secondary. The secondary ACBs and associated other breakers (MCCBs/MCBs) have mutual interlock function to avoid power source loss in any cases. The power is supplied independently through independent distribution switches as per the load categories such as: 400kV, 132kV switchyard, each auto transformer, main control building, local control houses and lighting.

9.2 References

IEC 60044	Instrument Transformers
IEC 60269	Low Voltage Fuses
IEC 60439-1	Specification for low voltage switchgear and control gear assemblies
IEC 60644	Specification for high-voltage fuse links for motor circuit applications
IEC 60898	Electrical Accessories - Circuit-breakers for overcurrent protection for household and similar installations
IEC 60947-1	Low-voltage switchgear and Control Gear - General
IEC 60947-2	Low-voltage switchgear and Control Gear - Circuit-breakers
IEC 60947-3	Low-voltage switchgear and Control Gear - Switches, disconnectors and fuse combination units
IEC 60947-4	Low-voltage switchgear and Control Gear - Electromechanical Contactors and motor starters

9.3 Switchboard Design

9.3.1 General

Main switchboards and MCB sub-distribution boards for substation and building supplies shall be constructed to IEC 439, (BS EN 60439) in accordance with the following:

The classification of the main switchboards shall be:

(a) The external design of switchboards shall be of the multi-tier, multi-cubicle type.
(b) Installation shall be indoors.
(c) Switchboards shall be free standing and fixed to the floor.
(d) Switchboards shall be of metal clad construction and enclosures degree of protection shall be not less than IP42.

(e) All instrumentation and metering shall be fixed to a hinged lockable compartment.
(f) Switchboards and all associated equipment shall be suitable for use on a 415/240 Volt, three phase, four wires, and 50 Hz system having the neutral solidly earthed.
(g) Each circuit shall be clearly labelled to show the destination of the associated cable and the "ON" and "OFF" positions of the switches.
(h) Distribution boards for exterior use shall be galvanized, weatherproof and to category IP55 degree of protection.

The equipment shall be of the single busbar type with circuit equipment housed in separate compartments. Where two or more incoming circuit breakers are provided at substations, these shall be mechanically and electrically interlocked to prevent more than one circuit closing at the same time.

The enclosures of all switchboards shall be dustproof and vermin proof. Access doors shall be mounted using concealed hinges. All removable covers shall be fitted with captive screws. Anti-condensation heaters with control switches shall be provided on switchboards. They shall be suitable for a tropical climate.

9.3.2 Rating

Incoming supplies to all switchboards shall be protected at the point of supply. All switchboards, breaker, equipment in LVAC distribution board or in the upstream level shall be suitably rated for a prospective short-circuit breaking capacity of 15 kA at 415 V for 3 seconds and switchboards, breaker, equipment in switchyard, SPR and downstream of LVAC distribution board shall be rated of 10 kA / 6 kA / 4 kA at 415 V for 3 s as appropriate. Necessary Calculation shall be submitted to the Employer / Engineer for approval for justification of cascading low kA MCBs in the downstream.

9.3.3 Busbars

Busbars shall be capable of carrying the full rated current continuously without exceeding the maximum temperature specified in IEC 60439 under site ambient conditions.

Busbars shall be of copper, individually covered with a heat resistant phase coloured PVC. Busbar links between panels shall not be used. Neutral busbars shall have the same cross-sectional areas as the phase busbars. Busbars shall be of the same current rating throughout their length and shall be capable of extension at both ends with the minimum disturbance to the busbar and cubicle enclosure.

9.3.4 Busbar and Circuit Shutters

For drawout equipment shutters, over busbar and circuit orifices to close automatically and positively when the equipment is isolated or withdrawn shall be provided. Means shall be provided for padlocking the sets of shutters. Busbar orifice shutters shall be painted signal red and labelled 'BUSBAR' in white letters. Circuit orifice shutters shall be painted lemon yellow.

One blanking cover of each size shall be provided to prevent access to a circuit compartment when the equipment has been completely withdrawn from the panel.

9.3.5 Circuit Labels

Approved type title labels are to be fitted externally on the front cover of each distribution board giving details of the points controlled by each circuit. The circuit list shall be typed or printed stating the location of the equipment served, rating of the protective unit and the circuit loading. The lists shall be mounted on the inside of the cover door and shall be protected by an acrylic sheet slid into a frame over the circuit list, the list and cover to be easily removable to permit circuit modifications.

9.4 Circuit Breakers

All MCB and MCCB circuit breakers shall be high speed fault limiting, thermal/magnetic type with quick break, trip free mechanisms which prevent the breaker being held in against overloads or faults, shall comply with IEC 60947 and be fitted with overcurrent releases of both thermal and instantaneous type. Short circuit performance shall be to IEC 60947.

Where circuit breakers incorporate thermal overload protection and short-circuit protection, their settings shall be subject to agreement with the Engineer.

Tripping arrangements shall be such as to ensure simultaneous opening of all phases. Arc extinction shall be by de-ionizing arc chutes.

Circuit breakers on the incoming circuits shall have facilities for locking in the "off" position.

The fault interrupting capacity of the circuit breaker shall not be less than that of the switchboard itself, or if this is not the case, back up fuses shall be included.

9.5 Switch-Fuses

Each switch-fuse unit shall be housed in a separate metal compartment and provided with a hinged metal door, interlocked with the switch mechanism so that:

(a) The door cannot be opened whilst the switch is closed.

(b) The door, on opening, automatically locks the switch in the "off" position. Facilities shall be incorporated to allow for the deliberate release of this interlock for maintenance purposes, should it be desired to observe the switch in operation.

An insulating barrier shall be fitted to segregate the fuses and neutral link from the switch and the connections of the latter shall be effectively shielded by an inner metal screen when the compartment door has been opened to obtain access to the fuses.

The switch-fuses may be either of the combination fuse-switch type or of the type with the switch and fuse in separate units. In either case, interlocking shall be provided to prevent access to the fuses until the associated switch is opened and provision shall be made for padlocking the switch in the "on" and "off" positions.

The switch shall have a quick make and quick break action, independent of the speed at which the switch handle is operated and shall be entirely suitable for switching the inductive loads associated with motor circuits.

9.6 Oil Filtration Socket Outlet and Plug

Not used.

9.7 Inspection and Testing

Inspection and testing during manufacture and after installation on site shall be in accordance with Clause 15 of this Section.

10. National Load Despatch Centre (NLDC) Control Facilities

10.1 Scope

In order to provide the tele-control and tele-metering facilities required for the bay extension works at the respective substations to the existing National Load Dispatch Centre (NLDC) at Rampura, the complete design, supply, delivery, installation, testing & commissioning of extension of the existing equipment including necessary adjustment, adaptation, modification, integration and configuration of existing equipment in NLDC, shall be provided under this Contract.

The NLDC is located in Dhaka (Rampura and Biddyut Bhaban) and connected through a fiber optic network to communication equipment and Remote Terminal Unit (RTU) / Industrial Gateway of SAS system located at the substations.

The SCADA system of NLDC is based on M/S Areva T&D e-terra platform.

The industrial gateway implemented at the substations are for remote monitoring and control from the NLDC. It provides all necessary control and monitoring facilities for 400 / 132kV level lines, transformers, and auxiliaries.

All plant supplied under this Contract shall be equipped with potential-free auxiliary contacts for indications and alarms, CT and VT circuits shall be fitted, where required.

Supply and installation of necessary equipment such as IED/relay, transducers, DI, DO card etc. for integrating new bay through existing RTU /Gateway at far end substation shall be provided under this Contract.

All HV breakers, motorized disconnectors, etc. shall be controlled from NLDC through the gateway / RTU of the existing substation automation system using IEC 60870-5-104 protocol. Cabling between the substation automation gateway and the communication equipment shall be included in this Contract.

- Necessary modification in the software and hardware at NLDC master station is also to be done under this Contract to accommodate the extended bays.

In order to provide the telecontrol facilities required at the NLDC, two (20 numbers of industrial gateway at each substation for integrating to NLDC SCADA system is provided.

Data communication from switch to gateway and switch to SAS server is independent.

The two (2) gateways are configured as master-hot standby mode or one gateway will report to main station and another will report to backup station.

All required electrical quantities (digital and analog) are transmitted to NLDC through the Industrial Gateway of the existing SAS.

The communication protocol used for data exchange between the NLDC and the substation is IEC 60870-5-104.

The gateway is capable of reporting to both main master station at Rampura (through VLAN network) and the Standby Master Station at Biddyut Bhaban (through routed network) simultaneously. It is configured according to the signal list, communication parameter, IP address, station address etc. provided by PGCB.

Analog data measurement scaling shall be done at RTU or Relay (preferable at relay). Analog data should be floating point. Analog data should be deadband with 1%. Frequency dead band should be 0%. Digital data shall be time stamp at field.

GPS has been provided at each substation, so that the RTU/Gateway can get exact time.

For securing SCADA system, hardware firewall device is provided between RTU/Gateway and communication device at field, so any type of cyber intrusion or malware is prohibited.

Necessary SCADA interfacing equipment such as transducers, digital input/output card, cabling, etc. is required for far end substation related to the substation.

Integration work

Integrating RTU/Gateway with NLDC following work shall be done at Master Station Rampura, Dhaka and Backup Station at Biddyut Bhaban, Dhaka. Scope of works shall include the following but not limited to:

Pre-database work:

a) Collection of network data for EMS application
b) Modeling, database creation, verification and update should be done at both NLDC
c) Modification and update of database for far end substations related to the Gopalganj and Aminbazar 400kV Substations
d) The following should be done at Master Station at Rampura and Backup Station at Biddyut Bhaban:
    1. SCADA Database Modelling
    2. Substation Display
    3. Network database Modelling
    4. Generation Database Modelling
    5. DTS Database Modelling
    6. Alarm database Modelling
    7. Validation
        - Cross validation of all databases and create update copy of those databases.
        - On-lining of databases in DTS (Simulator) server
        - Checking and modifying (if require) topology of Substations, Devices, Network, etc.
    8. RTU/Gateway configuration

       Configuring the RTU / Gateway according to attach signal list, mapping address, data communication parameter, Source IP, Destination IP, etc.
    9. Local Test

       The following test will be carried out at site using e-terra control software
        - Verification of all Analog Measurement and checking of Limit, Deadband, Polling Time
        - Verification of Digital signals status (OPEN, CLOSE, BETWEEN, INVALID)
        - Verification of ALARMS, EVENTS, etc.
        - Verification of Control and Interlock
    10. Database Update

        The following activities will be carried out in Master NLDC and Backup NLDC after successful site test.
        - On-lining of all databases in Running Servers
        - IP/VLAN Configuration on Polling servers and switch
        - Compilation and On-lining of all the displays on Web servers

11. End to End Test

    The following activities will be carried out in Master NLDC and Backup NLDC

    - Verification of all Analog Measurement
    - Verification of Digital signals and Controls
    - Verification of displays including Single line, Pop up, alarms, etc.
    - Verification of communication line for Redundancy
    - Verification of continuous and complete integration of the RTU/Gateway

12. Tuning of Power System Application
    - Tuning will be do required for all available Network and generation applications in SCADA/EMS server and Dispatcher Training Simulator (DTS)

Notes:

- Integrating RTU/Gateway with NLDC shall be in the scope of work in this Contract
- Data communication path creation for both Main and Backup station shall be in the scope of work in this Contract
- Collection of network data required for modeling network database shall be in the scope of work in this Contract

10.2 Requirements

10.2.1 Indications: Digital Input (Double Point)

The following indications shall be provided:

- Circuit Breaker, Isolator and Earth Switch Open / Close for line, bus coupler
- Circuit Breaker for bus reactor feeder

10.2.2 Load Flows, System Voltage and frequency

Electrical quantities shall be provided to enable the following measurements:

- Voltage (kV), Frequency (Hz) for Busbar
- Megawatt (MW), MegaVar (MVAR), Amperes (A), Voltage (kV) for line
- MVAR for Bus Reactor

10.2.3 Alarms: Digital Input (Single Point)

The following indications shall be provided:

- Remote / Local Switch for all circuit breakers
- Bay Fault (DC Fail for Transformer Panel)
- Breaker Fault (OR gate Spring Charge, SF6 Low)
- Protection Class-1 (Distance, Differential)
- Protection Class-2 (Over current, Earth fault)
- Protection Class-3 (Bus Bar).
- Auto reclose operated
- DC fail
- AC fail

10.2.4 Controls-Digital Output (Double Point)

The following facilities shall be controlled from NLDC:

- Circuit Breaker and Motorized Isolator Open / Close for Line and bus coupler

10.2.5 Network Parameters

Parameters on line length, line conductor type, short circuit data for zero sequence (%R, %X, % of full charging susceptance), etc. shall be provided.

10.3 Interfaces

Modification of existing Industrial Grade Gateway to the NLDC shall be in the scope of works in this Contract. 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.

11. Supporting Structures for Outdoor Equipment

11.1 Scope

Where specified structures shall be provided under this Contract for supporting the conductors, busbars, insulators, isolating switches, circuit breakers, current and voltage transformers, surge arresters, line traps, coupling capacitors, sealing ends or cable boxes, cables and other items of plant where necessary. Facilities shall also be provided where specified for the termination of the incoming transmission lines.

All structure designs shall be such as to facilitate inspection, painting, maintenance, repairs and operation with the continuity of supply being the prime consideration.

11.2 Structure Arrangement

The arrangement of the high-level structures supporting conductors and/or busbars shall be either lattice structures primarily composed of angle sections, or low visual impact A-frame type structures primarily composed of welded hollow or composite sections. Angle, hollow or composite sections shall be either steel or aluminium as specified. For lattice structures a fully triangulated system of bracings shall preferably be adopted. For A-frame structures the primary connections between major components shall be bolted, for ease of transportation and erection.

Low level support structures shall be either lattice structures primarily composed of angle sections or 'moment' type structures primarily composed of welded hollow or composite sections.

The design and arrangement of supporting structures shall be subject to approval by the Engineer.

The type of arrangement of high-level structures and acceptable materials for both high- and low-level structures shall be as specified in **Annex II-11-1** of this Section.

11.3 Design

11.3.1 General

The supporting structures shall be designed to ensure that the specified minimum phase, earth and section clearances are maintained under all conditions. Where applicable special attention shall be paid to the design of the line termination structures to ensure minimum phase clearance is obtained for the complete range of angles of entry specified.

The strength and rigidity of structures shall be such that the alignment of the equipment which they carry shall not be affected by the static and dynamic loads to which the structures are subjected.

The assumptions made in the overall structural design especially in the load transfer between the gantry beam and column shall be adequately reflected in the design and detailing of the beam-column connection.

11.3.2 Assumed Loading Combinations

The supporting structures shall be designed to resist the ultimate applied loading, determined in accordance with the following load combinations:

Load Combination 1 Design Wind, Coincident Temperature, (Ice)

(a) The wind pressure specified in **Annex II-11-1** of this Section, applied to the projected area of all conductors and electrical equipment

(b) The wind pressure specified in **Annex II-11-1** of this Section 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 **Annex II-11-1** of this Section 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 107 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 **Annex II-11-1** of this Section 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 **Annex II-11-1** of this Section 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.

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.

11.3.3 Line Termination Structures

For details of the incoming transmission line phase conductor and earthwire details, and angles of entry reference should be made to **Annex II-11-1** of this Section.

11.3.4 Partial Load Factors

The partial load factors to be applied to the loading combinations determined in accordance with sub-clause 11.3.2 shall be as specified in **Annex II-11-1** of this Section.

11.3.5 Wind Loading

The reference wind pressure to be adopted for the design of the outdoor supporting structures shall be based upon the value specified in the **Annex II-11-1** in this Section. The reference wind pressure qref N/m^2 at a height of 10 m 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:

$$F_w = q_{ref} \left[\frac{H}{10}\right]^{2\alpha} C_{shp} W_A$$

where Fw = The calculated total wind load on the structure or equipment:
q_{ref} = reference wind pressure
H = Height to top of the panel under consideration
α = power law index
Cshp = aerodynamic shape factor
WA = windward face area of the structure or equipment

The aerodynamic shape factor Cshp shall be as specified:

Flexible conductors	1.0
Earthwires	2
Tubular busbars Re < 4.1 x 10^5	1.2 [1]
4.1 x 105< Re < 8.2 x 105	0.6
Support insulators, porcelain for apparatus or cap and pin insulator strings	1.2 [2]
Flat truss structures consisting of profiles	1.6
Square and 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 and rectangular lattice towers & supports consisting of tubes	2.1

Notes: [1] Re = Reynolds Number
[2] Based on external diameter of insulator

11.3.6 Equipment and Conductor Terminations

All supporting structures shall be provided with such holes, bolts and fittings as may be necessary to accommodate insulators, isolating switches and other equipment provided under the Contract.

Where incoming transmission lines and/or conductors and/or earthwires are terminated at structures with tension sets, approved shackle or swivel attachments shall be provided. To facilitate maintenance and erection, additional attachment points shall be provided adjacent to the main termination attachment.

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 300 mm above the top of concrete. Foundation holding down bolts shall not be used for the attachment of earth connections.

11.3.7 Safety and Access Requirements

To facilitate safe inspection and maintenance all supporting structures which cannot be maintained from ground level shall be provided with climbing facilities, inter circuit screens, guards etc. in appropriate positions as agreed with the Engineer.

All members inclined at 40° or less to the horizontal, shall be designed to resist a mid-point load of 1.5 kN, with no other loading being considered.

Where specified step bolts of an approved type shall be fitted to supporting structures at not more than 450 mm centres starting as near as practicable to the base and continuing to within 1m below the top of the structure. It shall be noted on the erection drawings that all step bolts are to be removed after construction for a distance of 2.0 m 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 16 mm diameter, project not less than 150 mm, and be fixed with nut, washer and nut.

Where specified ladders of an approved type generally in accordance with the requirements of BS 4211, 450 mm wide and 350 mm 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 unauthorized 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 50 mm x 50 mm mesh formed from 3 mm diameter galvanized steel wire.

All structures shall be fitted with identification/notice plates as appropriate.

11.3.8 Structural Design

The allowable ultimate unit stresses used in the determination of the nominal member strength of supporting structures shall be based on the following:

Lattice steel structures	ANSI/ASCE 10 90
Steel A frame or moment structures	BS 5950
Aluminium structures	BS 8118: Part I

Partial factors to be applied to member nominal strength determined in accordance with the above stated codes shall be as specified in **Annex II-11-1** of this Section. 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 **Annex II-11-1** of this Section.

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 10 mm beyond the nut.

11.3.9 Design Submissions

The Contractor shall submit all design calculations, drawings 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 Employer / Engineer's approval of the calculation.

11.4 Materials

All steel shall comply with BS EN 10025 or BS EN 10210 as appropriate and shall be suitable for all usual fabrication processes including hot and cold working within the specified ranges. The Contractor must take due cognizance of the minimum ambient temperature, quality of steel, charpy impact value and stress relieving.

The quality of finished steel shall be in accordance with BS EN 10163. All steel shall be free from blisters, scale, lamination, segregation's and other defects. There shall be no rolling laps at toes of angles or rolled in mill scale.

Hot rolled steel plate 3mm thick or above shall be in accordance with the requirements of BS EN 10029.

Bolts and nuts shall be ISO Metric Black Hexagon to BS 4190 and shall be threaded ISO Metric.

Course Pitch to BS 3643: Part 2, Tolerance Class 7H/8g. Only one grade of steel shall be used per bolt diameter. Washers shall be in accordance with BS 4320 Grade E and BS 4464 Type B as appropriate.

Consumables used in metal arc welding shall be in accordance with the relevant standard.

All materials for aluminium. structures shall be in accordance with BS 8118: Part 2.

11.5 Workmanship

The Contractor 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 Contractor 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 Contractor 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 galvanizing or other protective coatings, using characters 10 mm high and shall be clearly legible after galvanizing.

11.6 Protective Treatment

Unless otherwise specified after fabrication, all structural steelwork, including bolts, nuts and washers shall be hot dipped galvanized to meet the requirements of BS 729. Bolt threads shall be cleaned of surplus spelter by spinning or brushing. Dies shall not be used for cleaning threads other than on nuts. Nuts shall be galvanized and tapped 0.4 mm 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.

Galvanizing thickness and aluminium protection procedure shall be as specified in **Annex II-11-1** of this Section.

11.7 Quality Control

11.7.1 General

Routine tests on raw materials and fabricated individual members shall be undertaken in accordance with BS EN 10025, BS EN 10210 and BS 8118 as appropriate.

All steel ex mills or received from merchant's stock shall be marked to identify the cast or casts from which it was rolled in accordance with Section 9 of BS EN 10025 and Section 10 of BS 102 10, and shall be covered by the appropriate (mill) certificate. The optional impact test BS EN 10210 option 1.6 for quality JO is required.

The material grades or alloy categories of individual pieces of steel/aluminium shall be capable of positive identification at all stages of the fabrication process.

Bolts and nuts shall be covered by the appropriate test certificate to prove compliance with BS 4190.

11.7.2 Welding

Unless specified to the contrary all structural welds shall be undertaken using approved welding procedures in accordance with BS EN 288. All welders shall be tested to the requirements of BS EN 287.

All welding shall be subject to a non-destructive testing (NDT) programme, which shall include visual, ultrasonic and magnetic particle testing as appropriate. Visual inspection shall be in accordance with BS 5289, ultrasonic to BS 3923 and magnetic particle to BS 6072. Acceptance criteria shall be in accordance with BS 5135, except for porosity and BS 8118: Part 2. All welds especially butt welds must be continuous to ensure a pickle tight connection when galvanized.

The Contractor's NDT programme shall be submitted to the Engineer for approval prior to the commencement of fabrication.

11.7.3 Check Erection

Prototype structures shall be check erected in order to verify the accuracy of detailing and fabrication.

The degree of check erection shall be sufficient to verify not only the main structure, but all auxiliary steelwork. Sufficient blocking and support shall be provided to prevent distortion and overstressing of members to ensure proper fit. Assembly shall be accomplished without extraordinary effort to align bolt holes, or to force pieces into position. Bolt holes shall not be reamed or enlarged. Any damage to protective coatings during check erection if the check erection is undertaken on coated structures, shall be recoated at the fabricator's cost.

11.7.4 Galvanizing

Tests on galvanized members and components shall be carried out at the works to ensure compliance with the requirements of BS 729.

11.7.5 Tolerances

The fabrication tolerances after galvanizing 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: ± 1 mm
(c) On centres of holes: ± 1 mm
(d) On groups of holes: ± 2 mm
(e) On back gauges: ± 1 mm
(f) On corresponding holes in opposite faces of a member: ± 1 mm
(g) On specified hole diameter on the punch side (in the black): ± 0.3%
or when drilled: 0 mm
(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): ± 1 mm
(i) On specified bends, open and closed flanges: ± 0.02%

The permitted tolerances for straightness after galvanizing shall not exceed an offset of 1: 1000.

Tolerances for aluminium structures shall be in accordance with BS 8118: Part 2.

11.8 Erection

The Contractor shall when requested, to provide the Engineer with a Method Statement detailing his proposed erection methods. Due cognizance 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 Contractor 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.

Annex II-11-1

No.	Description			
1.	Structure Arrangement [clause 11.2] High Level Low Level Primary Material		Lattice or A-Frame Lattice or Moment Steel	
2.	**Load Combination 1** [clause 11.3.2]		Structures only	Structures Busbars etc.
	Wind pressure at above G.L. q_{ref}	kN/m^2	3.54	1.21
	Power Law factor	α	0	0.095
	Coincident temperature	°C	5	
	Radial ice thickness	mm	0	
	Density of ice	kg/m^3	-	
	Load Combination 2			
	Minimum temperature	°C	5	
	Maximum operating temperature	°C	80	
	Load Combination 3			
	Seismic coefficient		0.1g	
	Coincident temperature	°C	5	
3.	**Line Termination Structure** [clause 11.3.3]		**Phase**	**Earthwire**
	Conductor Designation		Finch	7 x 4.0
	Type		ACSR	GSW
	Number of sub-conductors ***(All of the above three shall be finalized during execution)***		2	-
	Maximum working tension per Sub-conductor	kN	7.0	4.5
	Wind pressure	kN/m^2	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
	Low duty tension set wind area	m^2	0.7	-
	Mass	kgs	100	-
4.	**Partial Load Factors** [clause 11.3.4]		**Steel**	**Aluminium**

No.	Description			
	Load Combination	1	1.35	N/A
		2	1.0	N/A
		3	1.0	N/A
		4	1.5	1.5
5.	**Safety and Access Requirements** [clause 11.3.7]		**High Level**	**Low Level**
	Step bolts		YES	NO
	Ladders:		YES	NO
	Cage protection		NO	NO
	Fall arrest system		NO	NO
6.	**Partial Material Factors** [clause 11.3.8]			
	Steel		0.85	
	Aluminium		-	
	Foundations		0.76	
7.	**Minimum Member Thickness** [clause 11.3.8]		**Steel**	**Aluminium**
	Main member	mm	6.0	
	Other bracing members	mm	5.0	
	Secondary (redundant) members	mm	5.0	N/A
	Platesmm	mm	6.0	
	Bolt diameters	mm	16.0	
	Minimum thickness specified shall apply to both hot rolled and hollow sections			
8.	**Protective Treatment** [clause 11.6]			
	Galvanizing thickness	µm	85	N/A
	Protection procedure		BS 729	No

12. Buildings and Civil Engineering Works

12.1 General

This specification covers all earth work, foundations and building extension associated with the Project together with site preparation, roads, surfacing, cable trenches and tunnels, boundary walls, foul and storm drainage.

12.1.1 Scope of Work

The Work includes the design, detailing, construction and maintenance of the following:

i) performance of site survey and subsoil investigation
ii) site preparation including retaining walls, cutting or filling up to the level specified in sub-clause 12.1.4 and levelling
iii) foundations for all equipment to be installed in outdoor switchyards, extension of control buildings, and any other building required for the Project
iv) complete buildings consisting of structural reinforced concrete frames, brick walls, concrete roof and floor slabs.
v) roadways within sites, surfacing the entire area within site boundary and surface water drainage.
vi) modification / extension / dismantling of existing structures / roadways etc. as needed.
vii) cable trenches, cable tunnels, cable ducts and pipe ducts

Included in the scope of work is the detailing, construction and maintenance of the following items which shall generally be constructed as per the specification, but drawings shall be submitted to the Employer / Engineer for approval prior to any construction works:

(a) extension of boundary wall
(b) surface water, foul and storm drainage
(c) air conditioning and ventilation
(d) lighting, small power, external floodlighting, emergency lighting and fire protection

12.1.2 Contractor to Satisfy Himself as to All Conditions

The Contractor shall assess:

i) Existing access conditions to the sites, 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
vi) ground conditions and temporary works required to provide support during excavation

12.1.3 Wayleaves, 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 Contractor 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 Contractor 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 wayleave of the required land.

The Employer will be responsible for applying for planning permission. The Contractor 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.

12.1.4 Site Survey Drawings

The Contractor shall prepare a survey at 1:200 scale showing existing ground levels on a minimum 10 metre grid and details of all features above and below the ground within the site boundary and up to 15 metres 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 for approval by the Employer / Engineer and the approved substation building floor levels shall be given on site plan.

12.1.5 Earth Works

Fill where required shall be carried out by the Contractor. Source of fill material and retaining wall shall be planned and approved by the Employer. The Contractor shall be responsible for providing a level or uniform sloping site to suit the existing substation layout design. The final soil levels (i.e. the level below the brick surfacing) shall be stated on the site survey plan to be prepared by the Contractor.

All fill shall be compacted in layers not exceeding 150 mm deep to a minimum of 90% optimum density as defined by the Proctor Test.

12.1.6 Engineer's and Employer's Office/Surveying Equipment

The Contractor shall provide an office of approximately of size 5 m x 6 m equipped with desks, chairs, lights and air conditioners for the sole use of the Engineer and his inspectors. Similar facilities are to be provided for the Employer and his inspectors. In addition for Employer's office, sufficient desktop computers, one A4 B & W laser printer and one A3 color laser printer shall be provided.

Similar offices for Engineer and Employer shall be provided in Gopalganj substation, Aminbazar substation and both banks of Padma River.

The Contractor shall loan his surveying instruments to the Engineer and his inspectors when required. Instrument checks shall be carried out at semi-annually intervals.

12.1.7 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 six (6) weeks 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 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 drawings will be issued at least twenty-one (21) days before construction start.

The Construction programme shall be expressed in an 'S' curve for each substation extension works under this Contract, with the percentage (of the total value of work in the schedules) each month.

12.1.8 Monthly Progress Reports

In accordance with the Project requirements, the Contractor shall submit agreed progress reports before the seventh day of the next month. These reports 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 reports.

12.1.9 Temporary Facilities

The Contractor shall provide all temporary buildings, workshops, cement and lime stores and latrines required for his use. The Contractor shall agree the location of these buildings with the Employer / Engineer, after submitting a drawing showing their proposed location.

When the Contractor is given 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.

12.1.10 Site Supervision

Although the civil and building works may be let as a sub-contract to an experienced local contractor, the Contractor 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 Contractor shall notify the Employer and Engineer in writing of major field works two (2) days before the works start for the activities as described below:

i) subsoil investigation
ii) every concrete pour and foundation casting

12.1.11 Designs and Drawings

The Contractor shall obtain the Engineer's approval for the use of all design codes and standards before design work starts. All design and drawing work shall be completed in the Contractor's own country, in direct coordination with the electrical plant design.

The Contractor shall supply one softcopy of all of codes for the Employer / Engineer. If non-English equivalent National codes are adopted, the Contractor shall supply English translations of these Codes to the Employer / Engineer.

Calculations shall be submitted together with drawings. To avoid possible misunderstandings, calculations will not be approved separately from drawings.

The Contractor shall generally submit a complete set of drawings for approval after initially getting the electrical layout approved. Where possible, drawings shall be standardized, and general drawings (00) issued covering several sites.

The Contractor shall provide a coordination 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.

12.2 References

12.2.1 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-clause 12.2.2 below.

12.2.2 Design and Construction Standards

BS12	Portland Cement
BS EN 124	Gully and Manhole tops for vehicular and pedestrian areas
BS 812	Testing aggregates
BS 882	Aggregates from natural sources for concrete
BS 1377	Methods of test for soils for civil engineering purposes
BS 1722: Part 10	Anti intruder fences
BS 1881	Testing concrete
BS 2853	Design and testing of overhead runway beams
BS 3148	Methods of test for water for making concrete
BS 3921	Clay bricks
BS 4449	Steel bars for the reinforcement of concrete
BS 5262	External renderings
BS 5395	Stairs, ladders and walkways
BS 5572	Sanitary pipework
BS 5628	Code of practice for use of masonry
BS 5930	Code of practice for site investigations
BS 6031	Code of practice for earthworks
BS 6367	Code of practice for drainage of roofs and paved areas
BS 6399: Part 1	Code of practice for dead and imposed loads
BS 6399: Part 2	Code of practice for wind loads
BS 6465	Sanitary installations
BS 6651	Code of practice for protection of structures against lightning
BS 6700	Design, installation, testing and maintenance of services supplying water for domestic use
BS 8004	Code of practice for foundations
BS 8005	Sewerage
BS 8100	Lattice towers and masts
BS 8102	Code of practice for protection of structures against water from the ground
BS 8110	Structural use of concrete
BS 8206	Lighting for buildings
BS 8215	Code of practice for design and installation of damp proof courses in masonry

BS 8290	Suspended ceilings
BS 8301	Code of practice for building drainage

12.3 Design

12.3.1 Architectural and Structural Requirements of Buildings

Where applicable, all new buildings shall be designed to be architecturally pleasing in appearance and to withstand the tropical climate with minimal maintenance.

Architectural elevations of all elevations of buildings shall be agreed before other detail plans are prepared.

Air conditioning units shall be provided in rooms listed in Clause 13. Air-conditioned rooms shall have a false ceiling such that the overall thermal transmittance of the roof shall be below 0.45 Watts/m2°C. The false ceiling shall be made from non-combustible materials and shall be easily removable to provide easy access to small power cables.

All buildings shall be reinforced by a reinforced concrete frame which shall be capable of resisting a horizontal earthquake force of 0.2G. An external concrete open 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. A fixed ladder of galvanized steel shall be provided up to the roof.

The roof shall be waterproofed with lime terracing 2:2:7 lime, shurki (powdered brick) and brick chips 0.75" down, which shall be beaten in accordance with local practice. The entire roof area shall be laid in one continuous operation. The minimum compacted thickness of terracing shall be 25 mm 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 100 mm diameter cast iron pipe placed outside the wall but shall be enclosed in a facing brick buttress. There shall be at least one downpipe per 100 m^2 of roof. The Contractor shall guarantee the roof against leaks for a period of 3 years from the Taking Over Certificate date. The roof shall project at least 450 mm beyond the face of all walls 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 verandah 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 0.8 m high with an insitu concrete coping 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 blockwork (Mirpur ceramics or similar approved) to ensure good air circulation over the roof. Air bricks shall be provided at 750 mm centres in solid portions of parapet wall.

The head of each downpipe shall be fitted with an enlarged hopper and purpose made cast iron grill set into a recess in the roof projection.

Window openings shall be fitted with protruding concrete sunshades above and at the sides of the openings.

All external walls shall be 230 mm first class brickwork plus a 50 mm thick layer of Mirpur Ceramics facing bricks or similar approved or rendered with cement render and painted as required by the architectural plan. The internal walls shall also be generally of 105 mm thick first-class brickwork. Internal walls shall all be rendered and receive one sealer coat plus two finishing coats of emulsion

paint. All brickwork shall be tied into the concrete frame by galvanized ties. Externally, rendered walls shall receive primer plus two finishing coats of PEP acrylic external quality paint or similar approved. At least two air bricks shall be provided to each room in which staff work/rest.

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 height of rooms housing control equipment shall provide about 1 metre clearance over the top of the cabinets to the underside of the false ceiling. In the switchgear rooms, about 1 metre clearance shall be provided over the switchgear to the underside of the roof slab but the Contractor shall provide a greater clearance if it is required to remove equipment. The clearance maybe reduced below downstand beams provided no equipment is required to be removed from the top of the switchgear. All rooms in any building shall be one height.

Rooms shall have walls and roof slabs adequately insulated. Maximum thermal transmittance values for all rooms shall be 0.7 watts/m2/°C for walls and 0.57 for roofs. Air conditioning units shall be provided in rooms listed in Clause 13. Air-conditioned rooms shall have a false ceiling such that the overall thermal transmittance of the roof shall be below 0.45 Watts/m2/°C. The false ceiling shall be made from non-combustible materials and shall be easily removable to provide easy access to small power cables. Suspended ceilings, with acoustic tiling and incorporating lighting and air conditioning fixtures shall be used in corridors, offices, control and SCADA rooms of the buildings and as per schedule of finishes.

All structures shall be designed to carry the loads imposed by the structure itself, together with live loads 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 closuers of adequate capacity. Door labels incorporating electrical hazard warning in Bangla and English shall be fixed to each entry door. Vision panels shall be provided to frequently used doors.

Window openings shall be fitted with protruding concrete sunshades above and at the sides of the openings.

Float operated submersible pump of capacity 25 cum/hour at a head of 8 meters to be provided for sump of basement. The pumps shall be fixed in all respect ready for operation and discharge into stormwater drainage system.

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 Contractor 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.

Toilets shall be provided with one (1) no. western type WC, one (1) no. Asiatic type WC, one (1) no. wash hand basin, one (1) no. wall mounted mirror. All necessary fittings and accessories shall be provided.

Battery rooms shall be supplied with sink and drainer.

Control buildings housing switchgear and control equipment shall include a cable basement to facilitate connection to the equipment. Basements shall be constructed so as to protect the building substructure from water in accordance with BS 8102.

The Contractor shall provide the fire/heat detector and portable fire extinguishers for the extended portion of the 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 firefighting 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 / Engineer for approval.

12.3.2 Ground Conditions, Foundations and Site Investigation

(a) Fill Sites

Fill will be placed by the Contractor where required. On fill sites where the depth of fill exceeds 3 metres the Contract assumes piled foundations shall be installed below buildings.

Piles shall be concrete (cast insitu or precast) complying with BS 8004.

On every fill site, the Contractor shall prove that the switchyard foundation will not suffer settlement greater than 20 mm by constructing a foundation and load testing this to twice the design bearing pressure for a minimum of 20 days.

Outdoor equipment shall be provided with spread footings. The bearing capacity of proposed soil level for outdoor equipment shall be checked by the Plate Bearing Test. The Contractor 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 Contractor shall flood the site to a depth of 50 mm 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 Contractor 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.

The Contractor shall monitor settlement of the fill (by placing concrete posts 50 x 50 x 750 mm deep on a 10 metre grid and taking readings) at 30 day intervals from the time he is given access to each fill site.

When a fill site is handed over to the Contractor, the Contractor 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 Contractor may appoint a sub-contractor to carry out the site investigation but all work and all lab work shall be witnessed by one of his own staff who shall countersign all recorded data.

Boreholes shall be taken on a 25 m grid with at least four additional boreholes beside each building. 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 sub-clause 12.1.4. The boreholes shall be located to an accuracy of + 0.5 m and shall be located to site layout considering existing obstacles at the field.

Boreholes shall be a minimum of 20 m depth or twice building footing width, 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 1.0 metre intervals.
- Undisturbed samples shall be taken at around 2.0 metres depth and 3.0 metres depth and tested by unconfined compression tests.
- One dimensional consolidation test shall also be carried out on undisturbed samples taken at 2 metres depth. The samples shall be saturated, and the range of applied pressure shall fully reflect the insitu conditions. Graphs showing void ratio (e) and applied pressure shall be submitted along with the Coefficient of Compressibility for the range of loading anticipated. 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. Where collapse of the boreholes occurs, casing shall be used and left in until the water level remains constant for two days.
- In cohesive soils a vane test to BS 1377: Part 9 shall be carried out at three different depths. The Contractor shall check the sensitivity of soil and ground water at each site to concrete and take all measures necessary to ensure the long-term durability of concrete.

The Contractor shall give the Engineer the requisite period of notice prior to commencing the geotechnical investigation at the field.

(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 Contractor shall submit three (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.

If the Contractor uses a local site investigation contractor, the Contractor shall appoint one of his own staff to oversee the entire operation and each piece of data shall be countersigned by this person.

Where estimated settlement exceeds 25 mm, the Contractor shall construct one foundation at an early stage an test load this foundation to confirm settlement predictions.

(e) Foundations

Regardless of the result of soil investigation report, the foundations for the extension of substation control building (where required) and gantry structures for terminating lines shall be provided with piles.

The minimum depth of all foundations shall be:

(a) All other switchyard foundations 1.1 m
(b) Control building foundations including all wall foundations and internal wall foundations 1.5 m
(c) Boundary wall foundations 1.1 m

All formations shall be hand rammed or mechanically compacted before placing 70 mm minimum thickness of Class B concrete blinding, within 24 hours of bottoming excavation, which blinding shall project 300 mm 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 Contractor 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
ii) Soft soil shall be removed and replaced with compacted viti sand with the top 200 mm consisting of viti sand and brick chips.

The cost of this work shall be borne by the Contractor.

The Contractor 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 125 kN/m^2. Between column footings all walls, including all internal walls, shall be provided with a reinforced concrete strip footing of minimum dimension 800 mm wide by 250 mm deep placed at the same level as column footings and linked structurally to the footings. In addition, column footings shall be tied at foundation level and also floor level by beams to every adjacent column in both orthogonal directions.

These beams shall be designed to resist 1 in 200 differential settlement without distress and shall be capable of resisting the earthquake load of 0.2G.

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 seven (7) days of completing concreting.

All exposed concrete and the outer surfaces of cable trenches and cable tunnels shall receive two 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 Contractor shall monitor settlement of all foundations each month and report this settlement to the Engineer until settlement has reduced to less than 1.5 mm in three (3) months.

The tops of all foundations shall terminate 1000 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 1000 mm 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.

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 works, the Contractor shall clear all sites of trees, tree roots, shrubs, debris, surplus soil, and any buildings.

Foundations shall be designed to resist uplift, assuming the water table is at ground level and the weight of soil resting on a foundation is that included within a 15° frustum.

On fill sites where the depth of fill exceeds 3 metres, the Contractor shall provide piled foundations in accordance with BS 8004 for the extended portion of the substation control building and gantry structures for terminating lines. One working pile of each structure chosen by the Engineer shall be load tested at each site to 150% of design load in accordance with BS 8004.

12.3.3 Drainage

The entire surface within boundary walls shall be of uniform sloping site, sloping at 1 in 150 minimum slope to open channels around the entire perimeter. These channels shall be designed for a rainfall intensity of 60 mm per hour. Outside the boundary wall, the Contractor 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 70 mm above brick paving level to prevent run off entering the cable trench. The floors of all cable trenches/tunnels shall be sloped to soakway as described in sub-clause 12.3.16.

The cable trenches will thus form barriers to surface water drainage. If the cutoff area exceeds 30 m^2, it shall be drained by a 200 mm minimum diameter concrete pipe to the boundary drain. The Contractor's drainage design shall avoid all ponded water to avoid forming a mosquito breeding ground.

All drainage pipework within buildings shall be ductile iron, generally of 100 mm diameter. Floor drains shall be placed in each battery room and toilet.

External pipework shall be 150 mm minimum diameter concrete pipes at a minimum depth of invert of 700 mm. Where pipes, including existing pipes alongside site, are less than 400 mm 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 600 mm x 600 mm clear openings and airtight 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 80. Manholes shall not be located in roads.

Where required, the Contractor shall be responsible for all negotiations with local authority WASA where a connection to a public sewer is proposed. Where high water levels in public sewers may cause effluent to back up into a site, non-return valves shall be fitted. The Contractor 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 Contractor shall draw longitudinal sections of all pipelines.

The existing substation control building is provided with a septic tank designed for 10 users. Other buildings, if required, shall have septic tanks designed for the required number of users. The septic tank shall be located at least 15 metres from buildings. 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 two (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.

The Contractor 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 Contractor. The Contractor 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. Two vents of minimum height 2.2 m shall be provided on each septic tank.

12.3.4 Surfacing

For the whole of the switchyard outdoor equipment area, the ground shall be surfaced with gravel or other readily available local stone as approved by the Engineer. The switchyard surfacing shall be clean, thoroughly washed when necessary, and free from clay, soil or contaminating material and shall be graded from 20-45 mm, laid and lightly compacted to a finished thickness of 175 mm. Below the gravel layer there shall be a 75 mm brick layer with cement mortar (1:6), laid over a 75 mm level of fine sand spread over the finished fill site.

The substation plot, outside of the designated switchgear equipment areas, shall be turfed. Turf shall be of good quality, free from weeds and shall be a minimum of 40 mm thick. Samples of the turf which is proposed to use shall be submitted to the Employer / Engineer for approval. 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.

On sloping surfaces, the Contractor 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.

12.3.5 Roads

The existing substations are provided with access road from outside the site boundary connecting to to the adjacent public road. The Contractor shall provide all roads within the site boundary for the bay extension works. The road surface shall be finished by concrete paving or equivalent. All roads shall be of reinforced slabs of approximately 25 cm thickness fitted with construction joints at distances not exceeding 6.0 m. Paving schedule and methodology shall be approved by the Employer / Engineer. Road layout shall generally permit vehicles to turn easily to avoid having to reverse out. Road layout for the bay extension works shall be designed by the Contractor. The Contractor's liability for roads outside the site shall be as stated in this Section.

All roads within the site boundary shall be generally 6.0 m wide between the outer edges of kerbs for main road and 4.5 m wide for sub road.

The road edge shall be formed by a flush Class B concrete kerb 300 mm wide by 250 mm deep, placed over one layer of bricks laid flat. The road shall be a Class A concrete slab 150 mm deep with 1:50 cross fall and stiff broom concrete finish reinforced with 6 mm bars at 125 mm centres longitudinally

and 6 mm bars at 400 mm centres transversely placed 60 mm below the upper surface. Expansion and contraction joins shall be detailed on site plans. Expansion joints shall have an oil resisting grade polysulphide sealant. Below the slab shall be a layer of polythene 0.5 mm 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 75 mm 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 3.0 m 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 substation, a two (2) bay hard standing car port, complete with sun shades, is to be provided adjacent to the substation control building.

12.3.6 Water Supply

Not used.

12.3.7 Plumbing and Sanitary Fittings

Not used.

12.3.8 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 but around the perimeter walls a band of broken brick 600 mm wide shall be placed with drain holes placed in the walls at 2.5 metre centres. The floor and all cable trenches shall be made of Class A concrete. The floor slab shall have a minimum 125 mm reinforced concrete Class A thickness, plus 25 mm Terrazzo and it shall rest on the fill. Below the slab shall be placed a layer of polythene 0.5 mm and a layer of compacted broken bricks at least 75 mm deep, hand rammed to a smooth upper surface.

The floor/equipment layout shall minimize the number of cable trenches over which station staff have to walk. Where power cables traverse a building to reach a switchgear room on the far side, they shall generally be contained within a dedicated cable basement or cable tunnel.

All sand backfill shall be compacted to 90% 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 0.5 mm thickness.

Each substation control building is provided with a ramp at a slope of approximately 1 in 7.5, of 1.5 m minimum width with a Concrete Class A slab of min depth 125 mm with a stiff brush concrete surface finish, or non-slip surface.

All floors except battery rooms shall have homogeneous floor tiles. Verandahs and external steps shall also have homogeneous floor tiles where public access is given to buildings. 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. Maximum length or breadth of any panel shall be less than 1.75 metres. 200 mm high skirting shall be installed beside each wall. Concrete floors and steps shall also be treated with 3 coats of Lithurin or other approved concrete dust proofer.

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.

12.3.9 Cable Basement

Based on the substation control building layout drawings provided in this Section and Bidder's pre-bid site visit to the Gopalganj and Aminbazar Substations, the Bidder shall assess the available space for cables of the bay extension works in the cable basement. Should the available space in the existing cable basement is insufficient to accommodate the cables of the bay extension works, the shall extend the below ground level basement of the substation control buildings. The cable basement shall be of waterproof construction; designed and constructed in reinforced concrete to BS 8007 and BS 8102 [Type C (Drained protection)]. The external walls and base slab shall be a minimum 350 mm thick. The design shall assume that the ground water table is at ground water level.

The walls and floor of the basement shall have a drained cavity with ventilation provided. The cavity shall drain to a sump, equipped with one hand operated and one electric pump, to facilitate the removal of water. The electric pump shall be of the submersible type with automatic control by float switches. The hand driven pump shall be rotary action and valveless giving smooth non pulsating flow.

The basement shall be provided with air extraction equipment, 100% standby equipment to give uninterrupted ventilation, sufficient to change the air 6 times per hour. Air supply and exhaust shall be from within the building at ground floor level in a protected location and shall not connect directly to the outside. The stairs leading to the basement shall be enclosed with, from ground level and at basement floor level, entry through security doorsets. Sufficient air ducting shall be provided to ensure adequate ventilation to the basement even if the extract fans cease to operate.

The basement shall be equipped with lighting and small power.

Where cables enter the building all ducts and trenches shall be sealed; the ends of all ducts entering trenches shall be bell mouthed. The floor shall be screeded, the walls finished as per the schedule of finishes.

12.3.10 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 50 mm high around the opening with the annulus around the cable sealed after installation.

12.3.11 Control Room Floors

The existing Control Rooms in the Gopalganj and Aminbazar substation are provided with raised floor (Multi access floor). Based on the substation control building layout drawings provided in this Section and Bidder's pre-bid site visit to the Gopalganj and Aminbazar Substations, the Bidder shall assess the requirement for extension of the Control Rooms for the bay extension works. Where extension of the Control Room is required, the Contractor shall submit the drawings showing required details for construction of raised floor for approval by the Employer / Engineer.

The raised floor shall be made of poly-urethane material having functions of fire resistance, waterproof and soundproof. Each panel of raised floor shall be installed on the structure frame. The floor material shall have function to easily accommodate cables, communication wiring, etc. on its lower part. The floor material shall include the shock-absorbing material and finishing stuff.

Panel elements shall be produced without fading or peeling on the finishing stuffs and trim by the injection molding of finishing stuff with panel elements at the same time. By the injection molding, the panel's thickness and the other standard (width, length, thickness, opposite angle, right angle, flatness angle, etc.) should be precise.

Pedestal elements shall have the function of support for the panel element of raised floor material.

Shock-absorbing material shall be installed on the top of pedestal elements and prevent any vibration or impact of the panel elements.

The materials for raised floor shall be as shown below or similar. The details should be approved by the Employer / Engineer:

- Panel stuff: poly-urethane
- Panel dimension: 600 x 600 ± 0.5 mm (including finishing stuff, trim)
- Panel thickness: 40 ± 0.5 mm (including finishing stuff)
- Panel inside core: particle board 35 mm
- Panel frame: width 3 mm poly-urethane
- Finishing stuff: anti-static laminate tile
- Under structure: zinc electric galvanizing
- Central concentrated load transformation: less than 2.5 mm with 4,900 N

The materials should be kept on the well-ventilated places against rain and direct ray of light. When transporting and handling the stuffs, the handler should be alert not to be damaged. The damaged materials have to be taken out. The finishes of stuff have to be stuck in the panel element.

The floor surface must be dry before construction, also the impurities like dirt and other obstruction should be removed. The under-structures (Pedestal set) are installed at intervals of 600 mm from the starting point of construction like radial shape. At this time, the under-structure is fixed strongly on the floor surface by using an adhesive. When each supporting structure is connected to the frame (stringer), the leveling work shall be done together. Horizontal angle shall be checked again after the construction is finished.

Panel lifter and other accessories necessary for maintenance shall be provided by the Contractor.

12.3.12 Site Clearance, Obstructions and Adjacent Structures

The Contractor shall be responsible for clearance of:

(1) Trees, shrubs and any vegetation including the extraction of all roots and compaction of backfill where roots have been extracted.
(2) The removal of all buildings, sheds or any other structures above or below ground including the removal of any septic tanks, drains or other underground services.
(3) The removal of any existing surfacing, roads, foundations or any other obstruction.

All material cleared away by the Contractor shall be the property of the Employer and shall be removed by the Contractor to a site in the Project area upon instructions of the Employer.

Where an existing service, existing equipment or adjacent building is to be retained, the Contractor shall take all necessary measures to protect the item concerned from damage and shall be responsible for ensuring that no movement of foundations occurs during or after completion of construction.

Any existing electrical equipment/cables which have to be modified or repositioned shall be included in the works at no extra cost. Any buried gas or water main services which require to be diverted shall be undertaken by the Employer at his cost. However, where it is possible to retain these existing services and build new structures around them, the Contractor shall take all necessary measures to build in the service at no extra cost.

12.3.13 Boundary Walls and Fences

The Contractor shall base his design of boundary walls on the existing design. A chain-link fence shall be erected around the switchyard, where applicable, for further security with the approval of the Employer. Where sites are within existing boundary walls, the Contractor shall erect a permanent fence 2.9 m high in accordance with BS 1722 part 10 or similar approved.

12.3.14 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 below 2.5 metres from floor level but toilet windows may be higher. The bottom of windows shall be generally at least 1.45 metres above floor level to provide good protection to staff. Each window shall be provided with a sunshade projecting about 500 mm 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 6 mm thick glass, reinforced with wire mesh where windows are placed in or over doors.

Window frames shall be anodized aluminium.

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.

Where applicable, the Contractor 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.

12.3.15 Doors

Internal doors and door frames shall be anodized aluminium. Main Entrance/Exit doors and door frames shall be steel.

The minimum size of the structural openings for doors shall be 1550 mm wide for double doors and 930 mm wide for single doors. Door height shall generally be 2100 mm 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 2500 mm. 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 door leaf shall have three 150 mm heavy iron hinges equally spaced. 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 or a separate precast concrete canopy over the top and the upper sides of a door.

Where applicable, the Contractor shall prepare a schedule of all doors and all door furniture for each building.

12.3.16 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. Ten (10) bricks shall be tested in accordance with BS 3921 to determine water absorption and crushing strength, which shall exceed 20 N/mm^2. Mortar shall generally be of Mortar designation (iii), 1: 1: 5 to 6; cement, lime, sand.

All brick panels shall be tied to the concrete frame with galvanized ties of approved design. Ties shall be painted with bituminous paint.

Facing bricks shall be 8" x 2" x 2" facing bricks from Mirpur ceramics. Facing bricks shall be tied back to the main wall. External walls shall be 230 mm 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 with maximum variation of 0.75 m. 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 500 mm wide shall be reinforced for two (2) courses above and below the opening, two (2) 6 mm bars per course extending 900 mm beyond the opening both sides where possible.

All exposed brickwork shall be rendered and painted where not faced with facing bricks.

12.3.17 Expansion Joints, Joint Fillers and Sealants

Expansion joints shall be placed in floors beside all ground floor walls. All filler board shall be bitumen bound fibre board. Any expansion joints on roofs shall be raised and protected by a metal flashing.

All expansion joints shall be sealed by polysulphide sealants, applied in accordance with the manufacturer's instructions. Sealants shall be oil resisting grade where required. Sealant colours shall match or blend with adjacent wall colours.

12.3.18 Cable Trenches in Switchyards

Cable trench sizes shall be standardized as per the existing cable trench sizes. Layout drawings shall be submitted for each substation showing layout and size of trenches for the bay extension works. No trench shall cross a road; power cables shall be placed in ducts of minimum 150 mm diameter with bell mouthed ends. Ducts shall extend 1500 mm 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 150 mm thickness, with the external surface painted with two coats of bitumastic paint. Walls and covers shall protrude at least 70 mm 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 below the trench at low points; the volume of each soakaway shall be 2.5 m^3 per 150 m^2 of trench.

Covers shall be of reinforced concrete Class A. Each cover weigh less than 55 kg. The minimum depth shall be 70 mm, with downstand ribs along each side providing a minimum overall depth of 100 mm. The ends of the cover shall overhang the wall by 15 mm and in the centre of each end there shall be a hand hole of minimum size 100 mm by 20 mm 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 5 mm 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 250 kg point load at mid span. The Contractor shall provide ramps up to the edge of covers in several locations, as agreed on site, to enable the wheeled extinguisher to mount the covers. Longitudinal edges may be inclined at 10° to the vertical, thus creating a larger gap at the bottom of adjacent slabs, again to reduce heat buildup. 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.

12.3.19 Cable Trenches in Buildings

The base and walls of the trench shall be of reinforced Class A concrete of minimum thickness 110 mm with the outside face painted with two (2) coats of bitumastic paint. Cable trays may be supported by Unistrut P3300 inserts, or similar approved, or drilled anchor bolts.

Where power cables pass through a building to reach the far side, this shall generally be in a tunnel section. The Contractor 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 non-slip. Deflection shall be limited to 1/250 of span under a load of 3 kN/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.

12.3.20 Rainwater Pipes

Down pipes shall be 100 mm minimum diameter placed on the outside of walls but enclosed in a brick buttress of facing bricks. One downpipe shall be provided for each 100 m^2 of roof area. The head of the downpipe shall be enlarged to 200 mm 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.

12.3.21 Switchyard Foundations

The top of all foundations shall be set at the same level, which shall be raised above the general switchyard level for the purpose of preventing surface water coming into contact with the equipment structures and holding down bolts. The distance between the general surface level and the top of foundations shall be at least 200 mm. All exposed concrete surfaces shall be painted with an acrylic weatherproof 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 Contractor 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 0.2G 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 washer shall be used under a nut in all cases.

12.3.22 Transformer Bases

Note used.

12.3.23 Blast Walls

Not used.

12.3.24 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 Employer / 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 extended portion of the substation control buildings and boundary walls 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 two 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, including all brick ties, 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.

12.3.25 Furniture

Not used.

12.3.26 Concrete

Only two grades 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 shall all be reinforced Class A concrete.

	Class A	Class B
Min Cement Content	360 kg/m^3	170 kg/m^3
Max Water Cement ratio	0.55	-
Coarse Aggregate type	Broken stone	Jhama brick
Max Coarse aggregate size	20 mm (40 mm piling)	25 mm
Method of Batching	Volume batching	Volume batching
Min Characteristic of Trial Mix at 28 days	30 N/mm^2	-
Min characteristic strength of trial mix at 7 days	14 N/mm^2	-
Min characteristic strength of works cubes at 28 days	20 N/mm^2	-
Slump Range	30 mm (min) - 100 mm (max)	50mm min
Slump for concrete placed below water in piling	150 mm min	-

It should be noted that minimum specified cement content will produce significantly stronger concrete. The Contractor's design shall be based on a 28 day crushing strength of 20 N/mm^2. Design shall be in accordance with this Contract and BS 8110 or other agreed standard.

Minimum cover to rebars shall be 60 mm where concrete is in contact with backfilled soil against a shuttered face, 100 mm where concrete is cast against soil, and 30mm for all above ground concrete. In detailing bars which traverse a member, a reduction of 5 mm shall be made for a bent bar and 10 mm for a straight bar to ensure adequate cover. Exposed ends of sunshades and roof projection shall have 70 mm minimum cover.

All concrete design shall ensure easy access for vibrators of 50 mm 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. All cold joints shall be indicated on drawings. Roof slabs shall generally be cast in one continuous operation.

12.3.27 Concrete Reinforcement

The Contractor may use locally available mild steel bars from approved sources or import steel bars to any agreed standard. No bar or stirrup shall be smaller than 6 mm diameter to ensure adequate rigidity during concreting.

If locally purchased bars are used, bending tests and tensile tests shall be carried out to ensure the bars meet the design standard adopted and weight per unit length shall be tested regularly.

Bar bending lists shall generally be shown on drawings, where possible with a diagrammatic representation of each bar to ensure clarity and ease site communication. The Engineer will not systematically check the accuracy of every bar on bar lists when approving drawings. The Contractor shall therefore arrange to check all bar lists. Drawings shall detail all chairs and ties and include these on bar lists.

Bars shall be tied at every intersection and the ends of tie wire bent away from concrete surfaces.

Anti-crack bars shall be provided at changes in slab or wall thickness and at the corners of every rectangular opening.

12.3.28 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 3 mm spatterdash coat a 12 mm undercoat followed by a 9 mm 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.

12.3.29 Goalposts

In each outdoor switchyard with live conductors crossing roads, the Contractor 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 Clause 11 of this Section for the high voltage switchgear.

12.3.30 Lifting Beams

Not used.

12.3.31 Stairs

Not used.

12.4 Concrete Workmanship

12.4.1 General

At all stages in the production, mixing, placing and curing of concrete, the Works shall be inspected by the Employer / Engineer. 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 Employer / Engineer, shall be implemented.

12.4.2 Aggregates

Coarse aggregate shall be capable of passing through a 20 mm sieve and be retained on a 5 mm sieve. Fine aggregate shall be not larger than 5 mm and not smaller than 0.06 mm and shall be sharp in texture.

All aggregates shall be free of harmful quantities of organic impurities, clay, silt, salt or unsound particles. The amount of clay, silt and fine dust present in aggregate, whether as coatings or separate particles, may not be more than:

- 15% by weight in crushed sand
- 3% by weight in natural or crushed gravel sand
- 1% by weight in coarse aggregate

If the Engineer considers that any aggregate which the Contractor proposes to use contains an excess of fine particles or any harmful substances, the Contractor shall either replace the aggregate or, at his option and entirely at his expense, institute a series of approved tests at an approved laboratory to determine the nature and extent of the fine particles and harmful substances. Following receipt by the Engineer of the results of the analysis and tests, he will advise the Contractor in writing whether the proposed aggregate may or may not be used. The Engineer's decision in this respect shall be final.

Tests to determine the extent of impurities or fine particles shall include (but shall not be restricted to) the relevant tests specified in BS 882:1992, ASTM. C40 79 (Colormetric test) and ASTM C33 82.

12.4.3 Sampling

At least four weeks before the Contractor envisages first receiving aggregate from any source, the Contractor, in the presence of the Employer / 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 Employer / Engineer considers necessary to demonstrate the soundness of the material.

Such tests shall be carried out in an approved manner at the Contractor's expense and may include the manufacture, both in the laboratory and at site, of test cubes or cylinders to determine crushing strength.

12.4.4 Grading

The Contractor shall ensure that his offer includes the full cost of obtaining and transporting suitably graded stone aggregates to site.

Grading of aggregates should, together with the required minimum cement content and water cement ratio, ensure adequate durability, density and characteristic strength of the finished concrete. The Contractor shall submit in writing to the Employer / 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.

12.4.5 Cement

Ordinary Portland Cement shall comply with BS 12. The Contractor may obtain cement, bagged or in bulk, from any approved source in Bangladesh but shall always submit sufficient samples from each delivery, as required by the Employer / Engineer, to ensure that all cement complies with the minimum requirements of BS 12. All cement shall be stored in a weathertight shed at least 300 mm off the floor. Regular checks shall be made on the weight of cement in each bag.

12.4.6 Water

All water used in the preparation of concrete for foundations shall be 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.

12.4.7 Reinforcing

Where reinforcing is specified in any foundation design, it shall comply with BS 4449 or an approved similar standard. Before any reinforcing is used, the Contractor shall provide the Employer / Engineer with a certified mill certificate, verifying its grade and quality, and proof test such samples as the Employer / 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 Employer / Engineer may destroy or reduce bond.

12.4.8 Storage

The Contractor shall ensure that all the materials he provides for the preparation of concrete shall be stored in a manner which prevents contamination by dust, clay, water or any other harmful material.

Heaps of coarse and fine aggregate shall be separated by at least one metre.

Where aggregate is tipped directly onto the ground, the bottom 20 cm 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 Employer / Engineer considers it necessary, special precautions shall be taken to ensure that aggregate stored on site shall remain dust free. Such precautions may include the bagging of aggregate at the pit if sites are adjacent to dusty roads or if heavy rain is liable to wash out fine material or saturate the aggregate to an extent which might influence the water content of a mix.

Where the Contractor establishes central depots for receiving cement prior to 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 Employer / Engineer.

12.4.9 Design Mix

Prior to ordering any aggregate, the Contractor shall inform the Employer of the source(s) of his aggregates and deliver samples to the Employer. The Contractor will authorize at an approved laboratory tests to show the sieve analyses, relative densities, moisture content 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 Contractor will report to the Engineer on the expected water/cement ratio and the aggregate/cement ratio of concrete to be produced on site.

Following the successful testing of the laboratory samples, the Contractor shall make trial mixes at site (from which he will take at least 4 test specimens) using the proportions advised to the Engineer (and in the presence of the Engineer) and using the equipment he intends to use in the normal day to day manufacturing of concrete. The minimum 28 day crushing strength of any such test specimen shall be not less than 20.7 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 Contractor at his own cost.

12.4.10 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 Employer / 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 1.5 m^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 Employer / 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.

As a minimum standard, the following series of inspections should be carried out by the Contractor 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 Employer / Engineer may suspend concreting pending their implementation.

12.4.11 Testing of Concrete

Samples shall be taken and tested in accordance with BS 1881. Testing shall be carried out by an approved laboratory, who shall arrange to immediately notify the Contractor and the Employer in writing of any cube failure. Failed cubes shall be kept for reference.

Concrete for the test specimens shall be taken at the point of deposit. To ensure that the specimens are representative of the concrete, a number of samples shall be taken from different points. Each sample shall be large enough to make one test specimen and shall be taken from one point in the work.

The tests specimens shall be stored at the site at a place free from vibration, under damp sacks for 24 hours + 1/2 hour, after which time they shall be removed from the 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 14.8 N/mm^2 within seven days after mixing and 20.7 N/mm^2 within 28 days after mixing.

One cube shall be tested at 7 days to obtain an indication of the concrete strength. The remaining three cubes shall be tested at 28 days and the average of their strengths shall be calculated. Should the average of the cube strengths fall below the specified 28 days cube strength, the Engineer may order the affected concrete to be removed and replaced at the Contractor's expense, or the Engineer may allow the Contractor to take a cylinder for further testing in accordance with BS 1881, if Schmidt Hammer readings indicate below strength concrete.

The diameter of the cylinder shall be not less than three times the size of the maximum aggregate and its length will be at least double the diameter, after allowing for preparation and facing prior to the test. Both a report and compression test will be completed for the sample in accordance with BS 1881. Only one such test will be permitted from any one sample and if the crushing strength of the sample is in excess of that required by the design, the Engineer may, after the Contractor has made suitable repairs to the part disturbed by taking the sample, accept the concrete.

12.4.12 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 20 mm.

12.4.13 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.

12.4.14 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 50 mm minimum diameter, operating at speeds of at least 8,000 rpm 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 100 mm 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.

12.4.15 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.

12.4.16 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.

12.5 Workmanship of All Other Materials

This specification only describes concrete work in detail. All other materials workmanship shall be in accordance with an agreed standard. Before starting any new item of work, the Contractor shall submit samples of the materials to the Employer / 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 Employer / Engineer before other items are constructed.

13. Lighting, Small Power, Heating and Ventilation

13.1 Scope

This specification includes for the interior and exterior lighting, small power, heating and ventilation systems as required for the bay extension works.

Whenever practicable, fixtures shall be sourced locally. All lamps, fittings, plugs, sockets and general accessories of the same size and types shall be similar and interchangeable throughout the installation.

The lighting and small power equipment and installation shall comply with other sections of this specification as appropriate.

13.2 References

British Standards

BS 7671	Code of Practice Regulations for Electrical Equipment in Buildings 15th Edition. Institution of Electrical Engineers.
BS 6004	Specification for PVC insulated cables (non-armoured) for electric power and lighting
BS 6346	Specification for PVC insulated cables for electricity supply
BS 6500	Specification for insulated flexible cords and cables
BS 6121	Mechanical cable glands
BS EN 60947	Specification for control gear for voltages up to and including 1000 V AC and 1200 V DC
BS 4533	Luminaries
BS 3677	Specification for high pressure mercury vapour lamps
BS 1363	Specification for 13A fuse plugs and switched and unswitched socket outlets
BS 1362	Specification for general purpose fuse links for domestic and similar purposes (suitable for use in plugs)
BS 4568	Specification for steel conduit and fittings with metric threads of 150 form for electrical installation
BS 4066	Test on Electric cable under fire conditions.
BS 4434	Specification for safety aspects in the design construction and installation of refrigerating appliances and systems.
	Institution of heating and ventilation Engineers Guide to current practice.
	American Society of Heating Refrigeration and air conditioning Engineers
	Recommendations
	Heating and Ventilation Bidders Association of U.K. specification DW/ 121
BS 5970	Code of Practice for thermal insulation of pipework and equipment
BS 848	Fans for general purposes
BS 6540	Method of test for atmospheric dust spot efficiency and synthetic dust weight arrestance
BS 2871	Specification for copper and copper alloys: tubes
BS 1470	Specification for wrought aluminium and aluminium alloys for general engineering purposes, plate, sheet and strip

13.3 Defects Liability Period

The Contractor shall be responsible for the efficient and good working of the installations comprising as specified in this clause for the agreed period as set out in the Bidding Documents.

13.4 Approvals

The Contractor shall submit to the Employer / Engineer for approval of all his calculations forming the basis for the designs of the specified systems which shall be shown on the working drawings, also to be submitted for approval.

Any approvals shall not, however, relieve the Contractor of his contractual responsibilities which include obtaining local authority approvals for electrical wiring installations.

13.5 Lighting Requirements

The lighting installations shall be designed to give the standard service illuminations and shall incorporate emergency lighting as required. Where the bay extension works require extension of certain rooms in the existing substation control building such as control rooms, relay rooms, telecommunications equipment rooms, offices and stores shall have the service illumination measured at 850 mm above finished floor level. All other areas shall have the service illumination measured at floor level.

The installations shall also meet the limiting glare index requirements as set out in the specified codes of practice. As much as possible, the new installation under this Contract shall use similar types of lighting fittings as per the existing installation of the affected area including type of control to be employed, number of socket outlets and the types of mounting expected to be suitable for the respective areas. Where discharge and fluorescent light sources are to be used in areas containing rotating or reciprocating machinery, the fittings shall be allocated between the 3 phase and neutral in such a manner as to avoid stroboscopic effects. When 3 phase lighting installations are to be used, contactor switching controlled by pushbuttons located in the area to be illuminated is preferred.

In all rooms and corridors having two entrances the lighting installation shall have two-way switching, the switches being located in appropriate positions adjacent to the entrances.

Emergency lighting shall be arranged to illuminate all stairways, exits and entrances and provide some illumination in operational areas within the substation control building and switchyard.

Security lighting shall be installed around the perimeter walls illuminating the external area and shall be controlled from the gatehouse. The level of illumination for security lighting shall be measured at a distance of 3 metres outside the boundary wall.

13.6 Schedule of Design Requirements

The lighting system shall include provision for ease of erection, maintenance, cleaning, lamp replacement and future extension. Lamp replacement and maintenance should, unless otherwise approved, be possible without necessitating outages on main plant items.

Lighting apparatus shall be of top quality, designed to ensure satisfactory operation and service life under all variations of load, frequency and temperature. Sodium discharge lighting shall be used for road and security lighting. Switchyard floodlighting shall use 500W Halogen lamps unless otherwise specified.

Key to Abbreviations:

L	Local switches
S1, S2 etc.	Socket outlets or fused spur circuits
P.B	Pushbutton for remote control
T.S	Time switch control
C	Ceiling mounted

W	Wall mounted
P	Pole or earth mast mounted
M	Recessed modular mounting
D	Suspended
F	Flush installation
S	Surface installation
A	Automatic on mains failure
BH	Behind ceiling diffuser

13.7 Coding Systems

The Contractor shall, when preparing drawings showing the respective designs, use a code to identify each lighting fitting and socket outlet.

The code shall comprise letters and figures so compiled that the following information can be readily identified:

1. The lighting distribution board to which the fitting or socket outlet is connected.
2. If connected to the normal supplies or to the emergency DC supplies.
3. The circuit number and phase of the distribution board to which the fitting is connected.
4. The sequence of the fitting in a particular circuit.

13.8 Distribution Boards

The Contractor may assess and utilize the existing distribution boards using the available spares to supply the new installation works required by the bay extension works. Where no spare is available in the existing distribution boards, the Contractor shall supply distribution boards and all component parts manufactured and tested in accordance with the latest standards and designed to suit the fault level of the existing transformers. The Contractor shall demonstrate by calculation that this has been complied with.

Each, current carrying component shall be so designed that under continuous rated full load conditions in the climatic conditions at Site the maximum total temperatures permitted under the relevant Standards are not exceeded.

Each distribution board shall have a rustproof metal case of sheet steel with either a galvanized or enameled finish. The colour of the enamel finish shall match the colour of other switchgear. The metal casing is to be provided with a number of knock outs or other approved form of cable entries, corresponding to the circuit capacity of the distribution board, and a suitable screened brass earthing stud.

Busbars, including neutral bar, shall be of high conductivity copper supported to withstand all normal and fault condition stresses.

All busbars, neutral bars and primary conductors are to be PVC sleeved in respective phase and neutral colours.

Distribution boards for exterior use shall be galvanized and weatherproof.

Neutral bars shall have an appropriate number of ways relative to the size of the board. They shall have a rating not less than that of the associated phase busbars.

The metal surface adjacent to any live part and all spaces between phases shall be protected by barriers of fireproof insulation material.

The distribution boards shall be either single pole or triple pole and neutral types and shall be equipped with means to provide overcurrent protection to each circuit. This protection may comprise an HRC fuse or a miniature circuit breaker, both of which shall be removable without exposing live connections.

Fuse bases and bridges, where used, shall be of an approved non -hygroscopic insulation suitable for the receipt of HRC fuses.

Residual current circuit breakers shall be incorporated to protect all lighting circuits, socket outlets and supplies to appliances, etc.

The current rating of the busbars in each distribution board is not to be less than the sum of maximum current rating of all outgoing circuits. The neutral connection for each circuit is to be direct to the neutral busbar.

Title labels of an approved type and inscriptions are to be fitted externally on the front cover of each distribution board giving details of the points controlled by each circuit. The circuit lists shall be typed or printed stating the location of the equipment served, rating of the protective unit and the circuit loading. The lists shall be mounted on the inside of the cover door and shall be protected by an acrylic sheet slid into a frame over the circuit lists. The lists and cover are to be easily removable to permit circuit modifications.

The cables feeding the distribution boards shall be connected directly to the incoming isolator or neutral bar as appropriate, unless otherwise indicated by this specification.

Switchfuse units or isolators connected on the incoming side of a distribution board shall be mechanically attached to the board with solid copper electrical connections between the units. A suitable insulated barrier is to be supplied to prevent copper or carbon dust released under fault conditions passing from one unit to the other.

Distribution boards for use on the direct current system shall be double pole types equipped with adequately rated fuses.

Mixed capacity boards shall be employed, and all contactors and time switches associated with the respective outgoing circuits shall be accommodated within the distribution board.

13.9 Miniature Circuit Breakers

Miniature circuit breakers (MCB) shall comply with the requirements of this specification. Typical Catalogue and Sizing Calculation of MCB shall be submitted to the Employer / Engineer for approval.

13.10 Cables

Cables shall be XLPE insulated, single wire armoured and PVC sheathed overall and be manufactured and tested in accordance with the requirements of BS 5467, 600/1000 V grade or equivalent. The outer sheath shall be coloured black and incorporate flame-retardant characteristics to meet the requirements of BS 4066 and IEC 60332. Jute fillings will not be permitted. Cables shall comply with the requirements of the cable section of this specification.

Flexible type cables for pendant cords and final connections to fixed apparatus are to be butyl or silicone rubber insulated and sheathed, manufactured and tested in accordance with the requirements of BS 6500, 300/500 V or 300/300 V grade as applicable.

The conductor is to comprise multi strands of 0.25 mm wire. The number of strands shall be not less than 30 and in all cases of a number suitable for the protection rating of the respective circuits.

All cables used for lighting and small power shall have copper conductors.

The Bidder is to select conductor sizes for the respective final circuits to meet the following conditions:

(a) That the minimum conductor size for lighting circuits is to be 1.5 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 BS 7671. Diversity will not be allowed.

13.11 Cable Terminations

Terminations for cables shall comprise compression type glands with armour and bonding clamps to meet the requirements of Type E1 to BS 6121, or equivalent, and are to be designed to secure the armour wires, to provide electrical continuity between the armour and the threaded fixing component of the gland and to provide watertight seals between the cable outer sheath and gland and between the inner sheath and threaded fixing component. The glands are to project at least 10 mm above the gland plate to avoid moisture collecting in the cable crutch.

Earth bond terminal attachments are to be provided.

Terminations for rubber insulated cables are to comprise compression type glands where the function of the gland is to secure the outer sheath of the cable, in accordance with the requirements of Type A2 to BS 6121 or equivalent. A watertight seal is to be provided between the outer sheath and the gland.

Only one cable is to be terminated in each gland.

13.12 Sealing and Drumming

Immediately after the tests, both ends of all cables shall be sealed against the ingress of moisture, dirt and insects and the end projecting from the drum shall be adequately protected against mechanical damage during handling and shall be fitted with a pulling eye bonded to cores, sheath and armours.

13.13 Conduit

All wiring shall be installed in screwed heavy gauge welded steel conduit or heavy gauge PVC conduit, at the discretion of the Engineer. No conduit less than 20 mm diameter will be permitted.

Surface mounted – steel: switchrooms, battery rooms, i.e. painted blockwork

Flush mounted – PVC: relay control rooms which have a decorative finish

Steel conduits shall be manufactured in accordance with BS 4568, Part 1 or equivalent, heavy gauge screwed and welded Class B and shall be galvanized. Conduit fittings are to be manufactured of good quality galvanized malleable cast iron and of small circular pattern to BS 4568, Part 2 or equivalent, with internally tapped spouts minimum length 21 mm threaded to the correct length at intersections, tees, draw throughs and stop ends.

Conduit fittings of PVC shall be of the plain bore pattern suitable for a push on compression type joint and shall be sealed with a hard setting vinyl cement to prevent ingress of vermin, water, dust, etc.

Inspection bends, solid or normal bends, elbows or tees are not to be used except with the approval of the Employer / Engineer.

Conduit runs shall, wherever possible, be concealed in ceilings, voids and walls, chases etc., and in rooms of secondary importance (with back outlet entries to switch boxes etc. especially on fair faced brickwork) otherwise the conduits shall be securely fixed to the surface of walls using heavy cast distance saddles. Where plastered finishes are called for, buried conduit systems shall be provided.

Where the system of wiring is concealed, the 'loop in' system of conduit shall be used and the 'looping in' boxes shall conform to BS 31, Class B3.

A separate insulated earth conductor, coloured green and yellow, shall be run in PVC conduits and such facilities shall be provided at all terminal points.

Wherever the installation is specified as being flame proof, the conduit runs entering these areas shall have a barrier box inserted in the run immediately before the conduit passes into the flame proof area. All conduit work inside the flame proof area shall be carried out with solid drawn galvanized conduit and all conduit fittings, sockets and accessories shall be galvanized and certified suitable for Group 1 hazard. At the completion of the wiring all machine faces on accessories shall be thoroughly cleaned and greased, prior to the screwing or bolting of all accessory cover plates into their final flame proof secure position.

The ends of all steel conduits shall be reamered to remove all burrs or sharp edges after the screw threads have been cut. All dirt, paint or oil on the screw threads, the conduit, sockets and accessories must be removed prior to erection. All conduits shall be swabbed through prior to installation of cables.

The ends of the conduit shall butt solidly in all couplings. Where they terminate in fuse switches, distribution boards, adaptable boxes or non-spouted switch boxes, they shall be connected thereto by means of smooth bore male brass bushes, compression washers and sockets. All exposed threads and all bends shall be painted with an aluminium spirit paint after erection.

All conduit and accessories, after being installed, shall be examined and all parts where the surface has been chipped or scratched shall be painted.

All conduits shall be kept 80 mm clear of water, gas and other services. Should this prove impracticable, then they shall be properly bonded by means of pipe clamps or other device ensuring mechanically sound, electrically continuous connection.

The method of installing PVC conduit and fittings shall conform strictly to the manufacturer's recommendation. These recommendations shall be submitted when seeking approval to the system proposed. In general, the clauses dealing with steel conduit shall apply.

PVC tube not exceeding 25 mm in diameter shall be bent cold by means of the appropriate spring and the tube shall be saddled as quickly as possible after bending. When bending larger sizes of tube, the tube must be heated in an approved manner until it is pliable. A 90° bend shall have a radius of not less than five times the outside diameter of the tube.

Joints between conduits and conduit fittings shall be watertight and shall be made by means of a solvent adhesive as recommended by the manufacturer. Care shall be taken to ensure that the tube is clean and free from damp and grease and in particular dust, mould and oil.

The Contractor shall provide PVC tube ends and flexible covers to prevent ingress of concrete grout into the tubing and boxes.

All bends are to be made on Site to suit conditions and not more than two right angle bends will be permitted without the interposition of a draw box. No tees, elbows, sleeves, either of inspection or solid type, will be permitted. Generally long straight conduit runs from point to point shall have draw boxes installed at maximum intervals of 10 metres.

Deep boxes or extension rings on standard circular conduit boxes shall be used where necessary in order to bring the front of each box flush with the surface of the ceiling or wall. Where conduits are laid direct on the shuttering of the reinforced slab construction, conduit extension rings or deep boxes shall be used to raise the run of conduit to between the top and bottom reinforcing. Galvanized draw wires or other approved types shall be provided where conduits are not to be wired on completion or are to be wired by others.

All draw boxes and junction boxes shall be of ample size to permit the cables being drawn in and out. They shall be made of malleable iron or PVC approved type and the jointing surface machined to ensure a dust tight joint. All circular boxes shall be provided with long spouts internally threaded incorporating a shoulder for the proper butting of the conduit and a solid brass earth terminal tapped and screwed into the base of the box.

All conduit boxes shall be screwed on or in walls, ceilings etc. by countersunk wood screws of appropriate size. Holes in boxes shall be adequately countersunk to ensure the complete recession of the fixing screws. All inspection and draw in boxes shall be provided with covers fixed by round head brass screws.

Where surface conduit is specified, it shall be fixed by means of distance saddles and shall terminate in raised back pattern conduit boxes. Surface conduits shall not be bent or set to enter accessories, and where they turn through walls back outlet boxes shall be provided. Conduits shall be fixed at 1200 mm centres on vertical runs and 900 mm apart on horizontal runs.

Vertical conduit runs shall have saddles at 300 mm maximum from their points of emergence from floors or ceilings and the remaining saddles shall be fixed consistent with the requirements of spacing and appearance. Saddles shall be fixed on each side of every bend at 300 mm maximum from the point of intersection of the centre line conduit.

Conduits in ceiling cavities shall be supported independent of the suspended ceiling.

Where conduits cross expansion joints, the Contractor shall allow for the installation of expansion couplers at the positions of the expansion joint and at right angles to it. He shall provide a bonding earth wire between each terminal fitted in the nearest conduit box each side of the coupler.

All flexible metallic tubing shall be galvanized watertight pattern fitted with sweated brass adaptors. External earth conductors, wrapped around the tubing, shall be provided.

Where conduits are laid in slab floor etc., the Contractor shall arrange for a competent person to be in attendance whilst the concrete pouting or screeding operation is being carried out, in order to avoid damage being caused to the conduits and also to ensure that the conduit work is in sound condition, properly and efficiently maintained during this installation period.

Particular care should be taken when setting out conduit runs to outlet points where they are to be fitted to furniture, kitchen fittings, etc. The Contractor shall ascertain exact details of the furniture and fittings construction in order that all conduit work shall wherever possible be concealed.

Conduits installed in chases of walls and floors shall be firmly secured by wrought iron pipe hooks or crampets and these fixings shall in themselves be sufficient to hold the conduits in place. Conduits

installed in chases shall be painted with one coat of bitumastic paint before erection and a further coat shall be applied to all accessible surfaces including the hooks and the crampets after erection.

Recessed conduits buried in plaster shall permit a full 6 mm. depth of cover over its entire length.

Provision shall be made for the tapping of condensed moisture.

Care shall be taken to prevent water, dirt or rubbish entering the conduit system during erection. Screwed metal caps or plugs shall be used for protecting open ends.

All conduit systems shall be erected completely with all conduit accessories connected. They shall then be offered for inspection and approval by the Employer / Engineer before any cables are installed. Conduit boxes shall be fixed to the structure of the building independently of the conduit.

Where a conduit is exposed to different temperatures (either by surrounding air conditions or by virtue of the surrounding medium with which it is in contact) at any particular time, the section of the conduit at the higher temperature shall be isolated from the section at the lower temperature by means of a conduit box filled with an approved permanently plastic compound, after completion and testing of all wiring. Such a condition would arise if a conduit running in a warmed building is run to exterior points.

Where galvanized conduit is specified, all conduit, accessories, switch boxes and all associated apparatus used in the installation must also be galvanized. Galvanized conduit shall be used when mounted outside a building, installed in floor chases subject to dampness or accidental flooding, or buried in the ground. Conduit systems shall be weatherproof when erected outside a building. Exposed conduit threads shall be given a coat of zinc rich paint.

Conduit buried in the ground shall be wrapped with PVC self-adhesive tape half lapped. The taping shall be extended for a distance of 150 mm beyond the point where the conduit emerges from the ground. Joints in galvanized conduit systems shall be made watertight using lead, aluminiurn paint and hemp and/or gaskets. The joints shall be partially screwed up before the paint and hemp are applied to maintain continuity.

All adaptable boxes shall be grey iron pattern unless otherwise specified. Where adaptable boxes are fitted flush, the cover plates shall be heavy gauge metal with 12 mm overlap on all sides. The internal depth of a box shall be not less than 40 mm.

Covers shall be secured by a screw at each comer and by additional screws as necessary to provide a maximum spacing of 300 mm between adjacent screws. Fixing screws shall be brass (round or cheese head).

Covers for boxes shall be of the same material as the box. For boxes mounted in weatherproof situations, the cover shall have a machined surface around the perimeter mating with a similar machined surface on the box and shall be complete with a gasket.

Every flush outlet box to which a luminaire pull cord switch or similar is to be fitted, shall be equipped with an approved type of break joint ring.

13.14 Cable Trunking

Where trunking is specified it shall be constructed of 1.65 mm minimum thickness zinc coated mild steel or PVC and shall have a removable cover throughout its length with centre screw latch fixings. Trunking shall be rigidly fixed and supplied complete with purpose manufactured fittings, connectors, dividers, flanges, cable retaining clips, racks and copper earth continuity links. As an alternative, if approved, a

proprietary brand of heavy-duty plastic trunking may be acceptable. When submitting details for approval, full installation instructions as recommended by the manufacturer shall be included in the details.

All cables installed in trunking shall be labelled and identified in an approved manner. Clips shall be at 600 mm centres. Vertical cable trunking shall be fitted with cable pin racks arranged to avoid any strain on the cables.

All trunking shall be rust proofed, primed and painted and fixed at intervals not greater than 1,000 mm.

13.15 Cable Trays

Cable trays, where required, are to be the perforated galvanized sheet type.

Trays are to have upturned edges and be of a width suitable for the number of cables to be supported and are to be supplied with purpose made galvanized steel brackets suitable for mounting from the building structure. External cable trays shall be provided with covers.

Where site cutting of trays or support bracket steelwork is unavoidable, recutting bare steel shall be protected with two coats of an approved zinc rich paint immediately after cutting.

13.16 Cable Jointing

The Contractor shall be responsible for the sealing and jointing of all cables supplied and installed. Straight jointing of cables is not permitted without the written consent of the Engineer.

13.17 Contactors

Contactors shall comply with BS 5424 or equivalent and shall be of the electrically held-in types contained in heavy gauge sheet steel cases suitable for panel mounting. Each contactor shall be continuously rated and suitable for thirty inductive switching operations per hour.

13.18 Switches and Pushbuttons

Switches shall be rated for 15 amps, shall be single pole types and be provided with an earth terminal. Switches shall be one way, two way or intermediate as required and, where mounted together, they shall be fitted in a common box.

Switches for use in areas designated for surface installation shall be quick make quick break fixed grid industrial types mounted in galvanized malleable iron boxes with protected dolly and arranged where necessary for multigang switching.

Switches for use in areas designated for flush installation shall be micro break types fixed to white plastic cover plates and mounted in galvanized steel flush type boxes.

Switch boxes shall be galvanized and fitted with screwed stainless-steel front plates having a 6 mm overlap minimum for flush installations. They shall be suitably barriered and labelled where two phases are connected in the same box.

Switches mounted externally shall be of weatherproof pattern to IP55 level fitted with machined box and cover joint, brass operating handles, neoprene weathertight seals and external fixing feet.

Where DC emergency lighting circuits are to be switched, double pole quick make, quick break switches with pillar type terminals and earthing straps shall be provided.

Switches shall be mounted 1.4 m above finished floor level.

Pushbutton switches shall either be flush or surface types contained in galvanized steel boxes and be single pole rated for 5 Amps. Pushbuttons shall be made of non-hygroscopic material, be non-swelling and so fitted as to avoid any possibility of sticking.

The terminals for all switches shall be adequate to accommodate 2 conductors, each a minimum of 1.5 mm^2 in area.

13.19 Lighting Fittings

Illustrations and/or samples of all lighting fittings which the Contractor proposes to purchase shall be submitted to the Employer / Engineer for approval before issuing any sub-orders.

Lighting fittings for interior and exterior use are to be manufactured and tested in accordance with the appropriate sections of BS 4533, IEC 60162 or equivalent and together with all components are to be suitable for service and operation in the tropical climate stated.

Each fitting is to be complete with all lamp holders, control gear, internal wiring, fused terminal block, earth terminal and reflectors or diffusers as specified. The design of each fitting is to be such as to minimize the effect of glare and such that the ingress of dust, flies and insects is prevented, where open type fittings are used it is to be impossible for insects to become lodged therein.

The control gear for use with fluorescent lamps is to be quick or resonant start type without starters. Chokes are to be impregnated and solidly filled with polyester resin, or other approved high melting compound, are to be manufactured to restrict the third harmonic content to less than 17% of the uncorrected current value and are to be silent in operation.

The built-in ballast units shall comply with IEC 60082 and shall include radio interference suppressors and capacitors to correct the fitting power factor to a minimum of 0.85 lagging. Control gear noise levels shall be minimal.

Fittings shall be supplied complete with closed end vitreous enameled metal reflectors or totally enclosed opal plastic diffusers, which shall be fully interchangeable.

Dispersive reflector fittings suitable for mercury bulb fluorescent or tungsten filament lamps shall be of heavy gauge sheet steel finished vitreous enamel. They shall be fitted with anti vibrators and arranged for conduit box mounting, direct or pendant, on galvanized ball and socket dome type lids.

Bulkhead fittings shall have cast bases tapped for conduit entry, hinged bezels, heat resisting prismatic glasses fitted with neoprene gaskets and porcelain lampholders. Circuit cable shall not be connected direct to bulkhead fittings but shall terminate in a fixed base connector mounted in a conduit box adjacent to the fitting. Final connections to each fitting shall be carried out with silicone rubber covered cable. All bulkhead fittings shall be watertight pattern.

Internal connections are to comprise stranded conductors not less than 0.75 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 galvanized finish according to the manufacturer's standard product.

Lamp holders for tungsten lamps up to 150 watts shall be brass or porcelain BC type and for higher ratings shall be ES or GES type according to size. Fittings for housing tungsten lamps exceeding 150 watts rating are to be provided with an approved method of dissipating heat from the lamp cap and terminal housing.

Lamp holders as applicable are to be suitable for the lamp specified.

Lighting fittings are to be of the type description as generally set out in sub-clause 13.28 of this Section. The type references used are to be repeated in the Schedules and on the drawings.

13.20 Lamps

The Contract includes the supply and erection of all lamps and tubes necessary to complete the installation.

Fluorescent lamps shall be manufactured and tested in accordance with BS1853, IEC 60081 or equivalent, shall be bi pin types and shall have colour rendering values of X = 0.335 and Y= 0.342 (i.e., Colour 2) on the CIE chromaticity scale.

Tungsten lamps shall be manufactured and tested in accordance with BS 161 or equivalent and shall be bayonet cap for lamps up to and including 100 watts. Lamps rated for 150 watts and higher shall have Edison screw caps. Low wattage lamps used in exit signs and emergency lighting units may be small or miniature Edison screw.

Discharge lamps shall be manufactured and tested in accordance with BS 3677 or equivalent. Mercury vapour lamps shall be fluorescent types having a 10% red ratio colour correction, whenever used.

13.21 Socket Outlets and Fused Spur Outlets

Each socket outlet shall comply with the requirements of the BS 1363 or equivalent and shall be the interlocked shuttered and switched types arranged for surface or flush mounting in single or multi -gang units as appropriate.

Each fused spur outlet shall be equipped with double pole isolator, a fuse to BS 1362 or equivalent and where required front entry for flexible connection.

Each socket outlet and fused spur outlet shall be equipped with a galvanized metal box with earth terminal.

Each group of five socket outlets is to be provided with a matching fused plug top.

All socket outlets for exterior use shall be galvanized and weatherproof and be equipped with screwed dustproofed cap attached to the socket by means of a chain.

13.22 Time Switches

Time switches for use with lighting systems shall be the synchronous motor wound types protected by a suitably rated fuse for 230 volts operation with a nine hour reserve spring and are to be fitted with a twenty four hour hand set dial, two "off" and two "on" levers and manual operation pushbutton. The main contacts shall be rated for 20 Amps on a 230 Volt 50 Hz AC supply.

Time switches shall be suitable for mounting in the distribution boards supplying the circuits to be controlled.

13.23 Poles

Lighting poles shall be tapered, of hot dip galvanized steel with bituminous preservative inside and outside at the base and shall be approved by the Employer / Engineer.

Each pole shall be equipped with a base section compartment of 470 mm by 150 mm to house an inspection trap, lockable door, fused cutout, cable entry and terminations for both the incoming and outgoing power cables and secondary cables feeding the light sources.

Poles for substation lighting shall support the floodlights at 11 m above ground level and poles for access roadway lights shall support the lanterns at 4.5 m above ground level.

The Contractor shall ensure each pole is provided with foundations suitable for the ground conditions occurring at each Site.

13.24 Interior Installations

Wiring for the lighting and socket outlet installations shall comprise PVC cables drawn into conduits attached to walls, structural or roof steelwork or ceilings as appropriate (refer sub-clauses 13.13 and 13.14).

Surface and flush type installations are required according to the particular area as indicated in the schedule appended to this section.

In areas where flush type installations are indicated the wiring shall be drawn into conduits buried under wall finishes or concealed above ceilings as appropriate.

All fixings shall be of a type approved by the Employer / Engineer and all metalwork used shall be galvanized. Fixings to structural steelwork shall be with purpose made brackets or clamps; the drilling of structural steelwork will not be permitted.

Cleats with two screw fixings shall be used for supporting conduits at not greater than 2 m intervals.

All switchboxes, socket outlet boxes and items of a similar type shall be fixed with two screws or bolts.

Switches and pushbuttons for lighting circuits shall be mounted at 1400 mm above finished floor level. Socket outlets shall be mounted 500 m above finished floor level but those for use with workshop benches shall be mounted 150 mm clear of the bench working surface.

Lighting fittings shall be attached to ceilings, walls, trunking or roof steelwork or suspended therefrom as appropriate.

Where fittings are to be suspended, rod type suspension units shall be employed.

Final connections to all suspended lighting fittings shall be with heat resistant flexible cable terminated in porcelain clad connectors in the ceiling or junction box which shall also terminate the main circuit cable. The cable length shall be such that the suspension unit supports the full weight of the lighting fittings.

Where recessed type lighting fittings are to be installed suspension units shall be used to prevent the weight of the fittings being applied to the suspended ceiling. It shall be possible to carry out maintenance from the underside of the fitting without disturbing the false ceiling. To facilitate this, the final connection to each fitting shall be with heat resistant flexible cable from a plug-in type ceiling rose mounted above the false ceiling.

All cables not contained within conduit for their whole route shall be terminated with a cable gland.

Where lighting fittings are mounted direct on walls or ceilings, the main circuit cables may be connected into the fitting terminal block. Where terminal blocks do not exist within the lighting fitting, flexible heat resistant cable shall be used connected to a separate junction box.

Earth continuity shall be maintained throughout the entire wiring installation with separate insulated earth continuity conductors of adequate cross section ultimately connected to a common earth terminal at the respective distribution board.

Within the interior installation adequate provision shall be made for connection to small ventilating fans, which are not energized from the central air conditioning control and starter panel.

Each and every trunking route shall be bonded across all joints with external copper bonding links supplied for the purpose.

13.25 Exterior Installation

Exterior substation lighting fittings shall be attached to substation walls at high level or pole mounted as appropriate. Security lighting round the perimeter wall/fence is to be provided.

When locating the floodlights for the switchyard lighting, the Contractor shall ensure that all floodlights are outside safety clearance for the high voltage switchgear at the particular location.

Cables to exterior lighting shall be laid direct in ground, laid in concrete trenches or cleated to buildings structures as appropriate to the route requirement. The cables shall be terminated at a cut out located at the base of each support. Wiring between the cut out and the control gear or lantern shall be with multicore cable run within poles or with cable drawn into galvanized steel conduit attached to the supporting structure.

13.26 Emergency Lighting

Emergency lighting shall comprise lighting fittings of the types indicated in the schedule appended to in sub-clause 13.28.

The system shall be so arranged that on failure of the normal AC supplies to the lighting installation the emergency lighting system will automatically be switched on. Other than those of the "on demand" type, all emergency lighting shall be switched "off" 5 minutes after restoration of normal supplies. Each emergency lighting unit shall have a minimum 3-hour rating.

Sufficient fittings of Type E3 shall be provided in each room to enable the rooms and building to be evacuated safely.

In addition, in designated working areas emergency manually switched lighting, to give not less than 30 lux, shall be provided utilizing type E4 fittings. Switches shall be labelled to the approval of the Employer / Engineer.

The security lighting scheme shall illuminate the area to 6 metres inside the perimeter wall to the lighting level specified.

13.27 Telephone System

Not used.

13.28 Schedule of Lighting Fittings and Socket Outlets

All lighting schemes are to utilize fittings and lamp types which are available locally in Bangladesh to ensure that replacements are readily acceptable.

Lighting fittings described in this Schedule shall also meet the general requirements of the clause for Lighting Fittings of this specification.

TYPE F1 Shall indicate a basic channel complete with control gear and lamp holders for one fluorescent lamp, equipped with an open-ended metal reflector having upward light slots.

TYPE F2 Shall indicate a fitting which shall comply generally with the description for Type FI but be equipped for use with two lamps.

TYPE F3 Shall indicate a recessed modular fitting suitable for mounting in a suspended ceiling and equipped with a clear prismatic controller. The metalwork and trim are to comprise a rigid welded unit so arranged as to be invisible when erected complete with controller. The fitting is to be equipped with a pre wired removable gear tray and adjusting facilities to enable levelling relative to the ceiling to be carried out after erection. The assembly is to be complete with control gear and lamp holders for one 1500 mm long 65 watt fluorescent lamp.

TYPE F4 Shall indicate a fitting which shall generally comply with the description F3 but with an open type grid diffuser.

TYPE F5 Shall indicate a dust tight, weatherproof and vapour resistant fitting, having a grey polyester fibre glass reinforced chassis containing the control gear and having lamp holders for one 1500 fluorescent lamp. The fitting shall be complete with a vacuum formed acrylic diffuser which is secured to the body with injection moulded toggles and sealed with a neoprene gasket.

TYPE F6 Shall indicate a weatherproof bulkhead fitting with a cast aluminium base and vandal resistant diffuser equipped with control gear and lamp holders for two fluorescent lamps.

TYPE E1 Shall indicate a self-contained, self-sustained (normally off) emergency lighting unit, complete with integral batteries and control gear, with the words "EXIT" in white letters on red background in English and Arabic. It shall be energized 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 energized 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 energized 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 enameled 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 enameled white internally and equipped with reflector bowl of heat resisting glass, all suitable for housing the lamp holder and control gear for one 150 Watt sodium vapour lamp. The fitting to be equipped with pole arm suitable to give an outreach of 1 metre.

TYPE S1 Shall indicate a 13 Amp single or double gang flush mounted switched socket outlet.

TYPE S2 Shall indicate a 13 Amp single or double gang surface mounted switched socket outlet.

TYPE S3 Shall indicate an ironclad one gang heavy duty 4 pole interlocked switched socket outlet with scraping earth connection suitable for use on a 400 V 3 phase 4 wire 50 Hz for 125 A. Each socket is to be supplied complete with cable box with 2 glands, suitable for terminating a PVCWPVC cable and shall be fitted with a screwed dustproof cap attached to the top of the socket by means of a chain. Matching plugs to be provided in each socket.

TYPES4 Shall indicate a 15 amp 3 phase 4 wire switched socket outlet with plug flush mounted.

13.29 Schedule of Lighting Requirements

13.29.1 Control Building

	Location	Average Service Illuminance (Lux)	Glare Index
(a)	Control / Relay / Operator Room	250	25
(b)	Behind panels	100	-
(c)	Battery Room	200	-
(d)	Corridors, Stairs	80	20

The height of working plane should be 0.6 - 0.9 meter.

13.29.2 Outdoor Areas

	Location	Average Service Illuminance (Lux)	Glare Index
(a)	Switchyard Floodlighting	20	-
(b)	Roadway Lighting	20	-
(c)	Perimeter Wall Security	10	-
(d)	Control Building Exterior	15	-

13.30 Air Conditioning and Ventilation

13.30.1 Scope of Work

The Works under this Section covers the design, supply, delivery, installation, commissioning and setting to work of the heating and ventilating systems for the extended portion of the substation control buildings.

All heating and ventilating systems shall be fully automatic in operation and shall be capable of maintaining internal conditions within the bands of temperature and humidity specified hereafter. The substations are normally manned and allowance shall be made for at least four persons on site in the design.

13.30.2 Heating

Electrical heating shall be provided for each room of the extended portion of the substation control buildings. Except for the battery room, the heating shall comprise of 1500 mm long tubular heaters with a load of 60 watts/foot (300 mm) which shall be mounted in double tier banks. Electric heaters shall be fitted with bright plate safety guards affording full protection to the heating tubes. The Contractor shall assess the thermal performance of the building and ensure that the sizes of units are adequate to maintain internal temperatures of 5° C when the external temperature is -3°C, measured 1200 mm above finished floor level out of an air stream.

The heaters in each room shall be controlled by contactors which have thermostats connected into the coil circuit. Thermostats shall be located in each room and have a maximum cut-off temperature of 17° C.

Each heater bank shall be equipped with a local isolator. The lower tubular heater shall be mounted at 500 mm above finished floor level.

13.30.3 Air Conditioning

The following areas of the extended portion, as required, shall be air conditioned:

- Switchyard Control/Relay room
- Communication/SCADA/PLC room

Air conditioning shall be provided in the form of Air-Cooled Split System Air Handling Units. The systems shall handle predominantly recirculated air with a controlled quantity of fresh air introduced either at each unit or independently via a separate supply and extract system. Supply air distribution ducts for the Control/Relay room shall be located in the false ceiling serving supply diffusers. Return (recirculated) air shall be drawn in through the front of each unit.

The cooling medium for the split System Air Handling Units shall be direct expansion provided by air cooled refrigeration condensing units located on the roof of the building or wall mounted on building exterior and interconnected by refrigerant pipework to multi circuit direct expansion cooling coils.

Air conditioning system shall be thermostatically controlled to maintain internal conditions under continuous operation within the limits stated. Plant shall be arranged to facilitate maintenance and future replacement of equipment.

13.30.4 Mechanical Ventilation

Supply and extract ventilation shall be provided to serve the following areas of the extended portion, as required:

- Switchgear room

- Battery Rooms
- Cable basement

Supply air handling plants shall consist of a sand trap fresh air intake louvre, insect screen, pre-filter, bag filter, electric air heater battery, fan and distribution ductwork.

The air intake shall not face the prevailing wind.

Extract ventilation shall be provided by means of wall mounting fans, roof extract units or ducted systems with louvred discharges to atmosphere. Individual extract fans shall be provided for Battery room.

Extract fans for battery room shall be corrosion resistant throughout, with a 4 mm PVC lining.

13.30.5 Basis for Design

(a) External Design Conditions

The external conditions for the calculation of duties for the mechanical services shall be with mean monthly, maximum and minimum values as below:

Maximum ambient shade temperature		42 °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		100mW/sq.m

All plant and equipment installed externally, or which can be affected by external condition shall be capable of withstanding without damage or deterioration the effects of solar radiation, rain, wind, dust, sand storms or other weather phenomena prevalent in the area in which particular building is located.

(b) Internal Design Conditions

Air conditioning systems shall be capable of maintaining internal conditions in all airconditioned 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:

Switchgear Rooms	10
Battery Rooms	10
Cable basement	6
Other general areas	4

All air conditioning and ventilating systems shall be designed for continuous operation with n-1 contingency i.e. failure of one device shall not reduce the required/designed cooling and ventilation

Plant shall be arranged to facilitate maintenance and future replacement of equipment. Such provision shall be made available that, the Air Conditioning Device shall be remotely monitored and controlled.

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. The full Air Conditioning Design shall be submitted to the Employer / Engineer for review and approval. 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 and taken approval from the Employer / Engineer.

13.30.6 Air Cooled Condensing Units

The cooling medium for the air conditioning shall be direct expansion refrigeration provided by air cooled condensing units located externally.

The condensing units shall be of the fully packaged type requiring only site connection of refrigeration pipework, isolated electrical supply and input from the control system.

The individual item of refrigerant equipment shall be matched such that the required performance of the evaporator is achieved concurrently with the satisfactory operation of the compressor and adequate heat rejection at the condenser. Each system as a whole shall maintain the correct duty at the design ambient and operate at the maximum ambient conditions stated without exceeding the safe operational limits of any individual item of equipment and without causing any safety device to operate.

All electrical equipment, control, magnetic coils and solenoids shall be manufactured specifically for operation at the electrical characteristics specified herein and such items designed for any other characteristics shall not be used.

Air cooled condensing units and air handling units that are inter-connected on site with refrigerant piping shall all be supplied by the same manufacturer.

The casings of the condensing unit shall be weatherproof and shall incorporate adequate access and inspection panels secured in place by rustproof fasteners.

The whole of the casing shall be treated for corrosion and weather resistance and 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 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.

13.30.7 Refrigeration Systems

Liquid lines shall be insulated where they are in direct sunlight or where they pass though non-air-conditioned areas.

Suction lines shall be insulated over their entire length.

All insulation to refrigeration pipework shall be flexible closed cell foam phenolic rubber type with a temperature range of -40°C to +105°C and having a thermal conductivity of 0.0375 w/m °C at 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:

i) Suction Lines

Location	Insulation thickness for O.D. 6-10 mm	Pipe Sizes Range 12-22 mm
Exposed to weather	13 mm	19 mm
In air-conditioned spaces	9 mm	19 mm
In non-air-conditioned spaces	9 mm	9 mm

ii) Liquid Lines

Exposed to weather and in non-air-conditioned spaces	9 mm	9 mm

The refrigerant used shall conform to BS 4334 Group 1 or equivalent and shall be non-explosive, non-combustive, non-toxic and non-irritating.

Packaged air conditioning plant items requiring interconnection with refrigeration piping on site shall be leak tested by the manufacturers and delivered to site with a holding charge of refrigerant.

13.30.8 Console Air Conditioning Units

Console model room air conditioners shall be of the slim-line pattern and complete with 4-way adjustable grilles, heavy gauge zinc coated stove enameled sheet steel casing with single or two colour decorative finish. Electrical heaters shall not be fitted.

The casing and position shall be such as to protrude not more than 250 mm into the air-conditioned space and no external projection beyond the building line will be permitted other than the fixing of the condenser cooling air grille.

The units shall be extremely quiet ill operation, the noise level not being higher than 30 dB. All sections of the casing shall be acoustically and thermally insulated.

Compressors shall be of the fully hermetic type, fitted with resilient mountings and complete with thermal overload protection and starting relays.

Evaporators shall be manufactured of' copper tube with copper or aluminum fins mechanically bonded. The evaporator fan shall be of double inlet, double width type and complete with continuously rated totally enclosed electric motor.

Filters shall be of the washable type, suitably positioned for easy access for cleaning.

Automatic control by means of an integral thermostat shall be provided, together with the safety control to prevent excessive cooling.

Motors shall be air cooled and units shall be complete with internally mounted condenser cooling fans with totally enclosed motors.

Fresh air shall be introduced separately by means of a central fresh air plant, where these units are proposed to serve individual offices in a building.

Units shall be supplied as a whole and be suitable for easy removal and re-positioning should this be desired at a later date.

13.30.9 Ductwork

All sheet metal ducting shall be manufactured and installed in accordance with the Institution of Heating arid Ventilation Engineers Guide to Current Practice Section B 16, the American Society of Heating, Refrigeration and Air Conditioning Engineers, or the Heating and Ventilating Bidders Association of United Kingdom Specification DW/142 or equivalent international standards for sheet metal ductwork for low velocity low pressure air system with air velocity of up to 10 m/s.

All ductwork and fittings serving hazardous areas, such as battery rooms where corrosive fumes are expected, shall be of rigid PVC materials.

13.30.10 Condensate Drains

Provision shall be made for condensate to be passed into the rainwater drainage system. Condensate drains must be routed directly into the drainage system or individual soakaways. Pipes discharging onto substation or building brick paving will not be permitted.

13.30.11 Extract Ventilation Units

This clause covers fan powered extract ventilation units for mounting in walls and windows, on roofs and in plant rooms.

Extract units shall incorporate propeller, aerofoil, axial, centrifugal or hybrid type fans which shall be constructed in accordance with the relevant sections of this specification.

Roof units shall comprise a galvanized sheet steel base suitable for use as a weathering skirt, a mild steel fan/motor mounting frame and a spun aluminium cowl. The sheet steel base shall be constructed to support the fan/motor without distortion and where the fan is belt driven shall incorporate a rigid subframe for motor mounting. Fans shall be diaphragm mounted or fitted with a cylindrical casing designed for removal from the unit from inside or outside the building without disturbing the weathering skirt or cowl fixings. The cowl shall be weatherproofed and shall be hinge mounted to provide complete access to the fad/motor.

Lubricating points shall be extended to a convenient access point.

Stainless steel nuts, bolts and washers shall be used for all fixings exposed to the weather.

13.30.12 Air Filters

All filter media hall be properly bonded and protected against filter fibre or particle migration. The direction of air flow shall be clearly marked on all filter panels and on installation frames.

Access to filters shall be through removal panels fitted with quick release fasteners and rubber sealing gaskets.

Each disposable panel filter system shall be provided with 4 complete spare sets for use during the commissioning period. These sets shall be in addition to any filter cells supplied as spares in accordance wit11 the general clauses of this specifications.

Filter performance shall, unless otherwise noted, be taken to mean the Overall Gravometric Efficiency against BS 6540: Part I Duct Test or equivalent.

Filter media of all types and sizes shall be supported in rigid peripheral frames with internal or external wire support of the media to ensure that the media shall not collapse under air flow. The holding frames shall incorporate accurately sized channel sections to provide a good fitting for the filters.

The type of washable and/or disposal panel filters shall be subject to the Engineer's approval.

13.30.13 Grilles and Louvres

Grilles shall be of aluminum construction and shall be fixed by means of subframe with spring clips or screw fixings.

The corners of front flanges of grilles and subframes shall be mitred and jointed to produce a clean unbroken appearance and visible aluminum sections shall be free from extrusion marks.

Front flanges shall be at least 30mm wide and shall incorporate a lip of at least 4.5 mm and a felt gasket. Blades shall be fixed at even centers with intermediate mullions giving support for blades of more than 550 mm long. Grille finish shall be anodised natural aluminium colour except where otherwise indicated.

All grilles shall be fitted with an opened blade damper for regulation purposes and shall be fitted with acoustically lined inlet plenums where necessary in order to comply with the acoustic limits of this specification.

Outdoor air louvres shall be of all extruded aluminium construction fitted with opposed blade dampers in the connected ducting where necessary for air flow regulation, Movable blade louvres shall not be used.

Louvres shall be weatherproof and shall incorporate an aluminium wire mesh screen on the inside surface.

The dimensions of louvres for mounting in the building structure shall suit the concrete block or brick modules and shall be fixed to a hardwood frame.

13.30.14 Control Equipment

Each item of shall be provided with local isolation and/or emergency stop buttons to facilitate maintenance, inspection and emergency operation.

The control system shall be of the electronic type, capable of providing the degree of thermostatic control specified. The 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.

13.30.15 Electrical Connections

All electrical power control cables and wiring associated with the air conditioning and ventilation systems, including all connections between control panels, valves, thermostats, sensing probes and other like items shall be supplied, installed and connected up as part of this Contract.

The cabling and wiring system shall comply with the requirements of the relevant clauses of this Specification and be either surface or flush installation as appropriate.

Cables and wiring shall comprise either PVCWPVC laid in cleats or trenches, or PVC drawn into galvanized conduits and trunking.

Final connections to electric motors and all other items of plant subject to movement and vibration shall comprise flexible cable in flexible conduit.

13.30.16 Manufacturers

Wherever possible all air conditioning and ventilating plant shall be selected from a single manufacturer's product range and origin. Where this is not possible, because of practical or technical constraints. then the number of different sources of origin shall. be kept to a minimum. Local service facilities shall be available for the equipment proposed.

The Bidder shall provide, with his submission, illustrated technical literature covering all plant and equipment offered.

13.30.17 Standards

All air conditioning and ventilation equipment shall conform to British Standards, Chartered Institution of Building Services or ASHRAE recommendations or other recognized International Standards.

13.30.18 Approval

The Contractor shall submit to the Employer / Engineer for approval of all his calculations forming the basis and details for the selection of air conditioning and ventilating system and full working drawings. Such approval shall not relieve the Contractor of his contractual responsibilities.

13.30.19 Maintenance

The Contractor shall be responsible for the maintenance of all installations covered by this specification for the period stated elsewhere in this Bidding Documents.

13.31 Earthing and Bonding

All equipment being supplied shall be effectively bonded to ensure earth continuity throughout the system. Continuity may be provided by means of cable armouring but a separate earth continuity conductor shall be included with all wiring in conduits. No reliance shall be placed on metal to metal joints in conduits for earth continuity. The earth continuity conductors shall as far as possible be in one continuous length to the furthest part of the installation from the controlling switchboard. The earth conductor shall connect all metal cases housing electrical equipment. The branches shall be connected to the main conductor by permanently soldered on mechanically clamped joints.

13.32 Testing and Commissioning

The Contractor shall be required to prove that the installed system meets the design requirements and specification to the satisfaction of the Employer / Engineer.

14. Fibre Optic Multiplexer and Power Line Carrier Equipment for Communication and Protection

14.1 Scope

This specification describes the communication requirements for the transport of voice, data and protection signals between the Payra Substation, Gopalganj Substation, Aminbazar Substations and the National Load Dispatching Centre (NLDC) in Rampura, including engineering, configuration, testing, installation, and commissioning.

Extension of fibre optic multiplexer, wave trap and power line carrier terminal devices shall be made as required for Gopalganj and Aminbazar sub-stations.

Drawing in this Section shows the planned arrangements of fibre optic multiplexer equipment for communication and protection. 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.

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 this Contract.

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 standardization of operating performance and facilities offered equipment shall be compatible with the existing ones.

For standardization of operation performance, facilities and spare requirements, the fibre optic multiplexer equipment for communication and protection to be supplied under this Project shall consist of equipment which can totally be integrated into the existing telecommunication system in PGCB's network, including the telecommunication network management system. The fibre optic multiplexes 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 or GE (former Alstom). Since, some of the above mentioned make (i.e. ABB or GE (former Alstom)) Telecommunication System is already in PGCB's System and their performance is proven.

14.2 Summary of Standards

The Equipment shall comply with the latest ITU-T recommendations for the plesiochronous and synchronous hierarchies.

The equipment shall be independent type tested. In particular, the following recommendations shall be covered.

14.2.1 Recommendations on PDH Interfaces

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.711: Pulse code modulation (PCM) of voice frequencies
- ITU-T G.712: Transmission performance characteristics of pulse code modulation channels
- ITU-T G.732: General aspects of digital transmission systems – Terminal equipment - Characteristics of primary PCM multiplex equipment operating at 2048 kbit/s
- ITU-T G.735: Characteristics of primary multiplex equipment operating at 2048 kbit/s and offering synchronous digital access at 384 kbit/s and/or 64 kbit/s
- ITU-T G.736: General aspects of digital transmission - Characteristics of a synchronous digital multiplex equipment operating at 2048 kbit/s
- ITU-T G.737: Characteristics of external access equipment operating at 2048 kbit/s and offering synchronous digital access at 384 kbit/s and/or 64 kbit/s
- ITU-T G.823: The control of jitter and wander within digital networks, which are based on the 2048 kbit/s hierarchy
- ITU-T G.826: Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate

14.2.2 Recommendations on the Architecture of Optical SDH Interfaces

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 V1.1.2: Generic Processes and Performance
- ETS 300 417-2-1 / EN 300 417-2-1 V1.1.2: SDH and PDH Physical Section Layer Functions
- ETS 300 417-3-1 / EN 300 417-3-1 V1.1.2: STM-N Regenerator & Multiplex Section Layer Functions
- ETS 300 417-4-1 / EN 300 417-4-1 V1.1.2: SDH Path Layer Functions

ITU

- ITU-T G.707: Network node interface for the synchronous digital hierarchy
- ITU-T G.783: Characteristics of synchronous digital hierarchy (SDH): equipment functional blocks
- ITU-T G.803: Architecture of transport networks based on the synchronous digital hierarchy (SDH)
- ITU-T G.805: Generic functional architecture of transport networks
- ITU-T G.826: Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate
- ITU-T G.841: Types and characteristics of synchronous digital hierarchy (SDH) network protection architectures
- ITU-T G.957: Optical interfaces for equipment and systems relating to the synchronous digital hierarchy
- ITU-T G.958: Digital line systems based on the synchronous digital hierarchy for use on optical fibre cables

- ITU-T M.2101.1: Performance limits for bringing into service and maintenance of international SDH paths and multiplex section
- ITU-T T.50: International Reference Alphabet (IRA) - Information technology 7 bit coded character set for information interchange

14.2.3 Recommendations on the Synchronisation and Timing of Optical SDH Interfaces

ETS/EN

- ETS 300 417-6-1 / EN 300 417-6-1 V1.1.2: Synchronisation Layer Functions
- ETS 300 462-1 / EN 300 462-1-1 V1.1.1: 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)

14.3 Abbreviations

ADM	Add-drop multiplexed
ALS	Automatic Laser Shutdown
BIP	Bit Interleaved Parity
CAS	Channel Associated Signalling
CAP	Carrier-less Amplitude and Phase
CRC	Cyclic Redundancy Check
DTMF	Dual Tone Multi-Frequency
EN	European Norm
EOW	Engineering Order Wire
ETS	European Telecommunications Standards
GPS	Global
HDSL	High Density Subscriber Line
IEC	International Electrical Commission
ITU	International Telecommunication Union
IP	Internet Protocol
ISDN	Integrated Services Digital Network
MCMI	Multi Coded Mark Inversion
MS	Multiplex Section
NE	Network Element
NMS	Network Management System
LAN	Local Area Network
OS	Optical Section
OSPF	Open Shortest Path First
PDH	Plesiochronous Digital Hierarchy

PPP	Point-to-Point Protocol
RS	Regenerator Section
SDH	Synchronous Digital Hierarchy
SNMP	Simple Network Management Protocol
SOH	Section Overhead
STM	Synchronous Transport Module
TCP	Transmission Control Protocol
TTI	Trail Trace Identifier
VC	Virtual Container
VF	Voice Frequency

14.4 General Requirements

The digital multiplex equipment shall be universal, software-controlled, and provide various interface cards to connect tributary interfaces signals such as voice, teleprotection and data to aggregate interfaces. On aggregate level 2 Mbit/s and 8 Mbit/s electrical interfaces complying with ITU-T recommendations G.703 / G.704 and 2 Mbit/s HDSL interfaces shall be available. In addition, optical STM-4 aggregate interfaces of 622.8 Mbit/s for 132 kV line and STM-16 of 2.5Gbit/s for 400kV line 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 2 Mbit/s streams. Path protection on 64 kbit/s and 2 Mbit/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, tele protection 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
- 4-wire E&M voice interface
- G.703, 64 kbit/s data Interface
- X.24/V.11 (RS-422), Nx 64 kbit/s data interface
- V.24/V.28 (RS-232), data interface
- V.35, Nx 64 kbit/s data interface
- Data interface V.36 (RS-449), Nx 64 kbit/s data interface (V.10)
- Alarm collection interface
- Teleprotection command interface (preferably integrated, for Distance Protection)
- Binary signal (status and control) interface
- 2 Mbit/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-16 (2.5 Gbps) and STM-4 (622 Mbps) optical SFP based interface
- STM-1 (155 Mbit/s) optical 1+1 interface for medium and long distances, with automatic laser shut down.
- STM-1 (155 Mbit/s) optical add-drop interface for medium and long distances, with automatic laser shut down
- STM-1 (155 Mbit/s) electrical interface
- 2 Mbit/s HDSL interface

The equipment shall be equipped with a ringing generator for analogue subscriber interfaces.

14.5 General Conditions

The same equipment shall be used as a terminal, for through connections (transit, repeater) and as add-drop multiplexer (ADM) with integrated optical line modules.

First order multiplexing (2048 Mbit/s), second order multiplexing (8448 Mbit/s/s) and STM-4 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 shelf.

14.5.1 Channel Capacity: Digital Cross Connection

The equipment shall be equipped with a redundant cross connection function with decentralised cross connection functions on each board.

The cross connect capacity shall be minimum 40x2 Mbit/s, or 200x64 kbit/s non-blocking.

14.5.2 Redundant Centralised Functions

The equipment shall be equipped with redundant circuits for all centralised functions.

14.5.3 Power Supply

The multiplex equipment shall operate at 48 VDC +/- 15%. Redundant power-supply shall be supported. 48 VDC shall be taken from the existing 48 VDC system with extension of batteries / chargers / distribution system where needed.

14.5.4 ITU Compliance

The Equipment shall comply to the latest ITU-T recommendations for the plesiochronous and synchronous hierarchies, such as:

G.702-704, G.706, G.711-714, G.732, G.735-737, G.742, G.826, G.823, Q.552

14.5.5 Electromagnetic Compatibility and Safety Regulations

The equipment shall comply with the EN50022, EN50082, IEC 801-2, IEC 801-6 and shall be conformant with CE.

14.5.6 Ambient Conditions

Storage and transport: -40 ... +70°C; 98% (no condensation)
Operation: -5 ... +45 °C, humidity of max. 95% (no condensation)

14.5.7 Mechanical Construction

The equipment shall be of robust design. All tributary and aggregate units shall be integrated in the same shelf.

All connectors shall be accessible from the front.

14.5.8 Network Management System

The equipment shall be software programmable, either by a local craft terminal preferably notebook or 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 the PDH and SDH network.

14.5.9 1+1 Path Protection

The equipment shall provide means to protect 64 kBit/s channels. The protection shall be end to end from one interface (telephone or data) to the other. It shall switch automatically from the main channel to the standby channel. It shall be configurable whether the system switches back to the main channel (reversible switching) or not (non-reversible).

If a path has switched to its standby route because the main route is disturbed this shall be indicated with an alarm.

The switching shall be done within the multiplexer without using the Network Management System.

14.5.10 1+1 Section Protection

The equipment shall provide means to protect 8 Mbit/s and 622.8 Mbit/s connections. It shall be possible to use two independent links: one as the main and the other as the standby. The system shall automatically switch to the standby connection and generate an alarm if the main connection is disturbed.

The switching shall be done within the multiplexer without using the Network Management System.

14.5.11 Network Topology

It shall be possible to build point to point, linear, ring, T, and meshed networks.

14.5.12 Synchronisation

The equipment shall be synchronisable with an external clock, with connected 2048 Mbit/s signals and/ or with internal oscillator. The synchronisation shall be configurable and it shall be possible to distribute the synchronisation to other equipment as well.

The system shall have means to switch to select the synchronisation source as well as means to prevent the system from switching synchronisation loops. The equipment shall be capable select the synchronisation source by means of the SSM (Synchronisation Status Messaging) feature according to ITU-T G.704 or priority based.

14.5.13 Alarms

Each module shall supervise its functions and shall have an alarm-indication LED on its front. All alarms shall be collected by the NMS.

Each node shall be capable to collect up to 50 external alarms.

14.5.14 Test Loops

The equipment shall provide means to loop signals on 64 kBit/s level as well as on 2 Mbit/s level. It shall indicate an alarm if a loop is activated. It shall have the possibility to determine the time after which an activated loop is switched back.

14.5.15 Maintenance Facilities

Every Network Element shall have a built-in Signal Generator and Analyser to analyse communication paths. It must be possible to cross connect the Generator and Analyser to transmission channels and terminate the signal in other Network Elements. The configuration must be possible locally with the craft access terminal and remotely with the NMS or the craft access terminal.

It must be possible to loop-back signals locally and remotely using the craft access terminal or the NMS.

14.6 Requirements for Transport Level

14.6.1 SDH Aggregate Units

The interface shall be designed for use on single mode fibre at 1310 nm and 622.80 nm. The optical connectors shall be E2000.

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:

- 2x STM-1/4 & 2x STM-1 optical 4-port interface
- 2x STM-4/16 & 2x STM-1/4 optical 4-port interface

This interface shall provide Multiples Section Protection (MSP):

- 1+1 Section Protection
- STM-4 (622.8 Mbit/s) electrical 1-port interface

14.6.2 HDSL Aggregate Units

2 Mbit/s HDSL interface

The HDSL interface shall provide means to interconnect the multiplexer over two pairs of copper wire up to 12 km 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.

2 Mbit/s HDSL Desktop Terminal

This Terminal shall provide a HDSL interface to transmit 2 Mbit/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, 2 Mbit/s, 75 ohm
- G.703, 2Mbit/s, 120 ohm
- X.21/V11, Nx 64 kBit/s (N = 1 .. 32)
- V.35, Nx 64 kBit/s (N = 1 .. 32)
- V.36 / RS449, Nx64 kBit/s (N = 1 .. 32)

LAN connection:

10/100 BaseT 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 2 Mbit/s link over two pairs of copper.

HDSL Repeater:

An HDSL repeater solution for distances longer than 12 km shall be offered including a remote powering solution.

HDSL Line Protection:

The HDSL equipment shall (where necessary) be protected against influences of induced voltages up to 10 kV.

14.7 Tributary Units

14.7.1 4-Wire Interface (VF interface)

This interface shall provide 8 voice channels with a bandwidth of 300 Hz, 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 .. -16 dBr
Output: +7.0 .. -16 dBr

Modules where each interface can be individually configured with 1+1 path protection shall be available.

14.7.2 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 20 Hz, 25 Hz, and 50 Hz.

The following main functions shall be supported.

Downstream signalling:

- Ringing
- Metering
- Polarity reversal
- Reduced battery
- No battery

Upstream signalling:

- On/off-hook
- Pulse and DTMF dialling
- Flash impulse
- Earth key

General:

- Constant current line feeding
- Line test
- Permanent line checks
- CLIP (On-hook VF transmission)
- Metering after on-hook

14.7.3 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 .. +4 dBr
- output voice level –7.5 .. –1 dBr
- metering pulse enable/disable
- signalling bit definition
- loop back of voice to the telephone

14.7.4 Partyline 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 inband DTMF signalling to call another EOW-Terminal. The Terminal shall have an integrated DTMF decoder allowing to program a subscriber call number (1..4 digits), and two group call numbers (1..4 digits each).

14.7.5 V. 24/V.28 RS232 Interface

It shall support the following bit rates:

- 0 .. 0.3 kbit/s transp. (V.110)
- 0.6 .. 38.4kbit/s synchronous / asynchronous (V.110).

Modules where each interface can be individually configured with 1+1 path protection shall be available.

14.7.6 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.

14.7.7 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.

14.7.8 V.36 / RS 449 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.

14.7.9 64 kBit/s Codirectional Interface

This interface shall comply with the ITU-T G.703 part 1.2.1 for codirectional data transfer.

A module shall have at least 8 interfaces.

Modules where each interface can be individually configured with 1+1 path protection shall be available.

14.7.10 LAN Interface

There shall be a 10/100 BaseT interface available with Router Bridge and FRAD Function available. The following specification shall be covered:

Ethernet connection: 10/100 BaseT
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 Nx64 kBit/s and 2 Mbit/s.

14.7.11 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.

14.7.12 Teleprotection Interface

The protection of the lines shall be arranged as detailed in clause 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 250 VDC by means of software.
All inputs and outputs shall be isolated and with EMC immunity for harsh environment.

Security, Dependability and Transmission speed shall be selectable and programmable.

It shall be able to drop and insert commands, transfer commands as a transit station, it shall be possible to have AND- and OR-connections between commands.

The interface shall support T-nodes.

The Teleprotection interface shall provide an integrated non-volatile event-recorder which shall be synchronisable either internally or by GPS or a command counter which counts trip commands.

The teleprotection interface shall provide means for signal delay measurement. 1+1 protection must be available; the switching shall be done within less than 10ms.

The interface shall do automatic loop test every 60s.

Under no circumstances shall the interface cause trip-commands in case of power supply failure or when put in or out of service.

It shall be possible to synchronise all teleprotection interfaces with one GPS in one station. The GPS time shall be distributed over the teleprotection channel.

An 8-bit command addressing shall be used to prevent tripping if the signal is inadvertently re-routed through the telecommunication network.

14.7.13 Optical Protection Relays Interface

This interface shall have an optical port to connect protection relays for teleprotection to the multiplexer. It shall operate on 1300 nm use MCMI line coding and be suitable for teleprotection relays.

14.7.14 Optical Amplifier

In case of long-distance communication, which cannot be covered by a standard optical interface, optical amplifier shall be applied.

The amplifier shall:

- provide a power budget of at least 48 dB
- for bit rates from 8 Mbit/s up to 622 Mbit/s
- on a pair of single-mode fibre

- for single wavelength (single channel)
- have no dispersion limits for STM-4 applications up to 250 km.

14.7.15 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 24V DC - 60V DC.

Outputs shall be solid state relays.

The interface shall provide a 24V DC short circuit proofed auxiliary power supply.

It shall be able to drop and insert commands, transfer commands as a transit station, it shall be possible to have AND- and OR-connections between commands.

The Teleprotection interface shall provide an integrated event recorder, which shall be synchronisable either internally or by GPS.

14.7.16 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 24V DC - 60V DC.

Outputs shall be solid state relays.

The interface shall provide a 24V DC short circuit proofed auxiliary power supply.

It shall be able to drop and insert commands, transfer commands as a transit station, it shall be possible to have AND- and OR-connections between commands.

The Teleprotection interface shall provide an integrated event recorder, which shall be synchronisable either internally or by GPS.

14.7.17 2 Mbit/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 2 Mbit/s loop-back of the incoming signal as well as the loop-back of the internal signals.

14.8 Operational Telephone System

Not used

14.9 Communications DC Power Supply Equipment

14.9.1 General

(a) Basis of Design

The equipment shall comply with IEC 146 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 AC 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 AC mains supply, the rectifier shall automatically resume supply of the load requirements whilst simultaneously recharging the battery at the float voltage.

14.9.2 Configuration

The power supply installation shall comprise two batteries and two charging sources. Each charger shall be able to float charge both batteries as well as supplying the total load.

The total battery capacity shall be able to supply the total load (comprising the delivered load together with 20% spare for future use) for at least 10 hours in the event of failure of the AC mains supply.

The DC power supply equipment is required to limit the output voltage to the load within plus 15% and minus 15% of the nominal value, provided these values do not exceed the voltage guarantee of the load equipment. The power supply output positive shall be earthed.

14.9.3 Charger

(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 AC 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 AC 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 AC 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 DC output is required. This shall achieve a psophometric noise level at the output, for loads between 0 and 100%, not exceeding the equivalent of 2 mV at a frequency of 800 Hz after weighting as specified by ITU-T (CCITT).

The relative harmonic content of the input current shall comply with the European Directive for EMC, the EN 60555-2 standard. In the case of SMPS chargers active power factor correction (i.e. boost for step up converter) shall be provided to control the power factor.

The production of radio frequency interference voltages shall not exceed the values of suppression grade "N", as defined in EN 55014/55015 for thyristor-controlled type chargers, and suppression grade "B" as defined in EN 55022 for SMPS type chargers.

The performance of the DC 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 80%.

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:

- AC mains input circuit breaker
- DC output circuit breaker
- charger output current meter
- charger output voltage meter
- alarms for charge fail, DC volts high, etc.

Each alarm shall be provided with local annunciation and two sets of potential free contacts, for connection to external alarm monitoring systems.

14.9.4 Battery

(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 10 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 200 ampere hours at the 10 hour rate.

14.9.5 D.C. Distribution and Instrumentation

(a) General

The distribution section shall be designed for incoming and outgoing DC 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 48 V 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 of:

- battery ammeter (charge and discharge)
- battery voltage
- load current ammeter
- busbar voltage

An alarm indication shall be provided if the busbar voltage falls outside set limits.

The MCB auxiliary contacts and the high/low voltage alarm shall each provide local annunciation and two sets of potential free contacts, for connection to external alarm monitoring systems.

14.9.6 Housing

The above covers the mounting/housing for batteries.

A modular construction is preferred for the battery charger and DC 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 Bidders who do not offer a modular construction, separate cubicles are required for each charger and the DC distribution/instrumentation.

Annex II-14-1: Schedule of Requirements for Multiplexer

SL. No.	DESCRIPTION	UNIT	REQUIRED
1.0	**General**		
1.1	Type of multiplexer		SDH: ADM
1.2	Complying to ITU-T rec.		Yes
1.3	Transmission Capacity	Mbit/s	STM-4: 622.8
1.4	Access capacity on 64 kbit/s	channels	Minimum 200
1.5	Access capacity on 2 Mbit/s	channels	Minimum 40
1.6	Redundant central processor		Shall be available
1.7	Digital cross connect function		Fully non-blocking
2.0	**Available Aggregates**		
2.1	Optical aggregates (ITU-T G.957)		L-1.1, L-1.2
3.0	**Available Trunk Interfaces**		
3.1	HDB3, 2 Mbit/s interfaces per module	No.	Minimum 8
3.2	Complying to ITU-T rec.		G.703, transparent G.704, selectable
3.3	HDSL, 2 Mbit/s interface: no of copper wires Capacity on 2 Mbit/s or on 1 Mbit/s Capacity selectable	No. ch ch / pair of wire	4 or 2 30 or 15 30 / 2 pairs 30 / 1 pair 15 / 1 pair
4.0	**Available User Interfaces**		
4.1	**Voice interfaces for trunk lines**		
4.1.1	1 + 1 com path protection, available for all		yes
4.1.2	Analogue, 4 wire with E&M: Input level Output level	dBr	+7.5 to -16 +7.0 to -16.5
4.1.3	Analogue, 2 wire with E&M: Input level Output level	dBr	+6.5 to -12.5 –1.0 to -20
4.1.4	Digital, 2 Mbit/s CAS or PRI		yes
4.2	**Voice interfaces for remote subscriber**		
4.2.1	2 wire, subscriber side	dBr	-5 to +4 / -7.5 to -1
4.2.2	2 wire, PABX side	dBr	-5 to +4 / -7.5 to -3
4.3	**Integrated Teleprotection**		
4.3.1	**Interface for Commands**		
4.3.1.1	Number of independent commands	No.	4
4.3.1.2	Transmission time max.	ms	6
4.3.1.3	Signal voltage	Vpeak	250
4.3.1.4	1 + 1 com path protection		yes

SL. No.	DESCRIPTION	UNIT	REQUIRED
4.3.2	**Interface(s) for Differential Protection**		
4.3.2.1	Electrical interface: G.703	kbit/s	64
4.3.2.2	Optical Interface	kbit/s	Minimum 64
4.4	**Data: channels per module**		
4.4.1	1 + 1 com path protection, available for all		yes
4.4.2	V.24/V.28 (RS-232): up to 38.4 kbit/s	No.	4
4.4.3	V.11/X.24 (RS-422): 64 kbit/s	No.	4
4.4.4	V.35: 64 kbit/s	No.	4
4.4.5	V.36 (RS-449): 64 kbit/s	No.	2
4.4.6	G.703: 64 kbit/s	No.	8
4.4.7	Ethernet: 10/100 BaseT WAN capacity Protocols	No. Mbit/s	1 Min: 2x 2Mbit/s Min.: IP
4.5	**Integrated alarm gathering module**		
4.5.1	Number of external alarms per module	No.	Min. 20
4.5.2	Auxiliary power supply for ext. contacts		Yes
4.6	**Network Management System**		
4.6.1	Type/Name of configuration tool		
4.6.2	For fault / configuration management		Yes / yes
4.6.3	For local / remote operation		Yes / yes
4.6.4	Data communication network (DCN)		Ethernet / IP or Ethernet / OSI
4.7	**Ambient Conditions**		
4.7.1	Storage: ETS 300 019-1-1, class 1.2	°C / % hum	-25 .. + 55 / class 1.2
4.7.2	Transport: ETS 300 019-1-2, class 2.2	°C / % hum	-25 .. + 70 / class 2.2
4.7.3	Operation: ETS 300 019-1-3, class 3.1E	°C / % hum	-5 .. +45 / class 3.1E
4.8	**Power Supply**		
4.8.1	Operation	VDC	48 / 60 (-15/+20%)
4.8.2	Fully redundant power supply		Yes

Annex II-14-2: Communication Network with Services to Be Transmitted

Please refer to Drawings, Clause 18 of Volume 2 of 3 of the Bidding Documents.

Annex II-14-3: Schedule of Requirements for PABX

Not Used

15. Quality Assurance, Inspection, Testing, Commissioning and Warranty

15.1 Scope of Section

The whole of the plant covered by this Contract will be subject to inspection and witnessing the tests by the Employer / Engineer during manufacture, erection and on completion. The inspection and witnessing the tests at manufacturer's works may be done by the Employer / Engineer or an Independent Inspection agency. The approval of the Employer / Engineer or the passing of any such inspection or test will not, however, prejudice the right of the Employer to reject the plant if it does not comply with the specification when erected or when in service.

Within 40 days of the Letter of Acceptance for the Contract, the Contractor shall submit a quality assurance programme and a work quality programme for the Employer / Engineer's approval. A sample of the work quality for is provided at the end of this clause for the Contractor's reference.

The Contractor shall have an approved Quality Management System complying with BS5750 Part 1 or CEN 209001, which shall cover all activities being undertaken during the design, procurement, manufacturing, inspection, testing, packaging, shipping, storage, installation and erection and commissioning of the Works.

After the award of Contract, the Employer / 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 organizations within the Contract. The Contractor shall give all necessary help and assistance to the Employer / Engineer in carrying out such a quality assurance review. The Contractor shall consider and discuss the results of the review and make any reasonable improvements in his procedures.

Before any plant is packed or despatched from the manufacturer, all tests called for shall have been successfully carried out in the presence of the Employer / Engineer unless otherwise agreed.

30 days notice shall be given when the plant is ready for inspection or tests and every facility shall be provided by the Contractor and his vendor to enable the Employer / Engineer to carry out the necessary inspection and witnessing of tests.

In the cases where tests or inspection are specified as being carried out on only a sample of the total quantity of items in the Works, and where one or more items of the sample fail the test or inspection, a further batch of the items, at least equal in quantity to the proportion originally specified, shall be tested or inspected. This process shall continue until a sample proves completely acceptable.

15.2 Sub-Contracts

Within two months of the Contract award and in order to facilitate the inspection of bought out materials and plant, the Contractor shall submit to the Employer / Engineer for approval 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 Employer / Engineer. Any reference to price may be deleted from the copies so submitted.

The sub-orders and drawings submitted to the Employer / 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 Vendor's factory.

Sub-orders are to include a statement advising the Vendor that the items being ordered will be subject to inspection and test by the Employer / Engineer.

The Contractor shall advise his Vendors of all the pertinent clauses in the specification when ordering bought out plant, equipment or materials.

Every sub-order or sub-contract shall contain the following information:

(a) Main Contractor's name and sub-order or sub-contract number
(b) Quantities and description of work
(c) Delivery requirements
(d) Delivery consignment instructions
(e) Details of Employer and/or Contractor's applicable drawing or schedule numbers
(f) Name of the Engineer
(g) A note advising that the plant or equipment which is the subject of the order shall comply in every respect with the Specification and shall be subject to inspection by the Employer / Engineer and the Contractor.
(h) A reference, particularized in the accompanying specification, covering the following information:
    - Employer's name Project title
    - Contract No.
    - Engineer's reference number

    Vendors shall comply with all the applicable requirements of this specification and the onus is upon the Contractor to ensure that the Vendors comply with these requirements.

For the purposes of this clause, interworks orders shall be treated as sub-orders.

15.3 Guarantees

The Contractor shall state and guarantee the technical particulars listed in the Technical Schedules and other sections as specified by the Contract for testing procedures. These guarantees and particulars shall be binding and shall not be departed from without the written permission of the Employer / Engineer. The Contractor shall further guarantee that all equipment supplied complies with the Contract.

The tolerances permitted in the IEC and British Standards shall apply unless otherwise stated.

15.4 Quality Audit

The Quality Programme established by the Contractor shall be followed for all inspection and testing procedures.

The Employer / Engineer may, from time to time, visit the manufacturer to carry out a quality audit of the manufacturer's organization.

15.5 Measuring and Testing Equipment

At prescribed intervals, or prior to each use, all measuring and testing equipment used in inspection shall be calibrated and adjusted against certified equipment having a known valid relationship to internationally recognized standards.

The manufacturer shall prepare a calibration schedule showing equipment type, identification number, location, frequency of checks, method of checking and action to take when results are unsatisfactory.

15.6 Inspection Plan and Procedure

The Inspection Plan, as submitted by the Contractor to the Employer / Engineer for approval, shall cover the following:

(a) Relevant British Standards or equivalent International Standard. For each of the following stages of the work, the acceptance criteria shall be stated.

(b) The stages of inspection which shall include but not be limited to the following:

i) Tests to review or approve certification of material
ii) Review and approval of manufacturing procedures
iii) Witnessing tests or review and approval of certification of operator's qualification to carry out the work required
iv) Visual and dimensional examination of components
v) Pressure tests on casings and vessels
vi) Non-destructive examination of materials in progress
vii) Functional tests on sub-assemblies, performance tests, type tests on complete units
viii) Examination of painting, packing and documentation for shipment

The Engineer will indicate the inspection requirements on the agreed inspection programme in accordance with the following.

Hold point: Requires a mandatory inspection by the Employer / Engineer. This inspection or test shall be witnessed by the Employer / Engineer and further progress in manufacture shall not be made until the plant is approved by the Employer / Engineer.

Witness point: Inspection or test of material may be carried out by the Employer / Engineer at their discretion.

Document review: Certification of material and functional test shall be approved by the Employer / Engineer before despatch from the works.

15.7 Test Certificates

Triplicate sets of all test records, test certificates and performance curves, whether or not they have been witnessed by the Employer / Engineer, shall be supplied to the Employer / Engineer for all tests carried out in accordance with the provisions of this Contract.

Sets of all test certificates shall be endorsed with sufficient information to identify the material or equipment to which the certificates refer, and shall carry in the top right-hand comer the following reference:

Employer's name
Project title
Contract No.
Engineer's reference number

All test documentation shall be in the English language.

15.8 Material Tests

The Contractor shall provide test pieces as required by the Employer / Engineer to enable him to confirm the quality of the material supplied under the Contract. Such test pieces shall be prepared and supplied free of charge and any cost of the tests shall be borne by the Contractor.

If any test piece fails to comply with the requirements of the appropriate specifications for the material in question, the Employer / Engineer may reject the whole of the material represented by that test piece.

the Contractor's or Manufacturer's designers and metallurgists will be consulted before any material is to be so rejected.

If the Employer / 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.

15.9 General Requirements for Tests at Manufacturers' Works

15.9.1 Testing of Plant

Tests at manufacturers' works shall include mechanical, electrical and hydraulic tests to ensure that the plant being supplied complies with the requirements of this specification.

Works tests shall include all routine electrical, mechanical and hydraulic tests in accordance with the relevant IEC or British Standards, except where departures therefrom and modifications thereto are embodied in this specification.

Should the plant or any portion thereof fail under test to give the required performance, further tests which are considered necessary by the Employer / 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 Vendors' works.

The Employer or its representative or independent inspection agency may witness the tests. Sufficient notice (minimum of 30 working days) shall be given to enable the necessary arrangements to be made.

If the plant, or any portion thereof, fails under test to give the required performance, such further tests which are considered necessary by the Employer / 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 Vendors' works.

Tests shall be conducted in accordance with the specified standards. When no standards are specified, the test procedure shall be agreed between the Employer and the Contractor.

Specific details of tests to be carried out at the manufacturers' works are defined elsewhere in this specification.

15.9.2 Rejection of Plant

If any item fails to comply with the requirements of this specification in any respect whatsoever at any stage of manufacture, test, erection or on completion at Site, the Employer / Engineer may reject the item, or defective component thereof, whichever he considers necessary, and after adjustment or modification as directed by the Employer / Engineer, the Contractor shall submit the item for further inspection and/or test.

In the event of a defect on any item being of such a nature that the requirements of this specification cannot be fulfilled by adjustment or modification, such item is to be replaced by the Contractor, at his own expense, to the entire satisfaction of the Employer.

15.10 Specific Requirements for Tests at Manufacturer's Factories

15.10.1 Pressure Vessels

Not used.

15.10.2 Deleted

15.10.3 Relays

All relays and associated equipment shall be routine tested to prove the quality and accuracy. Routine tests shall be in accordance with relevant IEC Recommendations and BS 142:1966, supplemented by additional tests as are considered necessary by the Employer. Routine test reports shall be submitted for each relay and piece of equipment. The reports shall record all measurements taken during the tests.

All relays shall be subjected to the appropriate routine tests as listed below, the individual tests being as detailed in IEC 60255 or as otherwise agreed with the Employer.

(a) Accuracy of calibrated pick up and drop off levels over the effective range of settings
(b) Insulation tests
(c) Accuracy of timing elements
(d) Correct operation of flag (or other) indicators
(e) Mechanical requirements, integrity/safety of draw out units, check of contact pressure and alignment.

15.10.4 Instrument Transformers

Current transformers for differential protection shall be routine tested as sets.

(a) Short time current test
(b) Temperature rise tests
(c) Impulse voltage test

All instrument transformers shall be routine tested as per sub-clause 15.10.12.

15.10.5 Electrical Instruments and Meters

One instrument and meter of each type and rating shall be subjected to the tests as specified in IEC 60051.

15.10.6 AC Switchboards

Routine tests shall include general inspection and electrical operation tests.

15.10.7 Contactors

One contactor of each type and rating shall be subjected to type tests as specified in IEC 60292- 1.

15.10.8 PVC Cable

Each size and rating of PVC cable shall be subjected to type tests as specified in BS 6346. Routine tests are detailed in Clause 5 of this document.

15.10.9 Switchgear (Other than GIS)

Routine tests in accordance with IEC 60056 shall be carried out on all circuit breakers.

15.10.10 Disconnectors and Earth Switches

Routine tests to IEC 60271-102 for switch disconnection.

15.10.11 Deleted

15.10.12 Current and Voltage Transformers

Routine tests to IEC 60044-1 and IEC 60044-5.

15.10.13 Structures of Electrical Equipment

Sample tests on the assembly and galvanizing of the structures shall be carried out. A mechanical type test with the structure loaded with working load multiplied by the appropriate factor of safety shall be carried out.

15.10.14 Surge Arresters

Routine tests to the specified standards shall be carried out.

The following routine tests shall be carried out on all arrester units in accordance with IEC 60099 4:

(a) measurement of reference voltage
(b) residual voltage test
(c) partial discharge test
(d) housing leakage test
(e) current distribution test for multi column arrester.

The following acceptance tests shall be carried out on one complete arrester of each voltage rating and/or type being supplied, all in accordance with IEC 60099 4:

(a) measurement of power frequency voltage at reference current
(b) lightning impulse residual voltage at nominal discharge current
(c) partial discharge current
(d) accelerated ageing test followed by an operating duty test details are to be agreed with the Engineer

15.10.15 Batteries and Battery Chargers

Battery - The 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 Employer / Engineer shall select at random reference cells and the voltage curves thereof shall be checked when the battery is discharged over three and five hour periods. The alarm levels and the automatic voltage control feature of the charger shall be demonstrated over the specified load range. Where load changeover facilities are included, integrity of the changeover system without break or voltage variations during loading of the standby or test charger shall be demonstrated.

15.10.16 Control Panels

Routine operation tests and insulation resistance tests shall be carried out.

15.10.17 Busbars (other than GIS)

Routine tests including millivolt drop tests shall be carried out in accordance with the specified standard.

15.10.18 Instruments

Calibration tests shall be witnessed on all important pressure gauges and other instruments as required by the Engineer.

15.10.19 Neutral Earthing Resistor

Not used.

15.10.20 Power Transformers

Not used.

15.10.21 Outdoor Bushing Assemblies with Porcelain Insulators

Hollow insulators tested in accordance with IEC 60233

Complete bushings tested in accordance with IEC 60137

Routine Tests shall include:

i) Oil leakage test
ii) 50Hz dry withstand test
iii) Power factor/voltage test
iv) Partial discharge test on all bushings of which the major insulation is either oil impregnated paper or resin impregnated paper.

15.10.22 Tanks

Not used.

15.10.23 Cooling Plant

Not used.

15.10.24 Gas and Oil - Actuated Relays

Routine Tests:

(a) Oil Leakage:
When subject to an internal oil pressure of 207 kN/m^2 for fifteen minutes.
(b) Gas Collection
(c) Oil Surge
(d) Performance test under service conditions
(e) Voltage: 2 kV for one minute between electrical circuits and casing

15.10.25 Galvanizing

Routine Tests:
To the requirements of BS 443 or BS 729 whichever is applicable.

15.10.26 Earthing Transformers

Not used.

15.10.27 Fibre Optic Multiplexer Equipment

Works tests shall be in accordance with the IEC standard.

15.10.28 Deleted

15.10.29 Telephone Equipment

Not used.

15.10.30 Teleprotection Equipment

15.10.30 Teleprotection Equipment

Back to back tests shall be carried out to determine the satisfactory operation of the teleprotection equipment.

These tests shall be via fibre optic multiplexer equipment links, simulated lines or communication channels dependent on the actual application.

Random tests shall be performed which demonstrate to the Employer / Engineer the ability of the equipment to operate satisfactory (reliability) and within the specified time limits (speed) in the presence of interfering signals or noise and also the ability not to malfunction (security) in the presence of interfering signals or noise at levels likely to occur when the equipment is installed in the power system substations.

15.10.31 Transducers

Transducers shall be tested in accordance with IEC 60688-1.

15.11 Dismantling Prior To Shipment

After the satisfactory completion of all tests at the factory, the plant shall be submitted for the Employer / Engineer's approval during dismantling preparatory to shipping. No item of plant shall be despatched to site until the Employer / Engineer has given approval in writing.

15.12 Inspection and Testing During Site Erection

15.12.1 General

The Contractor shall be responsible for the submission to the Employer / Engineer of all plant supplied under the Contract for inspection and testing during site erection, to ensure correct erection and compliance with this specification.

During the course of erection, the Contractor shall provide access as required by the Employer / 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 Employer / 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 Employer / 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 Employer / 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 Employer / 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 Employer / 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 Employer / 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 Employer / Engineer where necessitated by changed conditions at Site or by differing design, manufacture, or construction techniques.

The Bidder is required to submit proposals for site dielectric tests and to include in his price the costs of such tests and of such equipment as deemed necessary.

15.12.2 Mechanical Equipment

The extent of testing during erection shall include, but not be limited to, the following:

(a) Checking the accuracy and alignment of plant erected. The accuracy shall comply with the relevant standards, the specification or the plant manufacturer's requirements as may be applicable or, where no requirements exist, to a standard to be agreed between the Employer / 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 that 4.5 bar for a period of 2 hours, or at such other conditions as may be required by the pipework design code.

Air piping shall be subjected to an air pressure test rather than a hydrostatic test.

(e) Site fabricated tanks and vessels shall be subjected to hydrostatic tests in accordance with the relevant standards.

(f) Hydrostatic tests shall be carried out on steam generating units in accordance with the boiler design code.

After the hydrostatic test is carried out, the complete assembly shall be drained and any 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 Employer / Engineer.

Should, in the opinion of the Contractor and with the agreement of the Employer / Engineer, a hydraulic test be impracticable due to excessive loading on foundations other than steel, an air pressure test may be employed in accordance with requirements set out in BS 5500.

Vacuum tests shall be carried out at the maximum test vacuum obtainable and the condition maintained for a period of two hours with the system isolated. The Contractor shall state in the Schedule of Guarantees the fall in vacuum anticipated during this period but the rate of fall shall not exceed that which would occur due to the designed air leakage rate being attained.

(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.

(j) Other tests as specified which have not been previously conducted.

15.12.3 Electrical Equipment

15.12.3.1 General

A general check of all the main switchgear and ancillary equipment shall be made and shall include a check of the completeness, correctness and condition of earth connections, labelling, arcing ring and horn gaps, clearances, painted surfaces, cables, wiring, pipework, valves, blanking plates and all other auxiliary and ancillary items. Checks shall be made for oil and gas leaks and that insulators are clean and free from external damage. A check shall be made that loose items which are to be handed over to the Employer e.g. blanking plates, tools, spares, are in order and are correctly stored or handed over.

The following general tests are to be carried out on electrical equipment after erection at site:

(a) Routine high voltage tests to the appropriate IEC Standard. Where no relevant standard exists, tests shall be agreed with the Engineer
(b) Insulation resistance tests on all electrical equipment
(c) Continuity and conductivity resistance tests
(d) Test operation of alarm and tripping devices from local and remote location
(e) Rotational tests on all motors
(f) Polarity tests on CTs and VTs
(g) Oil tests
(h) Grounding system and electrode tests
(i) Ratio, Vector Grouping and magnetizing current tests on each transformer
(j) Calibration of winding and oil temperature devices
(k) Vector group and phasing tests on VT circuits
(l) Magnetization current/voltage tests and winding resistance tests on all current transformers
(m) Primary and secondary injection tests on relays, protection devices and equipment

15.12.3.2 Circuit-Breakers

Circuit breakers shall be given a visual inspection.

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 66 kV and which are neither assembled at Site nor have mechanically ganged pole operation.

Local air components associated with pneumatic operation, including air compressors, shall be tested and air loss measurements and pressure and alarm settings checked. Tests shall be made also on mechanical and hydraulic operating systems.

15.12.3.3 Disconnectors and Earth Switches

Manual operation of disconnectors and earth switches shall be subject to operational tests to confirm contact pressures, contact resistances, simultaneous operation of all phases and the ease of operation.

Motorised operation of disconnectors, and earth switches shall be tested to prove the motor operation, including local and remote operation, and timing tests shall also be carried out. Motor protection shall be tested.

Checks shall be made on interlocks, local and remote indications and operation of auxiliary contacts.

Earth switches shall be tested to confirm the opening and closing sequences and checks shall be made on interlocks, indications and manual locking devices.

15.12.3.4 Busbars and Connections

Flexible busbars and connections shall be tested to ensure that the correct tensions, sags and clearances will be maintained over the range of environmental conditions and loads without stress to other equipment. If dynamometers are used to check the sags and tensions, they shall be checked both before and after use.

Rigid busbars and connections shall be tested to ensure that the busbars will not cause overloading of the supporting insulators under load conditions and under the range of climatic variations applicable to the site and that expansion and contraction of the equipment is fully accommodated by flexible connections.

Conductivity tests shall be carried out on all connections and joints which are made on site, without exception.

15.12.3.5 Earthing System

Tests shall be made on the effectiveness of the bonding and earthing which will include conductivity tests on selected joints, on the main earthing system, and at the connections to equipment and structures. Checks shall also be made on precautions taken to avoid possible corrosion attack on the earthing system.

Test probes at approximately 300 and 600 metres separation will normally be required to effectively test the earthing system. The use of transmission line conductors may be arranged to simplify these testing procedures.

The earth resistance shall be measured during the installation and on completion as follows:

(a) of each earth rod after driving
(b) of the earth grid after completion and backfilling of the trenches
(c) of each group of earth rods or earth point after completion of the connection from the test link terminal
(d) of the completed installation without any connections outside the substation

The tests shall be carried out by a method and with equipment approved by the Engineer. All tests are to be witnessed and the equipment and method used recorded with the test results.

The Contractor may also be called upon to provide assistance in the measurement of earth resistance after earth connections to the system have been completed.

15.12.3.6 Control Relays and Metering Panels, Instruments and Protective Devices

(a) Wiring

After complete erection and cabling, all circuits shall be subjected to the high voltage test specified in the relevant IEC or approved standard.

The insulation resistance of all circuits shall be measured before and after any high voltage tests.

For AC secondary injection tests a substantially sinusoidal test supply shall be used.

The operating and resetting level (current and/or voltage) and timing of all relays shall be measured over an agreed range of settings for all relays.

For directional relays 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:

i) establish that the equipment has not suffered damage during transit.
ii) establish that the correct equipment has been supplied and installed.
iii) confirm that the various items of equipment have been correctly interconnected.
iv) confirm performance of schemes designed on the bases of calculation e.g. differential protection.
v) to provide a set of figures for comparison with future maintenance values
vi) 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:

i) Local primary injection to establish the ratio and polarity of current transformers as a group, care being taken to prove the identity of current transformers of similar ratio.
ii) Overall primary injection to prove correct interconnection between current transformer groups and associated relays.
iii) Fault setting tests, where possible, to establish the value of current necessary to produce operation of the relays.

(f) DC Operations

Tests are to be carried out to prove the correctness of all DC polarities, the operating levels of DC relays and the correct functioning of DC relay schemes, selection and control switching, indications and alarms. The correct functioning of all isolation links and fuses shall also be checked.

(g) Tests on Load

Tests on load shall also be done to demonstrate stability and operation of protection relays as required by the Engineer.

All tripping, control, alarm and interlocking circuits shall be functionally tested to prove satisfactory and foolproof operation and/or resetting. The functional and safety aspects of all shorting and/or isolation links, fuses and switches devices shall be proved.

The total burdens connected to all voltage transformer circuits shall be measured and recorded.

The total capacitance of all wiring and apparatus connected to the negative pole of each main tripping battery shall be measured and recorded; the value shall not exceed 10 microfarad.

The continuous current drain of all trip circuit supervision relays shall be measured and shall not be greater than half the minimum current required for tripping. The supervision current shall be measured with the circuit breaker (or other device) both open and closed.

15.12.3.7 Batteries and Chargers

Tests shall be carried out on the batteries and chargers to confirm the charger ratings and adjustment, the battery and charger alarm systems and battery capacity.

The open circuit cell voltages of the batteries when fully charged shall be recorded.

The insulation to earth of the complete DC installation shall be tested.

15.12.3.8 Power Cables

Each completed circuit shall be tested for continuity and insulation resistance.

15.12.3.9 Current Transformers

A magnetization curve shall be obtained for each current transformer in order to:

(a) Detect damage in transit or installation
(b) Prove that the correct cores have been wired out to the relevant terminals
(c) For high impedance relay schemes, to confirm that correct relay settings have been calculated.

The DC resistance of each current transformer secondary winding shall be measured and also the transformers and connecting leads, each item being recorded separately.

The insulation resistance of all secondary circuits shall be measured at 1000 volt and recorded.

Primary current injection tests shall be conducted on all current transformers using adequate primary current to prove correct ratio, polarity and, for differential protection schemes, to prove the correct relative polarities of all current transformers of each scheme.

15.12.3.10 Voltage Transformers

The transformer ratio and polarity shall be checked using a primary voltage high enough to give a clearly measurable secondary voltage or by using rated primary voltage and comparison with an already proven voltage transformer. The phasing and phase rotation shall be checked. For three phase voltage transformers a test shall be conducted to show that energizing each primary winding produces an output from only the correct phase secondary winding. The residual voltage of any open delta or broken delta winding shall be measured with rated primary voltage applied.

15.12.3.11 Control and Instrumentation Equipment

The following general tests shall be performed on control and instrumentation equipment at site:

(a) High voltage testing of all circuits, as specified in the relevant IEC or approved standard
(b) Insulation resistance testing of all circuits
(c) Functional tests of all tripping, control, alarm and interlocking circuits
(d) The testing of all equipment in accordance with the manufacturer's instructions or as advised by the Engineer

15.12.3.12 Transformers and Ancillary Equipment

Not used.

15.12.3.13 FOX, Teleprotection and Communication

Tests shall be exhaustive and shall demonstrate that the overall performance satisfies every requirement specified.

The tests to be carried out shall be:

(a) Physical inspection unit testing and demonstration of diagnostic aids as appropriate of al equipment in standalone mode
(b) System testing of 48V power supply equipment
(c) System testing of FOX equipment for speech and teleprotection
(d) System testing of telephone equipment
(e) System testing of teleprotection equipment to plant

15.13 Staffing

During pre-commissioning, the Contractor shall provide all necessary supervisory and operating staff. The only involvement of the Employer's staff will be in accordance with the training and instruction as in this specification.

During the commissioning phase, the Employer's operating staff will operate plant and equipment under the supervision of the Contractor's supervisors.

The Contractor shall have satisfied himself as to the capability of the Employer's operators to carry out such operations as he may direct and shall remain responsible for the successful performance of such operations. Throughout the whole of the Commissioning Period the Bidder shall provide suitably

qualified and experienced operating staff, who shall instruct the Employer's staff in the correct operating procedures.

The Contractor shall provide a team of suitably qualified and experienced engineers and technicians to pre commission and commission the overall plant. The Contractor shall also ensure that a suitably qualified commissioning engineer from the respective manufacturer's own service organization 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 Employer / Engineer's satisfaction.

At all times the Contractor shall ensure that his staff and any Vendor's or seconded staff, observe all prescribed safety rules and permit systems.

15.14 Taking Over

After satisfactory completion of the tests on completion, the Employer will issue a Taking Over Certificate for the plant. The issue of any such certificate shall not however relieve the Contractor of any of his responsibilities in respect of proving that the performance of the plant meets the guaranteed values.

The Taking Over Certificate shall make reference to a schedule of outstanding minor defects and omissions which have been accepted by the Employer / Engineer as not affecting the full and safe operation of the plant. The Contractor shall rectify such defects and omissions not later than three (3) months after Taking Over.

The date certified in the Taking Over Certificate shall be the date on which the tests on completion were completed.

15.15 Defects After Taking Over

In accordance with the General Conditions of Contract, the Contractor shall be responsible for making good defects or damage which may appear or occur during a twelve (12) months guarantee period from the date certified in the Taking Over Certificate.

Following any remedial work or replacement of any component part during the twelve (12) months, the guarantee period for such a part shall be extended, commencing from the date at which the remedial work was completed.

Immediately prior to the completion of this period, the Employer reserves the right to request the 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 for the purpose of such inspection.

The Contractor shall submit for approval the arrangements he intends making under this Contract for the making good of defects and for providing the supervisory service detailed above.

15.16 Final Acceptance Certificate

Application for the Final Certificate may be made to the Employer 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.

Annex II-15-1: Sample of Quality Assurance Programme

<table>
<tr><td rowspan="2">REF. NO.</td><td rowspan="2">ITEM OR COMPONENT</td><td rowspan="2">PROCESS</td><td rowspan="2">DESCRIPTION OF OPERATION</td><td rowspan="2">DOCUMENTATION</td><td rowspan="2">SPECIFICATIONS / STANDARDS</td><td>PROG</td><td colspan="3">ACTION BY</td></tr>
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Client: Contract No:

Bidder Contract No:

Author: Checked by: Approved by:
Date</td><td colspan="4">Legend</td></tr>
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X2 Witness Point
X3 Record Review
QAS QA Surveillance</td><td colspan="2">Note Certification Requirements
Note Any Other Requirements</td></tr>
<tr><td colspan="4">QUALITY PLAN</td></tr>
<tr><td>Rev. No. / Date</td><td>1</td><td>2</td><td>3</td><td>4</td><td colspan="4">Number: Sheet</td></tr>
<tr><td>Revision</td><td></td><td></td><td></td><td></td><td colspan="4"></td></tr>
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Annex II-15-2: Notification of Works Inspection

To facilitate the handling of inspection notifications, the following procedure shall be observed.

At the commencement of all contracts, discussions shall be held with the Contractor's nominated representative and the Employer / Engineer to establish guidelines for the handling of inspection notifications and test documentation.

The Contractor shall prepare a notification form which shall include, but not necessarily be limited to, the following:

1. Inspection Notification Number
2. Project Title
3. Manufacturer and Full Address
4. Where Test / Inspection Will Be Carried Out
   (If Different from Item 3 Above)
5. Order / Sub-Order Number
6. Contact Name
7. Fax / Telephone Number
8. Details of Equipment to be Tested / Inspected and whether Equipment is Complete
9. Schedule of Tests
10. Manufacturer's Approved Drawing Number and Corresponding MEP Number
11. Date of Inspection

The Contractor shall be responsible for recording all inspection notifications in numerical order and shall submit copies of the appropriate record at monthly intervals to the Inspection Department.

16. Works and Equipment for Shunt Reactor Installation

16.1 Scope

This clause describes the general technical requirements for 400 kV Shunt Reactor and associated switchgears including all necessary works and services for installing Shunt Reactor and associated switchgears. The Contractor shall carry the EMTP Study and accordingly to recommend the need for Shunt Reactors including size of the reactors.

The scope of works may include based on study report as follows:

- 420 kV, 800 A, 63 kA/1sec, 50 Hz, 1425 kVp BIL, live tank type, gang operated, SF6 gas circuit breakers with spring-stored energy operating mechanism as specified in Clause 3 of this Section
- 420 kV, 800 A, 63 kA/1sec, 50 Hz, 1425 kVp BIL, horizontal double break, post type, motor operated disconnectors without earthing switch as specified in Clause 3 of this Section
- Single-phase, 5-core, 420 kV, 63 kA/1sec, 800 A, 50 Hz, 1425 kVp BIL, Bushing type current transformer as specified in Clause 3 of this Section
- Control, Protection, Monitoring & Substation Automation System including event recording function for Two (2) sets of Shunt Reactor line circuits as specified in Clause 5 of this Section (refer to drawing no. PGCB/GOPAL/400KVSS/22 in Clause 18 of this Section)
- One (1) lot of rigid tubular bus [Aluminium of grade 63401 WP], flexible conductors, insulators, fittings including all necessary clamps and connectors required for completing the connection of Shunt Reactor with the line as specified in the technical specifications and bid drawings (refer to drawing no. PGCB/GOPAL/400KVSS/01 & 02 in Clause 18 of this Section)
- One (1) lot of steel structures for gantry, equipment supports and civil works required for completing the connection of Shunt Reactor with the line as specified in the technical specifications and bid drawings (refer to drawing no. PGCB/GOPAL/400KVSS/01 & 02 in Clause 18 of this Section)

The Contractor is bound to provide complete works, even if the equipment or services to be provided are not specifically mentioned in the specification.

The supply and services to be performed by the Contractor shall comprise the design, manufacture, shop testing, packing, transport, insurance, unloading, storage on Site, construction works and erection, corrosion protection, site testing, submission of documentation, commissioning and warranty of the works.

Installation, testing and commissioning of Shunt Reactor shall be done by the Shunt Reactor engineer(s) of the Shunt Reactor manufacturer(s).

16.2 References

16.2.1 IEC Standards

IEC 60044 Instrument transformers - Part 1: Current transformers
IEC 60044 Instrument transformers - Part 2: Inductive voltage Transformers
IEC 60060 High voltage testing techniques (Part 1 & 2)
IEC 60076 Power transformers (Parts 1, 2, 3, 4, 5, 6, 7, 8 & 10)
IEC 60137 Insulated bushings for alternating voltages above 1000 V
IEC 60296 Specification for unused mineral insulating oils for transformers and switchgear

IEC 60422 Supervision and maintenance guide for mineral insulating oils in electrical equipment
IEC 60529 Degrees of protection provided by enclosures
IEC 60815 Guide to the selection of insulators in respect of polluted condition

16.3 Shunt Reactor

16.3.1 General

Shunt reactors shall be outdoor, oil-immersed, three-phase type. They shall comply with the requirements of the schedules and standards listed above and other relevant IEC standards.

The shunt reactors shall be suitable for continuous operation on a three-phase 50 Hz high voltage transmission system at the maximum system voltage as specified in the Technical Schedules.

Shunt reactors and associated equipment shall be designed in such a manner as to meet the requirements in this section, Technical Schedules and Drawings at ambient site conditions.

Shunt reactors shall meet the latest stage of development reached in design, construction and materials.

The shunt reactors and all associated facilities shall have the ability to withstand the effects of short-circuit currents, defined as symmetrical short circuit current in the Technical Schedules, according to requirements of IEC 60076-5.

All metal parts of the shunt reactor with the exception of the individual core laminations, core bolts and associated individual side plates shall be maintained at the same fixed potential. The earthing structure shall be designed to carry, without damage, the maximum possible earth fault current for a duration of at least equal to the short circuit withstand period of the main windings.

The design and manufacture of the shunt reactors and auxiliary plant shall be such that the noise level is at a minimum and that the level of vibration does not adversely affect any clamping or produce excessive stress in any material. The shunt reactor manufacturer shall supply sufficient information to the civil works Bidder to ensure adequate design of the reactor mounting structure.

Where noise measurements are specified, measurements shall be in accordance with IEC 60076-10.

The shunt reactors shall be designed with particular attention to the suppression of harmonic currents, especially the third and fifth, so as to minimize interference with communications circuits.

The shunt reactors shall be designed to ensure that leakage flux does not cause overheating in any part of the reactor.

The reactors shall be capable of withstanding the effects of periodic switching in and out without suffering stresses that may damage the unit or associated equipment or affect the life of the unit.

All outdoor terminal boxes, marshalling box etc. which are directly exposed to air shall have sunshades with capability to work as rain protection shield.

Shunt Reactors shall be equipped with HV bushing CTs for unit protection.

External earthing with proper copper jumpers shall be provided at all gasket joints in the shunt reactor such as radiator connection with the main tank. All copper jumpers shall be flexible bread conductor. Jumpers shall be tin platted.

16.3.2 Magnetic Circuit

The core shall be built up of high-grade, non-ageing, low-loss, high-permeability grain-oriented steel sheets. Both sides of each steel sheet shall be insulated with a durable, hot oil and heat resistant baked enamel varnish or other chemical treatment.

The cores shall be clamped and braced to withstand, without damage or deformation, the forces caused by short-circuit stresses, transportation, or handling, and to prevent the shifting of the core laminations. The bolts, nuts, and end plates of the assembly and clamp structure shall be of a nonmagnetic type, and shall be effectively insulated and locked so that they ensure an even pressure on the whole core assembly and are not loosened by vibrations caused by transport and operation. The supporting framework of the cores shall be designed to avoid the presence of pockets which could prevent complete draining of the tank or cause the trapping of air when filling during service.

Suitable axial cooling ducts shall be provided to ensure free circulation of oil and efficient cooling of the core. The ducts shall be so dimensioned that the maximum temperature at any point remains with the admissible limits.

Particular care shall be given to the design and construction of the corner joints between columns and yokes to avoid concentration of mechanical and magnetic stresses whilst allowing an easy dismantling of the joint for maintenance at site.

Adequate metallic bridges shall be provided between the core lamination packets in order to keep all portions of the core assembly at the same potential.

Lifting eyes or lugs shall be provided at suitable points of the core assembly.

The core shall be earthed to the clamping structure at one point only through a removable link with a captive bolt and nut, accessibly placed beneath an inspection housing on the tank cover or tank wall.

The core shall be free from overfluxing liable to cause damage or to cause maloperation of the protection equipment when the shunt reactor is operating under the continuous overvoltage condition specified in the Technical Schedules.

16.3.3 Windings

The windings shall be of high conductivity electrolytic copper. Paper shall be used for conductor insulation.

The conductors shall be transposed at sufficient intervals to minimize eddy currents and equalize the current and temperature distribution along the winding. Coils shall be constructed to avoid abrasion of the insulation, (e.g. on transposed conductors), allowing for the expansion and contraction set up by the changes of temperature or the vibration encountered during normal operation.

Windings shall be so designed as to obtain an optimal value for series and shunt capacities in order to ensure a favourable distribution of the voltage for full impulse waves and chopped impulse waves.

Leads from winding to bushings shall be adequately supported to prevent damage from vibration and short-circuit forces.

Permanent current-carrying joints or splices shall be welded or braced, properly formed, finished and insulated to avoid concentration of dielectric stresses.

The windings shall be subjected to a thorough shrinking and seasoning process. Compensation devices shall be provided for possible further shrinkage of the coils in service.

The coils, windings and leads shall be sufficiently braced and fastened to form rigid assemblies, preventing any relative movement due to transport, vibrations or other circumstances that may occur in service.

The windings shall be designed to reduce to a minimum the out-of-balance forces inherent in the shunt reactors.

The winding shall be capable of withstanding the forces to which it is subjected under all conditions, particularly the forces due to a short circuit between terminals or between any terminal and earth, with full voltage maintained on all other windings intended for connection to external sources of supply and allowing for any feedback through windings connected to rotating machines.

The assembled core and windings shall be dried in a vacuum to ensure proper moisture removal.

16.3.4 Neutral Earthing

The neutral point of shunt reactor shall be directly connected to earth.

16.3.5 Tank

The shunt reactor tank shall be of welded construction with bolted cover, fabricated from high tensile strength steel plate.

The tank shall be of adequate strength so that, when containing the core plus coil assembly and fully oil filled, any packing, lifting, rolling and handling shall not cause overstressing of any part of the tank or leakage. The main tank body, tap changing compartments, radiators and associated piping facilities shall be capable of withstanding full vacuum when empty of oil.

Each tank shall be provided with minimum of four jacking pads conveniently located to allow the raising or lowering of the completely mounted and oil filled shunt reactor. The load carrying capacity of each jacking pad shall not be less than 50% of the total weight of the shunt reactor. Lifting eyes or lugs for lifting the complete shunt reactor and tank cover and facilities for the pulling and pushing of the shunt reactor in any direction shall be provided for each unit. Tank stiffeners and mounting brackets shall be continuously welded to the tank.

The movement of the shunt reactor shall be achieved by a set of bi-directional wheels. The change of the direction shall be made after lifting the shunt reactor with hydraulic jacks.

The shunt reactors, when erected, will be left standing on their wheels. The wheel blocking devices necessary to fix the position of the shunt reactor shall be supplied together with the shunt reactors and shall be designed to withstand seismic forces acting upon the shunt reactors.

Wherever possible, the shunt reactor tank and its accessories shall be designed without pockets wherein gas may collect. Where pockets cannot be avoided, pipes shall be provided to vent the gas into the main expansion pipe. The vent pipes shall have a minimum inside diameter of 20mm and, if necessary, shall be protected against mechanical damage.

The shape and arrangement of the tank cover and external stiffeners shall permit rainwater and desert sand to flow easily and completely to the ground.

All oil-tight joints shall be made with machined flanges and approved types of gasket.

The gaskets shall be tight under all conditions, especially against the hot oil (synthetic rubber or neoprene-bonded cork is not permitted). Means shall be provided to prevent over compression of the gaskets. The tanks shall be provided with bolted type manholes for easy inspection of bushings and windings.

The tank cover shall be fitted with thermometer pockets, for oil and winding temperature indicators, with a captive screw cap and be located in the position of maximum oil temperature at continuous maximum rating.

A pressure relief device of self re-setting type and sufficient size capable of functioning without electrical power, shall be provided for the rapid release of any pressure that may be generated within the tank and which might result in damage to the equipment, but it shall be capable of maintaining the oil tightness of the shunt reactor under all conditions of normal service. The device shall operate at a static pressure of less than the hydraulic test pressure for shunt reactor tanks and shall be designed to prevent further oil flow from the shunt reactor during its operation.

The relief device shall be mounted on the main tank and if mounted on the cover it shall be fitted with a skirt projecting inside the tank to prevent an accumulation of gas within the device. Two sets of contacts shall be provided to initiate the alarm and trip relays.

Terminals shall be provided close to each corner at the base of the tank for earthing purposes and each shall be designed to meet system fault levels.

Each of the shunt reactors shall be provided with a tank access ladder made of galvanized mild steel with lockable hinged door and anti-climbing device securely fixed onto the tank cover and lower parts of the tank.

The following plates shall be fixed to the tank at an approximate height of 1.75 m above the ground level:

A. A rating plate bearing the data specified in IEC standard.

Following additional information shall be provided in the rating plate:

a. Loss in kW
b. Magnetizing current in %
c. HV winding resistance (ohm/ phase)
d. Reactance

B. A diagram plate
C. A property plate of approved design and wording
D. A title plate
E. A valve location plate showing the location and function of all valves, drain and air release plugs and oil sampling devices

16.3.6 Valves

Valves shall be of the fully sealing full-way type and shall be opened by turning counter-clockwise when facing the handwheel. They shall be suitable for operation between the minimum ambient and the maximum oil temperatures stated in the Schedules. All valves shall be lockable with appropriate sub-master series padlocks. Padlocks shall be provided for locking all valves in the "open" and "closed" positions. Valves other than filter and drain valves shall be provided with an indicator, readily visible from ground level, to show clearly the position of the valve. All valves shall have tags attached to it permanently clearly indicating its position (i.e. close / open) in normal service condition of the shunt reactor.

All valve handwheels shall be fitted with nameplates which shall be chromium plated brass not less than 3 mm thick with the engraving filed with enamel. All valves shall be fitted with spoked handwheels, the spokes and rims of which shall be smooth and where necessary, for appearance, shall be chromium plated.

Each shunt reactor tank shall be fitted at least with the following:

- One 50 mm valve at the top and one 50 mm valve at the bottom of the tank, mounted diagonally opposite each other, for connection to oil circulating and oil filtering equipment. The lower valve shall also function as a drain valve, for which a suitable combine arrangement shall be made
- Oil sampling devices at the top and bottom of the main tank
- All parts containing oil, and liable to trap air during filling, shall be fitted with a flanged type air release plug at their highest point
- Valves shall be provided on both sides of the gas and oil actuated relays

All valves opening to atmosphere shall be fitted with blanking plates.

16.3.7 Conservator

Shunt reactors shall be fitted with an oil conservator.

The conservator shall be made of welded steel. It shall be designed to withstand full vacuum. The conservator shall be of sufficient volume to enable expansion and contraction of oil within the highest and lowest oil levels in the conservator.

The conservator vessel shall be mounted at the highest point of the oil system and shall be connected to the highest point of the tank through a straight sloping pipe. Adequate isolating valves shall permit the removal of the main and tap-changer Buchholz relays while the conservator is still connected to the tank by a pipe bypassing the relays.

Each conservator compartment shall be equipped with filling valve, drain valve, lifting lugs, etc. The main tank conservator shall be fitted with a gauge glass or universal oil indicator other than magnetic oil level gauge. An oil level gauge complete with low-level alarm shall be fitted to each conservator. The indicated minimum oil level shall occur when the feed pipe to the main tank is covered with not less than 12 mm depth of oil. The oil levels at 15°C, 35°C and 90°C shall be marked on the gauge. The oil level indicator of the magnetic oil level gauge(s) shall be calibrated in such a way that its position at 90 degree level corresponds to approximately half level of oil.

The front cover of all gauges shall be made of glass. Size of text/indications shall be such that it can be visible from ground.

16.3.8 Oil

The shunt reactor oil shall comply with IEC 60296 and other relevant IEC standards. The oil shall be a highly refined mineral oil suitable for use as an insulating and cooling medium in shunt reactors. The oil shall be free from corrosive sulphur and PCB.

16.3.9 Cooling Plant

Shunt reactors shall be ONAN cooled.

All radiator valves shall be lockable with appropriate sub-master series padlocks. Padlocks shall be provided for locking all valves in the "open" and "closed" positions. Valves other than filter and drain valves shall be provided with an indicator, readily visible from ground level, to show clearly the position of the valve. All valves shall have tags attached to it permanently clearly indicating its position (i.e. close / open) in normal service condition of the shunt reactor.

16.3.10 Terminations

Termination bushings shall be resin impregnated paper type or oil impregnated paper type with a power factor test tapping and porcelain external insulator, in accordance with IEC 60137. All bushings and connecting leads shall have a minimum current rating of at least 120% the maximum line current in order to accommodate IEC 60354 loading. Routine power frequency test levels on bushings shall be at a test voltage at least 10% higher than the induced / applied values applied to the shunt reactor.

16.3.11 Neutral Connections

The neutral ends shall be brought out externally via separate bushings.

16.3.12 Protection, Measuring and Indicating Devices

The shunt reactors shall be equipped with several protection, measuring and indicating devices supplied by the shunt reactor manufacturer:

Buchholz relay shall be fitted to shunt reactor main tank. It shall have:

- Alarm contacts which close when gas collects or at low oil level
- Tripping contacts which close following an oil surge, and gas collection in the 2nd stage
- The normally open, electrically separate, alarm and tripping contacts shall not be exposed to oil
- The buchholz device shall be inserted in the pile work and provided with suitable valves on both sides of the devices to facilitate easy service
- By-pass with control valves shall be provided to enable oil to by-pass the buchholz device during oil filteration
- Each relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay from ground level

If fitted, the characteristics of any winding temperature indication devices shall be submitted for approval prior to the delivery of the shunt reactors and shall also be included in the operating and maintenance instructions.

- A dial type oil thermometer with two (alarm/trip) adjustable contacts shall be mounted in the control cubicle. It shall be of conventional construction with a sensing bulb positioned in a separate pocket arranged in the top oil capillary and connected with a dial.

- An oil thermometer, connected to a resistance (platinum 100 W at 0°C) inside a stainless-steel tube placed in a pocket located in the oil, suitable for remote and supervisory remote measuring.

All thermometer temperature sensing devices shall be with heating elements for the purpose of calibration at site.

All indicating instruments shall have hard glass font covers.

16.3.13 Control Cubicles

Each shunt reactor shall be fitted with a control cubicle of welded galvanized sheet steel housing, mounted on the shunt reactor tank, in a position easily accessible from the ground level. The cabinet shall contain protective equipment associated with the reactor cooling system, as well as the termination of all secondary circuits.

The internal arrangement of the cabinet shall keep the various circuits clearly separate from each other, permitting easy and safe independent maintenance and repair of each of them without disturbing the others.

16.4 Shunt Reactor Inspection and Testing

16.4.1 General

All tests shall be performed in accordance with IEC 60076 and other relevant IEC Standards.

16.4.2 Factory Test

Routine and Type Tests shall be generally in accordance with the requirements of IEC standards appropriate to the voltage class of the shunt reactor under consideration. Additionally, some tests identified as 'Special' in IEC 60076 are included, which may in practice be effectively a Routine or Type Test, as appropriate.

16.4.3 Routine Test

The following routine tests shall be performed:

1. Measurement of winding resistances
2. Measurement of reactance
3. Measurement of losses
4. Lightning Impulse (LI) test
5. Switching Impulse (SI) test
6. Induced-voltage test with partial discharge measurement
   a) Long Duration AC (ACLD)
7. Separate source voltage test
8. Oil test including Dissolved Gas Analysis and function tests of auxiliary equipment, before and after Dielectric Test
9. Measurement of insulation of core
10. Oil leakage test

16.4.4 Type Test

The following type tests shall be performed:

1. Temperature Rise Test
2. Dissolved Gas Analysis of Shunt Reactor Oil shall be carried out before and after the Temperature Rise Test.
3. Dielectric test (Lightning Impulse test, Switching Impulse test)

16.4.5 Special Test

The following 'special' category tests shall be performed and may be on each unit (equivalent to a routine test) or on one unit (equivalent to a type test) as indicated:

1. Dielectric tests; tests under Routine and Type Tests. The applicable special dielectric tests are:
   - Chopped wave lightning impulse. This test is a requirement at all system voltages on line terminals and shall be at 110% of the full wave impulse level: Routine test
2. Measurement of zero-sequence impedance: Routine test
3. Determination of sound levels to IEC 60076-10: Type test
4. Measurement of the harmonics of the no-load current: Routine test
5. Measurement of the mutual impedance between phases.
6. Determination of capacitance, windings to earth and between windings: Routine test
7. Measurement of insulation resistance to earth and loss angle of insulation system capacitances: Routine test
8. Determination of magnetic characteristic: to be linear up to 125% of nominal voltage
9. Vibration test (Routine): 200 µm peak-to-peak maximum.
10. Measurement of Capacitance & dissipation factor (Tandelta) for winding and bushings.
11. Measurement of current at low voltage
12. SFRA (Sweep Frequency Response Analysis) test

16.4.6 Site Test

The following tests, after installation on Site shall be performed:

1. Verification of correct and complete erection
2. Verification of the soundness of porcelain surfaces and sealing
3. Verification of correct connections to the earthing system
4. Checking of auxiliary and control wiring and cabling and operation of all electrical LV equipment
5. Voltage tests of all electrical LV circuits
6. Measurement of the physical, chemical, and electrical characteristics of the oil after filling
7. Resistance measurements of windings with records of oil & ambient temperatures
8. Insulation resistance tests on winding, bushings, core, etc.
9. SFRA (Sweep Frequency Response Analysis) test
10. Measurement of Capacitance & dissipation factor (Tandelta) for winding and bushings

16.4.7 Tests on Shunt Reactor Components

Tests during and after manufacture shall be carried out on the shunt reactor components in order to verify compliance with this specification, good workmanship and their capability to perform the required duties when in service.

Unless otherwise specifically mentioned these tests shall be made in accordance with the Clause 15 of this Section.

17. Power Line Carrier, Teleprotection and Communication Equipment

17.1 Power Line Carrier Equipment

17.1.1 General

Power Line Carrier equipment shall be extended as needed for both Gopalganj and Aminbazar sub-station on the 400 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 has been supplied by ABB of Switzerland. For the purpose of standardization of operating performance and facilities, the offered equipment shall be compatible with the existing ones.

Equipment providing increased signaling 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 shall 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.

17.1.2 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 licensing authority to ensure non-interference with Air Traffic Control, and Marine Navigation Beacons, etc.

17.1.3 Line Coupling

(a) General

The high voltage transmission system is a three phase 50 Hz 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)	50
Lightning Impulse Withstand Voltage (kVp)	1425
Continuous Switchgear Rating (A)	4000

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 Contractor's 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 utilizes non-linear resistor type arrestors and the nominal discharge current shall be 10 kA.

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) Manufacturer'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.

17.1.4 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 6000 pF 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 25 mm/kV (based on maximum phase to earth voltage).

Full technical details of the capacitor voltage transformers shall be provided in the Schedules of Guarantees and Technical Particulars.

17.1.5 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

The Contractor is 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 2440 mm above ground level.

Full technical details of the HF coupling units shall be provided in the Schedule of Technical Particulars.

17.1.6 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.

The Contractor shall clearly show the make-up of the cable, together with details of the cable mechanical and electrical characteristics. The Contractor shall also state the "short" time and continuous test voltages with which their cable complies.

17.1.7 Power Line Carrier High Frequency Unit

(a) General

The design and selection of equipment and components shall be based on achieving a minimum lifetime of 20 years when operating under the specified service conditions.

The design and performance requirements of the digital power line carrier equipment shall be equivalent or better than IEC 495.

The equipment to be provided shall be of the digital transmission signaling 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 signaling 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

Bidders 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 synthesizers 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 10 dB.

The Contractor 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 paralleling the digital PLC with other similar digital PLC terminals on the same transmission line, or with analogue PLC equipment. The Contractor 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 signaling 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 signaling.

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 crosstalk attenuation between speech and VF signaling 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 800 Hz and the VFT signaling 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 Clause 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.

17.2 Teleprotection Equipment

The protection of the overhead lines shall be arranged as detailed in Clause 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.

17.2.1 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 equipment used for "direct" and "permissive" signaling.

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.

17.2.2 Signaling Conditions

The Contractor 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.

The Contractor 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 signaling 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/signaling, shall also transmit guard codes.

17.2.3 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 200 ms.

The Contractor 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.

17.2.4 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 DC 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 output commands which have been executed.

17.2.5 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.

17.2.6 Voltage Withstand Requirements

Voice frequency, signaling and alarm circuits, when free from earth, shall be capable of withstanding without damage a voltage of 500 V DC 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.

17.2.7 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 100 ms, 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 6 dB from normal. The Contractor 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.

17.2.8 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.

17.3 Operational Telephone System

Not Used

17.4 Communications DC Power Supply Equipment

17.4.1 General

These clauses describe the general technical requirements for Batteries, Chargers and DC distribution switchgear for use in substations for 48 V DC power for use in communication systems.

Based on the existing Drawings attached in this Section, the Bidder shall assess the need for expansion of the existing 48V DC Distribution System to cater for the bay extension works as appropriate.

(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 AC 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 AC mains supply, the rectifier shall automatically resume supply of the load requirements whilst simultaneously recharging the battery at the float voltage.

17.4.2 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 AC mains supply.

The DC 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.

17.4.3 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 energizing.

The charger shall restart automatically upon restoration of the AC 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 AC 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 AC 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 DC 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 DC 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:

- AC mains input circuit breaker
- DC output circuit breaker
- charger output current meter
- charger output voltage meter
- alarms for charge fail, DC 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.

17.4.4 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.

17.4.5 D.C. Distribution and Instrumentation

(a) General

The distribution section shall be designed for incoming and outgoing DC 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 48 V 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.

17.4.6 Housing

The above covers the mounting/housing for batteries.

A modular construction is preferred for the battery charger and DC 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 a modular construction is not offered, separate cubicles are required for each charger and the DC distribution / instrumentation.

18. Drawings

The drawings provided in this Section are solely for the purpose of bid information and bid preparation.

They present the typical details of the project facilities and plant requirements for the following.

SL	Drawing No.	Drawing Title
1.	PGCB/ADB/400kV/GOPAL-SS/SLD.1	400 kV Single Line Diagram
2.	PGCB/ADB/400kV/GOPAL-SS/LAY_all	Overall Layout
3.	PGCB/ADB/400kV/GOPAL-SS/LAY_400	400 kV Switchyard Layout
4.	PGCB/ADB/400kV/GOPAL-SS/TLD_400kV	400 kV Line & Bus Protection
5.	PGCB/ADB/400kV/GOPAL-SS/Trans	400 kV Tr Protection
6.	PGCB/ADB/400kV/GOPAL-SS/SRP	400 kV Shunt Reactor Protection
7.	PGCB/ADB/400kV/GOPAL-SS/SAS	Substation Automation System architecture
8.	PGCB/ADB/400kV/GOPAL-SS/DC_1	110 V DC distribution scheme
9.	PGCB/ADB/400kV/GOPAL-SS/DC_2	48 V DC distribution scheme
10.	PGCB/ADB/400kV/GOPAL-SS/LVAC	LV AC distribution scheme
11.	PGCB/ADB/400kV/GOPAL-SS/COM	Communication Network Design
12.	PGCB/ADB/400kV/GOPAL-SS/OPT	Fibre Optic Multiplexer equipment
13.	PGCB/ADB/400kV/GOPAL-SS/MCR	Main Control Room
14.	PGCB/ADB/400kV/GOPAL-SS/SPR_400_1	400 kV Local Control building with Battery
15.	PGCB/ADB/400kV/GOPAL-SS/SPR_400_2	400 kV Local Control building without Battery
16.	PGCB/ADB/400kV/GOPAL-SS/SSF	Switchyard Surface Finishing
17.	PGCB/ADB/400kV/GOPAL-SS/CAR	Car Port