# PARTICULAR TECHNICAL SPECIFICATIONS 400 & 132 kV GIS EQUIPMENT AND ANCILLARY EQUIPMENT

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# 1. Main Requirements for New Equipment

The 400kV & 132 kV (GIS and AIS) equipment and ancillary equipment, which are subject of these Technical Specifications, shall be installed in the installed **in the new Aqaba 400/132/33KV (AAWDCP) substation and 33/11 kV BPS01 substation and feeding IPS & RO SS**.

The exact Scope of Supply, for each of the substations, has been presented in detail in the schedules at VOL 3.

400 & 132 kV (GIS and AIS) equipment and ancillary equipment shall be designed in such a manner to meet the requirements required in this Technical Specifications, Schedules of Technical Data and Drawings at climate conditions at the Site defined within General Technical Specifications.

The rated characteristics of 400 & 132 kV (GIS and AIS) equipment and ancillary equipment are given in Scope of Supply and Schedule of Technical Data for 400 & 132kV and 33kV.

In addition to the defined equipment delivery, the Contractor shall also be responsible for the complete substation design and integration of equipment and systems which shall be procured in the substation and integration of existing equipment and systems (for extension and replacement projects), necessary for proper functioning of complete substations. This shall include, but not limited to, detailed layout & cross section drawings of the substations showing equipment and systems which shall be procured in substation. substations single line diagrams, 400 & 132 kV (GIS and AIS) calculations, calculation of 400 & 132 kV & 33 kV cables, earthing and lightning protection calculations and drawings, AC & DC calculations and their drawings (single line diagrams, circuit & wiring diagrams, etc.), structural calculations of steel support structures for 400 & 132 kV & 33 kV outdoor apparatus and their foundations, calculation and selection of LV AC & DC power cables and control, signalling, measuring and communication cables, cable lists, circuit & wiring diagrams for overall control, protection and metering schemes, as well as communication schemes as per NEPCO standards and solution adopted for the particular substation. The Design documentation that shall be provided under this Contract has been defined in the Particular Technical Specifications.

All Contractor's Design documentation shall be a subject of Client's approval.

The Tenderer/Contactor shall visit the Sites (for existing SS and extension projects) and make himself aware of the details of the existing system/facilities. The modification work at the associated substation shall be compatible with the existing system.

# 2. Technical Description, Requirements and Data

## 2.1. General

This particular technical specification for 400 & 132 (GIS and AIS) equipment's applied and applicable on the **new Aqaba 400/132/33KV (AAWDCP) substation and 33/11 kV BPS01 substation and feeding IPS & RO SS**.

Wherever possible, these Particular Technical Specifications shall be applied in conjunction with the General Technical Specifications. In case of discrepancies between the Particular and Special Technical Specifications, the Particular Technical Specifications shall prevail.

Single line diagrams, layout and cross section drawings of the substations and main equipment have been presented within the *Drawings*.

## 2.2. Main Requirements for New Equipment

The 400 & 132 kV equipment and ancillary equipment for the new substation in the **new Aqaba 400/132/33KV (AAWDCP) substation and 33/11 kV BPS01 substation and feeding IPS & RO SS**.

shall include the following equipment and systems:

- 400 & 132 kV Gas Insulated Switchgear (GIS) Equipment,

- 400 & 132 kV & 33 kV & 11 KV Outdoor Equipment,
- 400 MVA 400/132/33 KV Auto-Transformers, earthing and auxiliary transformer, RTCC (AVR panel) and ancillary equipment's.
- 132/33 kV power transformer, earthing and auxiliary transformer, RTCC (AVR panel) and ancillary equipment's.
- 33 kV switchgears with pertaining control and protection panels
- 33 kV capacitor banks
- Neutral Earthing Equipment,
- 400 & 132 kV & 33 KV Control, Protection & Metering Equipment,
- 400 V AC Equipment,
- 110 V DC Equipment,
- 400 & 132 kV & 33 KV Cables and Cable Accessories,
- MV, LV and control Cables and Cable Accessories,
- Substation Earthing and lighting System.
- Civil and electromechanical work.

The exact Scope of Supply for Substation above has been presented in detail in schedule A: *Scope of Supply*.

400 & 132 kV (GIS and AIS) equipment and ancillary equipment shall be designed in such a manner to meet the requirements required in these Technical Specifications, Schedules of Technical Data (schedule D) and Drawings at climate conditions at the Site defined within the General Technical Specifications.

The rated characteristics of 400 & 132 kV GIS equipment and ancillary equipment are given in schedule A: Scope of Supply & schedule D: Schedule of Technical Data.

In addition to the defined equipment delivery, the Contractor shall also be responsible for the complete substation design and integration of equipment and systems which shall be procured with all interface contractor and integration of existing equipment and systems (for extension and replacement projects "if required"), necessary for proper functioning of complete substations. This shall include, but not limited to, detailed layout & cross section drawings of the substation showing equipment and systems, including the existing equipment and systems (for extension and replacement projects "if required"), substation single line diagrams, necessary calculations for 400 & 132 kV GIS, conductor calculations, calculation of 400 & 132 kV & 33 kV cables, earthing and lightning protection calculations and drawings, AC & DC calculations and their drawings (single line diagrams, circuit & wiring diagrams, etc.), structural calculations of steel support structures for, 400 & 132kV GIS, , 400 & 132 kV OHL gantries, 400 & 132 kV & 33 kV outdoor apparatus and their foundations, calculation and selection of LV AC & DC power cables and control, signalling, measuring and communication cables, cable lists, circuit & wiring diagrams for overall control, protection and metering schemes, as well as communication schemes as per NEPCO standards. The Contractor shall be responsible for complete scheme (control & protection schemes, metering schemes, etc.) and proper functioning of the equipment procured within this contractor. The Design documentation that shall be provided under this Contract has been defined in this Particular Technical Specifications.

insulation coordination study following requirement is applicable for main ss.

CONTRACTOR shall perform Insulation Coordination Study to bring the insulation strength of electrical equipment into the proper relationship with expected over voltages and with the characteristic of surge protective devices. Accordingly, the conclusion would be whether the insulation level is adequate or some mitigation (usually surge arrestor installation) would be suggested.

If predefined insulation levels are found not sufficient then CONTRACTOR shall propose mitigation measures and perform required works. Interim report shall be submitted for NEPCO review and also provided to Major Equipment Manufacturers.

CONTRACTOR shall design, supply, install/ perform, testing and commissioning for all mitigation measures as per approved Insulation Coordination Study.

The contractor shall supply the required power transformer, earthing& auxiliary transformer and AVR panels as mentioned in schedule A: Scope of work.

In order to enable the Contractor to prepare relevant Design documentation, the Client shall make available to the Contractor the As-Built documentation that he possesses regarding the extension and replacement projects. However, if any drawing or other document shows to be unavailable or that it is lacking the necessary data, the Contractor is obliged to obtain the necessary information at the Site by performing the necessary surveying personally.

All Contractor's Design documentation shall be a subject of Client's approval.

The Tenderer/Contactor shall visit the Sites and make himself aware of the details of the existing system/facilities. The modification work at the associated substation shall be compatible with the existing system.

## 2.3. Technical Description and Data of Existing Equipment (Not applicable)

Existing substations, Air-Insulated Substation (AIS) with single 400 & 132 kV busbar system, while all other SSs shall be (or are) AIS (or GIS) with double 400 & 132 kV busbar system (main & reserve) Furthermore, in order to enable the Contractor to prepare relevant Detail Design, the Client shall make available to the Contractor the As-Built documentation that he possesses regarding the extension and replacement project. However, if any drawing or other document shows to be unavailable or that it is lacking the necessary data, the Contractor is obliged to obtain the necessary information at the Site by performing the necessary surveying personally.

The rated characteristics of existing equipment within substations have been presented on the single line diagrams in the *Drawings.*

## 2.4. Guarantees, Penalties and Rejection of Supply

Contractor shall guarantee that 400 & 132 kV (GIS and AIS) equipment and ancillary equipment shall fully comply with technical specification and characteristics given in the schedule D: Schedule of Technical Data.

In case that the supplied equipment does not comply with requirements stated in these Particular Technical Specifications, as well as those stated in the Schedule of Technical Data, the Client has a right to reject the Supply.

# 3. Design, Materials and Workmanship

## 3.1. General

The design, materials and workmanship shall be in compliance with the General Technical Specifications (and particularly with these Particular Technical Specifications.

The 400 & 132 kV and ancillary equipment shall be designed and manufactured to fully correspond to the climatic and operating conditions specified in the General Technical Specifications.

## 3.2. Applicable Standards

Unless otherwise specified, the 400 & 132 kV equipment and ancillary equipment shall be fully designed and manufactured in accordance with these Technical Specifications and the latest editions of the following IEC, BS, and IEEE Standards:

- IEC 60050, International Electrotechnical Vocabulary (IEV),
- IEC 60417 DB, Graphical symbols for use on equipment,
- IEC 60617 DB, Graphical symbols for diagrams,
- IEC 60038, IEC standard voltages,
- IEC 60060, High Voltage Test Techniques,
- IEC 60071, Insulation co–ordination,
- IEC 61936, Power installations exceeding 1 kV a.c.,
- IEC 60721, Classification of environmental conditions,
- IEC 60529, Degrees of protection provided by enclosures (IP Code),
- IEC 61000, Electromagnetic compatibility (EMC),
- IEC 60085, Electrical insulation,
- IEC 60068, Environmental testing of electronic equipment,
- IEC 60376, Specification of technical grade sulphur hexafluoride (SF6) and complementary gases to be used in its mixtures for use in electrical equipment,
- IEC 60480, Specifications for the re-use of sulphur hexafluoride (SF6) and its mixtures in electrical equipment,
- IEC 62271-1, High-voltage switchgear and control gear - Part 1: Common specifications for alternating current switchgear and control gear,
- IEC 62271-100, High-voltage switchgear and control gear - Alternating-current circuit-breakers,
- IEC 62271-102, High-voltage switchgear and control gear - Alternating current disconnectors and earthing switches,
- IEC 62271-200 High-voltage switchgear and control gear. AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
- IEEE Std C37.20.2, Standard for Metal - Clad Switchgear
- IEC 62271-203, High-voltage switchgear and control gear - Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV,
- IEC 60871, Shunt capacitors for a.c. power systems having a rated voltage above 1000 V,

- IEC 60076-6, Power transformers – Reactors,
- IEC 60099-4, Surge arresters – Metal-oxide surge arresters without gaps for a.c. systems
- IEC 61869, Instrument transformers,
- IEC 60353, Line traps for a.c. power systems,
- IEC 60273, Characteristic of indoor and outdoor post insulators for systems with nominal voltages greater than 1000 V,
- IEC 60815, Selection and dimensioning of high-voltage insulators intended for use in polluted conditions,
- IEC 60672, Ceramic and glass insulating materials,
- IEC 60168, Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 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 61109, Insulators for overhead lines - Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1000 V - Definitions, test methods and acceptance criteria,
- IEC 60120, Ball and socket couplings of string insulator units - Dimensions,
- IEC 60372, Locking devices for ball and socket couplings of string insulator units - Dimensions and tests,
- IEC 60437, Radio interference test on high-voltage insulators,
- IEC 60575, Thermal-mechanical performance test and mechanical performance test on string insulator units,
- IEC 61089, Round wire concentric lay overhead electrical stranded conductors,
- BS EN 50182, Conductors for overhead lines. Round wire concentric lay stranded conductors,
- IEC 60888, Zinc-coated steel wires for stranded conductors,
- BS EN 50189, Conductors for overhead lines. Zinc coated steel wires,
- IEC 60889, Hard-drawn aluminium wire for overhead line conductors,
- IEC 61394, Overhead lines - Requirements for greases for aluminium, aluminium alloy and steel bare conductors,
- IEC 61284, Overhead lines - Requirements and tests for fittings,
- BS EN 50326, Conductors for overhead lines. Characteristics of greases,
- BS EN 50299-1 Oil-immersed cable connection assemblies for transformers and reactor having highest voltage for equipment Um from 72.5kV to 550kV- Part 1 Fluid-filled cable terminations
- BS EN 50299-2 Oil-immersed cable connection assemblies for transformers and reactor having highest voltage for equipment Um from 72.5kV to 550kV- Part 1 Dry-type cable terminations
- IEEE Std C57.32, IEEE Standard for Requirements, Terminology, and Test Procedures for Neutral Grounding Devices,
- IEC 61850, Standard for Substation Automation,
- IEC 60255, Measuring relays and protection equipment,
- IEEE C37.2, Standard for Electrical Power System Device Function Numbers, Acronyms, and Contact Designations,
- IEEE C37.90, Standard for Relays and Relay Systems Associated with Electric Power Apparatus,

- IEEE C37.230-2020, IEEE Guide for Protective Relay Applications to Distribution Lines,
- IEEE C37.99-2012, IEEE Guide for the Protection of Shunt Capacitor Banks,
- IEC 60688, Electrical measuring transducers for converting A.C. and D.C. electrical quantities to analogue or digital signals,
- IEC 62052-11, Electricity metering equipment - General requirements, tests and test conditions, Part 11: Metering equipment,
- IEC 62053-22, Electricity metering equipment (a.c.) - Particular requirements, Part 22: Static meters for active energy (classes 0,2 S and 0,5 S),
- IEC 62053-23, Electricity metering equipment - Particular requirements, Part 23: Static meters for reactive energy (classes 2 and 3),
- EC 62053-31, Electricity metering equipment (a.c.) - Particular requirements, Part 31: Pulse output devices for electromechanical and electronic meters (two wires only),
- IEC 62053-52, Electricity metering equipment (a.c.) - Particular requirements, Part 52: Symbols,
- IEC 62056-21, Electricity metering - Data exchange for meter reading, tariff and load control, Part 21: Direct local data exchange,
- IEC 60359, Electrical and electronic measurement equipment - Expression of performance,
- IEC 60255, Measuring relays and protection equipment,
- IEEE C37.2, Standard for Electrical Power System Device Function Numbers, Acronyms, and Contact Designations,
- IEEE C37.90, Standard for Relays and Relay Systems Associated with Electric Power Apparatus,
- IEEE C37.113, Guide for Protective Relay Applications to Transmission Lines,
- IEEE Std C37.104, Guide for Automatic Reclosing of Line Circuit Breakers for AC Distribution and Transmission Lines,
- IEEE C37.91, Guide for Protecting Power Transformers,
- IEEE Std C37.119, Guide for Breaker Failure Protection of Power Circuit Breakers,
- IEEE Std C37.234, Guide for Protective Relay Applications to Power System Buses,
- IEC 60688, Electrical measuring transducers for converting A.C. and D.C. electrical quantities to analogue or digital signals,
- IEC 62052-11, Electricity metering equipment - General requirements, tests and test conditions, Part 11: Metering equipment,
- IEC 62053-22, Electricity metering equipment (a.c.) - Particular requirements, Part 22: Static meters for active energy (classes 0,2 S and 0,5 S),
- IEC 62053-23, Electricity metering equipment - Particular requirements, Part 23: Static meters for reactive energy (classes 2 and 3),
- EC 62053-31, Electricity metering equipment (a.c.) - Particular requirements, Part 31: Pulse output devices for electromechanical and electronic meters (two wires only),
- IEC 62053-52, Electricity metering equipment (a.c.) - Particular requirements, Part 52: Symbols,
- IEC 62056-21, Electricity metering - Data exchange for meter reading, tariff and load control, Part 21: Direct local data exchange,
- IEC 60359, Electrical and electronic measurement equipment - Expression of performance,

- IEC 60664, Insulation coordination for equipment within low-voltage systems,
- IEC 60947, Low-voltage switchgear and control gear,
- IEC 61439: Low-voltage switchgear and control gear assemblies,
- IEEE 1115-2014, IEEE Recommended Practice for Sizing Nickel-Cadmium Batteries for Stationary Applications,
- IEC 60623, Secondary cells and batteries containing alkaline or other non-acid electrolytes - Vented nickel-cadmium prismatic rechargeable single cells,
- IEC 60993, Electrolyte for vented nickel-cadmium cells,
- IEC 60146, Semiconductor's converters - General requirements and line commutated converters,
- IEC 60051, Direct acting indicating analogue electrical measuring instruments and their accessories,
- BS 7194: Specification for direct-current and low-frequency electronic measuring instruments with a digital display,
- IEC 60269, Low-voltage fuses,
- IEC 60502, Power cables with extruded insulation and their accessories for rated voltages from 1 kV (*U*m = 1,2 kV) up to 30 kV (*U*m = 36 kV),
- IEC 60840, Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV),
- IEC 62271-209 High-voltage switchgear and control gear. Cable connections for gas-insulated metal-enclosed switchgear for rated voltages above 52 kV. Fluid-filled and extruded insulation cables. Fluid-filled and dry-type cable-terminations
- IEC 60228, Conductors of insulated cables,
- IEC 60811, Electric and optical fibre cables - Test methods for non-metallic materials,
- IEC 62444, Cable glands for electrical installations,
- BS 6121-1, Mechanical cable glands. Armour glands. Requirements and test methods,
- IEC 61537, Cable tray systems and cable ladder systems for cable management,
- IEEE Std 998-2012, Guide for Direct Lightning Stroke Shielding of Substations,
- IEC 62305, Protection against lightning,
- IEEE Std 80, Guide for Safety in AC Substation Grounding,
- BS EN 1990, Basis of structural design,
- BS EN 1991, Actions on structures,
- BS EN 1992, Design of concrete structures,
- BS EN 1993, Design of steel structures,
- BS EN 10025, Hot rolled products of structural steels,
- BS EN 1090, Execution of steel structures and aluminium structures,
- BS EN ISO 898, Mechanical properties of fasteners made of carbon steel and alloy steel,
- BS EN ISO 1461, Hot dip galvanized coatings on iron and steel articles,
- BS EN ISO 14713, Zinc coatings — Guidelines and recommendations,

- BS EN 12163, 12164, 12167 - Copper and copper Alloys (Table 8 for chemical composition and mechanical properties of phosphor bronze for pins or locking devices).

If the Tenderer offers design, equipment, workmanship or testing in compliance with any Standard which deviates from the above-mentioned Standards, such deviations shall be submitted along with his Tender.

Application of any Standard other than the above mentioned, shall be the subject of the Client's approval.

## 3.3. General Design Requirements

The design and manufacture of the entire equipment shall be in accordance with the latest international standards in this field and it shall be envisaged for a long-term operation.

Particular attention shall be paid to preparation of adequate conceptual solution, easy access, simple operation, and logical arrangement of individual parts.

Parts of the equipment having the same rated values and characteristics shall be identical and completely interchangeable.

Spare parts shall be fabricated to enable easy installation and accurate fitting, without the need for subsequent adjustments.

Easy and smooth maintenance of the 400 & 132 kV equipment and ancillary equipment shall be ensured.

During continuous operation with rated characteristics, no part of the equipment shall be damaged due to overheating.

400 & 132 kV (GIS and AIS) equipment and ancillary equipment shall be designed in accordance with the values of short-circuit currents specified in the schedule D: Schedule of Technical Data. 400 & 132 kV (GIS and AIS) equipment and ancillary equipment shall be designed so that the influences of maximum short-circuit currents, which may occur due to any reason, do not cause any damage (electrical or mechanical) on the equipment.

The 400 & 132 kV (GIS and AIS) and ancillary equipment shall be able to withstand, without any damage, the highest voltages and loads which might occur in any conceivable operating condition.

All elements exposed to significant wear shall have removable wearing parts in order to enable easy and cost-effective repair or replacement.

All outdoor equipment shall be suitable for live washing.

## 3.4. Substation Design

The equipment arrangement within substation shall be as shown on the Tender Drawings. These drawings are intended to show the basic requirements to be fulfilled, i.e., general equipment arrangement, site location and available area, line terminations, etc. It shall be the Contractor's obligation to prepare a detailed layout drawing showing the manner in which the proposed equipment shall be accommodated to best advantage within the available area.

The arrangement shown on the Tender Drawings may be modified as necessary to accommodate the various equipment, provided the basic principles are maintained.

The substation design shall minimise the number of levels of conductors and shall ensure that the consequences of a failure of one set of high-level conductors are limited to the loss of that circuit and a single busbar section. This principle shall also be applied to earth wire conductors.

Vehicle access for transport of the major substation equipment shall be provided. This shall be achieved without the need to de-energise circuits. Access for vehicles that requires the de-energisation of circuits shall be kept to a minimum.

The Contractor shall provide all necessary input data for design of all cable trenches and cable ducts within the substation, both in the outdoor part and in the control building as well. All cable trenches shall be designed with adequate cable trays and ladders.

The Contractor shall provide all necessary input data for design of adequate transformer's oil pits taking into account the amount of oil for each transformer. The necessary documentation and inputs related to the transformers (transformer outline drawing, etc.), which are in scope of supply in this contract.

Rooms within substations control buildings may be smaller or, if necessary, larger than shown on the Tender Drawings to meet the requirements of the equipment being supplied. Site boundaries cannot be extended.

All prescribed clearances indicated on the cross-section drawings shall be fulfilled.

All gantry type structures supporting conductors shall include facilities for ready access to all insulator sets. There shall be permanently attached climbing devices with guardrails and access to high level beams shall not be possible without proper authorisation. Safety screens shall be provided between adjacent circuits to maintain the specified safety clearances and to prevent accidental access to live circuits.

All gantry and lightning mast structures shall be steel lattice type, the same as already used in NEPCO substations. The typical drawings of currently designed gantries will be submitted to the Contractor. Contractor will need to verify the design according to EN standards.

New gantries shall be suitable for future extensions. End gantry towers shall be designed to withstand the same loading as middle ones.

Since the connection to the substation is by overhead line, overhead line conductors shall be terminated at the substation gantry structures. The overhead line conductors complete with pertaining tension insulators are not in Scope of Supply and shall be supplied and installed, between the substation terminal gantry and the last overhead line tower, under a separate Contract.

The Contractor for shall be responsible for providing and connecting all dropper connections between the overhead line and the substation equipment terminals. Connectors and clamps (bi-metallic where necessary) required to connect the down droppers to equipment provided under this Contract, shall be provided under this Contract as well.

The Contractor shall also provide strain plates or anchor bolts, as necessary, for the anchorage of the tension insulators and OPGW tension clamps and terminal boxes, provided under a separate Contract, together with any earthing thereto.

| NEPCO color code | |
|---|---|
| **Outdoor equipment** | |
| Porcelains | Brown |
| Structures | Galvanized |
| Cubicles and enclosures | RAL 7044<br>RAL 6019 for 132,33kV |
| **Indoor equipment** | |
| LCC, Control and relay panels exterior | RAL 7044 for 400kV<br>RAL 6019 for 132,33kV |
| LCC, Control and relay panels interior | White |
| LVAC and DC boards | RAL 6019 |
| Metal clad switchgear | RAL 6019 |

## 3.5. Clearances for Outdoor Equipment

The clearances for busbars and connections, based on the BS EN 50522 and IEC 61936-1, are given in the Table below.

| Rated System Voltage | 36 kV | 145 kV | 420 kV |
|---|---|---|---|
| Basic Insulation Level (BIL) | 170 kV | 650 KV | 1425 |
| Minimum clearance between live metal and earth | 0.32 m | 1.3 m | 3.4 m |
| Minimum clearance between live metal of different phases | 0.43 m | 1.5 m | 3.9 m |
| Safety working clearance horizontal | 2.3 m | 3.2 m | 2.4 m |
| Safety working clearance vertical | 2.9 m | 3.7 m | 6.4 m |
| Minimum height to base of insulation | 2.4 m | 2.4 m | 2.7 m |

Clearances apply only to equipment not subject to impulse voltage type tests and they apply to conditions of maximum conductor swing and sag.

## 3.6. Structural design

All supporting structures, including their foundations, shall withstand the anticipated structural stresses. The structural system from conductors to foundations shall be verified by calculation considering the limit states at which the components become unfit for their intended use.

All equipment support structures shall be of circular hollow cross section.

The supporting structures shall be designed to give at least the required minimum phase to earth, phase to phase and insulation height clearances, for all associated equipment and connections and shall be equipped with flag holders.

Calculations for structural design shall be carried out in accordance with the Structural Eurocodes BS EN 1990 to BS EN 1999. Consideration of structural forces shall include normal forces, bending, shear and torsion and combinations thereof. Calculations shall take into account end restraint conditions for conductors.

For rigid busbar systems the effect of the wind force shall be added to the effect of the short circuit and the sum of these shall than be vectorially added to the effect of dead load.

The following actions shall be taken into account:

- Dead load,
- Tension load (for flexible conductors),
- Erection load,
- Wind load,
- Ice load,
- Mechanical operation (switching forces),
- Short-circuit forces.

The self-weight of the conductor system and support structures shall be determined in accordance with BS EN 1991-1-1 or from manufacturer's literature.

Conductor tension shall be considered for the minimum ambient temperature.

An erection load of 1.0kN should be applied vertically downwards at the most critical position of a supporting structure, tensioning portal, etc. The erection load should not be applied to conductors.

Wind loading shall be determined in accordance with BS EN 1991-1-4. Partial factor should be applied to the wind force, not the wind speed. Where the force coefficient method is used, the following may be used:

- Circular sections, see BS EN 1991-1-4 section 7.9.2,
- Lattice structures, see supplementary information in BS EN 1993-3-1 Annex B,
- Insulators, see BS EN 50341 section 4.4.2.

Ice load shall be considered as a 10mm coating around each component – conductor, equipment or structure. Density of ice to be taken as 9.0kN/m$^3$.

Where appropriate, the end-effect factors should be obtained from BS EN 1991-1-4, Section 7.13.

The Supplier shall define operational loadings based on the proposed substation arrangement. Mechanical operation forces shall be applied as a variable action and considering this to be a transient design situation in accordance with BS EN 1990.

The mechanical effects of short circuit currents shall be considered on the conductor, plant and components, and supporting structure including foundations. Short circuit forces shall be applied as the accidental action in the accidental design situation, in accordance with BS EN 1990. A model factor γ = 1.05 shall be applied to the effect of all actions under the short circuit combination, for calculations for plant, support structures and foundations, and this is indicated in the table below. Short circuit forces shall be calculated according to BS EN 60865-1.

The load effects (moment, shear, force, etc.) in the conductors and supporting structures shall be calculated using an appropriate structural model.

Actions shall be combined and applied in accordance with the principles of BS EN 1990, using the partial factors and combinations of actions which are provided in Table below:

| Combination | Dead weight | Tension | Erection | Wind | Ice | Operation | Short circuit |
|---|---|---|---|---|---|---|---|
| 1. ULS, max wind | 1.35 (1.0) | 1.1 | - | 1.5 | - | - | - |
| 2. ULS, max ice | 1.35 (1.0) | 1.1 | - | 0.45 | 1.5 | - | - |
| 3. ULS, construction | 1.35 (1.0) | 1.1 | 1.5 | 1.2 | - | - | - |
| 4. ULS, operation | 1.35 (1.0) | 1.1 | - | 1.2 | - | 1.2 | - |
| 5. ULS, short circuit | 1.05 (1.0) | 1.05 | - | 1.05 | - | - | 1.05 |
| 6. SLS, max wind | 1.0 | 1.0 | - | 1.0 | - | - | - |
| 7. SLS, max ice | 1.0 | 1.0 | - | 0.3 | 1.0 | - | - |
| 8. SLS, construction | 1.0 | 1.0 | 1.0 | 0.8 | - | - | - |
| 9. SLS, operation | 1.0 | 1.0 | - | 0.8 | - | 1.0 | - |

The maximum horizontal deflection of the support structure and the support insulator at busbar level or line landing level shall be limited to a value that will not interfere with the operation of the plant subject to a maximum of 100mm. The maximum deflection of the support structure shall be limited to 1/250th of its span or height. Deflections shall be assessed using the Serviceability Limit State (SLS) combinations.

Maximum slenderness (ratio of unsupported length to their least radius of gyration) of structural elements shall be as per table below:

| Member type | Max Slenderness |
|---|---|

| | |
|---|---|
| Main members (legs, beams, etc.) | 120 |
| Bracing members | 200 |
| Tension only members | 350 |
| Redundant members | 250 |
| | |

## 3.7. Substation Lightning Protection System

The substation outdoor equipment shall be adequately protected against direct lightning strikes, by the use of shield wires located on the lightning masts and other substation structures. The height, location and number of lightning masts and shield wires shall be such as to protect all outdoor equipment installed within the substation to a failure rate of shielding of not greater than 0.1% per annum. Substation lightning protection system shall be in accordance with IEEE Std 998-2012.

The substation gantry structures shall be arranged to receive overhead line earth wires, and this shall be extended to the substation earthing system as required. Clamps, etc. required to connect the closing span of earth wire shall be provided by the Contractor.

Buildings within substation not covered by the lightning protection system composing of lightning masts and shield wires, shall be provided with owns lightning protection system in accordance with IEC 62305. The main components of a lightning protection system for buildings shall be as follows:

- Air terminations,
- Down conductors,
- Earth termination,
- Joints, bonds, test joints, etc.

Where a building has a large flat roof an air termination network mesh of approximately 10×20 m shall be used. Down conductors, one for each 20 m of the building perimeter shall be used. Each down conductor should be provided with a test joint. Nuts and bolts at the test joints, which are to remain detachable, shall be made of copper-nickel-silicon-bronze.

The earthing ring around a building installed as a part of the main earth electrode system shall be used for connecting to the air termination network.

Down conductors shall be connected to the earthing ring around the buildings. The connection points shall be protected against corrosion by bitumen.

## 3.8. Substation Earthing System

The Contractor shall design adequate earthing system for the substations and shall supply the necessary equipment and materials. In addition, the Contractor shall design the extension of existing earthing system for Substations (if required) and shall supply the necessary equipment and materials as well. Installation of earthing system shall be performed by Client.

Electrical measurements of the substation subsoil will be performed and the results of preliminary soil resistivity measurements for new substation according to site survey.

The substation earthing system shall be composed of a mesh grid, formed by copper flexible conductors or strip/tapes, buried directly in the ground, and arranged so as to fully utilise the available site area, and earthing rods. A continuous conductor shall be laid outside the periphery of the substation site at a distance of 1.5 ÷ 2.0 m from the boundary fence and at a depth of 0.3 ÷ 0.4 m below the surface. A mesh earthing system shall be formed by interconnection at various points to the perimeter conductor. The spacing between conductors forming the mesh earthing system shall be such as to limit the grid potential rise to a value that limits the touch voltage to a value not greater than the maximum tolerable touch potential for defined fault clearance time.

The depth of laying of earthing mesh grid shall be defined in engineering/design stage according to Contractor's calculations, but shall be in range of 0.6 ÷ 1 m.

The substation earthing system shall be designed to meet the requirements of this Technical Specifications and shall be in accordance with IEEE Std 80. The Contractor shall submit the calculations (both manual and in appropriate software) and adequate drawings to indicate that earthing system meets these requirements in terms of earthing system resistance, maximum grid potential rise, touch & step voltages, transferred potentials, etc.

The substation earthing system shall be designed so as to include all overhead line terminal towers, which shall be earthed by extending the earthing system so as to envelop all towers within the earthing system. Each tower shall be bonded directly to the earthing system from at least two (2) locations. Steel structures, lightning masts and security surveillance equipment shall also be within the perimeter of the substation earthing grid. No fixed low voltage equipment, with the exception of a warning or alarm button and intruder alarms which shall be of a double insulation type, shall be erected outside the perimeter of the substation earthing grid.

Gradient control mats shall be installed adjacent to each circuit breaker, disconnector, and earthing switch operating mechanism. The mat shall be connected by a conductor to the operating handle or to the operating mechanism cubicle. This conductor shall not form a part of the main earthing conductor of the circuit breaker, disconnector, or earthing switch.

All steel structures within substations shall be bonded by copper and connected to the substation earthing grid.

The substation metal fence shall be bonded electrically to the substation earthing grid on each side at spacing not exceeding 0.25×r (where r is the equivalent circular plate radius), at points adjacent to each corner and immediately below any overhead line entering or leaving the Site. The location of the mesh conductors shall be such as to enable all items of equipment to be connected to the earthing system via the shortest possible route.

Gateposts forming part of the substation fence shall be bonded together with below earth connections and the gates themselves shall be electrically bonded to the posts.

Connections to the earthing grid of all non-current carrying metal parts such as steel structures, water pipes, etc., shall be not less than 60 $mm^2$ and shall be of adequate size and current carrying capacity.

The current density of the earthing conductor shall be not greater than 200 $A/mm^2$ for a 1 second short time current rating and 100 $A/mm^2$ for a 3 second short time current rating. Single connections between equipment and the earthing system shall carry the total short circuit current, but the cross-sectional area of branch connections may be reduced to take account the current distribution in two or more conductors. A distribution of 60% shall be assumed for this purpose, i.e., the cross-sectional area of branch connections may be reduced to 60% of the corresponding single conductor.

In the event that substation resistance obtained with the foregoing installation being of a magnitude unacceptable to the Client, then where practicable, the ground area enclosed by the earthing system shall be increased by installing a copper conductor directly in the ground in the form of a ring around the site at a significant distance from the boundary fence. Alternatively, earthing conductors can be directly buried radially outside the substation perimeter fence and the number of the earthing rods can be increased. The use of earthing plates as current carrying electrodes shall not be acceptable.

The alternative approach of independently earthing the fence and placing it outside the earthing grid area shall only be adopted if the above-mentioned procedures prove insufficient or impracticable. The Contractor shall provide calculations to show that this approach produces safe touch voltages at the fence and shall ensure that the fence is isolated from all other buried metalwork.

Metal parts of all equipment, other than those forming a part of an electrical circuit shall be connected directly to the main earthing system via a single conductor. The arrangement of the mesh earthing system shall be such as to minimise the length of these single connections.

Earthing for high frequency coupling equipment and surge diverters shall be via a copper rod driven directly into the ground at a position immediately adjacent to the equipment being earthed in addition to the normal earthing connection.

Each earthing electrode shall consist of clusters of copper rods at least 15 mm diameter and each 3.5 meters long. Each rod electrode shall be complete with approved nonferrous clamps for the connections of the earthing conductors and with a hardened steel tip and cap for driving by means of a power hammer. Where necessary, in areas of high soil resistively, longer rods shall be used if the resistively decreases with depth.

Electrode link chambers and concrete covers shall be provided under other Contract (Civil Tender) to enable easy inspection of the connection.

The Contractor shall ensure that the resistance between any point of each system and the related earthing electrodes does not exceed 0.1 Ω and that the overall resistance between the earthing system and the general body of the earth shall, if possible, be less than 1 Ω under any climate conditions.

Earthing connections/leads to surge arresters, transformer neutral points and earthing resistors shall be made direct to the nearest group of earthing rods and interconnected to the rest of the earthing system.

All main parts of structural steelwork shall be earthed by copper connections bonded to the steelwork.

Connections to apparatus and structures shall be made clear of ground level, preferably to a vertical face and protected against electrolytic corrosion.

Earthing conductors installed directly into the ground shall normally be laid bare and the trench backfilled with fine topsoil. Where the soil is of a hostile nature, precautions must be taken to protect the earthing conductor.

Copper to copper joints on strip conductor shall be brazed, using zinc-free brazing material with a melting point of not less than 600 °C, or by approved exothermic welding.

All exposed joints shall be at a minimum height of 150 mm above floor or ground level.

Earthing conductor joints that are required to be broken for testing or maintenance shall have mating surfaces tinned.

A facility shall be provided on the earth bar run between the equipment and the base of the structure, comprising a looped copper strip, so as to permit the attachment of portable earth connections for maintenance purposes.

After installation of the earthing system the Client shall measure the resistance of the substation earthing system. The preferable method shall be the "fall of potential" method, requiring the availability of a local low voltage supply, but other methods using an earthing resistance megger will be acceptable in the event that a local supply is unavailable.

If measurement indicates that earthing system parameters does not comply with the design and relevant standards Contractor may be obliged to re-design earthing system.

## 3.9. Operation at Voltage and Frequency Different than Rated Values

The 400 & 132 kV equipment shall be designed and constructed to operate within voltage and frequency deviations in the electric power system as defined in the latest edition of NEPCO Transmission Grid Code.

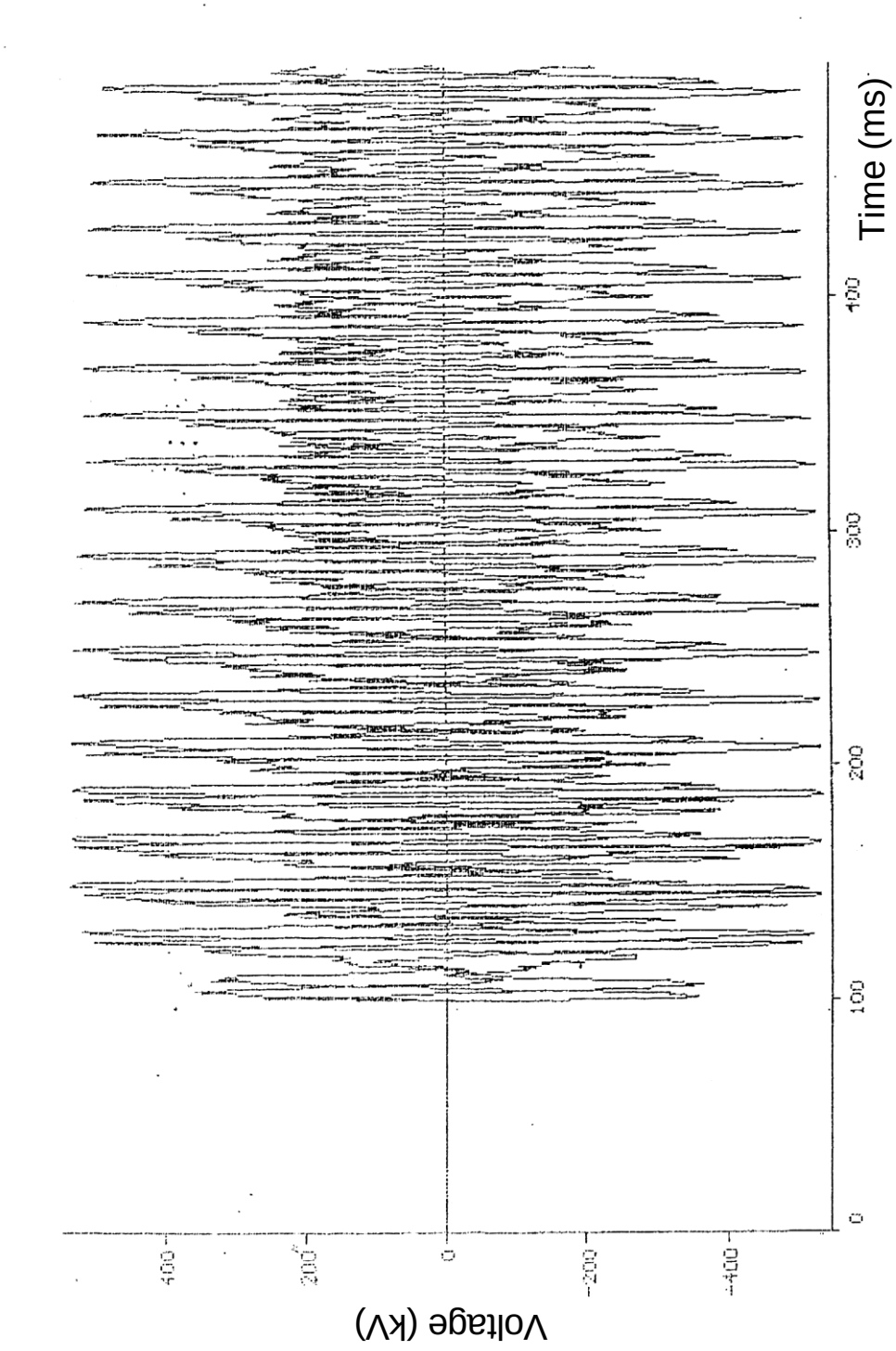
## 3.10. Ability to Withstand High Temporary Overvoltage (TOVs)

Electro Magnetic Transient Program (EMTP) studies of the NEPCO 400 KV AND 132 kV system indicate that the system is characterised by high Temporary Overvoltage (TOVs). The design of the 400 KV AND 132 kV equipment shall take into account the presence of such TOV's and the Contractor shall guarantee that the life of the 400 KV AND 132 kV equipment shall not be significantly shortened if subjected to such overvoltage.

The voltage-time characteristic of the TOVs is given in the Table below.

| **Time (sec)** | **400 (420) kV system (kV Crest/pu)** | **132 (145) kV system (kV Crest/pu)** |
|---|---|---|
| 0-1 | 530/1.55 | 170/1.45 |
| 1.5 | 500/1.45 | 160/1.35 |
| 2.0 | 460/1.35 | 150/1.27 |
| 6.0 | 415/1.21 | 140/1.2 |
| 10.0 | 400/1.17 | 130/1.1 |
| 15.0 | 342/1.0 | (N/A) |

A typical voltage waveform for the above conditions is shown on the following page:




## 3.11. Interlocking Philosophy

### 3.11.1. General

The applicable recommended interlocking defined in IEC 62271 shall be provided. Padlocking to the requirements of this Specification shall be provided for operational and maintenance security.

All disconnecting and earthing devices within the substation shall be interlocked in a manner to ensure that they always operate safely. The applied system shall satisfy two (2) distinct categories:

- Operational interlocking - Interlocking associated with normal system operation and switching, intended to ensure that a predetermined switching sequence is satisfied. Such interlocking shall be achieved by electrical means in a manner that permits the equipment to perform any safe operation. Contacts used for interlocking shall be auxiliary contacts of the main devices which are directly driven,
- Maintenance interlocking - Interlocking associated with a series of switching operations to enable the equipment or sections of the substation safe for access and maintenance by personnel. Such interlocking shall be achieved by mechanical interference type interlocks.

The following assumptions shall be made:

- Disconnectors shall be capable of switching the capacitive currents of associated circuits,
- Disconnectors shall have neither load making nor breaking capacity,
- Disconnectors shall not be capable of making or breaking transformer magnetising current,
- Disconnectors shall be capable of the duty imposed when operated under parallel switching conditions,
- It shall not be possible to operate any disconnector if an associated earthing switch is already closed,
- Circuit breakers shall be interlocked so that, except under maintenance conditions, it shall not be possible to close a circuit breaker unless the pertaining busbar disconnector and line disconnector are closed.

### 3.11.2. Particular Interlocking

#### *3.11.2.1. General*

For all interlocking within the substation, the Client shall have the right to add any interlocking which he considers necessary for safe operation during the engineering/design stage.

#### *3.11.2.2. EHV/HV/MV example132/33kV Transformers, applicable to 400/132/33kV AT also*

*The HV/MV (33kV) circuit breaker for each transformer shall be interlocked with associated EHV/HV 132kV circuit breaker such that:*

i) *The 33kV circuit breaker cannot be closed unless the 132kV circuit breaker is already closed.*
ii) *The 33kV circuit breaker is tripped if the 132kV circuit breaker is opened*

#### *3.11.2.3. Neutral Earthing Equipment*

i) *Neutral earthing resistor disconnector and switch for solid earthing may not both be open at the same time i.e. the system is earthed at all times.*
ii) *The transformer neutral disconnectors must be closed before the associated transformer can be energized i.e. before closing circuit breakers.*

#### *3.11.2.4. Capacitor Banks (connected with 400 kV)*

i) *The transformer 400kV circuit breaker cannot be closed unless the associated capacitor bank circuit breakers are open.*
ii) *The capacitor bank circuit breakers cannot be closed unless the transformer 400kV and 33kV circuit breakers are closed.*
iii) *The capacitor bank circuit breakers must be opened prior to isolating the associated power transformer from the 132kV and 33kV sides. (Operational procedure).*
iv) *The capacitor bank circuit breakers cannot be closed unless the necessary time delay to*

*discharge the associated capacitor bank after the last opening of the circuit breaker has elapsed.*

v) *See also section 25.11 "Access and Interlocks" with regards to interlocks required for access doors in the capacitor bank enclosures.*

vi) *Special care to be taken for:*

– *33kV SWG bus section disconnector. It must never put the two auto transformers in parallel.*

– *400kV OHL AIS Earth Switch (ES) used for maintenance of the lines must be interlocked with GIS earth switches.*

***3.11.2.5.*** *33 kV Switchgear*

*For operation of the 33 kV circuit breakers, the following interlocks are required:*

*-The 33 kV circuit breakers shall be tripped when the associated power transformer 132 & 33 kV circuit breakers are tripped for any reason, including manual tripping,*

*-Any 33 kV circuit breaker shall be prevented from closing unless its circuit protection trip relay is reset and the associated power transformer 132 & 33 kV circuit breakers are closed,*

*-Interlocking between the 33 kV circuit breakers and associated earthing switches shall be such that:*

- The earthing switch cannot be closed unless the associated circuit breaker is opened and disconnected,
- The circuit breaker cannot be closed unless the associated earthing switch is opened.

Additional interlocking is required on the capacitor bank circuits as follows:

– Capacitor bank circuit breakers shall not be closed unless the necessary time delay has elapsed after last opening of the circuit breaker to allow the associated capacitor bank to discharge,

– Locking devices of capacitor bank fence gates (provided under this contract) and earthing switches shall have the following interlocks:

– The fence gate cannot be opened unless the earthing switch of the associated capacitor bank is closed,

– The earthing switch cannot be opened unless the associated fence gate is closed.

For the 400/132/33 Substation, where 33kV reactors, connected on tertiary windings of 400/132/33kV transformers, through dedicated 33kV switchgear, the following interlocking is required:

- Interlocks:

❖ Transformer feeder:-

The 33kV circuit breaker for each transformer shall be interlocked with its associated 400kV circuit breaker and 132kV circuit breaker such that:

– The 33kV circuit breaker cannot be closed unless the 400kV circuit breaker is already closed or 132kV circuit breaker is already closed.
– The 33kV circuit breaker is tripped if the 400kV circuit breaker is opened and 132kV circuit breaker is opened.
– The 33kV ES can't be closed if the 400kV DS is closed or 132kV DS is closed.
– If the 33kV ES is closed, 400kV and 132kV DS can't be closed.
– 400kV ES and 132kV ES can't be closed unless 33kV CB is opened.
– 33kV cable voltage supervision is required to release the 33kV ES.

❖ Reactor feeder

- Reactor CB can't be closed at dead busbar,
- The transformer CB can't be closed if the same section reactor CB is closed or (BS CB closed with the other section Reactor CB closed).
- 33kV cable voltage supervision is required to release the 33kV ES.

• Intertrip:

- If the same section transformer CB is open and bus section CB is open, reactor will receive an intertrip.
- If both transformers circuit breakers are open. reactor will receive an intertrip.

### *3.11.2.6. 132/33 kV Transformers*

The 33 kV circuit breaker for each main transformer shall be interlocked with its associated 132 kV circuit breaker such that:

- The 33 kV circuit breaker cannot be closed unless the 132 kV circuit breaker is already closed,
- The 33 kV circuit breaker shall be tripped if the 132 kV circuit breaker is opened.

### *3.11.2.7. Neutral Earthing Equipment*

For the substation neutral earthing equipment, the following interlocking shall be applied:

- Neutral earthing resistor disconnector and earthing switch for solid earthing shall not both be open at the same time i.e. the system shall be earthed at all times,
- The transformer neutral disconnectors shall be closed before the associated transformer can be energised i.e. before closing the circuit breakers.

### *3.11.2.8. Capacitor Banks*

For the 33 kV capacitor banks, the following interlocking shall be applied:

- The transformer 132 kV circuit breaker cannot be closed unless the associated capacitor bank circuit breakers are open,
- The capacitor bank circuit breakers cannot be closed unless the transformer 132 kV and 33 kV circuit breakers are closed,
- The capacitor bank circuit breakers must be opened prior to isolating the associated main transformer from the 132 kV and 33 kV sides (operational procedure).

### *3.11.2.9. 33 kV Switchgear*

For operation of the 33 kV circuit breakers, the following interlocks are required:

- The 33 kV circuit breakers shall be tripped when the associated power transformer 132 & 33 kV circuit breakers are tripped for any reason, including manual tripping,
- Any 33 kV circuit breaker shall be prevented from closing unless its circuit protection trip relay is reset and the associated power transformer 132 & 33 kV circuit breakers are closed,
- Interlocking between the 33 kV circuit breakers and associated earthing switches shall be such that:
    - The earthing switch cannot be closed unless the associated circuit breaker is opened and disconnected,
    - The circuit breaker cannot be closed unless the associated earthing switch is opened.

Additional interlocking is required on the capacitor bank circuits as follows:

- Capacitor bank circuit breakers shall not be closed unless the necessary time delay has elapsed after last opening of the circuit breaker to allow the associated capacitor bank to discharge,
- Locking devices of capacitor bank fence gates (provided under this contract) and earthing switches shall have the following interlocks:
    - The fence gate cannot be opened unless the earthing switch of the associated capacitor bank is closed,
    - The earthing switch cannot be opened unless the associated fence gate is closed.

# 4. Detailed Requirements for the Equipment

## 4.1. 400 & 132 kV Gas-Insulated Switchgear (GIS)

### 4.1.1. General

The 400 & 132 kV switchgear shall be metal-enclosed switchgear SF6 Gas-Insulated (GIS) type of modern design and shall be fit for purpose.

The complete metal-enclosed gas insulated switchgear shall be constructed in accordance with IEC 62271-203 and filled with SF6 gas, which complies with IEC 60376 and later the gas shall be checked and handled in accordance with IEC 60480.

400 & 132 kV GIS shall provide maximum degree of safety for the operators and others in the vicinity of the switchgear under all normal operating conditions, under all short circuit and internal arcing fault conditions (IAC AFLR). The interlocking provided shall prevent all mal operation. The switchgear shall be suitable for satisfactory continuous operation at the specified minimum rating, at the maximum site ambient temperature of 50 ºC. Satisfactory test evidence shall be submitted to confirm the performance of the equipment at all site conditions.

The arrangement of the switchgear shall provide adequate access for operation, checking and maintenance; at the same time overall space required for the equipment shall be kept to a minimum to provide a compact design. Where required for operational convenience access platforms, catwalks and ladders shall be provided, designed such that they do not unduly impede access for maintenance and repair. Catwalks and platforms shall not be supported from any of the GIS compartments and operating cubicles.

All components of the switchgear, which are on ground potential, shall be electrically connected and all earthing materials shall be of copper “All grounding connections and earth busbars shall be copper”.

The 400 & 132 kV switchgear shall be fully type-tested in accordance with IEC 62271-203, IEC 62271-1, IEC 62271-100, IEC 62271-102, etc. All type tests preferable shall be carried out by independent testing laboratories, not associated with the manufacturers.

In front and rear side of each switchgear bay, “R”, “Y” and “B” phase labels shall be provided. Similar phase marking shall be provided on each end of the busbar enclosure. In addition, labels indicating the bay number (as per NEPCO standard) and the circuit name shall be fixed at the front and rear of each bay and on the Local Control Cubicle (LCC). All labels shall be of stainless-steel plates with black enamel engraving. For the phase labels, the background of the plates shall be coloured (i.e., Red / Yellow / Blue) representing each phase.

Circuit breakers, disconnectors, earthing switches, high speed earthing switches, current transformers, voltage transformers, etc. shall be clearly marked to identify them by mimic diagram in the gas compartment zones of the enclosures. Identification labels of each device shall be arranged in such a way to view them clearly from the ground level. Number of labels that is to be provided on each device is not limited to one. Identification labels shall be provided on the operating mechanism box and at the “ON/OFF” (or “CLOSE/OPEN”) indication boxes for viewing them from ground level. “ON/OFF” or “CLOSE/OPEN” status indication shall be clearly visible from ground level without any obstruction and difficulty. All labels shall be of stainless steel with engraved identifications. The labels shall be riveted or screwed and not adhesive.

Wherever Inspection windows shall include protective covers. Are fitted.

The Contractor shall fix on a wall in GIS room the display board showing GIS schematic depicting all gas zones, gas filling ports, valves, internal arrangement of each typical gas compartment etc. Wall panels shall show the physical location of moving contacts of earth switches, Disconnectors, Circuit breakers etc. Communication gas barriers which can be opened and closed from outside shall be provided with permanent label stating the operating instruction with pre-caution near to the operating knob/plug. The gas zones of different rated gas pressure shall be of different colour. The CB gas compartment may be of red colour to indicate having higher gas pressure than

the gas pressure of other compartments of the switchgear bay. The display board type shall be subject to approval.

Access shall be available for each, and every device mounted on the GIS for doing the maintenance and testing.

Due to safety reasons, operating linkages shall include protective shrouding for personnel safety. Operating linkages of the devices (CB, DS and ES) shall be shrouded to prevent the operating/inspecting personals in contact with moving rods.

Exterior colour as follow: (approved by Clint)

RAL 7044 for 400kV

RAL 6019 for 132,33kV

### 4.1.2. Gas-Insulated Switchgear (GIS) Enclosures

GIS Enclosures shall be designed in accordance with the requirements of IEC 62271-203 and 62271-1 for bolting together and the method of ensuring electrical conductivity between enclosures shall be the subject of Client's approval. The live parts of the switchgear and busbars shall be supported on barriers of insulating material with proven long-term compatibility with SF6 gas and associated arc degradation products. The insulating barriers shall be discharge free at all working voltages. Each insulator used shall be tested for partial discharge as a routine test prior to assembly in the switchgear.

GIS enclosures on all installations shall be divided in gas zones of suitable gas volumes. Each gas zone enclosure shall be fitted with filter and sufficient quantity of molecular sieve to absorb the residual and entering moisture and recombine all SF6 decomposition and degradation products resulting from switching or interrupting fault current arcs for at least ten (10) years.

The design of the enclosure shall be such as to keep the loss of SF6 gas to a minimum. It is expected that replenishment of gas shall not be necessary for at least 10 years. The gas leakage rate of any gas compartment must be less than 0.5 per cent of its volume per year. Gaskets and seals shall be designed for a life expectancy of at least 30 years, and this shall be demonstrated by tests or otherwise.

All static and moving gas seals shall be non-hygroscopic, containing no silicon, non-ageing, non-shrinking, retain resilience for a long time and stable at all temperature and it shall withstand exposure to SF6 gas and its decomposed products without deterioration for the service life of the GIS equipment. Details of the material shall be specified in the Schedules of Technical Data. Seals exposed to risk of deterioration due to their use in outdoors, intended to use between different insulating media, sliding or rotating surfaces shall preferably include multiple seals.

The Equipment in each compartment shall be designed to withstand normal operating voltage even if the gas pressure inside the compartment decreases to atmospheric pressure.

The switchgear gas enclosures shall be sectionalized into gas zones with gas tight barriers between sections or compartments. The sections shall be arranged to minimize the extent of plant rendered inoperative when gas pressure is reduced, either by excessive leakage or for maintenance purposes, and to minimize the quantity of gas that has to be evacuated and then recharged before and after maintaining any item of equipment. External piping is not permitted either between two gas zones or between two gas compartments. Gas filling port of GIB shall be accessible from ground level, preferably at 1.5 m above ground level. Also, terminal boxes of external equipment such as VT shall be provided at 1.5 m above ground level.

In order to minimize the extent of equipment outage in the event of gas loss when gaining access inside equipment for maintenance or when an item of equipment needs to be removed, the overall equipment shall be divided into discrete gas zones isolated from each other by gas-tight bulkheads. Separate gas-zones shall be provided for busbars and isolators. To avoid any internal fault damaging the complete system, each busbar shall be segregated into separate compartment with at least one compartment per bay. The gas-tight support insulating barriers shall be capable of withstanding a pressure differential of a vacuum on one side and on the other a

pressure equal to the design gas pressure or the maximum gas pressure under conditions of an internal fault if this is greater.

The design of the enclosure assemblies shall be such that in the event of an internal fault, the damaged items can be replaced with minimum disturbance to the adjacent compartments. Each gas-tight zone shall be provided with a device (bursting disc) to relieve any pressure rise developed during internal flashover. Overpressure created by internal arcing within an enclosure shall be relieved by means of bursting discs venting into the atmosphere and directed away from people in the vicinity. The method of pressure release shall prevent permanent distortion of adjacent enclosures. Pressure relief by collapse of internal gas barriers is not acceptable.

The arrangement of any pressure relief device shall be such that any expulsion of disc debris or gas will be directed in a manner that will not endanger any personnel. The relief vents shall be provided with deflectors or vent pipes as appropriate to satisfy this requirement. This shall be verified by an internal arcing test on the smallest volume chamber. The duration of the fault arc test shall be determined by the operation of the main and back-up or breaker failure protection (whichever is greater) plus the fault clearance time for the equipment under all fault conditions. This shall be verified by relay setting calculations.

During the internal arcing fault test period, burn through of the enclosure by the fault arc is not permitted. The chamber shall remain intact and emission of all hot gases and arc products shall only be discharged through the pressure relief device and directed away by diverter nozzle, from the normal operation position of the switchgear so that persons standing there are not endangered. Enclosures shall be tested in accordance with established pressure codes according to internationally agreed safety factors for this type of equipment.

The GIS gas compartments shall be designed to facilitate easy, selective and safe maintenance, disassembly and repair. It shall include but not limited to the following:

- Redundant current paths (like busbars within a double busbar concept) shall be segregated in order to allow minimum one busbar in service whilst elements from the other busbar (such as busbar, busbar sectionalizer or busbar disconnector) are under maintenance, replacement or repair,
- During disassembly or repair of a circuit breaker gas compartment and other line compartments, all the busbars shall remain in service.

### 4.1.3. Busbars and Connection Chambers

The busbar conductors shall be of aluminium alloy or electrolytic copper. The gas-insulated switchgear (GIS) and all busbars and the contacts for the conductors shall be suitable for the minimum specified continuous current with addition overload factor as per IEC 62271-1/203., at a site ambient temperature of +50 °C.

To minimize the extent of dismantling necessary to remove a part of a main busbar, it is required that discrete lengths of busbar shall be able to be withdrawn without disturbing adjacent busbar lengths; this may be achieved by the use of compressible bellows or other approved means. Joints of different metals that could lead to electrolytic corrosion must be avoided.

The equipment shall be arranged to avoid excessive dismantling in the event of a main busbar fault. Information shall be provided with the Tender to indicate the facilities incorporated in the equipment to allow removal of busbars and the consequential maximum extent of dismantling that may be involved in the event of such a fault.

All busbar connections shall be colour coded to indicate the phase colour associated with the connection as defined elsewhere in this Technical Specification.

The Bus coupler bays shall not be arranged at the extreme ends of the switchgear.

All gas pipe work shall also be colour coded and where more than one pipe follows a common route, each pipe shall be ring coded or labelled at regular intervals to identify the gas zone with which it is associated. Adequate mechanical protection shall be provided for external SF6 piping.

### 4.1.4. Enclosure Gas Zones

The switchgear SF6 gas enclosures shall be sectionalised into gas zones with gas-tight barriers between sections or compartments. Gas-tight barriers shall be identifiable and durable; colouring optional as approved by Client. The gas zones shall be arranged to minimize the extent of plant rendered inoperative when gas pressure is reduced, either by excessive leakage or for maintenance purposes, and to minimize the quantity of gas that has to be evacuated and then recharged before and after maintaining any item of equipment.

Flat copper strips of adequate capacity shall be provided for bridging the enclosures so as to ensure perfect electrical continuity between enclosures, during all kinds of fault conditions and normal service conditions.

### 4.1.5. Expansion Joints and Flexible Connections

Expansion joints or flexible connections shall be provided in the busbars and metal enclosures to absorb the thermal expansion and contraction of the SF6 equipment. This shall include the switchgear supporting structures and shall accommodate differential settlement of the foundations and floors on which the equipment is mounted.

The method of compensating for temperature variation and differential settlement as well as the number and position of the compensating devices shall be stated in the Schedules of Technical Data and shall be the subject of Client's approval.

### 4.1.6. Future Extensions

The design of the switchgear shall be such that each installation shall be suitable for future extension on either end without any drilling, cutting or welding on the existing equipment and not having to take more than one busbar out of service. Other circuits shall remain available for continuous uninterrupted service.

Where the distance between adjacent circuits is the width of a switchgear bay or greater, a removable straight through busbar section shall be included. It shall be possible to interchange this section with a future bay, if required, without having to take more than one bar out of service and without interruption of other connected circuits.

### 4.1.7. Condition Monitoring of Gas Insulated Switchgear and Circuit Breakers

The 400 & 132 kV GIS shall not be equipped with on-line monitoring system" specially PD monitoring". However, 400 & 132 kV GIS shall be equipped with internal UHF PD sensors/couplers "Each bay shall include UHF PD sensors as per IEC 62478.".

The UHF couplers shall meet the following conditions:

- Type: Maintenance free disc antenna,
- Detection sensitivity level: < 2 pC,
- Detection spectra range: 200 MHz to 1.8 GHz,
- Output: > -15dBm,
- Connector type: N-Type (Impedance 50 ohm) with shorting cap,
- Cable: Coaxial Cable,
- Over voltage & transient protector: To be provided,
- Automatic earthing device (when coaxial cable or shorting cap are removed): To be provided

The sensor (UHF Coupler) location shall be determined by the Manufacturer to satisfy the sensitivity test. The sensitivity test shall be included in the Site Acceptance Test and shall be the acceptance criteria for the sensor location of the GIS.

The Factory Acceptance Test for GIS shall include as "Routine Tests" all necessary tests to prove that the sensor meets the above technical requirement.

The signature records taken by the Manufacturer prior to energization shall be made available to the Client for future comparison purposes.

### 4.1.8. Gas Monitoring and Handling

All gas zones and gas compartments shall be filled to the design pressure with pure SF6 gas to IEC 60376. Each gas zone and gas compartment shall be monitored individually and shall be fitted with temperature compensated pressure switch, numerically graduated temperature compensated pressure gauge and pressure transducer to constantly monitor gas-pressure and gas-density both locally and remotely. Gas measuring devices shall be temperature compensated pressure gauges which are numerically calibrated to indicate the pressure of the compartment. Pressure gauges having only red/green zones without numerical readings are not acceptable. The pressure gauge shall be suitably damped to ensure that it is not subject to transient pressure oscillations either during switching or operation of the switchgear. It is preferable that liquid dampeners are avoided to prevent risk of leakage. Also, it shall be ensured that there is no contact bounce (chatter) in micro switches/relays associated with the pressure gauge during switchgear operation/switching.

The location of such measuring points shall be reasonably accessible. Each gas monitoring device shall be connected to the gas compartment via a self-sealing valve to facilitate easy removal of the device for maintenance. The use of stop valves for this purpose is not acceptable. Gas monitoring devices shall be capable of being calibrated and replaced while the respective compartment/equipment is in service and without removing gas from the compartment.

Each gas compartment shall be supplied with temperature compensated numerically graduated gas monitoring devices which continually monitors the gas within the compartment. Each device shall provide a remote signalling contact for alarm purposes when the gas density falls below the recommended level. This shall generate SF6 Stage1 alarm. A second signalling contact shall be made when the density reaches the minimum recommended operating level. This shall generate SF6 Stage 2 alarm. When Stage 2 level is reached in any compartment, the further operation of equipment in that particular compartment shall be blocked. Stage 2 gas alarm of one compartment shall not block the operation of other equipment in compartments having adequate SF6 gas level. All alarms generated shall be shown in LCC alarm facia/display, SCS and NCC. The alarm text shall include the gas compartment designation and SF6 Stage 1 or 2 depending on the signalling contact activated. The local control cubicle shall be adequately labelled to allow easy identification of signals from each gas section.

A two-stage low gas pressure alarm and lockout system with local and remote indications shall also be provided on each circuit breaker.

In view of the dependence of system security on the reliability of the SF6 gas-monitoring device, and in view of the large number of relays involved in any regular relay checking procedure, the gas monitoring device shall have a high degree of reliability. Consideration shall be given in the design of the relay to allow easy checking of its proper operation.

SF6 gas taken from the GIS equipment shall be checked and handled in accordance with IEC 60480.

SF6 filling ports and devices of the GIS shall be compatible with DILO fitting DN20. All required adaptors compatible with DILO instruments shall be supplied for measurement of dew point, purity and decomposition of the SF6 gas.

Pressure gauges for all GIS compartments for a bay shall be visible from ground level.

For each bay of GIS, there shall be an engraved stainless-steel plate which contains the following minimum details:

- Design maximum gas pressure,
- Filling gas pressure at 20 ºC,
- Normal working gas pressure at 20 ºC,
- Stage 1 gas pressure at 20 ºC,
- Stage 2 gas pressure at 20 ºC.

Above details shall be provided for each type of compartment. Also, stainless steel plate showing SF6 pressure versus Temperature shall be provided. All SF6 alarms in GIS shall be of fail-safe mode.

### 4.1.9. Local Control Cubicles

Local control cubicles (LCC) shall be separate, floor mounted cubicles, provided adjacent to each switchgear section which shall contain all facilities for control, indication, local/remote/maintenance control selection, protection and alarms associated with that switchgear section. A mimic diagram incorporating switches, contactors and relays necessary for local electrical control of circuit breakers, disconnectors and earthing switches together with position indication, metering instruments, annunciator shall be included, including all necessary equipment for the safety and efficient operation of the switchgear.

Dedicated Bay Control Units (BCU) for each individual circuit/bay shall be provided. Contents of BCU shall be as per Contractor's design, which is subject of Client's approval.

Any plug and socket cable connections between switchgear sections and their associated local control cubicles shall be provided with a secure means of locking the connection to prevent inadvertent disconnection.

Exterior colour as follow: (approved by Clint)

RAL 7044 for 400kV

RAL 6019 for 132,33kV

### 4.1.10. Gas Insulated Bus-Duct (GIB) and Bushings

Where applicable, $SF_6$ gas insulated bus-ducts and supporting structures and foundations shall be provided between circuits as indicated on the Tender Drawings. The bus-ducts design shall suit the arrangement of the main GIS switchgear to which the bus duct is connected.

The $SF_6$ enclosures shall be constructed from the same materials as the bus bar enclosures provided with the main GIS switchgear. The materials used shall prevent overheating at the minimum specified currents. To reduce the effect of solar gain all $SF_6$ insulated bus duct exposed to direct sunlight shall be covered with metallic sun shielding. The bus duct shall be complete with all components, enclosures, gas seals, gas monitors, gas compartments, gas filters, gas barrier and supporting insulators as per the previous Clauses.

The bus-ducts shall be terminated at one end direct on to the GIS switchgear and at the other end on to outdoor porcelain-clad or approved composite-material-clad bushings for OHL feeders.

The design of the bus-ducts shall make full allowance of the thermal expansion associated with the switchgear, wall mounted bushings and any other equipment between which the bus ducts are connected. The Contractor shall fully co-ordinate the requirements of the $SF_6$ insulated bus duct connections between the GIS switchgear feeder bays and outdoor porcelain-clad or approved composite-material-clad bushings for OHL feeders.

The design and installation of the bus-ducts shall as such be fully coordinated with the manufacturers of the equipment to be connected and shall also be coordinated with the civil design and works in relation to the building height, wall openings, wall/roof embedment, structural, etc. apart from the foundation requirements described herein.

The gas filling/drain ports for the Bus ducts/Bushings shall be accessible from ground level. SF6 monitoring and filling/draining provisions of the bus ducts shall be provided in a covered box at a height of 150 mm from ground level. The preferred location of this facility is inside the GIS room. Provision shall be allowed access and disconnection links for equipment HV testing as may be required at Site.

### 4.1.11. GIS Circuit Breakers

#### *4.1.11.1. Circuit Breaker Design*

The SF6 gas insulated circuit breakers shall be the single-pressure puffer or other type approved by Client, suitable for indoor-installation.

GIS Circuit Breakers shall be designed in accordance with requirements of the Standard IEC 62271-203 and shall be fully type-tested in accordance IEC 62271-100, IEC 62271-1, IEC 62271-101 and with the requirements of this Specification. Type-test certificates shall be submitted to Client for approval.

GIS Circuit Breakers shall have high reliability during operation and shall require minimal maintenance and shall have a long lifetime.

The design of the circuit breaker shall be such that inspection and replacement of contacts, nozzles and any worn or damaged component can be carried out quickly and easily. The circuit breaker shall be fitted with the "open/close" position indicators easily visible from ground level. The "Open" position indication shall be inscribed as "OFF" and the "Close" position indication shall be inscribed as "ON". The maximum pole scatter during makes shall be less than 3.3 ms and during opening shall be less than 3 ms.

The design of the circuit breakers shall be such that one set of contacts and nozzle (or nozzles as the case may be) shall be able to successfully interrupt at least twenty 100% fault currents without excessive erosion. Circuit Breakers shall be designed to withstand the over voltage impact during small inductive/reactor current switching. This capability shall be proved by satisfactory and valid test evidence in accordance with the applicable IEC. In any case where the CB fails to meet this requirement, suitable devices shall be equipped to control the switching timing and to limit the over voltage resulted from the switching. The contractor shall ensure that very fast transient over voltage generated in the set up envisaged in particular substation, shall be less than specified over voltage.

The Contractor shall carry out study to demonstrate Very Fast Transient Over voltages (VFTO) generated by circuit breaker operation, slow operation of disconnecting switches and high-speed earthing switches, etc. The GIS modelling/study shall include all probable switching scenarios of the substation. The study report, design calculations and results shall be submitted to the Client for approval. Also, GIS shall be designed to minimize the effect of Transient Enclosure Voltage (TEV) associated with the very fast transients during switching operations or earth faults inside the GIS. Internal collapse of voltage in the SF6 gas, internal re-strikes across circuit breaker or disconnect switch contacts shall not develop dangerous transient voltages on the "grounded" enclosures. Scope of VFTO study shall prove proposed GIS is within safe limit of TEV.

The sound pressure levels of the breaker during the mechanical operations shall comply with the local and national health and safety regulations.

A suitably quantity molecular sieve shall be used in the circuit breaker tank to absorb any moisture, SF6 degradation product and any contaminant for at least ten years in service.

The circuit breakers shall be suitable for at least 10,000 satisfactory open and close mechanical operations in accordance with IEC 62271-100.

A two-stage low gas pressure alarm and lockout system with local and remote indications shall be provided on each circuit breaker. The low pressure/density alarm switches shall instantly provide an instruction to the operator, lockout the circuit breaker on 2nd stage and subsequently inhibit their further operation until suitable remedial action has been taken.

#### *4.1.11.2. Operating Mechanism*

##### *4.1.11.2.1. General*

The circuit breakers shall preferably be fitted with power-spring mechanism but other types of reliable mechanisms such as leak-free hydraulic mechanism shall also be considered, provided they comply with the above circuit breaker mechanical operations requirement. Pneumatic mechanism shall not be acceptable.

A positively driven open/closed, mechanical indication device to show the position of the main contacts and with local manual operated features for tripping, closing and spring charging, visible without the necessity to open the mechanism door, shall be provided. The drive for the device shall be positive in both directions.

The mechanism shall fully close the circuit breaker and sustain it in the closed position against the forces of the rated making current and shall fully open the circuit breaker without undue contact bounce at a speed commensurate with that shown by tests to be necessary to achieve the rated breaking capacity in accordance with IEC 62271-100. The mechanism shall be capable of being locked in either the open or closed position. The operating mechanism shall be capable of fully closing and opening again after the auto-reclose time interval specified, i.e., performing a complete O-0.3 sec-CO-3 min-CO duty.

Mechanical counters, to record the number of closing operations, shall be provided for each circuit breaker mechanism. The mechanism and the connected interrupters shall satisfy the mechanical endurance requirements of IEC 62271-100 and all additional requirements specified herein.

Means shall be provided to prevent the mechanism from responding to a close signal when the trip coil is energized or to re-closing from a sustained close signal either after opening due to a trip signal or failure to hold in the closed position, i.e., shall include an anti-pumping device. Any relays to accomplish these provisions shall be continuously rated and mounted at the circuit breaker. The mechanism shall also incorporate manual-trip facility fitted with a guard to preclude inadvertent operation.

Means shall be provided to detect phase discrepancy in the event of one or two phases failing to complete a close or trip operation and to trip all three phases after a time delay of 1 second. Each mechanism shall be fitted with duplicate trip-coils and phase discrepancy remote indication shall also be provided.

The following facilities shall be provided at each circuit breaker local control point:

- Emergency Trip Device, suitable for manual operation in event of failure of electrical supplies. The device shall be accessible without opening any access doors and distinctively labelled and protected (without padlocks) against inadvertent operation. Flipping open and lockable security cover loosely attached over emergency trip button shall be provided.
- Manual Closing Device, suitable for manual operation in event of failure of electrical control supply. The Manual Closing device shall be protected and pad-locked to prevent inadvertent operation.

The selector switch shall be lockable in both positions and the control switch shall be lockable in the neutral position. For maintenance purposes, means shall be provided for manual operation including the slow closing and opening of those circuit breakers whose moving contacts are mechanically coupled to the direct linkage mechanism. Such operation shall be possible without the necessity of gaining access to the interior of the power unit and shall not require excessive physical effort.

CBs shall be provided with mechanical indication for spring charged/discharged condition, and it shall be clearly visible from the ground level. The condition of mechanism charge shall be clearly indicated literally in English as "*Spring Charged*" and "*Spring Free*" instead of graphical symbols.

#### *4.1.11.2.2. Spring Mechanisms*

Provision shall be made for remote indication of "*Spring Charged*" and "*Spring Charge Fail*" conditions. A spare normally open spring-drive limit switch shall be provided.

It shall be possible to hand charge the operating springs with the circuit breaker in either the open or closed positions. In normal operation, recharging of the operating springs shall commence immediately and automatically upon completion of the closing operation and shall be completed within 30 seconds.

Closure whilst a spring charging operation is in progress shall be prevented and release of the springs shall not be possible until they are fully charged. The state of charge of the operating springs shall be indicated by a mechanical device which shows "*Spring Charged*" when operation is permissible and "*Spring Free*" when operation is not possible.

The insertion of spring charge handle shall disconnect electrical supply to the spring charging motor to enable safe manual spring charging operation. For maintenance purpose, and to prevent inadvertent operations, means shall be provided to switch-off power supply to CB drive mechanism and to discharge spring.

#### *4.1.11.2.3. Hydraulic Mechanisms*

Hydraulic mechanism shall be leak-free. The hydraulic pressure shall be maintained automatically, a numerically graduated gauge being provided to give indication of the pressure. The pressure gauge shall be suitably damped to ensure that it is not subject to transient pressure oscillations either during pumping or during operation of the circuit breaker.

A lockout device with provision for remote alarm indication shall be incorporated in each circuit breaker to prevent operation whenever the pressure of the operating medium is below that required for satisfactory subsequent operation at the specified rating. Such facilities shall be provided for the following conditions:

- Trip lockout pressure.
- Close lockout pressure.
- Auto-reclose lockout pressure.

Alarm contacts shall be provided to indicate above mentioned conditions. For two trip systems, the trip lockout shall apply to both systems.

A sudden fall in pressure of the operating medium to a level below which a safe operation is not possible shall not result in slow opening or closing of the circuit breaker contacts. The mechanism shall be locked in position and electrical trip and close signals shall be isolated during this period. Facility shall be provided to enable the available operating energy stored by the mechanism to be determined prior to operating the circuit breaker, together with an alarm in the event of the potential energy falling below a minimum rated level. Facility for hand charging of hydraulic systems shall be provided.

Circuit breakers having independent operating mechanisms on each phase shall block tripping, closing, and auto-reclosing of all phases if the operating pressure is below a minimum rated level in one or more of the mechanisms.

A pump or compressor or motor running time meter shall be fitted and an alarm shall be provided to indicate excessive running time and shall initiate a power supply trip of pump/compressor/motor in case of excessive running time. For maintenance purpose and to prevent inadvertent operations means shall be provided to switch-off power supply to CB drive mechanism and to discharge spring/hydraulic system.

#### *4.1.11.2.4. Mechanism Housings*

Adequate heaters controlled by thermostat and hygrostat shall be provided. Means for locking shall be provided for the doors of each mechanism housing. Mechanism housings degree of mechanical protections shall be IP5X.

### 4.1.12. GIS Disconnectors and Earthing Switches

#### *4.1.12.1. GIS Disconnectors*

The GIS Disconnectors shall be designed in accordance with requirements of the Standard IEC 62271-203 and shall be fully type-tested in accordance IEC 62271-102, IEC 62271-1 and with the requirements of this Specification. Type-test certificates shall be submitted to Client for approval.

GIS Disconnectors shall have high reliability during operation and shall require minimal maintenance and shall have a long lifetime.

The disconnectors design shall incorporate features, which shall reduce or eliminate very high frequency voltage transients during disconnector operation.

The disconnecting function of disconnectors shall still be effective when adjacent equipment components are dismantled. It is preferred that disconnector contacts can be maintained and replaced with the associated earthing switch closed.

Disconnectors shall be fitted with the "open/close" position indicators easily visible from ground level. The "Open" position indication shall be inscribed as "OFF", and the "Close" position indication shall be inscribed as "ON". Viewing windows for confirming the positions of disconnector and earthing switch contacts shall be provided.

The disconnectors shall be provided with motor operating and manual operating mechanisms. The motor operation of the disconnectors shall be capable of being controlled from a local or remote point. Each motor operating disconnector shall be complete with a lockable "LOCAL/REMOTE" selector switch and "OPEN/NEUTRAL/CLOSE" control switch. The function of all control and selector switches shall be clearly labelled.

Motor operating mechanisms shall be capable of being locked in the "OPEN" or "CLOSED" positions. They shall also be suitable for the operation from voltage specified in the Schedules of Technical Data. Operating motors shall be provided with thermal overload protection and in the case of 3-phase motors, phase unbalanced protection.

The disconnectors shall be suitable for slow closing operation. Manual operation of the disconnectors for maintenance purposes shall be provided.

The number of normally open (NO) and normally closed (NC) auxiliary switches required shall be as dictated by the particular scheme of application plus 30% extra as spare. Where any particular scheme requires special timing of auxiliary contacts, these shall be provided.

Electrical control circuits shall be so arranged that once initiated, an operation shall be completed unless prevented by loss of supply or operation of the motor protection. On restoration of supply the operation shall be completed. Emergency hand operation shall be provided on motor-operated disconnectors and the motor drive shall be mechanically disconnected during hand operation. It is required that the manual effort to operate the disconnectors shall be less than 150 N. There shall be adequate access for the manual operation. All manual operations shall be possible from the front of the component (i.e. facing the component).

In the case where the operating mechanism comprises an energy storage system followed by triggering for completion of the operation, the design shall exclude any possibility of operation by accidental triggering. Switch operation shall be effective only after full charging of the operating mechanism and after deliberate operator action.

The operating handles for manual operation of power-operated mechanisms may be detachable, in which case only two (2) handles of each type are required.

Common alarm shall be generated in the LCC/SCS for the following conditions of disconnectors & earth switch operations:

- D/ESw not in end position,
- D/ESw in intermediate position,
- D/ESw incomplete operation.

#### *4.1.12.2. GIS Earthing Switches and Maintenance Earthing Devices*

##### *4.1.12.2.1. Earthing Switches*

Earthing Switches shall be designed in accordance with requirements of the Standard IEC 62271-203 and shall be fully type-tested in accordance IEC 62271-102, IEC 62271-1 and with the requirements of this Specification. They shall be provided with motor and manually operated mechanisms and shall be provided on one or both sides of the earthing switch dependent upon the locations.

The electrical operation shall be performed from their control cubicles.

The Earthing Switches and Maintenance Earthing devices shall also be provided with manually operated mechanism. The power drive shall be mechanically disconnected during hand operation. Earthing Switches and Maintenance Earthing Devices shall be fitted with the "open/close" position indicators easily visible from ground

level. The “Open” position indication shall be inscribed as “OFF” and the “Close” position indication shall be inscribed as “ON”. Viewing windows for confirming the positions of contacts shall be provided.

Each power-operated Earthing Switch and Maintenance Earthing device shall be complete with a lockable “LOCAL/REMOTE” selector switch and “OPEN/NEUTRAL/CLOSE” control switch. The function of all control and selector switches shall be clearly labelled.

Power operating mechanisms shall be capable of being locked in the open or closed positions; they shall also be suitable for the operation from voltage specified in the Schedules of Technical Data. Operating motors shall be provided with thermal overload protection and in the case of 3 phase motors, phase unbalanced protection.

The Earthing Switch and Maintenance Earthing device shall be suitable for slow closing operation. Manual operation of the Earthing Switch and Maintenance Earthing device for maintenance purposes shall be provided as well.

The operating mechanism of High-Speed Fault Making Earthing Switches shall be motor wound spring-operated type. The closing spring shall remain in discharged position when the switch contacts are in open or closed position. The closing spring shall be charged only when the closing command is given either electrically or manually and the contacts shall close or open automatically after the spring is fully charged.

The number of normally open (NO) and normally closed (NC) auxiliary switches required shall be as dictated by the particular scheme of application plus 30 % extra as spare. Where any particular scheme requires special timing of auxiliary contacts, these shall be provided.

Electrical control circuits shall be so arranged that once initiated, an operation shall be completed unless prevented by loss of supply or operation of the motor protection. On restoration of supply the operation shall be completed. It is required that the manual effort to operate the Earthing Switch and Maintenance Earthing device shall be less than 150 N. There shall be adequate access for the manual operation.

In the case where the operating mechanism comprises an energy storage system followed by triggering for completion of the operation, the design shall exclude any possibility of operation by accidental triggering. Switch operation shall be effective only after full charging of the operating mechanism and after deliberate operator action.

The operating handles for manual operation of power-operated mechanisms may be detachable, in which case only two handles of each type are required per substation.

Each separate section of switchgear, which can be disconnected, shall have provision for earthing in accordance with the following requirements:

- All incoming and outgoing supply circuits shall be earthed by a device having a making current rating and short time rating equal to that of the associated circuit breaker.

  When specified, the earth switch shall be fully insulated and the connection to earth brought out through the metal cladding by means of an insulating bushing in order that the earth switch may be used for various test purposes. A removable bolted link shall be provided for connecting the insulated earth switch connection to the actual earthing terminal. The earth switch and connection bushing shall be capable of withstanding an applied power frequency voltage of 10 kV.

  It shall be possible to visually verify the status of the high-speed earthing switch. For this purpose, viewing window with facility to illuminate GIS enclosure shall be provided.

- Sections, which can be established as having been disconnected, shall be earthed by a device having a short time rating equal to that of the circuit breaker.

  The earthing switch and the test injection points arrangement shall be suitable for a test current equal to the rated normal current of the connected bus bars for a duration of 5 minutes.

- Earthing switches on line circuits shall be capable of closing onto an energised circuit and of interrupting the current induced in the line by a parallel fully loaded line. The interrupting duty required is as specified in the schedules.
- The terminal lead connection/ junction of line earth switch (.x1) and maintenance earth switch (.xM) should be of removable type to facilitate testing of circuit breaker and power cables. The earth switch (.x1) and maintenance earth switch (.xM) shall be fully insulated and the connection to earth brought out through the metal cladding by means of an insulating bushing in order that the earth device (.x1 / .xM) may be used for various test purposes. A removable bolted link shall be provided for connecting the insulated earth switch connection to the actual earthing terminal. By removing this link all phases shall be independently accessible and shall withstand 10 kV (AC & DC).

  The earth switch operating mechanism shall be capable of being locked in the open or closed position.

#### *4.1.12.2.2. Portable Maintenance Earthing Devices*

Where portable earthing is required, provision shall be made for applying fully rated portable maintenance earthing devices to the primary conductors of the equipment.

The design of the device shall be such that the chamber in which the device is applied can be refilled with SF6 gas when the device is in the closed position

### 4.1.13. Current Transformers

The Current Transformers (CTs) shall be single-phase, ring type, designed in accordance with the requirements of the Standards IEC 62271-203, IEC 61869-1&2 and other relevant Standards if not otherwise required in this Specification.

The rated transformation ratios, rated outputs and other rated characteristics of current transformers are given in schedule A: Scope of Supply & schedule D: Schedule of Technical Data.

The rated extended primary current shall be 120% of the rated primary current.

The current transformers windings shall be made of copper only.

Current transformers shall have the following accuracies:

- Class 0.2S for tariff metering,
- Class 1 for instruments,
- Class 5P for overcurrent & earth fault protection,
- Class X (PX according to IEC 61869-2) for differential & high impedance busbar protection.

The Contractor is obliged to determine the rated outputs and other characteristics of the current transformers protective and measuring cores for the normal and transient operating conditions, as well as to coordinate them with the protection and measuring devices. The Contractor shall submit all necessary calculations and analysis to the Client for approval.

Design calculations for current transformers for use with all types of relays shall be submitted to the Client for approval within three (3) months of contract award. CT design shall be based on a maximum fault level equivalent to the 400 & 132 kV switchgear rating.

For distance measuring protection, phase comparison protection and current differential protection schemes the Contractor must state clearly the accuracy necessary for the correct functioning of the protection system offered and show that the secondary output of the current transformer is satisfactory for this purpose.

Each current transformer secondary winding circuit shall be earthed at only one point. Wherever possible the connection to earth shall be on the side of the S2 terminals (S3 on CTs with tappings).

Where adequate earth screens are fitted between the primary and secondary windings, earthing of the secondary winding shall be via a link mounted in the related protection or instrument cubicle. Where such earth screens are not fitted, a separate earth system may be necessary.

Where multi-ratio transformer windings are specified, multi-ratio primary windings shall only be considered where the protection arrangement makes these suitable for all aspects of the installation.

The location of the Current Transformers shall be as near as possible to the Circuit Breaker compartment. In any case the CTs shall not be located so as to cover any part of the cable or cable termination of the feeder. This is to exclude cable or cable termination being considered in the bus bar zone protection. Secondary leads of current transformers housed inside the GIS shall be properly identified using ferruling approved by Client.

Facilities shall be provided to allow primary injection testing of the current transformers with the minimum disturbance to the switchgear and particularly without requiring an outage of the bus bars. The disturbance shall be limited to the particular Bay where the CTs are subject to Primary Injection Test

Current transformer should not be housed in SF6 circuit breaker housing.

### 4.1.14. Voltage Transformers

The Voltage Transformers (VTs) shall be single-phase or three-phase, inductive type, designed in accordance with the requirements of the Standards IEC 62271-203, IEC 61869-1&3 and other relevant Standards if not otherwise required in this Specification.

SF6 / Equivalent insulated voltage transformers shall be of the inductive type, constructed and tested in accordance with IEC.

The GIS VTs shall be housed in a tank which complies with the internal arcing requirements of IEC 62271-203.

The rated transformation ratios, rated outputs and other rated characteristics of voltage transformers are given in schedule A: Scope of Supply & schedule D: Schedule of Technical Data

Voltage transformers shall have the following accuracies:

- Class 0.2 for tariff metering,
- Class 1 for metering and instruments,
- Class 3P for protection.

The Contractor is obliged to determine the rated outputs and other characteristics of the voltage transformers protective and measuring secondary windings for the normal and transient operating conditions, as well as to coordinate them with the protection and measuring devices. The Contractor shall submit all necessary calculations and analysis to the Client for approval.

The voltage transformers shall have a voltage factor of 1.2 continuous / 1.5 for 30 seconds.

Voltage transformers shall not be loaded to more than 75% of their rated output.

The voltage transformers windings shall be made of copper only.

The voltage transformer secondary circuits shall be complete in itself and shall be earthed at one point only. A separate earth link shall be provided for each secondary winding and shall be situated at the transformer. For each secondary core of the voltage transformer 3 pole MCB shall be provided in local control panel. Each VT secondary MCB shall have its own proper identification label.

Where voltage transformers are supplied which are, or may be, connected to different sections of the bus bar, it shall not be possible for the voltage transformer secondary circuits to be connected in parallel.

An auxiliary switch or relay shall be provided in each phase of the secondary circuit of the synchronising and metering voltage supply connections to break the circuits automatically as soon as the circuit breaker is opened.

To prevent ferro-resonance, suitable damping devices shall be provided for connection to the transformer secondaries.

Secondary leads of voltage transformers housed inside the GIS shall be identified properly identified using ferruling approved by Client.

The GIS VT tank shall have a suitable lifting facility. The high voltage cast resin insulators (barriers) shall be suitable for withstanding the differential pressure i.e., the normal working pressure on one side and the vacuum on the other side. They shall be compatible with $SF_6$ gas and its degradation products.

The pressure of the gas at normal temperature and pressure shall be such that it remains in its gaseous state when operating at the lowest temperatures stated in the Schedules of Technical Data. Facilities shall be provided for constant local monitoring of the $SF_6$ gas pressure inside the tank, topping up or sampling the gas.

All bus bar VTs shall have motorized disconnectors and maintenance earthing switches in a separate gas compartment and all feeder VTs shall have manually operated disconnectors for VT isolation purpose and to facilitate the injection testing of GIS equipment when required. It shall be possible to carry out HV tests on cables without removal of the voltage transformer by opening of VT disconnector only. The motorized disconnectors shall also have facility for manual operation to facilitate operation in event of power supply/motor failure. The specification of the VT disconnector shall be same as GIS disconnector as mentioned in previous clause of 4.1.12

For safety reasons, a bursting disc shall be fitted to the voltage transformer housing.

### 4.1.15. Surge Arresters

#### *4.1.15.1.* *General*

The Surge Arresters (SAs) shall be single-pole, metal-oxide, gapless type, suitable for use on three-phase, 50 Hz system with solidly earthed neutral point. The application and rating of surge arresters shall be determined by insulation co-ordination studies.

Surge Arresters shall be gas insulated (GIS) or, where indicated, suitable outdoor type surge arresters.

Surge Arresters shall be designed in accordance with the requirements of the Standards IEC 60099-4 and other relevant Standards if not otherwise required in this Specification.

The rated characteristics of surge arresters are given in schedule A: Scope of Supply & schedule D: Schedule of Technical Data.

The Contractor is obligated to determine the characteristics of surge arresters for the normal and transient operating conditions and perform necessary coordination with the equipment which needs to protect. The Contractor shall submit all necessary calculations and analysis to the Client for approval.

Surge Arresters shall be designed to ensure satisfactory operation under the atmospheric conditions given in the General Technical Specifications and under such sudden variation of voltage as may be met with under working conditions on the system.

The surge arresters shall be positioned as near to the equipment to be protected so that they can provide maximum protection in accordance with IEC 60099.

#### *4.1.15.2.* *Gas Insulated Surge Arresters*

Surge arresters which are integrated into GIS switchgear shall be single-pole, gas-insulated, metal-oxide, gapless type. The application and rating of surge arresters shall be determined by insulation co-ordination studies.

The surge arresters shall be designed to incorporate a pressure relief device to prevent shattering of the blocks/or housing, following prolonged current flow or internal flashover. They shall be designed to ensure satisfactory operation under the atmospheric conditions given in the Schedules, and under such sudden variation of voltage as may be met with under working conditions on the system.

A combined surge counter and leakage current meters shall be provided with each surge arrester. The surge counter shall be operated by the discharge current passed by the surge arrester. Surge counters shall be of the electro-mechanical type and designed for continuous service.

The surge counter shall be connected in the main earth lead from the diverter in such a manner that the direction of the earth lead is not changed or its surge impedance materially altered. A bolted link shall be provided so that the surge counter may be short circuited and removed without taking the arrester out of service.

The leakage current meters provided shall be for installation in the earth connection of the surge arresters and shall be designed for continuous operation. The internal parts shall be weatherproofed to IP 65 with a transparent cover to provide an unobstructed view of the ammeter.

### 4.1.16. Cable Termination Unit

The HV power cables shall be terminated directly in the SF6 metal clad switchgear using cable terminations designed for use in SF6 gas which shall comply with IEC 62271-203.

Cable terminations shall be suitable for terminating the specified cables directly into the GIS switchgear using 400 & 132kV plug-in type cable termination. The bushing part (socket) of plug-in-type termination system and accessories shall be supplied, installed and tested by the GIS manufacturer as part of GIS scope of supply.

The dimensions and terminal arrangements shall be submitted for approval by the Client. Cable terminations shall be suitable for connecting 2 cables per phase with cross section of min. 800 $mm^2$ copper/XLPE 132 kV cable fore OHL feeders and 1 cable per phase with cross section of min. 500$mm^2$ for transformer feeders. For all circuits, GIS shall be complete with the bushing part (socket), connecting conductors, shields, accessories, etc.

Where required to reduce local heating when single-core cables are adopted, non-magnetic gland plates shall be provided or alternatively, non-magnetic inserts.

The cable termination fixing requirements shall be coordinated with cable termination manufacturer for fixing the cable termination. (Plug-in type)

The cable connection to the switchgear shall be in accordance with IEC 62271-209.

The manufacturer of the switchgear must coordinate the design of SF6 filled enclosures with that of cable terminations supplied by cable manufacturer. For cable connections the switchgear Bidder/Contractor shall provide the cable connection assemblies according to the limits of supply described in IEC 62271-209 with all tests related to them.

Isolating links shall be provided between the cable terminations and the GIS to enable HV testing of the same as well as fault location measurements.

The Contractor shall be responsible for the design, testing and supply of the insulating barrier, which provides sealing between SF6 and air and also between SF6 and the cable insulation. The Contractor shall ensure that there will be no leakage of SF6 gas, oil or moisture across the sealing-joint from one chamber to the other throughout the service life of the equipment. This barrier shall be designed to accept the cable termination provided by Cable Contractor. The switchgear Contractor shall also be responsible for providing the electrical connection between the cable termination and his equipment.

Suitable cover plates and seals shall be provided as part of the switchgear contract for sealing each aperture where a cable termination is to be fitted, to enable the switchgear to be completely filled with SF6 gas and tested when a cable termination is not available or fitted.

Testing isolation facilities shall be provided as follows (Isolating links shall be provided between cable terminations and the GIS to enable HV testing of the same as well as fault location measurements).

a. High Voltage Tests

All of 400 & 132 kV cable circuits will be tested with a mobile AC test with $2U_0$ for 60mins. The 400 & 132 kV cables shall be terminated using plug-in type terminations. The GIS shall incorporate the insulator cones from the selected cable plug-in system such that the cable terminations can be plugged-in without degassing the GIS. The plug-in cable terminations shall be tested by the Cable Contractor using a suitable test adaptor. This test adaptor shall permit the cable system to be tested outside of the GIS chamber and thus the GIS requires no modification for cable testing other than the incorporation of the cable Manufacturer's insulator cone. The insulator cone shall be designed according to IEC 62271-209.

b. Low Voltage Tests

The cable earth switches shall be fully insulated and connected to earth through a bolted link, as specified, so that the LV cable test equipment (of rated voltage less than 10 kV) may be connected to the cable without opening any of the metal clad gas enclosures.

Control Cables provided between GIS and Local Control Cubicle shall be screened unarmoured cables, prefabricated control cables with screen are also acceptable subject to approval during detailed engineering.

### 4.1.17. Sulphur Hexafluoride Gas (SF6)

#### *4.1.17.1.* *General*

The sulphur hexafluoride (SF6) gas shall comply with the requirements of IEC 60376, IEC TR 62271-303 and IEC 60480.

The SF6 gas shall be supplied in 45 kg cylinders.

The dew point of the gas shall be lower than -45 °C. Sufficient quantity shall be provided to fill all SF6 equipment supplied under this Contract plus an additional 20 per cent as spare for future use.

The high-pressure cylinders in which the SF6 gas is transported to, and stored on site, shall comply with the requirements of local regulations and byelaws.

Under normal conditions the SF6 gas of temperature and pressure is colourless, odourless and non-toxic. It is however five-times heavier than air and the arced gas and degradation products are toxic and harmful. It is therefore important that all personnel working on GIS equipment are kept fully informed of the potential risks and appropriate health and safety regulations.

The Contractor (GIS equipment Supplier) shall be responsible to provide:

- Adequate safety training to Client's staff regarding gas detection, the disposal of arced products and storage.
- Sufficient numbers of facemasks, goggles, hand gloves and respirators, protective clothing and gloves.
- First aid equipment including an eye wash bottle filled with distilled water.

#### *4.1.17.2.* *Gas Handling Equipment*

The number of mobile gas handling plants for filling, evacuating, and processing the SF6 gas in the switchgear equipment shall be supplied as part of the Contract to enable any maintenance work to be carried out. These plants shall include all the necessary storage tanks or cylinders for temporarily storing the evacuated SF6 gas as well as spare gas for maintenance purposes and shall be suitable for transportation on public roads.

The capacity of the temporary storage facilities shall be at least sufficient for storing the maximum quantity of gas that could be removed when carrying out maintenance or repair work on the largest section of the switchgear and associated equipment.

The provided plants shall be suitable for evacuating and treating the SF6 gas by the use of desiccants, driers, filters, etc. to remove impurities and degradation products from the gas. This shall comply with IEC 60480. The

capacity of the plant shall be such that the largest gas zone, with the exception of the circuit breaker, can be evacuated in less than half one hour.

The plant shall also be capable of reducing the gas pressure within the circuit breaker to a value not exceeding 8 millibars within 2 hours.

It shall be capable of operating satisfactorily in the temperature range up to +45° C.

#### *4.1.17.3. Desiccants, Filters, Pipes and Couplings for the Connection of SF6 Gas*

The necessary desiccants, filters for drying and cleaning the gas and all pipes, couplings, flexible tubes and valves for coupling to the switchgear equipment for filling or evacuating all the gases to be used, with all necessary instructions for the storage of this equipment, shall be provided.

### 4.1.18. GIS Crane

This article covers the supply of crane for the handling of the GIS equipment, including all operating machinery (hoist, cross-travel/long-travel motors, hoist control and long/cross travel control panels), platform, crane bridge and all other parts and accessories required for their safe and efficient, operation. The crane shall be used for erection work and for maintenance, repair and overhaul purposes of the installed GIS equipment, with enough capacity for lifting and moving the heaviest GIS part.

The cranes shall be of the overhead traveling type, of all welded, double box-girder or I-beam construction, electrically operated through pendant type control switches as well as radio remote control switches from anywhere in the operation area. All parts of the crane shall be in accordance with DIN, VDE, BS, EN, FEM, or other Standards and/or accident prevention rules approved by Client.

Each crane shall be designed to guarantee fail-safe operation in accordance with the specification and continuity of service. Structural steel to be used for manufacturing the crane bridge shall be at least grade S 235JRG2, according to BS/DIN EN 10027-1

Overhead traveling crane shall consist of a bridge, lifting trolley, crane running mechanism and electrical control system. The pick-up device is a hook. Crane shall be electrically operated and controlled.

The Bidder/Contractor shall define the height and the span of the crane in accordance with the building and equipment design. The crane shall be capable of lifting the maximum erection/maintenance weight, however, at least five tons. A safety factor of 1.5 times of a complete switchgear bay shall be applied for the maximum working load in all stress calculations and also shock loading in case the design and construction of the crane is performed different from DIN/FEM. The lifting equipment shall be specified for an average daily working time of 2 to 4 hours and an equal share of small, medium and heavy loads (normal duty).

Sufficient guards shall be provided to protect personnel from accidents caused by moving mechanism etc. The guards shall be removable for inspection and maintenance.

The cranes shall be provided for all fittings, lowering, transporting and accurately positioning purposes in the relevant switchgear-room.

The crane shall be used for all fitting lowering/lifting, transporting and positioning purposes in the GIS room.

Cranes up to 25 t capacity shall have a crab with one hoist, cranes between 25 and 50 t capacity shall have a crab with one hoist and a second crab with one auxiliary hoist of one (1) ton capacity, cranes above 50 t capacity shall have a second crab with an auxiliary hoist of 2.5 t capacity.

The bridge girder shall be securely jointed to the end carriages, to prevent cross racking. It shall not under any circumstances be possible for the crane to fall from the gantry in the event of derailment. The end carriages shall be equipped with flexible rubber/plastic buffers in both directions of the long-and-cross-travel motion.

The holding of hoist load shall be affected by means of an automatic spring set, electrically or electro-hydraulically released conical brake, actuated by the axial displacement of the conical rotor or disk break. The brake capacity shall not be less than 200% of the torque caused by the maximum nominal load of the crane. The brake must prevent the load from descending until the hoist motor is energized for operation in lowering sense.

Bridge and trolley drives shall be equipped with a spring-set, electrically (solenoid or electro- hydraulic) released shoe or disc brake, whose capacity shall be at least 1.5 times the full operating torque of the drive. The brake shall be applied when the motor control switch or main power switch is in the “off” position and/or when the current fails.

The gears and bevel wheels shall be completely covered with oil-tight gearboxes made of cast steel, cast aluminium or welded steel plates. All gearing shall be made of steel and shall be machine cut.

Double-flanged, spherical cast iron traveling wheels of suitable diameter and width for running on the runway rail profile shall be fitted, and it must be possible to readily withdraw the wheels for inspection or repair. The wheel bearings shall easily be renewable.

All the arrangement drawings shall be submitted for approval. Warning light/horn for crane movement shall also be included in the submittal. The submittal shall also include all clearances, height, span, motor, quality/grade of steel, etc.

The crane motor shall be provided with dual speed control and the speed shall be as specified in the Technical Data Sheets.

All the cables shall be clearly identified by suitable tags or durable markings to facilitate the installation and maintenance.

The crane shall be equipped with following enclosed limit switches of the closed-circuit type:

- Limit switch to limit upward travel of the load blocks
- Double switches to limit travel of bridge in both directions; first switch to reduce the speed before the end position is reached, second switch to stop at the end position
- Double switches to limit travel of trolleys in both directions; first switch to reduce the speed before the end position is reached, second switch to stop at the end position
- Lower hoist limit switch
- Overload limit switch

Limit switches shall be arranged to reset by reversing the associated controller. Only the motion being limited shall be affected by tripping the limit switch.

Design, structural calculation, drawings, detailing and welding details, etc. of longitudinal/gantry girder and rails shall be done by the manufacturer of crane, and will be subject of Client’s approval.

The Bidder/Contractor shall supply suitable load plates on both sides giving details of the lifting capacity of the crane. These nameplates shall be clearly visible to anyone who may use the crane and shall be written in Arabic and English.

An expansion shall be accommodated at every joint. The maximum suspension distance shall not exceed 2m. It shall be suitable for an ambient temperature up to $45^0$ C. The holding brackets for the main power supply line along the crane runway, the main switch as well as the raiser cable from the main switch to the main power supply line is not scope of the crane supplier.

All crane accessories shall be kept in the suitable metallic lockable box.

Crane power outlet shall be at side.

The crane power supply shall have lock facility.

## 4.2. 400 kV &132 kV & 33 kV Outdoor Equipment

### 4.2.1. Current Transformers

The Current Transformers (CTs) shall be single-phase, oil-insulated, hermetically sealed, post type for outdoor installation.

Current transformers shall be designed in accordance with the requirements of the Standards IEC 61869-1&2 and other relevant Standards if not otherwise required in this Specification.

The current transformer shall be composed of a sealed housing for the cores and primary and secondary windings conductors, supported by a porcelain insulator and pedestal along with secondary leads, insulation, and low voltage terminal box.

The following facilities shall be provided:

- Expansion chamber and diaphragm,
- Visual means of determining the level of oil from the ground level within the transformers. This shall be by means of an internal bellows type oil gauge,
- Oil drain cock and sampling device,
- Low voltage terminal box,
- Earthing terminal.

Also, facilities shall be provided which will allow primary injection testing of the current transformers with the minimum disturbance to other equipment within substation.

Current transformers shall be delivered with complete supporting structures required for erection. The steel structure shall be hot dip galvanized.

The rated transformation ratios, rated outputs and other rated characteristics of current transformers are given in schedule A: Scope of Supply & schedule D: Schedule of Technical Data.

The rated extended primary current shall be 120% of the rated primary current.

Current transformers shall have the following accuracies:

- Class 0.2S for tariff metering,
- Class 5P20 for overcurrent & earth fault protection,
- Class X (PX according to IEC 61869-2) for distance, differential & high impedance busbar protection,
- Class P for low impedance busbar protection.

The Contractor is obliged to determine the rated outputs and other characteristics of the current transformers protective and measuring cores for the normal and transient operating conditions, as well as to coordinate them with the protection and measuring devices. The Contractor shall submit all necessary calculations and analysis to the Client for approval.

Design calculations for current transformers for use with all types of relays shall be submitted to the Client for approval within three (3) months of contract award. CT design shall be based on a maximum fault level equivalent to the switchgear rating.

Current transformers shall have a secondary terminal, outside the high voltage housing, mounted in suitable accessible earthed boxes with a hinged door and a removable plate in the outside bottom of the box for cable entry. Each terminal box shall be equipped with the thermostatically controlled heating element, as well. The CT terminal box shall have IP55 degree of mechanical protection according to IEC 60529.

All secondary leads must be wired to shorting type terminals on the terminal strip in the pertaining marshalling kiosk.

Each current transformer secondary winding circuit shall be earthed at only one point. Wherever possible the connection to earth shall be at S3 terminals.

The base tank or pedestal shall be made of metal, shall be of waterproof and hermetically sealed construction and shall support rigidly the transformer unit.

The HV terminals shall be suitable for horizontal connection of aluminium connectors.

### 4.2.2. Voltage Transformers

The Voltage Transformers (VTs) shall be single-phase, oil-insulated, hermetically sealed, capacitive type for outdoor installation.

Voltage transformers shall be designed in accordance with the requirements of the Standards IEC 61869-1&5 and other relevant Standards if not otherwise required in this Specification.

The following facilities shall be provided:

- Oil expansion system,
- Oil level indicator,
- Provision for oil drain/sampling valve,
- Provision for oil filling,
- Low voltage terminal box,
- Earthing terminal.

Voltage transformers shall be delivered with complete supporting structures required for erection. The steel structure shall be hot dip galvanized.

The rated transformation ratios, rated outputs and other rated characteristics of voltage transformers are given in schedule A.: Scope of Supply & schedule D: Schedule of Technical Data.

Voltage transformers shall have the following accuracies:

- Class 0.2 for tariff metering,
- Class 1 for metering and instruments,
- Class 3P for protection.

The Contractor is obliged to determine the rated outputs and other characteristics of the voltage transformers protective and measuring secondary windings for the normal and transient operating conditions, as well as to coordinate them with the protection and measuring devices. The Contractor shall submit all necessary calculations and analysis to the Client for approval.

The voltage transformers shall have a voltage factor of 1.2 continuous / 1.5 for 30 seconds.

Voltage transformers shall not be loaded to more than 75% of their rated output.

Voltage transformers shall have a secondary terminal, outside the high voltage housing, mounted in suitable accessible earthed boxes with a hinged door and a removable plate in the outside bottom of the box for cable entry.

The secondary connections shall be protected with MCBs and wired on the terminal strip in the pertaining marshalling kiosk. The MCBs shall be located in the local terminal boxes for each phase of the voltage transformer. Each terminal box shall be equipped with the thermostatically controlled heating element, as well. The VT terminal box shall have IP55 degree of mechanical protection according to IEC 60529.

Each voltage transformer secondary winding circuit shall be earthed at only one point. A separate earth link shall be provided to each secondary winding.

Where voltage transformers are supplied which are, or may be, connected to different sections of the busbar, it shall not be possible for the voltage transformer secondary circuits to be connected in parallel.

An auxiliary switch or relay shall be provided in each phase of the secondary circuit of the synchronising and metering voltage supply connections to break the circuits automatically as soon as the circuit breaker is opened.

The base tank or pedestal shall be made of metal, shall be of waterproof and hermetically sealed construction and shall support rigidly the transformer unit.

The capacitive voltage transformer consists of a series of capacitor elements housed in high strength porcelain enclosure, fabricated of low loss and high-grade insulation materials. Each capacitive voltage transformer is formed by section, depending on its voltage rating. Each capacitor shall include an expansion chamber to allow changes in the fluid volume under varying temperature condition and to allow the fluid to escape outside the porcelain should there be an excessive pressure build-up due to insulation break down.

The capacitive voltage transformer shall be designed with a great transient response performance which should include, among others, ferro resonance suppression feature such as reactors and resistors damping circuit. Ferro resonance features shall not produce sustained frequency oscillations or overvoltage within 10 Hz of rated frequency. The equipment shall not amplify oscillations existing on the primary network within 5 ÷ 200% of rated voltage and 0 ÷ 100% of rated output.

The HV terminals shall be suitable for vertical connection of aluminium connectors.

Where specified in schedule A: Scope of Supply, capacitive voltage transformers in middle (Y) phase of 132 kV feeder bays shall be suitable for simultaneous use as coupling and voltage measuring capacitors and shall, be capable of supporting the associated line trap unit. Furthermore, terminal box for capacitive voltage transformer in middle (Y) phase shall be specially designed for that purpose.

### 4.2.3. Outdoor Surge Arresters

Outdoor type surge arresters shall be single-pole, metal-oxide, gapless type. They shall be delivered with complete supporting structures required for erection. The steel structure shall be hot dip galvanized.

Each single-pole surge arrester assembly shall be provided with a suitable insulating base for mounting the arrester on a steel structure.

Arrester unit shall be equipped with pressure relief device to limit internal pressure to a value which will prevent explosion of shattering of the housing.

The surge arrester shall be porcelain housed type.

The surge arrester shall be of robust construction and shall be designed to facilitate handling, erection and cleaning and particular care shall be taken to avoid pockets in which water can collect. All joints shall be made in an approved manner so that the arrester is hermetically sealed with material which will not be deteriorated under any service conditions.

The surge arrester short-circuit/pressure relief capability shall be 63 kA or according to specification at scope of work.

Suitable grading device/ring shall be provided for each surge arrester.

The HV terminals shall be suitable for vertical connection of aluminium connectors.

Surge arresters shall have a surge (discharge) counter along with a built-in milliammeter to monitor the leakage (internal) current of the surge arrester continuously for each phase.

The surge counter shall record the number of lightning and switching discharges of the surge arrester automatically on a five-digit (at least) cyclometer dial. The surge counter shall be non-reset table and capable of registering up to 5 discharges per second.

The leakage current indicator shall measure the internal current flowing through the surge arrester. The scale range shall be 0-30 mA peak/$\sqrt{2}$ (non-linear scale).

The surge counter and leakage current indicator unit shall be maintenance-free, weatherproof, sealed type.

Insulated cable connection shall be provided between surge arrester earthing terminal and surge counter. The insulation withstand of the cable shall be 5 kV minimum, while the cable cross section shall be determined by Contractor's calculation approved by Client but shall be not less than 150 mm$^2$.

By-pass shunt shall be provided to establish continuity to ground from the surge arrester ground terminal for easy maintenance.

Surge arrester shall be connected to the substation earthing system through surge counter in the shortest way. Earthing connection via steel support is not acceptable.

### 4.2.4. Insulators

#### *4.2.4.1. Post Insulators*

The Post Insulators (PIs) shall be made of high-quality porcelain, and they shall be suitable for outdoor installation.

Post Insulators shall be designed in accordance with the requirements of the Standards IEC 60273, IEC 60815, IEC 60672, IEC 60168, and other relevant Standards if not otherwise required in this Specification. Hollow insulators shall comply with IEC 62155.

Post insulators shall be envisaged for the minimum creepage distance defined in the General Technical Specifications.

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

Post type insulators shall be built up of interchangeable units and shall be sufficiently strong to withstand all shocks which may be met in operation.

The fixing arrangements of post insulators shall be in accordance with the IEC 60273.

Insulating material shall not be in direct contact with hard metal. Where cement shall be used as a fixing medium, cement thickness shall be as small and even as possible, and proper care shall be taken to centre and locate the individual parts during cementing.

Fixing holes shall be equally spaced on the appropriate pitch circle, which shall be concentric with the axis of the insulator. Holes in top and bottom fittings shall be in line and they shall be so arranged as to permit the use of normal hexagon bolted heads and nuts.

Each insulator shall be legibly and indelibly marked as required by the appropriate IEC Standard together with such other marks as may assist in the representative selection of batches for the purpose of type tests. Marking of porcelain insulators by indentations shall not be accepted.

#### *4.2.4.2. Suspension Insulators*

Suspension insulators shall be of composite type.

Composite insulator shall consist either of individual sheds mounted on the core, with or without an intermediate sheath, or alternatively, of a housing directly moulded or cast in one or several pieces on to the core.

Core of the composite insulator shall be designed to ensure the mechanical characteristics. The core shall consist of glass fibres which are positioned in a resin-based matrix in such a manner as to achieve maximum tensile strength.

Housing and sheds of a composite insulator shall provide the minimum creepage distance defined in the General Technical Specifications and shall protect the core from the weather. An intermediate sheath made of insulating material shall be a part of the housing. A shed shall be a projecting part of the housing intended to increase the creepage distance. The sheds can be with or without ribs.

Metal fitting of a composite insulator shall be intended to connect to a supporting structure, or to a conductor, or to an item of equipment, or to another insulator.

The coupling shall be the part of the metal fitting which will transmit the load to the accessories external to the composite insulator.

Crazing shall be made of surface micro-fractures of depths approximately 0.01 mm to 0.1 mm.

Any surface fracture of depths greater than 0.1 mm shall not be permitted.

Retaining pins or locking devices for insulator units shall be of phosphorous bronze or stainless steel or other approved tough material.

They shall be so formed that when set, and under any conditions, nothing but extreme deformation of the retaining pin or locking device shall allow separation of the insulator units or fittings or shall permit accidental displacement of the retaining pins or locking devices. Their design shall be such as to allow an easy removal or replacement of insulator units or fittings without removal of the insulator sets from the structures. The retaining pins or locking devices when in position shall be incapable of rotation.

All ball and socket joints on insulator sets shall be lightly coated with an approved grease.

### 4.2.5. Conductors

#### *4.2.5.1. General*

The conductors shall be designed with a sufficient mechanical strength to withstand the mechanical and electromechanical stresses that may occur in service, together with the safety factors.

Specified wind and ice loading and forces that occur due to thermal expansion and contraction or short circuit under the specified conditions shall be taken into account.

All conductors shall be installed so that the minimum clearances given in the Clause 2.6 of these Particular technical Specifications are maintained under all conditions of temperature, loading and service.

Conductors shall be designed so that the equipment is corona-free and the voltage stress at the conductor surface shall not exceed 16.5 kV/cm at sea level.

All conductors shall be envisaged for outdoor installation and their cross-sectional areas and other characteristics shall be determined according to the Contractors Design, approved by Client.

#### *4.2.5.2. Tubular Conductors*

132 kV busbars and rigid connections between the 132 kV & outdoor 33 kV apparatus in substation shall be made of tubular aluminium conductors.

Busbar conductors shall be in accordance with BS 159. Welding of 132 kV aluminium busbars shall not be acceptable. Bending of tubular conductors shall be avoided in the design wherever is possible.

Where tubular conductors shall be used, the distance between the supports shall be such to ensure that the tube will not resonate at its natural frequency under the influence of wind. The associated supporting structures shall be kept to the lowest possible height, whilst conforming to safety clearances and other requirements. Design of

tubular conductors shall also envisage tube aeolian vibrations caused by wind and means for reducing vibration amplitudes.

All tubular busbars & connections shall have their ends capped. Provision of tubular conductor portable earthing points (PEP) shall be provided within the design.

#### *4.2.5.3. Stranded Conductors*

Elastic connections between the outdoor 132 kV & 33 kV apparatus in substation shall be made of stranded TACSR (*Thermal-resistant Aluminium-alloy Conductors Steel Reinforced)* conductors, according to the Standard BS EN 50182. TACSR conductors shall be of the standard design, with steel core (consisting of galvanized wires) and aluminium sheath consisting of several thermal aluminium alloy wires. Conductor core shall be additionally protected against corrosion by means of the appropriate protective grease.

The stranding of each layer of the conductor shall be as close and even as possible. The outermost layer shall be right-handed.

Quality and certain mechanical and electrical characteristics of the conductors shall be in accordance with the Standards IEC 61089, BS EN 50182, IEC 60888, BS EN 50189, IEC 60889, and other relevant Standards if not otherwise required in this Specification.

Characteristics of the protective grease for TACSR conductors shall be in accordance with the Standards IEC 61394 and BS EN 50326.

The stranded conductors shall be supplied on non-returnable drums which shall comply with DIN 46391. The design of the drums shall enable the conductors to be run out smoothly. Drums shall be clearly marked with type, size, and length of conductor and with an arrow showing the correct direction of rotation for rolling from place to place. Wooden drums and battens shall be constructed from seasoned softwoods and shall be impregnated with a preservative against fungal and termite attack. The preservative shall not react with the conductor materials and the drum surface shall be covered with a waterproof covering to ensure no damage to the conductors.

#### *4.2.5.4. Overhead Shield Conductors*

For Substation 132/33 kV overhead shield conductors shall be supplied to provide the specified degree of lightning protection.

Overhead shield conductors shall consist of stranded galvanised steel wires and shall comply with the requirements of Standard IEC 61089 and other relevant Standards if not otherwise required in this Specification.

The arrangement of overhead shield conductors shall be such that failure of a single conductor cannot predictably fall across both busbars in a double busbar substation.

### 4.2.6. Connectors/Clamps

Connectors shall be made of high-quality aluminium, and they shall be suitable for operation at 132 kV & 33 kV voltage level. The connectors shall be the standard products with the appropriate Certificates.

Connectors shall be with stainless-steel bolts, all type of washers and nuts. Also, where necessary, special combined bi-metal (Al-Cu) connectors shall be provided.

All connectors shall be envisaged for outdoor installation and their shape and dimensions shall be determined according to the Contractors Design, approved by Client.

Connectors shall be designed and tested in accordance with the requirements of the Standards IEC 61284 and BS 3288.

### 4.2.7. Steel Structures for Outdoor Equipment and Their Foundations

#### *4.2.7.1. General*

Contractor shall use approved NEPCO drawings for gantries and lightning masts, wherever applicable. For the substations which are to be extended, with different gantry structures, contractor shall take measures from the sites to ensure possibility of connecting of existing and new gantry structures.

All other structures (equipment supports) shall be designed as circular hollow sections of the corresponding height.

The structures shall be designed to carry the equipment and associated connections, insulator sets, earth conductors and all fittings under all specified conditions of service of operation and loading.

Where appropriate provision shall be made on all structures for the attachment of stringing and maintenance equipment.

The substation gantry structures shall be designed to carry any down lead spans. All structures intended to carry equipment or materials on more than one side of the structure shall be designed to cater for all possible stages of equipment erection, installation and maintenance. The terminating gantries shall be designed to terminate the overhead line down lead spans, which may enter 20° vertically. Horizontal entry angles may be up to 45°. To cater for a large range of horizontal angles, gantries shall be provided with alternative anchor points to maintain clearances between phases and extended anchor straps and to maintain safety clearances from live conductors & insulator strings to access ladders or adjacent bays.

Busbar structures shall be designed to be suitable for future substation extensions.

Anchor bolts and template for all required steel structures should be provided as part of steel structures.

The recycle steel structures are not accepted.

#### *4.2.7.2. Conductor spacing and clearances*

Structures shall be dimensioned to maintain the specified minimum phase to earth, phase to phase and insulation height clearances under conditions of maximum conductor swing and sag. The spacing between individual conductors, phases and the clearance between the clamps, arcing horns, jumper loops or other live metal and the structure steelwork and other obstacles under all specified conditions of temperature and loading and under short circuit conditions shall not be less than the specified values.

#### *4.2.7.3. Construction*

The structures shall be of approved design and construction. All stressed members (tension and compression) of steel structures shall consist of rolled steel sections unless otherwise approved.

The material used for the members shall not be less than 6 mm thick except for unstressed members where the thickness may be reduced to 4 mm.

No bolt hole shall be more than 1.5 mm larger than the corresponding bolt diameter. As far as possible, bolt heads, rather than nuts, shall be on the outer or upper faces of structure connections.

The design shall be such as to keep the number of different parts to a minimum and to facilitate transport, erection and inspection. Pockets and depressions likely to hold water, if not avoidable, shall be properly drained.

Base plates shall have grouting holes of 40mm diameter minimum.

In general, the width and depth of latticed girders shall not be less than 1/16 of the span taken as centre to centre of the supporting towers. Lattice girders shall be fabricated with a camber. The minimum width for latticed towers shall preferably be not less than 1/6 of the total height. A cross frame shall be provided in towers and girders at points where required to distribute loadings and provide adequate stiffness

To facilitate inspection and maintenance all structures shall, where necessary be provided with steps, ladders complete with hoops and fall arrest systems to BS 4211, handrails, screens, guards and other appropriate facilities. Step bolts are not acceptable for substation structures.

Where the structure is to terminate overhead transmission lines supplied under another contract suitable provisions shall be made to accept the transmission line insulator fittings and earth conductor clamps or OPGW clamps. Extension straps shall be provided to ensure adequate safety clearance between insulator strings and access ladders and gantries for adjacent bays.

Means shall be provided for fixing and bonding copper strips to the steelwork at sufficient points to obtain efficient earthing without imposing undue strain on the earthing strip. Earth connections shall be made to a vertical face, clear of the ground; foundation bolts shall not be used for their attachment.

After erection all supports shall be vertical within a tolerance at the support top of 0.5 per cent of the support height before equipment erection. All steelwork within 150 mm of the upper surface of the concrete and the upper surface of the concrete itself shall be painted with two coats of bituminous or other approved paint.

#### *4.2.7.4. Material*

All rolled steel sections, flats, plates and bolt and nut bars used shall consist of steel manufactured by an approved process and shall be to the requirements of BS EN ISO7668, BS EN 10029, BS EN 10025-1,2, BS EN 10020 for grades S275 and S355 steel or equivalent from other national standards, the provisions of which in respect of tests and analyses shall be extended to include steel less than 6 mm thick. The steel shall be free from blisters, scales, laminations and other defects. Steel sections shall preferably be British Standard or metric Standard sections chosen with a view to avoiding delays in obtaining material.

High tensile steel when stored in the fabricator's stockyard prior to fabrication and galvanising shall be marked continuously throughout its length with a light blue water paint line. In addition, the grade of steel shall be painted on and ringed round with paint.

All members shall be cut to jig and all holes shall be drilled or punched to jig. All parts shall be carefully cut, and holes accurately located so that when the members are in position the holes will be truly opposite to each other before being bolted up. Drifting or reaming of holes will not be allowed.

The drilling, punching, cutting and bending of all fabricated steelwork shall be such as to prevent any possibility of irregularity occurring which might introduce difficulty in the erection of the towers on the Site.

All bends in high tensile steel shall be formed hot.

All bends made by cutting and welding shall be to approval. Detailed welding procedures are to be supplied to the Client for approval when welded components are offered.

Tension only members shall be detailed with 1 mm "draw" per metre length of member with an additional 1 mm for each joint in the member.

Built members shall, when finished, be true and free from all kinks, twists and open joints, and the material shall not be defective or strained in any way.

If the structures are fabricated or galvanised by Sub-contractors, the Contractor shall, if required by the Client, provide a resident inspector at the works of each Sub-Contractor during the time that the steelwork is being fabricated or galvanised.

Before leaving the Manufacturer's Works all tower members shall be hard stamped in approved positions with distinguishing numbers and/or letters corresponding to distinguishing numbers and/or letters on approved drawings or material lists to be submitted by the Contractor. The erection marks shall be stamped before galvanising. Care shall be taken to distinguish between various grades of steel.

All metal parts shall be secured by means of bolts and nuts and single washers. All bolts and nuts shall comply with BS 4190 or other equivalent national standard. Bolts and nuts shall be of steel, with hexagonal heads. The nuts of all bolts for attaching to the tower, plates, brackets or angles supporting insulator sets or earth conductor fittings shall be locked by means of locknuts. Screw threads shall not form part of the shearing plane between members. Bolts of any given diameter shall be of one grade of steel and marked for identification.

All bolts and screwed rods shall be galvanised, including the threaded portions; all nuts shall be galvanised with the exception of the threads, which shall be oiled.

When in position all bolts or screwed rods shall project through the corresponding nuts, but such project shall not exceed 10 mm.

Where spring washers are used, these shall comply with BS 4464 or other equivalent national standard.

Except where specified to the contrary, all iron and steel used in the construction of the Contract works shall be galvanised after all sawing, shearing, drilling, punching, filing, bending and machining are completed.

Galvanizing of all material shall be in accordance with the requirements of this specification and shall be applied by the hot dip process to provide thickness of zinc coating as per BS EN ISO 14713, but not less than 610 gm of zinc per square metre of surface on steel bars, plates, sections and fittings. Threaded work shall have a coating weight of 305 gm of zinc per square metre. The zinc coating shall be smooth, clean, of uniform thickness and free from defects.

The preparation for galvanizing and the galvanising itself shall not adversely affect the mechanical properties of the coated material. Tests shall be carried out in accordance with the Schedules.

Sherardising or other similar process shall not be used.

#### *4.2.7.5. Workmanship*

All members shall be cut to jig and all holes shall be drilled or punched to jig. All parts shall be carefully cut and holes accurately located so that when the members are in position the holes will be truly opposite to each other before being bolted up. Drifting or reaming of holes will not be allowed. All burrs shall be removed before galvanizing.

The drilling, punching, cutting, bending and welding of all fabricated steelwork shall be carried out before galvanizing and shall be such as to prevent any possibility of irregularity occurring which might cause difficulty in the erection of the supports on the Site.

Steel gauges of the stud type shall be provided to enable the Client to carry out such checking of members, as he may consider necessary.

Built members shall, when finished, be true and free from all kinks, twists and open joints and the material shall not be defective or strained in any way.

In order to check the workmanship not less than one per cent of the members corresponding to each type of support shall, if required, be selected at random and assembled to form complete supports in the presence of the Client at the manufacturer's works.

### 4.2.8. 400 KV EARTH SWITCHES AND MAINTENANCE EARTHING DEVICES

Earth switches shall be complete with interlocking facilities. Interference type interlocks between the earth switch and associated disconnectors shall be such that the operating linkages are not strained.

HIGH SPEED EARTH SWITCHES ON LINE CIRCUITS SHALL BE CAPABLE OF CLOSING ONTO AN ENERGIZED CIRCUIT AND OF INTERRUPTING THE CURRENT INDUCED IN THE LINE BY A PARALLEL FULLY LOADED LINE. THE INTERRUPTING DUTY REQUIRED IS AS SPECIFIED IN THE SCHEDULES.

#### Open terminal switchgear

Earth switches. Earth switches shall comply with the requirements of IEC 62271-102 and shall be motorized operated. The mechanism housing shall include auxiliary switches etc to the requirements of this Specification, in order to facilitate remote indication.

The earth switch operating mechanism shall be capable of being locked in the open or closed position.

Maintenance earthing devices. Maintenance earthing devices shall be capable of being operated by one man, and if possible, from ground level. Sufficient flexible leads shall be provided to meet the short time current rating specified in the Schedules. Clamps at the earth end of the leads shall be suitable for attaching to the earth conductor loops provided on the support structure.

**Portable Maintenance Earthing Devices**

Maintenance earthing devices shall be capable of being operated by one man and if possible, from ground level. Sufficient flexible leads shall be provided to meet the specified short time current rating. Clamps at the earth end of the leads shall be suitable for attaching to the earth conductor loops provided on the support structure.

## 4.3. Neutral Earthing Equipment

### 4.3.1. General

For new Substation 132/33 kV, this equipment shall comprise of the following:

- Current Transformers for Main Transformer HV (132 kV) Neutral Point,
- Current Transformers for earthing Transformer LV (33 kV) Artificial Neutral Point,
- Neutral Earthing Resistor (NER) Cubicle for outdoor installation for substation with the following equipment:
    - Neutral Earthing Resistor (NER),
    - Neutral Earthing Disconnectors & Earthing Switch,
    - Neutral Earthing Current Transformer.

For extension and replacement projects (if required), where main transformer is in scope of supply, current transformers for main transformer HV & LV neutral points shall be supplied as well, while existing NER cubicles shall be used.

The rated characteristics of neutral earthing equipment are given in schedule A: Scope of Supply & schedule D: Schedule of Technical Data.

### 4.3.2. Current Transformers for Main Transformer HV (132 kV) Neutral Point

The Current Transformers (CTs) for main transformer HV (132 kV) neutral point shall be single-phase, oil-insulated, hermetically sealed, post type for outdoor installation.

The design requirements for current transformers for main transformer HV neutral point are given in these Particular Technical Specifications.

The rated transformation ratios, rated outputs and other rated characteristics of current transformers for main transformer HV neutral point are given in schedule A: Scope of Supply & schedule D: Schedule of Technical Data.

The Contractor is obliged to determine the rated outputs and other characteristics of the current transformer protective cores for the normal and transient operating conditions, as well as to coordinate them with the protection devices. The Contractor shall submit all necessary calculations and analysis to the Client for approval.

### 4.3.3. Current Transformers for Main Transformer LV (33 kV) Artificial Neutral Point

The Current Transformers (CTs) for main transformer LV (33 kV) artificial neutral point shall be single-phase, oil-insulated, hermetically sealed, post type for outdoor installation.

The Current Transformers (CTs) for main transformer LV (33 kV) artificial neutral point shall comply with the requirements stated in these Particular Technical Specifications wherever these are applicable.

The rated transformation ratios, rated outputs and other rated characteristics of current transformers for main transformer LV neutral point are given in schedule A: Scope of Supply & schedule D: Schedule of Technical Data.

The Contractor is obliged to determine the rated outputs and other characteristics of the current transformer protective cores for the normal and transient operating conditions, as well as to coordinate them with the protection devices. The Contractor shall submit all necessary calculations and analysis to the Client for approval.

### 4.3.4. Neutral Earthing Resistor (NER)

The value of resistance, rated current and voltage of the NER system shall done by the contractor and approved by clint.

The neutral earthing resistor shall be used for limiting the earth fault current within the 10 s. It shall be purely resistive, air-cooled, steel-grid type for outdoor installation.

Neutral Earthing Resistor shall be designed in accordance with the requirements of the Standard IEEE Std C57.32 and other relevant Standards if not otherwise required in this Specification.

Active part of the resistors shall be made of stainless steel and shall be placed on the porcelain post insulators.

Neutral Earthing Resistor shall be designed in order to absorb the required amount of energy, without exceeding the temperature limits defined within IEEE Std C57.32 Standard.

The resistor shall be a robust shock-proof structure.

The resistor shall be complete with lifting and jacking lugs, access manhole, holding down bolts or clamps, earth terminals, connectors and connections and bushings suitable for the system phase to neutral voltage.

The rated resistance is specified 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 Schedules.

Neutral Earthing Resistor shall be installed within the metal enclosed cubicle made of hot-dip galvanized steel, for outdoor installation with IP55 degree of mechanical protection. If necessary, adequate insulating barriers shall be provided to prevent internal flashover. Design of the NER cubicle shall enable easy access to any part of the resistor and pertaining equipment from all sides. The NER cubicle shall be equipped with the louvres and with the lifting lugs/eyes.

### 4.3.5. Neutral Earthing Disconnectors

Neutral earthing disconnectors shall be double-column, post type, designed in accordance with the requirements of the Standard IEC 62271-102 and other relevant Standards if not otherwise required in this Specification. Neutral earthing disconnectors shall be installed in Neutral Earthing Resistor (NER) cubicle.

Neutral earthing disconnector within NER cubicle shall enable maintenance of the neutral earthing resistor when the rest of the neutral system is in service and shall be so located that the minimum safety clearances stated in BS162 are always fulfilled.

Neutral earthing disconnectors shall be envisaged for manual operation from ground level. Disconnector operating mechanisms shall be so designed that the disconnector cannot be opened by forces due to fault currents.

Neutral earthing disconnectors shall be provided with supporting steelwork/base and other necessary auxiliaries. Disconnectors operating mechanisms shall be of robust construction carefully fitted to enable that operation isn't affected by the climate conditions at the Site. Mechanisms shall be as simple as possible and comprise a waterproof enclosure complete with auxiliary switches, terminal blocks, and removable cable gland plates. All steel and forged iron parts, including the supporting steelwork/base and fixings shall be galvanised.

Operating conditions require that neutral earthing disconnectors shall remain alive and in continuous service for periods of up to two (2) years in the climatic conditions at the Site and without operation or maintenance.

Each neutral earthing disconnector shall be interlocked with the other disconnectors in each circuit to ensure safe operation of the equipment under all service conditions.

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

Locking facilities shall be provided on disconnector operating mechanisms in both the open and closed positions. Locks and keys shall be in accordance with the relevant Clauses of the General and Particular Technical Specifications.

#### 4.3.6. Neutral Current Transformer

Neutral current transformer for stand-by earth fault protection shall be provided in the connection between the neutral earthing disconnectors and neutral earthing resistor.

The neutral current transformer shall be single-phase, cast in epoxy resin type.

Neutral current transformer shall be installed in Neutral Earthing Resistor (NER) cubicle.

Current transformers shall be designed in accordance with the requirements of the Standards IEC 61869-1&2 and other relevant Standards if not otherwise required in this Specification.

The active part of the current transformer shall be cast in epoxy resin, which shall ensure proper electrical insulation characteristics and mechanical protection of transformers. The epoxy resin insulation shall be done by means of a single moulding operation in order to obtain a uniform and compact insulating block, free of blow holes or other internal irregularities which might affect its characteristics and performance.

The rated transformation ratios, rated outputs and other rated characteristics of neutral current transformers are given in schedule A: Scope of Supply & schedule D: Schedule of Technical Data.

The rated extended primary current shall be 120% of the rated primary current.

The Contractor is obliged to determine the rated outputs and other characteristics of the neutral current transformer protective cores for the normal and transient operating conditions, as well as to coordinate them with the protection devices. The Contractor shall submit all necessary calculations and analysis to the Client for approval.

The secondary terminal box shall be casted together with current transformer and protected by a detachable cover in a position easily and safely accessible for inspection and maintenance. Design of the terminal box shall prevent any possibility of accidental opening of the secondary circuits.

Each current transformer secondary winding circuit shall be earthed at only one point. Wherever possible the connection to earth shall be at S3 terminals.

#### 4.3.7. Neutral Earthing Connectors and Connections

All electrical connections shall be of copper and shall include all the connectors and connections necessary between the transformer neutral bushings and the neutral earthing isolators and neutral earthing resistor.

## 4.4. Control Equipment

### 4.4.1. General

At all substations the Control facilities shall comply with these Technical Specifications , schedule A: *Scope of Supply* and schedule D: *Schedules of Technical Data* and the facilities required for supervisory operation from the National Control Centre shall be terminated in a Main Distribution Cubicle. The RTU required for the SCADA connection to NCC is not subject of this tender.

Control panels and control desk supplied and installed in the substation control/relay room under this Contract shall provide all necessary facilities for the safe and effective control of the substation and equipment being supplied under this and other Contracts. A control selector switch labelled "*Remote/Supervisory*", lockable in both positions shall be provided for each bay (each Control & Protection panel) as detailed in the schedule A: Scope of

Supply. A selector switch "*Substation Attended/Substation Unattended*" on Alarm and Control Station Desk shall in the "*Unattended*" position disconnect all indications, visual and audible alarms in the substation.

At all substations, the control philosophy for new equipment shall match the existing schemes.

### 4.4.2. Mimic Diagrams

Control panels shall be provided with a mimic diagram, which shall be aligned and clearly showing the main power connections in single line schematic form at a convenient height so as to permit operation and visual inspection of discrepancy control switches and indicator switches shall be incorporated. The single line to be formed from a plastic strip, minimum dimensions 2×10 mm (thickness × width), which must be permanently fixed to the panels by screws or an approved adhesive. The strip colour should be as follows:

| System voltage kV | Colour acc. to BS 381C |
|---|---|
| 400 | Blue |
| 132 | Black |
| 33 | Green No 221 |
| 0.4 | Light orange No 557 |

For replacement and extension projects, the mimic diagrams shall comply and shall be aligned with the existing mimic diagrams on existing control & protection panels.

Discrepancy control switches and semaphore indicators shall be incorporated into the mimic diagrams. Discrepancy control switches shall be provided for all circuit breaker, disconnector and fault making earth switches. Semaphore indicators shall be provided for non-fault making earth switches and for indication of the position of certain circuit breakers and disconnectors as required by the schedule A: *Scope of Supply*. Discrepancy lamps shall be arranged to light when the position of the main power device is at variance with the indicator and shall extinguish when the main power device and indicator are in agreement. An audible warning (control room buzzer) shall also sound during the discrepancy condition.

Discrepancy switches shall be push-to-rotate type (two actions). Each discrepancy switch shall be marked with corresponding operation number.

### 4.4.3. Synchronizing Facilities

Synchronising facilities are required on all circuit breakers as specified in the appropriate sections of this Specification.

### 4.4.4. Annunciators

#### 4.4.4.1 General Arrangement

- A multi-way alarm annunciator shall be provided on each control panel for indication of all alarms associated with circuits controlled from that panel.
- Each alarm shall be displayed on an individual annunciator window.

#### 4.4.4.2 Alarm Indication Devices

- All alarm indications shall use heavy-duty LED lamps.
- Incandescent lamps are not permitted.
- LED lamps shall be suitable for continuous duty, high visibility, and long service life (Confirmation & guaranteed 150000 operating hours at least).

#### 4.4.4.3 Alarm Operation and Indication pattern

Each alarm shall operate with the following three conditions:

4.4.4.3.1 Alarm Operated

- LED flashes on the annunciator window.
- Audible alarm operates:
  - "Trip" alarms: shall initiate a common bell.
  - "Non-Trip" alarms: shall initiate a common buzzer.

4.4.4.3.2 Alarm Accepted

- Audible alarm silenced.
- LED remains continuously illuminated.

4.4.4.3.3 Alarm Cancelled (reset)

- Audible alarm silenced.
- LED extinguished.
- Alarm ready for subsequent operation.
- Cancellation shall only be possible after the initiating condition has reset.

4.4.4.4 Alarm Initiation

- Alarm annunciator ways shall accept initiation by:
  - Normally open or normally closed contacts.
  - Fleeting or persistent signals.
- Initiation of a new alarm after acceptance of a previous alarm shall:
  - Cause the new alarm LED to flash.
  - Re-activate the audible alarm.

4.4.4.5 Controls and Functions

- All annunciators shall have common (in control desk):
  - Accept
  - Reset (Cancel)
  - Lamp Test
- Acceptance of one alarm shall not inhibit operation of any other alarm in the group.
- Alarms may be accepted but shall not be cancelled (reset) until the initiating condition clears.
- A lamp test shall illuminate all LED lamps and the common bell and buzzer.

4.4.4.6 Audible Alarms

- "Trip" alarms shall operate a common bell.
- "Non-Trip" alarms shall operate a common buzzer.
- Buzzers for alarm annunciation shall be distinct from discrepancy switch buzzers.
- A common audible silence function shall be provided, without affecting visual indication.
- Audible alarms shall re-sound upon initiation of any new alarm.
- No audible alarm shall be used on the alarm fascia itself (if applicable), only the common bell or buzzer is required to be activated while substation is attended. Otherwise, A common audible silence function shall be provided, without affecting visual indication

4.4.4.7 Power Supply

- Alarm system supply shall be dual (operate on 110 V DC and 230 VAC).
- A dedicated DC supply failure alarm relay shall be provided.
- The DC failure alarm annunciator shall:
  - Be separate from the main annunciator.

- Be supplied from an independent power source, not from the 110 V DC battery system.

4.4.4.8 Spare Capacity

- A minimum of 20% spare alarm windows, with not less than two (2) spare windows, shall be provided on each annunciator.

4.4.4.9 Trip / Non-Trip Classification

- Each alarm shall be selectable as:
  - Trip (Urgent), or
  - Non-Trip (Non-Urgent).
- Classification shall determine operation of common bell or buzzer.
- Selection shall be performed at the alarm relay level.

4.4.4.10 Fascia and Alarm Transmission

- A common alarm fascia shall be provided for each circuit and mounted on the associated control panel.
- Fascia shall be multi-window type with self-seal-in relays and flashing LED indication.
- The fascia shall not provide repeat relay contacts for transmission to NCC.
- Alarm transmission to NCC shall be derived directly from alarm relays, not from fascia contacts.
- Fascia indication shall be for local visual indication only.

4.4.4.11 Attended / Unattended Operation

- A selector switch shall be provided on the station control desk for:
  - Substation Attended
  - Substation Unattended
- In Unattended mode:
  - All audible alarms shall be inhibited.
  - Alarm relays shall continue to operate and transmit alarms to NCC.
- Upon change to Attended mode:
  - All alarms that operated while unattended shall:
    - Initiate dedicated LED audible alarms (common bell or buzzer).
- Alarms shall only be accepted or cancelled (reset) locally or from substation control desk in Attended mode.

4.4.4.12 Remote Status Indication

- The attended/unattended selector switch shall provide:
  - One potential-free contact closing in Attended position.
  - One potential-free contact closing in Unattended position.
- These contacts shall be wired to the remote control and supervisory system.

4.4.4.13 13. Alarm Equipment

- The alarm scheme shall include:
  - Alarm relays
  - Auxiliary relays
  - Flasher relays
  - Audible devices (bells and buzzers)
- At least 20% spare alarm contacts shall be provided.

### 4.4.5. Instruments and Meters

Indicating instruments and integrating meters shall be provided as specified in the appropriate sections of this Specification.

Where specified instruments shall be provided with internal recording facilities.

### 4.4.6. Supervisory Control, Telemetering and Indication

At all the substations, the equipment supplied shall allow control from, and provide indication and measurands to the National Control Centre. RTU equipment for connection to National Control Centre is not subject of this tender.

#### *4.4.6.1. Control*

Equipment shall be provided to allow control of the following from the National Control Centre, when the remote/supervisory switch is in the supervisory position:

- Close/trip of all circuit breakers,
- Close/open of disconnectors,
- Acceptance of all active alarms incoming from a substation,
- Resetting of all electrically reset trip relays.

The duration of the control pulse from the supervisory equipment is two seconds and any equipment required to obtain satisfactory operation with the two second pulse shall be provided.

#### *4.4.6.2. Indications for 132kV Switchgear*

On/off position indication shall be provided to the National Control Centre for the following items:

- For each feeder or transformer circuit:
    - Circuit breaker,
    - Disconnectors,
    - Line or transformer earthing switch,
    - Supervisory control in service,
    - Local/remote control in service.
- For each main transformer:
    - Control selection (auto/manual),
    - Control selection (remote/supervisory),
    - Tap change in progress,
    - Tap position indication (potential free contacts on multi position switch).

These indications shall be transmitted to the NCC via RTU irrespective of the position of the panel mounted “Local/Remote/Supervisory” selector switch or the “Local/Remote” selector switch.

#### *4.4.6.3. Indications for 33kV Switchgear*

On/off position indication shall be provided to the National Control Centre for the following items:

- Circuit breaker,
- Earthing switch,
- Automatic/Manual selection,

- Supervisory control in service,
- Local/remote control in service.

These indications shall be transmitted to the NCC via RTU irrespective of the position of the panel mounted "Local/Remote/Supervisory" selector switch or the "Local/Remote" selector switch.

#### *4.4.6.4. Alarms*

All alarms annunciated in the station control room shall be repeated to the National Control Centre (NCC).

#### *4.4.6.5. Measurements and Transducers*

Programmable Transducers with multi outputs shall have the following characteristics:

- Type of connection: 3-phase, 4-wire,
- Programmable inputs primary and secondary for CT, VT and programmable analogue outputs between full range (-20 mA DC to +20 mA DC),
- Multi outputs 4 analogue outputs (MW, MVAr, V, A), each output to be programmed for any quantity,
- Response time: less than or equal 300 ms,
- Aux supply: 125 V DC,
- Accuracy class: 0.5 for (MW, MVAr, V, A) or better,
- The continuous overload rating of the transducer shall not be less than 1.3 times rated voltage and 2 times the rated current,
- Programming kit (software + communication cables) via RS485 port,
- Additional USB programming port is preferable.

The peak-to-peak noise current delivered by transducers shall not exceed 2 per cent of the maximum signal current. The response time shall be approximately 300 milliseconds or less to reach 90 per cent of the full rated output.

For new substations, the temperature and humidity equipment and transducer will be installed on the roof of the substation building and their outputs wired to supervisory interface panel.

Signals shall be provided for the National Control Centre (NCC) as follows:

- Feeder MW, MVAr, kV and A,
- Transformer A (on HV side),
- Transformer MW, MVAr, kV and A (on LV side),
- Busbar (phase to phase) voltage,
- Busbar frequency,
- Substation temperature,
- Substation humidity.

### 4.4.7. Marshalling Cabinets

Separate floor mounted marshalling cabinets shall be provided under this contract to form the interface between the substation equipment and the RTU equipment.

For all 132/33 kV new substations and substation extensions, the supply and installation of cables for connections from the RTU equipment to the marshalling cabinets are included.

All terminals shall incorporate open circuiting/short circuiting links, as necessary, to permit isolation and testing of circuits to the supervisory control equipment.

### 4.4.8. Time Synchronization (Master Clock)

Time Synchronization (Master Clock) shall be provided for the new substations.

Time Source Synchronized with GPS satellites shall provide a complete precision time synchronization for fault recorders, events recorders, control systems and software based protective relays and other electronic devices.

It shall be complete with:

- GPS signal receiver including high gain outdoor weather-proof antenna,
- The necessary number of synchronization signals (1PPS, I RIG-B modulated/ demodulated, etc …),
- Number of slave clocks accordingly to specifications.

### 4.4.9. Control & Relay Panels General

Each Control and Relay cubicle shall form a complete enclosure and should be associated with only one circuit.

Cubicle arrangement shall be divided into two equal sections segregated from each other by steel sheet sectioning barriers. The upper part for Control equipment and the lower is for protection equipment. With separating all wiring and termination of each section from the other, noting that flexible conductors and wiring shall be used for connection hinged equipment and terminations.

Control and Relay cubicle shall have front access with one separate door for each section. Those doors should be separate from each other and should have glass door for relay section of control and relay panels, should have close fitting lockable and lift-off, opened through 180, hinged so that control and relay equipment movements shall be controlled to be as minimum as possible.

Relay equipment should be flush mounted in dust proof cases with filter breather.

The interior of each cubicle section shall be finished with a light-coloured paint and interior 240 V AC lamp controlled by a door-operating switch and shall be fitted at the top of each section. In addition, anti-condensation heaters controlled be thermostats are also to be fitted in each section, and each cubicle shall be well-ventilated top and bottom through vermin proof louvers fitted with brass gauze screens.

Panel dimension shall be 800×800 mm (Width × Depth).

Panel degree of protection shall be IP41.

Panel exterior finish and colour of all indoor equipment and cubicles shall be RAL 6019.

Schematic drawings of control and protection circuits should be separate from each other and typical schematic for similar circuits shall not be accepted.

Equipment for each circuit shall be installed and mounted on one panel as specified and shall be erected in substation control building.

Trip links should be used as open/close terminals marked and labelled to be distinguished from other terminals, CT terminals should be of short/open terminals type and VT terminals should be of open/close terminals type.

For each 33 kV switchgear cubicle, a freestanding control and protection panel shall be provided, i.e. each 33 kV circuit shall be arranged in a separate control & protection panel, unless otherwise specified in schedule A: *Scope of Supply*.

The width of the 33 kV control & protection panels shall be maximum 600 mm, unless otherwise specified in schedule A: *Scope of Supply*.

Each switchgear cubicle shall be provided with electrical control of the circuit breaker for use under maintenance or emergency conditions. A lockable selector switch shall also be provided on the switchgear cubicle labelled “local / remote”.

The control and protection panel associated with each switchgear cubicle shall be provided with a lockable selector switch marked “remote / supervisory” to allow control from the National Control Centre.

### 4.4.10. Inter-tripping Schemes (General)

All 132 kV feeders with distance protection at both ends will be fitted with high-speed permissive transfer tripping via PLC circuits or fibre optic cable to ensure that all line faults are cleared at each end of the feeder in as near as possible to the first zone time, provided the starting relays have operated. The necessary contacts, wiring, push buttons, selector switches, indication lamps and fuse links, etc., shall be included in order to send to and receive from signals from the communication equipment.

### 4.4.11. Automatic Control for Capacitor Banks

The circuit breakers controlling the capacitor banks shall be closed and tripped automatically depending upon the value of the system voltage. The system voltage shall be obtained from a voltage selection scheme which selects the voltage on either of the busbars, providing that the busbar is live. Capacitor banks shall be switched-in when the voltage falls and switched-out when the voltage subsequently rises again. Typical voltage settings, in terms of nominal voltage, are 95% for switching-in capacitor banks and 100% for switching-out again. However, it shall be possible to adjust these setting values.

An automatic control panel shall be provided in each of the 33 kV switchgear control & protection panels which will control capacitor bank circuit breaker.

The automatic control system shall allow for the switching of four (4) capacitor banks. When the system voltage falls below the capacitor bank switch-in voltage level, capacitor banks shall be sequentially switched-in after a time delay as long as the system voltage remains below the switch-in level. When the system voltage rises above the capacitor bank switch-out level, capacitor banks shall be switched-out sequentially as long as the system voltage remains above he switch-out level.

The time delay shall typically be 5 seconds but shall be adjustable between 1 and 10 seconds.

Means should be provided to change the sequence of closing and tripping of capacitor bank circuit breakers so that the switching duties are shared between circuit breakers.

Automatic or manual operation shall be selectable either at the automatic control panel or from the National Control Centre (NCC). A latching relay shall be used which must be positively driven to either the automatic or manual position. The selection at the automatic control panel shall be by means of a switch automatic/neutral/manual, which shall be spring return to neutral and lockable in the neutral position. Indication of automatic/manual selection shall be given at the automatic control panel and a signal shall be sent to the NCC

## 4.5. Protection Equipment

### 4.5.1. Protection Philosophy

The primary network shall be considered as consisting of a number of elements, the limits of each element being its associated circuit breakers.

For the 132 kV network, each element shall be provided with a single high-speed discriminative protection, capable of detecting all "credible" faults and issuing tripping commands to the associated circuit breakers within the prescribed time. The high-speed discriminative protection shall be augmented with back-up overcurrent and earth fault protection, incorporating directional characteristics and sensitive earth fault protection as necessary. Circuit breaker failure protection is required for the 132 kV circuit breakers.

High-speed discriminative protection systems shall be engineered as complete schemes, due account being taken of CT and VT (or CVT) performance. The defined fault clearance time shall take account of the circuit breaker response and shall include the total time to elimination of the primary fault current irrespective of the magnitude, fault location or fault current characteristic subject only to an upper limit of circuit breaker specified duty.

Attention shall be paid to the total performance including the behaviour pattern in the presence of system transients for faults "in zone", faults "out-of-zone", and during the period immediately following a switching operation irrespective of whether that operation is to eliminate a network short-circuit or is to energise or to de-energize any part of the network.

The protective equipment shall remain unoperated following the normal and correct discharge operation of one or more surge arresters.

For the 33 kV network, each element shall be provided with a single high-speed discriminative protection, capable of detecting all "credible" faults and issuing tripping commands to the associated circuit breakers within the prescribed time. The high-speed discriminative protection shall be augmented with back-up overcurrent and earth fault protection, incorporating directional characteristics and sensitive earth fault protection as necessary. Circuit breaker failure protection is required for the 33 kV circuit breakers.

### 4.5.2. Discrimination

On the occurrence of a fault on the power system network high speed discriminating protection systems shall rapidly detect the fault and initiate the opening of only those circuit breakers which are necessary to disconnect the faulted electrical element from the network. Protection equipment associated with adjacent electrical elements may detect the fault but must be able to discriminate between an external fault and a fault on the electrical element which it is designed to protect. Sequential time delayed tripping is not permitted except in the following specific circumstances:

- Operation of time graded back-up protection takes place as a result of either the complete failure of the communication links associated with the main protection systems, or the fault resistance is substantially greater than the value specified in this specification.
- Operation of line back-up protection to disconnect primary system faults in the case of a circuit breaker failing to operate, (i.e. circuit breaker failure protection).

All back-up protection systems shall be able to discriminate with main protection systems, circuit breaker fail protection and with other back-up protection systems installed elsewhere on the transmission system.

### 4.5.3. Fault Clearance Times

Fault clearance times (from fault initiation to arc extinction) for the 132 kV system shall not exceed the following:

- Substation and transformer faults: 80 msec,
- Line faults: 100 msec,

- Breaker failure with direct transfer tripping: 300 msec.

### 4.5.4. Construction and General Facilities

Protection systems shall preferably be accommodated in 19-inch rack or hinged rack cubicles and be of modular construction with factory assembled and tested wiring. The construction method shall offer the benefits of minimum site construction times and circuit outage requirements.

For modular protection systems, means shall be provided to lock positively each withdrawable module or unit in the "service" position. It shall not be possible to remove any module without first short-circuiting all associated current transformer circuits.

Protection relays shall, with the exception of high impedance differential protection relays, be of numeric design.

Modular relays (e.g. rack mounted numeric relaying equipment) shall be tested as a complete assembly and details of such tests shall be agreed with the Client when details of the construction are known.

All relays which are accommodated in cubicles having a separate cubicle door shall be provided with individual relay covers. The intent of this requirement is to enable access to indication reset facilities without also allowing unauthorised access to relay setting adjustments.

For extension to existing installations, all new relay panels shall match the existing method of construction and installation as closely as possible.

### 4.5.5. Indications

Each relay or protection scheme shall be provided with an adequate number of indications to ensure that the appropriate faulted phase, zone, etc can be easily identified after a fault condition. Each indicator shall be visible and capable of being reset without removing the relay cover. Unless otherwise approved, indications shall only be given by the protection(s) causing the fault to be cleared.

Where illuminated indicators are used (e.g. light-emitting diodes) the following shall apply:

- Long term storage of the indication must not be dependent upon an auxiliary supply,
- A lamp test facility shall be provided.

### 4.5.6. Contacts

Each protection relay or protection scheme shall be provided with an adequate number of output contacts of suitable rating to carry out the prescribed tripping functions, alarms, indication and fault recorder functions and such supplementary signalling functions as may be necessary for the initiation of automatic reclosing or automatic switching control, etc. In all cases, contacts intended for tripping duty shall be designed so that they cannot inadvertently interrupt trip coil current.

For contacts intended to be used to energise circuit breaker trip coils directly, information shall be provided to show that the contact rating is compatible with the trip coil parameters of the associated circuit breaker. Where appropriate, details shall also be given of the operating characteristics of any reinforcing contactor and, in particular, the pick-up and drop-off threshold levels of series connected (current dependent) contactors.

### 4.5.7. Numeric Relays

Numeric protection relays shall utilise numerical techniques for both measurement and logic functions and in addition to the main protection functions, shall incorporate communication, fault, event and disturbance recording, instrumentation, configurable scheme logic, alternative setting groups, self-supervision facilities and control commands.

The communication facility should allow all information available locally at the relay front panel to be accessed remotely. It shall also be possible to carry out bulk transfer of settings, fault record information etc using the appropriate PC based software.

All protection systems shall be provided with an integral local operator interface facility to enable communication with the relay without the use of external equipment. Any facilities provided for connection to an external computer shall be an additional feature to the local operator interface.

The protection relay shall also be supplied with the facilities identified below:

- Identification: Each protection system shall have a unique identifier which is clearly visible, and the software reference and issue level shall be identified.
- Settings: Each protection system shall provide a means by which the user can easily access the protection system to apply the required settings. Access to this shall be password protected. A display of the selected settings shall be provided on the protection system.
- Indications: Each protection system shall provide indications as specified in the appropriate second level protection system specification.

The Contractor shall be obliged to provide adequate compatibility between protection relays and corresponding current transformer cores and shall submit all necessary calculations and analysis as evidence to Client for approval.

### 4.5.8. Trip Circuit Supplies

The 132 kV circuit breakers shall be provided with duplicate trip coils. The 132 kV main and backup protection shall trip both trip coils, each protection utilising separate contacts for each trip coil and each trip coil supplied from a different battery.

### 4.5.9. Trip Circuit Supervision and Auxiliary Supply Monitoring

Means shall be provided to continuously supervise the integrity of the circuit breaker tripping circuits and give an alarm in the event of the following fault conditions:

- Loss of DC tripping supply, e.g. removal of DC trip fuse,
- An open circuit in the trip circuit including the trip coil, circuit breaker auxiliary switch and all associated connections (supervision to be effective with the circuit breaker in either the open or closed condition).

The alarm shall be time-delayed preventing it operating during momentary dips in the DC supply. The alarm shall also be inhibited when the circuit breaker auxiliary switch interrupts the trip coil circuit, on circuit breaker opening.

All DC auxiliary supplies, essential for the operation of the protection relay scheme shall be monitored and the loss of any supply shall be indicated on the relay panel and an alarm given.

### 4.5.10. Commissioning and Routine Testing Facilities

Each functional relay scheme shall be so arranged that operational and calibration checks can be carried out with the associated primary circuit(s) in service.

Adequate test facilities shall be provided within the protection system to enable the protection and auto-reclosing equipment to be tested from the front of the protection equipment with the primary circuit(s) in service.

Adequate facilities shall be provided to isolate all DC and AC incoming and outgoing circuits so that work may be carried out on the equipment with complete safety to personnel and without loss of security in the operation of the switching station.

All test equipment required for commissioning and routine testing of the offered protection equipment shall be listed in the tender documents. Where test equipment is specified, it shall include such injection transformers, test leads and plugs as are necessary to carry out secondary injection tests on each type of relay scheme and, for the more complex schemes, such special test equipment as may be necessary to verify the accuracy of timing and verify the effective operating characteristics of the equipment. **(not applicable, just test leads and test plugs)**

For numeric equipment, such test equipment as may be required to carry out on-site investigation into the performance of individual modules or printed circuit cards shall be listed in the tender documents. At least one

complete set of any special test equipment shall be included within this Contract together with such additional connections, dummy extension boards, etc as may be necessary. **(not applicable)**

### 4.5.11. Relay Settings

Not less than 6 months before commissioning, suitable settings shall be recommended for all relays and protection to be supplied for all substation equipment (excluding OHL and cables). The recommended settings will ensure satisfactory operation in accordance with the intent of this Specification and the specified system operating conditions. The recommended setting shall not only include those normally available on the front of a relay but also the positions/settings of any internal links, plugs, etc not normally adjusted after installation. These settings shall be applied to the equipment prior to performing the commissioning tests. The settings for line protection shall be such as to permit correct operation of the protection for earth faults up to 100 ohms fault resistance. Any limitations imposed on the power system as a result of the settings proposed shall be explicitly stated, settings regarding capacitor banks to be provider from the manufacturer.

### 4.5.12. Environmental Requirements

#### *4.5.12.1.* *Temperature*

The standard nominal range of ambient temperature shall be -10°C to +55°C.

The protection system shall operate satisfactorily when tested to the following requirements:

- IEC Publication 60068-2-1 with severity class -10°C, 96 hours,
- IEC Publication 60068-2-2 with severity class 55°C, 96 hours

The protection system shall be able to withstand the temperature requirements for storage and transportation and shall be tested to the following requirements:

- IEC Publication 60068-2-1 with severity class -25°C, 96 hours,
- IEC Publication 60068-2-2 with severity class 70°C, 96 hours.

#### *4.5.12.2.* *Relative humidity*

The protection system shall operate correctly with a relative humidity of 93 per cent and shall be tested to IEC Publication 60068-2-78 with severity class 56 days.

#### *4.5.12.3.* *Enclosure*

The protection relay shall meet the requirements of the tests detailed in IEC Publication 60529 with classification IP50 (dust protected). If the individual enclosure of the relay is to a class less than IP50 then the Tenderer shall provide a cubicle to classification IP50 to accommodate the relay.

### 4.5.13. Mechanical Environment

#### *4.5.13.1.* *Vibration*

The protection system shall meet the requirements of the tests detailed in IEC Publication 60255-21-1 with severity class 1.

#### *4.5.13.2.* *Shock and Bump*

The protection system shall meet the requirements of the tests detailed in IEC Publication 60255-21-2 with severity class 1.

#### *4.5.13.3.* *Seismic*

The protection system shall meet the requirements of the tests detailed in IEC Publication 60255-21-3 with severity class 1.

### 4.5.14. Electrical Environment

#### *4.5.14.1.* *DC Auxiliary Energising Quantity*

The protection systems shall be capable of being energised from a DC auxiliary energising voltage of 110 V (nominal).

The protection system or its associated power supply for use in a 110 V (nominal) DC supply system shall operate correctly over a voltage range of 88 V to 137.5 V and shall withstand a maximum voltage of 143 V.

Numeric protection systems shall meet the requirements of IEC Publication 60255-26 with interruptions to the DC auxiliary energizing quantity of 10 ms.

#### *4.5.14.2.* *Frequency*

The standard rated frequency shall be 50 Hz.

The nominal range of frequency shall be -5 per cent to +5 per cent.

### 4.5.15. Insulation

#### *4.5.15.1.* *Rated Insulation Voltage*

The rated insulation voltage of circuits connected to current transformers of high impedance relays shall be 1000 V. All other circuits shall have an insulation voltage of 250 V.

All open contacts of the protection system shall withstand a voltage of 1000 V.

#### *4.5.15.2.* *Dielectric Tests*

The protection system shall comply with the dielectric test requirements of IEC Publication 60255-27. The test voltage shall be selected according to the rated insulation voltage of the circuits being tested form Series C of Table 1 of IEC Publication 60255-27.

#### *4.5.15.3.* *Impulse Voltage*

The protection system shall comply with the impulse test requirements of IEC Publication 60255-27 with test voltage of 5 kV.

### 4.5.16. Electromagnetic Compatibility.

The requirements of this section of the specification are specifically applicable to numeric protection systems. The requirements may also be applied to some electro-mechanical relays that are very sensitive or of high speed, at the discretion of the Client.

#### *4.5.16.1.* *1 MHz Burst Disturbance*

The protection system shall comply with the requirements of IEC Publication 60255-26 with severity Class III.

#### *4.5.16.2.* *Electrostatic Discharge*

The protection system shall comply with the requirements of IEC Publication 60255-26 with severity Class III.

#### *4.5.16.3.* *Radiated Electromagnetic Field Disturbance*

The protection system shall comply with the requirements of IEC Publication 60255-26 with severity Class III. The test shall be carried out by using Test Method A and by sweeping through the entire frequency range 27 MHz to 500 MHz.

#### *4.5.16.4.* *Fast Transient Disturbance*

The protection system shall comply with the requirements of IEC Publication 60255-26 with severity level IV.

### 4.5.17. Thermal Requirements

The requirements of this section apply to protection systems rated at 1 A associated with line circuits where the load current is carried by current transformers which supply the protection system.

The protection systems shall have a minimum continuous thermal withstand of 2.4 A.

The thermal withstand currents for short duration overloads, after having reached a steady temperature with an input current of 2.0 A, shall not be less than given in the table shown below.

| Duration (mins) | 20 | 10 | 5 | 3 | 2 |
|---|---|---|---|---|---|
| Current (amps) | 2.5 | 3.5 | 4.0 | 5.0 | 6.0 |

### 4.5.18. Inverse Time Overcurrent and Earth Fault Relays

Inverse time overcurrent and earth fault relays shall be of the numeric type and shall have selectable characteristics, i.e. normal inverse, very inverse and extremely inverse.

The operating time characteristic shall be continuously variable over the minimum range 0.1 to 1.0 times the nominal time at any multiple of current setting.

The current settings shall be adjustable as a percentage of nominal relay rating over setting ranges which are at least:

- Overcurrent relays: 50 to 250%,
- Earth-fault relays: 10 to 80%.

The actual relay pick-up current shall not exceed 1.3 times the relay setting, and the reset value shall not be less than 90 per cent of the pick-up current.

All relays shall comply with the accuracy requirements of IEC 60255, the required class index of the reference limiting error being 5.

### 4.5.19. High Set Overcurrent, Instantaneous Overcurrent and Earth Fault Protection

High set overcurrent, instantaneous overcurrent and earth fault protection shall be of the high-speed type and provided with a current independent selectable time delay with a setting range from instantaneous (no intentional time delay) to 100 secs in steps of 0.01 secs.

High set over current elements shall be of the low transient overreach type, i.e. the magnitudes of the current with and without the presence of a DC transient at which operation occurs shall be approximately the same. The value of the system reactance to resistance ratio at which the performance of the element is claimed should be stated. When applied to the protection of power transformers, high set overcurrent elements must be capable of being set to remain stable for maximum through fault currents associated with faults across the remote winding terminals.

### 4.5.20. Directional Overcurrent and Earth Fault Relays

Directional relays may either be provided as separate relays or as part of an overcurrent or earth fault inverse time relay combination.

A range of characteristic angle settings shall be provided so that correct directional discrimination will be achieved for all credible system faults. Preference will be given to relays in which voltage polarising, current polarising or dual polarising can be achieved.

Where directional features are applied to overcurrent and earth-fault inverse-time relays, the following requirements apply:

- The operating time of the directional element shall have negligible influence on the total operating time of the composite relay,

- The current setting of the directional element shall be low enough so as not to increase the overall setting of the composite relay for all faults in the operate direction,
- The angle setting of the directional element shall be selectable.

#### 4.5.21. Overcurrent and Earth Fault Definite Time Delay Relays

Preference will be given to relay designs in which the current settings for phase-to-phase faults are the same as those for three phase faults and in which the current settings for single phase to earth faults are the same irrespective of the phase involved.

The current measuring elements shall be of the low transient overreach type and the value of the system reactance to resistance ratio at which the transient overreach performance claim is made shall be stated. Their operating time shall be less than 30 milliseconds at 5 times setting and their drop off to pick up ratio shall not be less than 90 per cent.

The associated timing relay shall have a timing range (or ranges) adjustable between 0.1 and 10 seconds minimum, the setting adjustment being either continuous or stepped, with a maximum of 20 milliseconds per step. The accuracy of setting shall be at least ± 5 per cent of setting or 20 milliseconds whichever is the greater.

#### 4.5.22. Circulating Current Protection

The principle of operation of the circulating current protection shall be based upon the well-known differential, current balance system with high impedance type relays.

The protection shall remain unoperated for all out of zone fault currents ranging from 0 to 15 times full load rating of the protected circuit and all other system transient conditions, such as inrush currents, which are not due to internal faults.

Definite operation shall occur for faults between windings of different phases involving as few turns as is practical within the fault loop. A setting of 10 per cent or less is preferred.

The operating time shall be 30 ms or less at 5 times setting.

#### 4.5.23. Tripping Relays

The tripping relays shall be of the low burden, multi-contact type.

All multi-contact tripping relays shall be suitable for panel mounting. The design of the operating coil shall be such as to permit operation in conjunction with series trip flag relays should these be specified. When provided on the relays, economy contacts used to reduce the level of energisation of the operating coil after operation shall be delayed in operation sufficiently long enough to ensure that series flag relays operate correctly.

All contacts shall operate within the prescribed time for the particular category which shall not, in any case, exceed 10 milliseconds from the time at which the operating coil is first energised to the time of complete contact closure.

Tripping relays shall be with flags and shall be of the mechanically latched type and shall be self-reset or electrical/hand reset type as specified.

#### 4.5.24. Circuit Breaker Failure Protection

The purpose of circuit breaker fail protection is to clear a fault which has been correctly detected by the appropriate protection but for which the associated circuit breaker(s) has (have) failed to open.

In the event of a circuit breaker failing to operate, the circuit breaker fail protection shall be arranged to trip all circuit breakers capable of feeding fault current to the faulted circuit. For this purpose, the tripping circuitry of busbar protection may be used. Inter tripping shall also be initiated where appropriate.

Two basic criteria shall be satisfied before tripping can take place. Fault current must be flowing, and the appropriate protection must have failed to reset within a pre-set time. Initiation of a circuit breaker fail trip

condition should therefore be dependent on both the pre-set time elapsing and the current detecting elements being operated, outputs from both these functions being effectively connected in series.

A time delay shall be available to provide the pre-set time delay. This shall have facilities for continuous adjustment of time over the range 50 - 500 ms unless it is clearly shown that the range of settings provided is sufficient to meet the particular application requirements.

The current detecting elements shall have settings which are low enough to ensure correct operation during minimum plant conditions. The settings shall be equal to or lower than the settings of the associated protection.

The continuous current rating of the current detecting elements shall be at least twice their nominal current rating, the current settings selected being the lowest available.

The resetting time of the current detecting elements on cessation of fault current shall not be greater than 20 ms. The current detecting circuits must be arranged so that, when single pole tripping is specified, correct operation of the scheme occurs during the dead time, i.e. the presence of load current in the healthy phases should not cause maloperation operation of the scheme.

### 4.5.25. Manual Synchronising Facilities

The following equipment, plus any additional auxiliary equipment necessary to ensure correct functioning of the scheme, shall normally be provided:

- A socket into which a synchronising trolley plug must be inserted. This shall enable the appropriate incoming and running supplies to be applied to a check synchronising relay and synchronising instruments. The insertion of the plug also prepares for closure of the circuit breaker via the discrepancy control switch and a contact of the check synchronising relay.
- A check synchronising relay as specified in the appropriate section of this Specification. Where check synchronising relays for manual synchronising are provided, these may be utilised for auto-reclose requirements. A guard feature shall be provided to ensure that the check synchronising relay contact is closed before the closing switch is operated to close the circuit breaker. If the closing switch is operated before the check synchronising relay, contact closes then circuit breaker closing should be prevented. A facility should also be included to detect welding or permanent closure of the synchronising relay contacts and prevent closing of the circuit breaker.
- Interposing transformers for incoming and running voltage supplies. Phase to neutral voltages shall be used for synchronising purposes and the synchronising equipment shall operate satisfactorily over the range of 80 to 120 per cent of its rated value.
- Voltage selection equipment, either auxiliary contacts from primary equipment or voltage selection relays, where specified.
- Synchronising instruments consisting of incoming and running voltmeters, frequency meters and synchroscope. These instruments shall be continuously rated.

A synchronising trolley, containing the common synchronising equipment together with cable and plug is required.

DBC/DLC interlocks. If check synchronising is provided, closure of a circuit breaker interconnecting two circuits may be required where the conditions for synchronising cannot be satisfied due to the absence of either running or incoming supply. In these cases, and where specified, Dead Line Check (DLC), Dead Bar Check (DBC) and “Synchronising Override” interlocks shall be provided.

A DBC interlock permits reclosure only if the busbar is de-energized on all three phases. A DLC interlock permits reclosure if the associated line is de-energized on all three phases. In both cases the opposite supply to that which is de-energized must be energized. A busbar or line is considered to be de-energized when the voltage is less than 20 per cent of rated voltage and considered to be energized when at least 80 per cent of rated voltage.

A key interlocked check synchronising override switch per circuit breaker shall be provided to enable the contact of the check synchronising relay in the closing circuit to be by passed. Operation of this switch shall be interlocked with the voltage interlocks of DBC or DLC above, to prevent override of check synchronising unless one or both voltage supplies are absent.

### 4.5.26. Check Synchronising Relay

Check synchronising relays shall be provided as specified to enable a check of synchronism between appropriate incoming and running voltages for manual and automatic reclosure of each circuit breaker.

Measurement of the following parameters of incoming and running voltages must be provided:

- Phase angle difference. Adjustment of the phase angle between incoming and running voltages over which the relay contacts will close shall be provided over the range 20°to 45°. (Note this results in a total angular segment over which circuit breaker closure is permitted of 40° minimum to 90° maximum).
- Rate of change of phase (slip). The maximum slip frequency at which closure is permitted is a function of circuit breaker closure time and adjustment shall be provided for this. The method of measurement of slip in which it is ensured that the true phase angle difference does not exceed the set phase angle difference for more than a given time, is preferred. A time range of 2 to 10 seconds is required. Alternative methods, e.g. direct instantaneous measurement of true slip frequency, are permitted and a range of settings of 0 to 0.125 Hz/sec is required. If the preferred measurement method is not used, a timer shall be provided so that at least 2 seconds must elapse between application of both ac supplies to the check synchronising relay and an output being given.
- Voltage difference. A voltage check feature shall be incorporated which shall inhibit operation of the check synchronising relay if either one or both of the synchronising voltages is less than a pre-set percentage of rated voltage. The voltage check feature shall be adjustable over the range 80 per cent to 90 per cent of the relay rated voltage.

### 4.5.27. 132 kV OHTL Protection

#### *4.5.27.1. Distance Protection*

Distance protection for 132kV feeders a single three zone distance relay shall be provided. 132 kV distance protection shall operate in conjunction with tele-protection channels over power line carrier (PLC) and/or fibre optic circuits.

The 132 kV distance protection relays and tele-protection channels shall form either of the above schemes as defined in the Schedules.

The 132 kV protection schemes shall be:

- Suitable for complete simultaneous multi-phase and earth fault three zone measurement. Phase selection and sequential measurement are not acceptable,
- Suitable three pole tripping and auto-reclose operation,
- Suitable for application on a double circuit line, i.e. include mutual zero sequence compensation,
- Provided with power swing blocking facilities suitable for blocking zones 1, 2, 3 as required.

Overcurrent starting will not be accepted. However, schemes employing overcurrent elements that act as a check to prevent maloperation of the measuring elements during line de-ener0.2ation or resetting measuring elements during single-pole auto-reclose dead time are acceptable.

132 kV distance protection relays shall have facilities for independently tripping circuit breakers and initiating auto-reclosing, breaker failure protection, inter-tripping, alarms, fault recorders, etc.

The Contractor must guarantee that any distance relay offered will operate satisfactorily under the conditions described herein and with the distance relays at the remote substation.

Each distance relay shall operate for all types of phase and earth faults. Separate phase and earth fault distance measuring elements shall be provided; separate elements shall also be provided for each zone. Phase and earth fault compensation features shall be incorporated to ensure accurate distance measurement for all types of faults and to allow for the variation in the path of earth faults on the system.

Distance relays zone 1 and 2 elements shall operate only for faults on the protected line direction. Under no circumstances shall the relay operate for reverse faults even when the voltage supplied to the relay falls to zero on all three phases, nor shall they operate due to the transient response of the line capacitive voltage transformers during or following the clearance of close-up faults behind the relay. Details of methods used for polarizing relays to deal with all types of faults close to the relaying point shall be provided. The relay characteristics shall ensure adequate fault resistance coverage under minimum plant and single outage conditions. Zone 3 shall be non-directional and shall be capable of being independently off-set in both directions. No measuring element shall operate during normal system switching or during de-energisation of the transmission line.

The relay characteristic of impedance measuring starting relays shall cover the protected line plus the longest line emanating from the remote station taking current in-feed into account. This requirement may be relaxed at the Client's discretion in the case of extremely long lines. The starting relays shall not operate during maximum power transfer. When single phase to earth faults coincides with maximum power transfer, only the starting or measuring relay associated with the faulted phase shall operate. The starting relays can be employed as zone 3.

On long lines the minimum load impedance presented to the relay during maximum power transfer may encroach an offset mho zone 3 characteristic. Zone 3, therefore, (and any associated power swing blocking characteristics, if applicable) shall be capable of being shaped to avoid load impedance.

The reach of each measuring zone and starting relay shall be individually adjustable. The characteristic angle shall be adjustable between approximately 60 and 85 degrees.

Zone 2 and zone 3 shall have time delay setting ranges of 0 - 1 seconds and 0 - 3 seconds respectively.

The sensitivity of the protection shall be adequate for definite operation under minimum plant conditions and single outage conditions and shall not exceed 30 per cent rated current.

The operating time of each zone shall be substantially independent of fault current magnitude. Curves shall be provided showing the effect on operating time of line and source impedance, fault position and operating current and point on wave of fault application.

A switch on to fault 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.

The switch onto fault feature in the relay proposed for use in the permissive under reach transfer tripping scheme shall also be capable of being enabled during the auto-reclose dead time. This is to ensure fast clearance of non-transient end zone faults where delayed zone 2 clearance would normally occur when the local end is reclosed before the remote end.

The distance protection shall include a voltage transformer supervision unit to prevent possible unwanted operation of the distance relay comparators in the event of a failure of one, two or three phases of voltage caused by open or short circuit faults in the voltage transformer secondary circuits or due to removal of VT fuses. In the event of loss of one, two or three phases the distance relay shall be blocked, and a time delayed alarm initiated.

The VT supervision shall not operate during energisation of the line or of any power system transformers, nor during any other power system primary disturbance. It shall also be inhibited during a single pole auto reclose cycle to ensure there is no delay in tripping remaining poles if a second fault occurs during the single pole dead time. Single pole auto-reclosing is not utilised at 132 kV, however the above requirements of the VT supervision during a single pole reclose cycle shall also be met for the 132 kV distance protection.

The VT supervision unit shall be faster than the distance relay measuring units under all circumstances.

Distance to fault (fault locator) feature shall be included and have an accuracy such that the maximum error of any measurement will not exceed ± 3 per cent of the total line length, irrespective of the total fault clearance time.

Tele-protection channels over power line carrier and/or fibre optic circuits will be used in conjunction with the distance relays to form:

- A permissive under reaching transfer trip scheme,
- An overreaching blocking scheme, and any other standard scheme.

Main (PLC) Telecom Route:

Teleprotection equipment type NSD50 – ABB Power Automation Switzerland

Catering for 4 teleprotection commands on Power Line Carrier equipment Type ETL 81 - ABB Power Automation Switzerland

Standby (Fibre Optic) Telecom Route:

Teleprotection equipment type TEBIT – ABB Power Automation Switzerland

Catering for 4 teleprotection commands on SDH Fibre Optic equipment Type TN-1X – Nortel and PDH Fibre Optic Equipment Type FOX-U – ABB Power Automation Switzerland.

Teleprotection equipment type RFL 9745 GD catering 4 teleprotection commands on PDH fiber optic equipment Type Umax 1500 – RFL company.

Typical operating times of the teleprotection signalling equipment are as follows:

| | NSD50 | TEBIT | 9745 GD |
|---|---|---|---|
| Permissive/Blocking | 11msec | 6 msec | 12 msec |
| Prolongation Time | 25 msec | 100 msec | 200 msec |
| Direct Transfer Trip | 15 msec | 7 msec | 8 msec |
| Directional Earth Fault | 15 msec | 7 msec | 8 msec |
| Prolongation Time | 234msec | 100 msec | 100 msec |

NEPCO will provide similar tele-protection equipment including main and standby routes for distance relays on 132 kV circuits.

A separate fully adjustable timer delayed on reset shall be provided to delay the resetting of the blocking signal received during fault current reversal conditions on a parallel circuit. The Tenderer shall recommend a minimum time setting for this timer.

A reverse looking, fast operating element shall be provided for initiating the transmission of the blocking signal. This element shall preferably have an offset mho characteristic to ensure that a blocking signal is definitely sent for any type of fault immediately behind the relay. As the relay will also respond to faults in the forward direction of the protected line, the blocking signal shall be interlocked with the forward-looking zone 2 elements and shall not be sent if zone 2 elements operate. Under no circumstances shall a blocking signal be transmitted for faults in front of the relay. Since the reverse looking element must definitely operate for any type of fault behind the relay, its sensitivity must be at least equal to and preferably higher in all respects to the remote end zone 2 overreaching elements.

The distance relays shall incorporate indicators to show the zone in which the relay tripped, and phase or phases faulted, whether the relay operation was due to aided trip, switch onto fault, power swing blocking, VT fuse fail or directional earth fault if appropriate. Indication must not be lost in the event of a supply failure.

In addition to sufficient tripping contacts, the protection shall have, where necessary, contacts for initiating three pole auto-reclosing, two sets of circuit breaker failure protection, fault locators, fault recorders, protection signalling and alarms.

Each distance protection shall be suitable for single and three pole tripping and for use in single and three phase auto-reclosing schemes as specified.

Selection facilities are required to permit or inhibit auto-reclosing if the carrier is or is not in service.

Where appropriate the protection and associated auto-reclose equipment shall incorporate whatever means are necessary to ensure that all measuring and starting elements in the healthy phases of the faulted line and all measuring elements on the parallel circuit remain reset and are unaffected by the fault and load currents which flow in the healthy and parallel circuit during the single phase reclosure dead time. Additionally, the inter-phase fault measuring elements on the faulted circuit shall be stable in the presence of a heavy close-up earth fault. The methods used to ensure correct stability of healthy phase elements during single phase dead times and during fault conditions shall in no way prejudice the ability of the protection and auto-reclosing scheme to respond to faults during the dead time and reclaim time.

The necessary feature shall be incorporated in the relay to inhibit the zone 1 and zone 2 phase fault elements when necessary during single phase to earth faults and during the single pole auto-reclose dead time. Provision shall also be made to ensure the faulty phase earth fault elements definitely reset during the single pole auto-reclose dead time.

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 132 kV distance relays shall include power swing blocking function.

Power swing blocking for offset zone 3 characteristics or starters shall comprise a characteristic, which encompasses the distance relay impedance starter or zone 3 characteristics.

Facilities shall be provided to block zones 1, 2 and 3 of the distance relays as required and an alarm signal to be initiated.

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 distance relay starter characteristic. Blocking shall not take place until the apparent impedance has passed through the two power swing characteristics and the timer has expired.

The associated time delay relay shall have a setting range encompassing 50 - 250 msecs.

Relays shall be of numeric design. The setting range of the power swing relay characteristic angle shall at least be adjustable over the same range as the distance relay starting or zone 3 characteristic.

Reset times shall be fast enough to ensure that the associated distance relay reverts to its normal role as soon as possible following a power swing.

Where applicable, power swing blocking shall be inhibited during the single pole dead time of an auto-reclose cycle so that if a power swing develops during this period the distance protection can give an immediate three phase trip. The Tenderer shall advise whether it is possible to extend the inhibition of the power swing blocking to cover a period immediately following auto-reclosing so that if a power swing develops on reclosing onto a permanent fault a three-phase trip would be permitted. The Tenderer shall also advise whether power swing blocking can be inhibited if an earth fault occurs during a power swing.

If the associated VT supplies are lost due to VT fuse failure, the power swing blocking relay shall not operate.

#### *4.5.27.2. Auto-Reclosing*

Three-pole only, single shot auto-reclosing equipment shall be provided for 132 kV overhead line circuit breakers. All auto-reclosing schemes shall include synchronising relays with dead line and dead busbar checks.

Reclosure shall only take place on overhead line circuits and shall be initiated following tripping by the distance relay zone 1 equipment or following an aided trip in the permissive under reach transfer trip scheme or in the blocking scheme. Reclosure shall not be initiated in the event of a three-phase fault, any type of fault in the second or third back-up zones or when the circuit breaker is closed onto a fault on a previously de-energized line.

For 132 kV overhead line circuits the backup directional overcurrent, directional earth fault and sensitive earth fault protection shall not initiate an auto-reclose sequence.

The following options are available for auto-reclosing in NEPCO 132 kV systems:

- Three pole delayed auto-reclosing: Delayed auto-reclosing shall only be initiated in the event of a single phase or two-phase fault. Three-phase faults shall result in tripping without auto-reclosing.
- No auto-reclosing for three-phase tripping.

For 132 kV overhead line circuits, three pole delayed auto-reclosing and no auto-reclosing shall be selectable by means of a lockable switch, located adjacent to the auto-reclose relay.

Tentative range of the delayed three-pole reclose dead time shall be 3 to 30 seconds, and equipment offered should cover these ranges. Tenderer shall state the available ranges.

The reclaim time shall be chosen to match the duty cycle of the circuit breakers, assuming the shortest available dead time is chosen. The reclaim time shall not, however, be less than 10 seconds, and the reclaim timer range shall extend to 180 seconds. The duration of the closing command shall be limited to two seconds, after which time the reclosing equipment shall be automatically reset without resetting the reclaim timer. The reclosing equipment shall also reset if dead line check, dead busbar check or synchronism check conditions are not satisfied within five seconds of the check relays being energised.

A counter shall be provided to record the number of reclosures and shall lockout after a pre-selected number of protection trips has been reached.

Check synchronising relays and dead line check and dead busbar check interlocks shall be provided for three-phase auto-reclosing as specified elsewhere in this Specification.

A signal shall be provided from the dead line check relays for interlocking of the line earth switches to prevent the switches being closed on a live line.

#### *4.5.27.3.* *Tele-protection Signals*

Cable lists for the protection signalling and direct inter-tripping signals between the protective relay panels and the tele-protection equipment are to be provided under this Contract. At the tele-protection equipment end, the cables are to be terminated in cable glands, cable cores identified and marked with identification ferrules. Cable glands are to be provided in this contract. Separate cables are to be used for each tele-protection channel.

At the protective relay panels, the cables for the tele-protection signals are to be terminated on terminals, which are wired directly to isolating links. This is to enable the tele-protection equipment to be readily isolated from the protective relays and the 110 V DC tripping and control supplies. Disconnecting links incorporated in the terminal blocks will not be accepted for this purpose.

For each discrete tele-protection channel, a two-position test switch ("test/service") is to be installed on the front of the relay panel to enable the functioning of the tele-protection channel to be tested. The switch is to be lockable and provided with a lock and duplicate keys. An indication lamp is to be provided for indicating that the test switch is in the "test" position. A push-button is to be provided to initiate a test signal to the tele-protection equipment. A second indicating lamp shall be provided to indicate that a test signal has been received from the remote station.

#### *4.5.27.4.* *Numerical Line Differential Protection*

Line differential protection relays shall preferably utilise the phase segregated current differential principle and shall be suitable for use with both dedicated optical fibre links, or multiplexed communication systems. The relay

shall provide phase selective differential protection for two terminal lines and shall operate simultaneously at both terminals of the protected circuit to provide rapid fault clearance irrespective of whether the fault is fed from both terminals or from one end of the line only.

Line differential protection relays shall be provided for line remote end also.

High speed tripping for all in-zone faults, stability for all out-of-zone faults and correct operation for developing faults must be assured for all practical conditions of load and fault current flow.

The line differential protection relay shall operate correctly for all in-zone phase-to-phase and phase-to-earth faults occurring at the same time, or shortly after, an out of zone fault, and for all other types of evolving faults

Relay operating time shall not exceed 30 ms with fault resistance up to 100 ohms.

Relay reset time, from cessation of any condition, which would cause the relay to operate, shall not exceed 100 ms.

The returning ratio, defined as the differential current at which the relay resets divided by the differential current at which the relay operates, shall not be less than 70%.

The relay shall continuously monitor the propagation delay of the communication channel used for transmission of the protection measurement quantities and shall provide compensation for the effects of the propagation delay. The relay shall continuously adjust the propagation delay compensation to the prevailing delay value such that automatic re-routing of the communications channel does not cause incorrect operation of the protection relay.

Each relay shall be uniquely addressable, so that if it receives incorrect messages (e.g messages from the wrong remote relay, or messages are looped back to itself via the communications channel) as a result of incorrect operation of the communications channel, the incorrect messages will be rejected, and the relay will not mal-operate.

The line differential protection relay shall provide an inter-trip facility to enable a relay at the remote end to be energized via the communications channel used for the line differential protection, when a relay contact at the local end is closed. This facility shall be available to be assigned to any trip or signalling function such as direct transfer trip or block auto-reclose.

The line differential protection relay shall provide a permissive inter-trip facility to enable a relay at the remote end to be energized via the communications channel used for the line differential protection, when a relay contact at the local end is closed and the current detected by the remote end line differential protection is above the threshold level for operation.

The line differential protection shall incorporate indicators to show: Relay operation, Inter-trip operation, Permissive inter-trip operation, Relay out of service, Relay available. Indication must not be lost in the event of a supply failure.

Supervision facilities which include a periodic self-check of the key elements within the relay and a continuous self-monitoring of all internal power supplies, microprocessor operation and communication equipment shall be provided. The indications provided shall be designed to allow the defective item to be quickly identified. The status of the DC power supplies shall be permanently indicated. A defect in any of the self-supervision facilities shall not cause mal operation of the protection relay.

The line differential protection relay shall include facilities for the storage of fault records. A minimum of four records shall be capable of being stored in non-volatile memory within the relay for post-fault analysis.

The line differential protection relay shall be compatible with as wide a range of communication equipment and media as possible, and to achieve this the relay shall be designed to operate within the signalling bandwidth of a basic 56/64 kb/s pulse code modulated (PCM) signalling channel.

The relay shall be capable of providing redundancy of communication by transmitting and receiving messages over two communication channels, both of which are continuously monitored by the relay. If one channel fails, the relay shall continue to operate correctly over the remaining channel.

The relay shall be capable of operating over a dedicated optical fibre communication channel, or over a digital communication channel which is multiplexed and shared with other protection and telecommunications equipment employing optical fibres or conventional media. The design of the protection relay shall preferably be such that the various communication channel requirements can be accommodated within the relay with only the communication interface requiring to be changed to suit different requirements.

#### *4.5.27.5. Directional Phase Overcurrent Protection*

The directional phase overcurrent protection shall operate for transformer and 132 kV line faults.

The protection shall comprise overcurrent elements and directional elements. The directional elements shall control the overcurrent elements such that the overcurrent elements operate only when current flows towards the transformers.

The overcurrent elements shall be of the inverse definite minimum time type and shall comply with the requirements specified for non-directional relays.

The directional elements shall utilize current from one phase and voltages from the other two phases, for example, the relay in phase A shall use phase A current and the voltage between phases B and C. The relay shall be compensated such that maximum torque occurs when the current lags the system phase to neutral voltage by 45 degrees. Positive operating torque shall be assured for line voltages down to 5 percent rated voltage.

#### *4.5.27.6. Sensitive Earth Fault Protection*

Sensitive earth fault protection shall be provided to cater for high resistance earth faults which remain undetected by the main protection and shall comprise a definite time overcurrent relay.

The current setting shall be adjustable between 3 and 5% of CT rated secondary current. The time delay shall be adjustable between 1 and 10 seconds.

As the relay has a very low setting, it is essential that the burden imposed by the relay is small.

#### *4.5.27.7. 132 kV Back-up Protection*

Back-up protection for 132kV OHL feeders shall comprise three phase directional overcurrent, directional earth fault and non-directional sensitive earth fault relays. These relays shall initiate a three-phase trip of the associated 132 kV circuit breaker and prevent auto reclosing. The directional overcurrent relays are to have setting ranges of at least 0.5 to 2 times nominal current, the directional earth fault relay shall have a setting range of at least 0.1 to 0.8 times nominal current and the non-directional sensitive earth fault relay shall have a setting range of at least 0.005 to 0.05 times nominal current.

Back-up protection for the 132 kV transformer circuits shall comprise three phase non-directional overcurrent and earth fault relays. These relays shall initiate a three-phase trip of the associated 132 kV circuit breaker. The overcurrent relays are to have setting ranges of at least 0.5 to 2 times nominal current and the earth fault relay shall have a setting range of at least 0.1 to 0.8 times nominal current.

Back-up overcurrent and earth fault protection relays, both non- directional and directional shall be of the numeric type and shall have selectable characteristics, i.e. normal inverse, very inverse and extremely inverse and at least one high set instantaneous element. They shall also incorporate circuit breaker fail facilities which can be initiated both from operation of the relay or an external trip. The high set instantaneous elements shall have separate trip output terminals which shall be disconnectable.

### 4.5.28. 132 kV Transformer Protection

#### *4.5.28.1. Differential Protection*

The protection shall remain unoperated for all out of zone faults up to a minimum of 15 times the transformer nominal rating at all transformers tapping settings and all steady state and transient power transformer magnetising in rush currents.

The protection shall operate for all internal faults with a sensitivity of at least 20 per cent of full load rating of the protected circuit.

The operating time shall be 40 milliseconds or less at 5 times setting current.

Biased differential protection relays shall be provided with integral ratio and vector group compensation, eliminating the need for interposing current transformers.

#### *4.5.28.2. HV Restricted Earth Fault (REF) Protection*

Transformer windings with YN connection shall be provided with restricted earth fault protection. Relay shall be of the high impedance circulating current type necessary protection against over-voltage.

The sensitivity of the protection scheme shall not exceed 25 per cent of the rated current of the protected winding in the case of solidly earthed systems and 15 percent of the minimum current available for an earth fault at the transformer terminals in the case of resistance earthed systems. These values are to include the effect of current transformer magnetising current and the current taken by the voltage limiting device.

The protection shall remain stable up to the maximum through fault current corresponding to the rated system short circuit level. This may be taken as 16 times the rated current of the protected winding of the power transformer, unless otherwise advised by the Client.

Associated current transformers shall be class X (PX according to IEC 61869-2), or other class as recommended by the relay manufacturer and approved by the Client. Contractors shall submit at an early stage, design calculations for current transformers for approval.

#### *4.5.28.3. Protection of Tee-Off Circuits, Auxiliary/Earthing Transformers*

Where a tee off transformer is included within the high-speed protection zone of the main transformer, faults which occur beyond the tee off transformer LV fuses or LV circuit breaker shall be regarded as out of zone faults. The Contractor shall supply evidence to show that for such faults the magnitude of the operating current as seen by the protection or, in the case where LV fuses are provided, the duration of the operating current, is low enough not to operate the high-speed protection.

If non-operation cannot be ensured for the above out of zone faults, the Contractor shall provide current transformers on the tee off circuit so as to exclude the tee off transformer from the high-speed protection zone of the main transformer.

Whichever of the above arrangements are provided, the fault settings of equipment protecting the tee off transformer shall be comparable with the anticipated fault currents which may arise for faults in the tee off transformer zone.

#### *4.5.28.4. Buchholz and Temperature Indicator Repeat Relays*

The Buchholz, temperature and other trip devices at the power transformer will, normally, have only one contact each. For maximum security it is preferred that these contacts shall operate the appropriate trip relays directly. For local and remote alarms, a current operated repeat relay shall be connected in series with each transformer protection trip device and the trip relay. These repeat relays shall have hand reset flag indicators and sufficient contacts for all remote alarm and indication functions.

Similarly, Buchholz, temperature and other alarm devices at the power transformer will have only one contact. To provide flag indication and sufficient contacts for all remote alarms and indication functions, voltage operated repeat relays shall be provided.

The number of repeat relays required will depend upon the number of transformer protection devices, details of which will be supplied to the Contractor when the design of the transformers has been finalised.

#### *4.5.28.5. Over-Flux Protection*

The protection shall monitor one or more of the phase voltages and tripping shall occur in time to prevent damage to the primary equipment due to over fluxing etc, when the phase voltages exceed the setting. Preference will be given to schemes in which the operating time decreases with increase in voltage so as to match the overheating characteristics of the protected plant.

The voltage settings shall be adjustable within the range of 110 ÷ 130 per cent of nominal voltage.

The drop-off/pick-up ratio shall be greater than 95 per cent at any setting. The setting error shall be less than 5 per cent.

The operating times shall be adjustable. Typical operating time at 125 per cent voltage is 5 seconds.

The voltage circuit shall be designed with an adequate factor of safety to withstand the anticipated overvoltages without damage to the relay and without saturation of the relay circuit.

#### *4.5.28.6. Transformer Tripping Scheme*

Tripping circuits with its own electrical/hand reset tripping relay and DC supply shall be provided. The transformer protection tripping circuit shall be arranged as follows:

Both 132 kV & 33kV circuit breakers shall be tripped by the following relays:

- Biased differential,
- Over-flux protection,
- HV restricted earth fault,
- HV over current,
- 132 kV busbar protection,
- LV restricted earth fault,
- HV Stand-by earth fault protection,
- Buchholz surge of the main and earthing/auxiliary transformers,
- HV earth fault,
- Tap changer surge (main Transformer),
- Pressure Relief valve.

The 33 kV circuit breaker only shall be tripped by the following relays:

- Winding Temperature - stage 2,
- Oil temperature - stage 2,
- Directional overcurrent,
- 33 kV busbar zone protection,
- LV earth fault.

The 33 kV stand by earth fault relay shall trip:

- The 33 kV transformer incomer circuit breakers on stage 1,
- The 132 kV transformer circuit breakers on stage 2.

The 132 kV circuit breakers are equipped with duplicate tripping coils; only one trip coil is allocated for protection tripping functions. Each trip relay shall operate into the 132kV trip coil allocated for protection functions, i.e. each 132 kV circuit breaker shall receive a total of two trip commands.

The winding temperature trip devices shall be arranged to trip the appropriate circuit breaker only, i.e. HV and LV winding temperature shall trip the LV breaker only.

#### 4.5.29. High Impedance Busbar protection

The busbar protection shall operate for both phase to phase and phase to earth faults. The principle of operation shall preferably be based on the simple circulating current system with high impedance relay circuits. The operating time of the measuring relays shall not exceed 30 msecs at five times the relay current setting.

The equipment shall be stable for all out of zone phase to phase and phase to earth fault currents up to the short circuit current rating of the switchgear, applied gradually or suddenly and irrespective of the distribution of current between the individual circuits.

There shall be fully discriminative clearance of busbar faults on any section of busbar without introducing sequential tripping of coupler or section circuit breakers. All circuit breakers connected to a faulty busbar shall be tripped simultaneously, whether they feed fault current or not.

Care shall be taken to ensure that the protection does not maloperate as a result of faults in the associated secondary wiring when the primary circuit is carrying load current. Continuous or automatic cyclic supervision shall be provided for this purpose. Arrangements shall be provided to make the zone containing the faulty circuit inoperative. Where the operation of the supervision device is dependent upon the load current in the primary circuit, operation shall occur at current of 25 amperes or 10% of the circuit rating whichever is the greater.

The following test and isolation facilities shall be provided on the front of the protection panel:

- Short circuiting and isolation of current transformers,
- Isolation of individual tripping and inter tripping circuits,
- Isolation of tripping and individual zones.

Inter-tripping, where required, shall be affected by means of electrically separate outputs. The inter-tripping scheme shall be a subject of Client's approval.

The sensitivity shall be such that definite operation occurs for phase to phase and phase to earth short circuits during minimum plant conditions, irrespective of the number of circuits in service and the distribution of load and fault currents. The sensitivity level shall not exceed 30% of the minimum fault level for all types of faults.

Isolator auxiliary switches employed in current transformer circuits shall be of the heavy duty; silver plated type and two switches in parallel shall be used per current transformer connection.

The Contractor shall clearly specify the number of secondary circuits which must be switched, the duty of the switches and the timing between individual switches; the Contractor shall be responsible for selecting switches which are adequate for the intended duty.

The busbar protection shall have the following features:

- Two (2) independent systems (Discriminating and Check) fed from separate CTs, shall be provided for each busbar section. The Discriminating system associated with each busbar section is unique, however the Check system is common to all busbar sections. Each system shall be capable of detecting all types of faults under all system generation conditions,
- Each system shall comprise a single relay connected in parallel across busbar protection CT bus wiring. The Check system shall be connected in parallel across the busbar protection CT bus wiring associated with all incomers and feeders, the Discriminating system shall be connected in parallel across the busbar protection CT bus wiring associated with the bus coupler and bus section and only with circuits connected to a particular busbar section. Coincident operation of one Check system relay and one Discriminating system relay shall be arranged to initiate tripping of the appropriate busbar section,
- Shall be provided with a single busbar protection tripping system. Contacts on the appropriate the Check and Discriminating system relays shall be connected in a series arrangement so that coincident operation

of one Check system and one Discriminating system relay is necessary in order to initiate tripping of the appropriate busbar,

- A single hand reset busbar protection trip relay shall be provided for each circuit breaker with the exception of the bus coupler and bus section circuit breakers which shall be provided with two hand reset busbar protection trip relays, one for each discriminating zone of busbar protection. The busbar protection tripping system may also be used for back tripping from the circuit breaker failure protection.
- For 132 kV systems, the busbar protection trip relay shall be arranged to trip both trip coils.

### 4.5.30. Low Impedance Busbar protection

The Low Impedance busbar protection shall operate for both phase to phase, 3 phase and phase to earth faults. The principle of operation shall preferably be based on low impedance differential protection. The operating time of the relays shall not exceed 30 msecs at five times the relay current setting.

The equipment shall be stable for all out of zone phase to phase, 3 phase and phase to earth fault currents up to the short circuit current rating of the switchgear, applied gradually or suddenly and irrespective of the distribution of current between the individual circuits.

There shall be fully discriminative clearance of busbar faults on any section of busbar without introducing sequential tripping of section circuit breakers. All circuit breakers connected to a faulty busbar shall be tripped simultaneously, whether they feed fault current or not.

Care shall be taken to ensure that the protection does not maloperate as a result of faults in the associated CT wiring when the primary circuit is carrying load current. Continuous or automatic cyclic supervision shall be provided for this purpose. It shall be possible to make the zone containing the faulty circuit inoperative and/or to bring up an alarm. Where the supervision is dependent upon load current in the primary circuit, operation shall occur at a primary current of 25 amperes or 10 per cent of the circuit rating whichever is the greater.

The following test and isolation facilities shall be provided on the front of the protection panel:

- Isolation of individual tripping and inter tripping circuits,
- Isolation of individual zones.

Inter tripping, where required, shall be affected by means of electrically separate outputs contacts of the trip relay. The inter tripping scheme shall be to the approval of the Client.

The Bus bar protection shall be capable of operating with class P CTs.

The sensitivity shall be such that definite operation occurs for phase to phase and phase to earth short circuits during minimum plant conditions, irrespective of the number of circuits in service and the distribution of load and fault currents. The sensitivity level shall not exceed 30 per cent of the minimum fault level for all types of faults.

The busbar protection shall have the following features:

- A single hand reset busbar protection trip relay shall be provided for each circuit breaker with the exception of the bus section circuit breakers which shall be provided with two hand reset busbar protection trip relays, one for each discriminating zone of busbar protection.
- The busbar protection tripping system may also be used for back tripping from the circuit breaker failure protection.
- Signalling lamp for each Zone (i.e. Bus Bar protection operated for each Zone, Busbar protection fail for each Zone, DC healthy, Busbar protection in/out of service for each zone…).
- Features of the Low impedance busbar protection relay:
  - Input currents to be 1 A secondary,
  - The relay to be low burden,

- The relay to be supplied with a numerical display, showing the magnitude and phase of each current,
- The relay to be insensitive to harmonics, and transients on the network,
- Parameters and settings shall be able to be changed from the local interface & by computer access,
- The relay should be stable during busbar selector switching operations,
- The relay shall have Self-test capability with a watchdog contact.

### 4.5.31. Fault Recorder Equipment

#### *4.5.31.1. Ratings*

The fault recorder equipment shall have the following ratings:

- Current transformer secondary current: 1 A,
- Voltage transformer secondary voltage: 110 V AC, phase-to-phase,
- Frequency: 50 HZ,
- Auxiliary DC supply voltage: 125/110 V,
- Low Burden: < 1 VA.

#### *4.5.31.2. Function of The Fault Recorders*

The recorders shall provide permanent records for subsequent analysis of electrical network voltage and current waveform and sequence of the various protective equipment and circuit breakers during faults and disturbances.

The recorders shall include internal fault locator, which will detect all types of faults and to indicate the distance to fault directly in kilometres with error of (≤3%).

#### *4.5.31.3. Triggering*

- Analog triggering: Initiated at selectable minimum and/or maximum threshold, minimum and/or maximum rate of change for each analog waveform,
- Digital triggering: Initiated at selectable change of state close to open or open to close or rising and/or falling edge,
- Inter-triggering: Inter-triggering between recorders should be provided,
- Manual triggering: manual triggering to be provided for test purpose.

Triggering sample rate shall be ≥ 5 kHz.

#### *4.5.31.4. Recording Parameters*

- Recording Time Accuracy: 1 microsecond,
- Pre-Fault Time: selectable from 50 ms to 1500 ms,
- Post-Fault Time: selectable from 100 ms to 5000 ms.

Print out scale should be adapted automatically in relation to the maximum current or voltage and shall be readable and an accuracy maintained for a current between the nominal current up to twenty times nominal current.

DFR records & triggers slow scan to be saved on non-volatile memory and not to be lost during switching off the power supply.

The (digital) events channels should be printed out beside the analog channel.

Substation name, circuit name, Triggering Date, and precise time to the nearest millisecond to be printed out.

Slow scan trigger for power quality monitor.

#### *4.5.31.5. Programming and Analysis*

All recorder's parameters and functions should be programmed locally and/or remotely.

Recorder analysis using software program compatible with win98/win2000/winXP to download fault records directly and/or remotely via modem with analysis function including impedance, power and harmonic analysis.

Fault records to be COMTRADE file type compatible.

The software should have the facility of file saving and transferring.

#### *4.5.31.6. Communications*

Direct Connection to Laptop PC (using RJ45 connection) and/or USB-Serial connection.

Remote connection to be supplied by internal MODEM and/or ETHERNET connection (10BASE_T) and to be connected to the normal telephony systems.

Standard MODEM protocol compatible with win98/win2000/winXP.

#### *4.5.31.7. Time Synchronization*

The recorder shall include internal GPS time synch. (receiver and antenna).

Master and slave time synch. shall be available.

#### *4.5.31.8. Fault Recorder General Specifications*

The recorder shall give different alarms indicating the following:

- Recorder operated,
- Recorder faulty (watch dog),
- Loss of time synchronization.

Recorder memory shall be able to store at least 100 fault records.

### 4.5.32. Combined Protection Relays for 132 kV Circuits

Combined protection relays for 132 kV circuits are acceptable only as follows:

**132 kV OHL**

| Item | Protection Function |
|---|---|
| 1 | Differential/Distance / Auto reclose / Synchro check |
| 2 | Directional over current / Directional Earth fault / Sensitive Earth fault |
| 3 | Self-reset trip relay |
| 4 | Circuit breaker failure |
| 5 | Trip circuit supervision |

**132 kV Short OHL/Cable circuit**

| Item | Protection Function |
|---|---|
| 1 | Distance / Fault Locator / Auto reclose / Synchro check |

| | |
|---|---|
| 2 | Directional over current/ Directional Earth fault |
| 3 | (OHL/Cable) Differential Protection |
| 4 | Self/Electrical reset trip relay (as applicable) |
| 5 | Circuit breaker failure |
| 6 | Trip circuit supervision |

**132/33 kV Transformer circuit**

| Item | Protection Function |
|---|---|
| 1 | Differential Protection / HV Restricted Earth fault / Over-flux |
| 2 | Over current/ Earth fault |
| 3 | Stand-by earth fault |
| 4 | Auxiliary relays for transformer mechanical protections |
| 5 | Electrical reset trip relay |
| 6 | Circuit breaker failure |
| 7 | Trip circuit supervision |

**132 Bus Section and Bus Coupler circuit**

| Item | Protection Function |
|---|---|
| 1 | Over current/ Earth fault / Synchro check |
| 2 | Self-reset trip relay |
| 3 | Circuit breaker failure |
| 4 | Trip circuit supervision |

Communication standard (IEC 61850) shall be included in protection relays.

### 4.5.33. 33 kV Feeder (Cable/OHL) Protection

#### *4.5.33.1. Numerical Line Differential Protection*

Line differential protection relays shall preferably utilise the phase segregated current differential principle and shall be suitable for use with both dedicated optical fibre links, or multiplexed communication systems. The relay shall provide phase selective differential protection for two terminal lines and shall operate simultaneously at both terminals of the protected circuit to provide rapid fault clearance irrespective of whether the fault is fed from both terminals or from one end of the line only.

High speed tripping for all in-zone faults, stability for all out-of-zone faults and correct operation for developing faults must be assured for all practical conditions of load and fault current flow.

The line differential protection relay shall operate correctly for all in-zone phase-to-phase and phase-to-earth faults occurring at the same time, or shortly after, an out of zone fault, and for all other types of evolving faults

Relay operating time shall not exceed 30 ms with fault resistance up to 100 ohms.

Relay reset time, from cessation of any condition, which would cause the relay to operate, shall not exceed 100ms.

The returning ratio, defined as the differential current at which the relay resets divided by the differential current at which the relay operates, shall not be less than 70%.

The relay shall continuously monitor the propagation delay of the communication channel used for transmission of the protection measurement quantities and shall provide compensation for the effects of the propagation delay. The relay shall continuously adjust the propagation delay compensation to the prevailing delay value such that automatic re-routing of the communications channel does not cause incorrect operation of the protection relay.

Each relay shall be uniquely addressable; so that if it receives incorrect messages (e.g messages from the wrong remote relay, or messages are looped back to itself via the communications channel) as a result of incorrect operation of the communications channel, the incorrect messages will be rejected, and the relay will not mal-operate.

The line differential protection relay shall provide an inter-trip facility to enable a relay at the remote end to be energized via the communications channel used for the line differential protection, when a relay contact at the local end is closed. This facility shall be available to be assigned to any trip or signalling function such as direct transfer trip or block auto-reclose.

The line differential protection relay shall provide a permissive inter-trip facility to enable a relay at the remote end to be energized via the communications channel used for the line differential protection, when a relay contact at the local end is closed and the current detected by the remote end line differential protection is above the threshold level for operation.

The line differential protection shall incorporate indicators to show: Relay operation, Inter-trip operation, Permissive inter-trip operation, Relay out of service, Relay available. Indication must not be lost in the event of a supply failure.

Supervision facilities which include a periodic self-check of the key elements within the relay and a continuous self-monitoring of all internal power supplies, microprocessor operation and communication equipment shall be provided. The indications provided shall be designed to allow the defective item to be quickly identified. The status of the DC power supplies shall be permanently indicated. A defect in any of the self-supervision facilities shall not cause mal operation of the protection relay.

The line differential protection relay shall include facilities for the storage of fault records. A minimum of four records shall be capable of being stored in non-volatile memory within the relay for post-fault analysis.

The line differential protection relay shall be compatible with as wide a range of communication equipment and media as possible, and to achieve this the relay shall be designed to operate within the signalling bandwidth of a basic 56/64 kb/s pulse code modulated (PCM) signalling channel.

The relay shall be capable of providing redundancy of communication by transmitting and receiving messages over two communication channels, both of which are continuously monitored by the relay. If one channel fails, the relay shall continue to operate correctly over the remaining channel.

The relay shall be capable of operating over a dedicated optical fibre communication channel, or over a digital communication channel which is multiplexed and shared with other protection and telecommunications equipment employing optical fibres or conventional media. The design of the protection relay shall preferably be such that the various communication channel requirements can be accommodated within the relay with only the communication interface requiring to be changed to suit different requirements.

#### *4.5.33.2. Pilot Wire Differential Protection*

Pilot wire differential protection shall be provided where specified and shall be of an approved type employing preferably not more than two (2) cores in a multicore pilot cable with 1/0.9 mm telephone conductors. Other cores in the same cable may be used for remote control equipment, tele-metering, high speed inter-tripping and speech channels, all of which are to operate satisfactorily and without mutual interference with the feeder protection.

The protection shall operate for phase faults and earth faults within the protected zone and remain stable for through faults equal to the maximum rated breaking capacity of the associated switchgear.

Phase and earth fault sensitivities shall not be more than 125% and 45% respectively of the nominal rated load of the circuit operating time characteristics shall be stated.

Pilot wire supervision facilities shall monitor the pilot circuit via a spare pair of pilot cores. All necessary associated pilot isolating transformers, power supply units and insulated supervision relays shall be provided. Overcurrent and earth fault guard relays of the instantaneous type having setting ranges of 50% ÷ 200% of CT nominal current for overcurrent relays and 10% ÷ 40% of CT nominal current for earth fault relays.

Relay and associated equipment insulation shall be at least 15 kV.

#### *4.5.33.3. Sensitive Earth Fault Protection*

Sensitive earth fault protection shall be provided to cater for high resistance earth faults which remain undetected by the main protection and shall comprise a definite time overcurrent relay.

The current setting shall be adjustable between 3 and 5% of CT rated secondary current. The time delay shall be adjustable between 1 and 10 seconds.

As the relay has a very low setting, it is essential that the burden imposed by the relay is small.

#### *4.5.33.4. 33 kV Delayed Automatic Reclosing Relays*

Three phase single shot delayed automatic reclosing equipment shall be provided for all 33 KV overhead line feeders. Reclosure shall be initiated by the instantaneous overcurrent and earth fault relay elements incorporated in the overcurrent and earth fault relays. During the dead time, the auto reclose relay shall interrupt the instantaneous element trip circuits so that if the fault is permanent, the circuit breaker shall be tripped by the inverse time relays and a second reclosure will not take place. Reclosure shall not be initiated in the event of an operation of the sensitive earth fault relay or when the circuit breaker is closed onto a fault on a previously de-energized line.

The dead time following fault clearance shall be adjustable between 3 and 30 seconds. The reclaim time, i.e. the time following automatic reclosure during which further faults result in tripping and lockout, shall be chosen to match the circuit breaker duty cycle assuming the shortest available dead time is selected. The reclaim time shall however, be adjustable between 5 and 200 seconds.

The closing command shall be limited to 2 seconds after which time the reclosing equipment shall automatically reset.

A counter shall be provided to record the number of tripping and lockout the equipment after a pre-selected number of operations. An alarm shall indicate when the “lockout for maintenance” situation is approaching.

A switch shall be provided to switch the auto-reclose equipment in or out of service.

### 4.5.34. 33kV side Transformer Protection

#### *4.5.34.1. Low Voltage (LV) Restricted Earth Fault (REF) Protection*

Transformer windings with YN connection shall be provided with LV restricted earth fault protection. Relay shall be of the high impedance circulating current type necessary protection against over-voltage.

The sensitivity of the protection scheme shall not exceed 25% of the rated current of the protected winding in the case of solidly earthed systems and 15% of the minimum current available for an earth fault at the transformer terminals in the case of resistance earthed systems. These values are to include the effect of current transformer magnetising current and the current taken by the voltage limiting device.

The protection shall remain stable up to the maximum through fault current corresponding to the rated system short circuit level. This may be taken as 16 times the rated current of the protected winding of the power transformer, unless otherwise approved by the Client.

Associated current transformers shall be class X (PX according to IEC 61869-2), or other class as recommended by the relay manufacturer and approved by the Client. Contractors shall submit at an early stage, design calculations for current transformers for approval.

#### *4.5.34.2. Transformer Cable Circulating Current*

The transformer cable circulating current relay shall be used for each transformer circuit (where capacitors are connected to the 33 kV transformer side), as follows:

- The protected zone is the 33 kV cable from the transformer to the indoor 33 kV transformer CB,
- The CT secondary from the transformer outdoor 33 kV CTs, transformer indoor 33 kV CTs shall be supplied to the relay,
- Instantaneous tripping for all dedicated CBs,
- Relay ratings:
  - Operating time: ≤ 30 ms,
  - The relay shall be low burden,
- Features of the relay:
  - Operation of the relay shall be based on low impedance differential protection principle which operates with all CTs types & classes,
  - The relay shall be supplied with a numerical display, showing continuously & instantaneously magnitude and phase of each current,
  - The relay shall be insensitive to voltage fluctuation, harmonics, and transients on the network,
  - The relay shall be stable during capacitor operations,
  - The relay shall be suitable to be used for inputs with different CT ratios & different CT classes (5P10/20/30),
  - The relay shall be stable for all out-zone faults, even for 20×In,
  - Signalling LED for operation of the relay,
  - Self-check watch dog shall be provided.

### 4.5.35. Standby Earth Fault Protection

Standby earth fault protection shall be provided for all resistors, fed from a current transformer in the resistor connection.

The protection shall comprise a two-stage definite time overcurrent relay. The operating current shall be adjustable between 10 and 40 per cent of the resistor value. The two-time delay stages shall be adjustable between 1 and 10 seconds. As an alternative to a definite time delay, and with the approval of the Client, a long inverse time relay may be offered together with a second stage timer.

### 4.5.36. Under Frequency Load Shedding

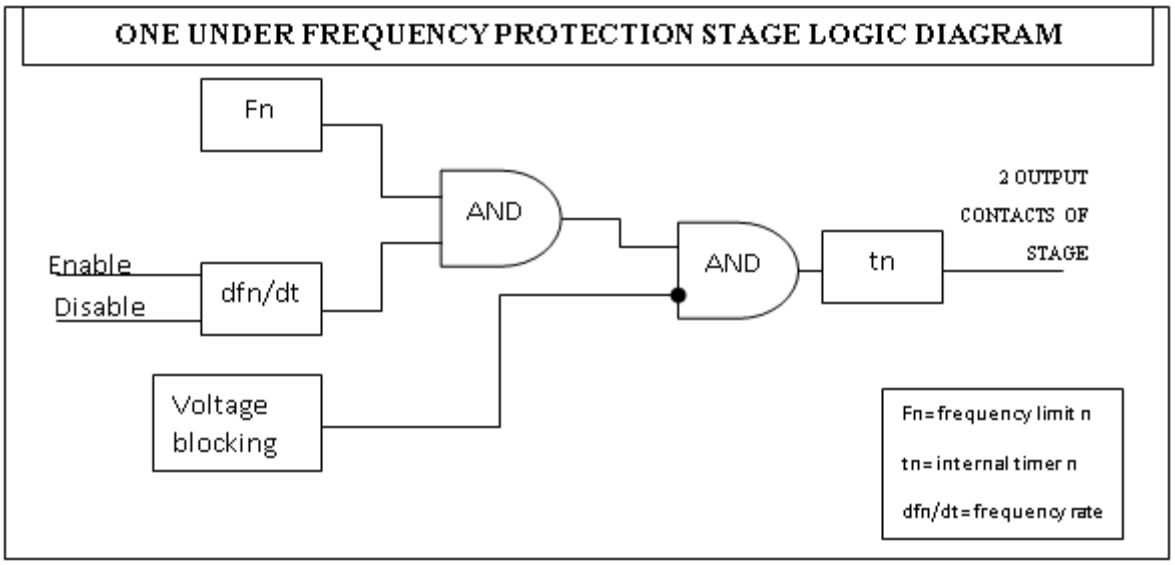
The load shedding scheme shall consist of one (1) cubicle located in 33 kV Control & Protection room, which includes load shedding relays and voltage selection relays, as the following:

- Voltage selection scheme (AC voltage inputs from 33 kV VT secondary 110 AC for each Transformer Circuit, AC voltage output is to be used to supply UF relays),
- Under frequency relays with at least of 16 stages (one relay or multiple relays) of independently settable frequency & df/dt,

- The tripping commands shall be sent to all 33 kV feeders and the capacitor banks, through fuse links to trip the CBs,
- Alarm facia/display shall be included.

Each under frequency relay shall have the following characteristics:

- Relay ratings:
  - Frequency setting range: 40 to 60 Hz, step of 0.05 Hz,
  - Frequency rate of change setting range: 0 to-10 Hz/sec, step 0.05 Hz/sec,
  - Time setting range: 0 to 20 sec., step 0.01 sec,
- Features of the under-frequency relay:
  - Measure the frequency and its rate of change with respect to time,
  - The relay shall be supplied with a numerical display, showing continuously & instantaneously network frequency,
  - Self-check watch dog shall be provided,
  - The relay shall be insensitive to voltage fluctuation, harmonics and transients on the network,
  - Internal settable minimum voltage blocking,
  - Minimum two (2) output contacts for each stage tripping (totally 32 output contacts),
  - Additional two (2) output contacts for alarming and signalling,
  - Keypad access to enable setting, resetting, ...etc., of the relay,
  - Facility to switch the relay ON/OFF, and test output contacts,
  - Each stage shall have an independent setting for frequency, time and frequency rate of change,
  - Each stage shall have an independent LED showing the stage operation,
  - Each stage shall include the following functions (as per the following diagram):




Each voltage selection relay shall have the following characteristics:

- The relay shall be supplied by two (2) AC voltages, one as main supply and the other as alternative supply,

- The relay shall be used to switch-on automatically the alternative supply if main supply fails.

### 4.5.37. Capacitor bank protection

The following protection functions shall be enabled for protection of capacitor banks:

- Current unbalance protection - Each capacitor bank shall have a two-step current unbalance protection, the first step of which initiates alarm and the second of which trips the associated circuit breaker. The Contractor shall recommend the necessary current and time delay ranges and settings. The settings shall allow for uneven temperatures and tolerance of capacitance,
- Phase and earth fault inverse time overcurrent protection - The protection shall be an inverse time relay, which shall initiate tripping of the bank, associated 33 kV circuit breaker,

  A circuit breaker failure function shall be included in the relay of phase and earth protection,

  The CBF shall initiate tripping of associated 132 kV transformer circuit breaker and bus section circuit breakers; the timer of the CBF function shall be adjustable,

  High set elements of the inverse time relays shall trip the associated capacitor bank circuit breaker. The Contractor shall ensure that the available setting range is wide enough to allow a selection of a setting higher than the maximum possible charging current of the capacitor banks,
- No volt protection to disconnect the capacitor bank instantaneously in the event of power supply interruption,
- Overvoltage protection with an inverse time characteristic to match the overvoltage characteristics of the capacitor bank,
- Overload protection with an inverse time characteristic.

The Contractor shall provide a comprehensive calculation to demonstrate the co-ordination and performance of the various protection levels (fuses, current unbalance protection and overcurrent and earth fault protection) under the normal, switching and fault conditions including the recommended settings.

### 4.5.38. Combined Protection Relays for 33 kV Circuits

Combined protection relays for 33 kV circuits are acceptable only as follows:

**33 kV OHL Circuit**

| Item | Protection Function |
|---|---|
| 1 | Over current / Earth fault / Sensitive Earth Fault / Circuit breaker failure |
| 2 | Synchro check / Auto reclose |
| 3 | Self-reset trip relay |
| 4 | Trip circuit supervision |

**33 kV Cable Circuit**

| Item | Protection Function |
|---|---|
| 1 | Cable differential |
| 2 | Over current / Earth fault / Synchro check / Circuit breaker failure |
| 3 | Electrical reset trip relay |
| 4 | Trip circuit supervision |

**33 kV Transformer Circuit**

| Item | Protection Function |
|---|---|

| | |
|---|---|
| 1 | LV Restricted Earth Fault |
| 2 | Directional Over current / Earth fault / Synchro check / Circuit breaker failure |
| 3 | Electrical reset trip relay |
| 4 | Trip circuit supervision |

**33 kV Bus Section**

| Item | Protection Function |
|---|---|
| 1 | Over current / Earth fault / Synchro check / Circuit breaker failure |
| 2 | Self-reset trip relay |
| 3 | Trip circuit supervision |

**Neutral Earthing Resister**

| Item | Protection Function |
|---|---|
| 1 | Stand-by Earth Fault protection |

**33 kV Capacitor Banks**

| Item | Protection Function |
|---|---|
| 1 | Over current / Earth fault / Overload / Over voltage / Under voltage / Circuit breaker failure |
| 2 | Unbalance Current |
| 3 | Electrical reset trip relay |
| 4 | Trip circuit supervision |

Communication standard (IEC 61850) shall be included in protection relays.

### 4.5.39. Protection Test Equipment (NOT applicable)

To facilitate automatic testing of the distance protection relays, overcurrent relays, etc. to be carried out regularly and rapidly and with a minimum of disturbance to relay equipment, the Tenderer shall include one set of programmable computers controlled automatic test equipment. This shall include computer unit, keyboard, monitor, general purpose software, software for testing operation in a single pole tripping scheme, etc.

The protection test equipment shall be subject to the Client's approval.

## 4.6. Energy Meters (NOT applicable)

### 4.6.1. Main Characteristics

Energy meters shall be fully designed and manufactured in accordance with all applicable/related IEC standards.

Meter approvals and certifications shall be from internationally recognized and accredited laboratories only. A copy of each Certificate relating to meter approval/compliance shall be submitted.

For the purposes of this Tender, the required accuracy class for all active energy measurement shall be Class 0.5, and for reactive energy measurement accuracy class shall be 0.5.

Energy meters shall function normally in the following conditions:

- Ambient temperature: -5 °C to 50 °C,
- Storage conditions: between 0 °C and 30 °C,

- Humidity: 75%.

Energy meters shall have the following electrical characteristics:

- Nominal voltage (Un):
  - Measuring circuits (from voltage transformer): 3×100/120 V AC,
  - Auxiliary circuits (Universal auxiliary power supply): 1×85 ÷ 240 V AC and DC,
- Maximum voltage (Umax): 130% Un,
- Nominal current (In): 1 A,
- Maximum current (Imax): 120% In,
- Starting current: 0.05% In,
- Nominal frequency: 50 Hz±2%.

In case that meter auxiliary supply fails, the meter shall automatically switch to the VT input supply voltage and the recording of data shall not be interrupted.

Primary values for voltage and current shall be programmable using the configuration software. Immunity from electrical interference shall be as required in the appropriate IEC Standard.

Energy meters shall be three-phase, four-wire (3ph, 4w), and shall be connected in delta.

A SuperCap or lithium battery shall provide backup power for Real Time Clock (RTC) and the storage of register values and configuration data for up to one year without mains power applied.

The meters shall be provided with transformer losses compensation, Line losses compensation and energy measurement error factor applied by the user; these compensations shall be activated or de-activated depending on the user choice.

Energy meters shall be surface mounted within pertaining energy meter panels. Any accessories to mount the meter on the surface of the panel shall be provided.

Drawings indicating the dimensions of meter shall be provided either separately or included in brochures or data sheets.

### 4.6.2. Functionality

The following energy meter generated alarms and events shall be provided:

- Internal battery low,
- One or more phase failure (programmable threshold level – sampling frequency period to be stated),
- Overvoltage (programmable threshold level – sampling frequency to be stated),
- Meter re-programmed (incl. CT or VT ratio changed and RTC reset),
- Meter last accessed time and date (local and remote),
- Meter error (self-test),
- Voltage unbalance (programmable threshold and time delay).

Energy meters shall have a minimum of two (2) programmable relay inputs in order that externally generated alarms can be reported back to the Head-end, data collection system.

Energy meters shall have a minimum of three (3) configurable/programmable available relay outputs.

The following meter registers are required:

- Cumulative energy registers for:
  - Active energy – Import,
  - Active energy – Export,
  - Reactive energy – Import,
  - Reactive energy – Export,
- Programmable period (configurable from one minute to 60 minute), required registers for:
  - Active power – Import,
  - Active power – Export,
  - Reactive power – Import,
  - Reactive power – Export,
- Five Time of Use registers (Programmable by hour, day, month and season),
- Five Programmable Billing cycle registers (Wh and VArh) (Programmable by hour, day, month and season).

All registers shall be programmable to display W, kW, MW, etc.

No multiplication factors shall be allowed.

The energy meter shall have two (2) separated load profiles and each one of them have the setting for the required integration period (i.e. configurable from one minute to 60 minute) and each of them shall have the ability to store any measured value from the meter including the tariff registers.

Data registers (Load Profiles) shall have adequate capacity to store three (3) months on site data to allow for any interruptions to the automatic data Collection System, including:

- Demand log (as per above),
- Time of Use registers (Programmable by hour, day, month and season),
- Programmable Billing cycle registers (Wh and VArh),
- Voltage and current for each phase,
- Total power factor (the total power factor shall be registered in both directions export and import with sign indication).

Also, to facilitate the storage of data, meters shall be fitted with an internal power supply e.g. battery, which shall have a typical life under normal operating conditions of ten (10) years.

Start and end periods for Daylight Saving Time shall be programmable in the meter once only i.e. should not require re-programming each year (the setting shall have date and time of switching depending on customer settings and not depending only on choosing the Time Zone).

Adjustment for Daylight Saving shall occur in the meter automatically or as programmed i.e. ability to change automatically every year according to the setting of summer and winter time in the meter. Current Jordanian summertime starts on last Thursday in March at midnight, ending on last Friday in October at 01:00 am.

RTC shall not drift beyond second per month.

Energy meters should have local and remote time synchronization capability if the time drifts outside acceptable limits the synchronization will be done through the AMR server(s).

In case of energy meter auxiliary supplies failure, to ensure continuity of remote data collection, and meter operation (and the transmission of alarms and events), the energy meters shall include the facility for feed the meter from voltage transformer secondary supply using electronics within the meter.

These auxiliary supplies shall normally be taken from the 110 V DC system within each Substation, but when fail, change-over to the VT input supply voltage shall be enabled.

### 4.6.3. Communications

#### *4.6.3.1. Protocols*

Energy meters should use different protocols to connect for both AMR/MDM system and SCADA system to achieve that two communication ports are required. The Meters purchased will be required to integrate to the Current AMR/MDM system type ZFA-F from ITF-Froschl, and it is a condition of this tender that the bidder ensures that this is possible and supplies the required meter driver if it is not in the current NEPCO AMR/MDM system. the preferred Protocol to connect to the AMR system is DLMS.

To connect the system with SCADA a MODBUS protocol is required to be implemented.

To achieve the above-mentioned connections the meter shall support the two communication protocols via the two required communication port

simultaneously without interruption or affect the other port.

Meters may also be specified as IEC 61850 compatible for future Smart Grid integration.

#### *4.6.3.2. Remote*

The TCP/IP over Ethernet communications can be either built-in type or as an internal module and the physical connectivity shall be via RJ45 socket.

Energy meters shall have an RS-485 output to connect the meters in Multi Drop connection to connect via MODBUS for SCADA, as well as an RJ45 output from the Ethernet communications module to connect the meters to the AMR/MDM system.

#### *4.6.3.3. Local*

Local communications for meter reading and configuration purposes shall be possible via an optical port located on the front of the meter or by direct connection port.

For calibration purposes, the optical port shall also be capable of providing a suitable output pulse to calibration equipment for both active (W) and reactive (VAr) power.

All accessories to communicate with the meter shall also be supplied.

#### *4.6.3.4. Configuration Software(s)*

Meter configuration software shall be provided to enable local and full remote (via the data network without the necessity to operate any hardware for the meters locally) programming of, but not limited to, the following:

- Measurement transformer ratios
- Measurement transformer compensation
- Time and date
- Demand period duration
- Display sequence
- Time of Use registers

- Billing period

A minimum of four test points from the combined error of the current transformer and voltage transformer should be capable of being programmed in the meter.

The configuration software shall run on a Microsoft Windows environment and be compatible with a laptop computer (to be specified by the bidder – max. 15-inch screen).

The laptop quoted shall be capable of supporting multiple configuration software packages for meters of different models and manufacturers.

NEPCO will carry out all energy meter programming related to CT and VT information.

### 4.6.4. Labelling

Energy meters shall be marked "*The Property of National Electric Power Company*" and shall be individually serial numbered according to NEPCO approved format. Circuit names shall also be labelled on the front of the meters (NEPCO will provide these labels following Contract award).

Primary and secondary values for voltage and current shall also be displayed on the meter nameplate as well as the circuit name (these will be provided by NEPCO).

### 4.6.5. Security

Configuration of the energy meter shall be controlled through appropriate multiple level password protected access – to be defined by the Contractor.

Meter cover and terminal cover shall have appropriate facilities for the application of a wire (or similar) security seal.

### 4.6.6. Energy Meter Panels

Energy meter panel shall be constructed from 1.5 mm sheet steel and painted with primer then undercoat and finished in paint code 7035. Meter panels shall be tested to a degree of mechanical protection level of IP52.

Completed energy meter panels shall be packed to a suitable level of protection for sea freight shipping to ensure no damage occurs in transit.

A minimum of four (4) floor-fixing points shall be pre-drilled and available in the base of the cabinet. Gland plates suitable for a range of cable sizes shall be included at the base of the cabinet.

Cabinets shall be 800÷850×600×2000÷2250 (W×D×H), and rack type with transparent (shatterproof plastic) single front door hinged on the right hand side. Rear opening shall be by two (2) equally sized sheet steel doors with locking facility incorporated into the handle. Appropriate lifting eyes shall be fitted on the top of the panel and should withstand the additional weight of eight (8) energy meters.

The Contractor shall submit the General Arrangement and Wiring Diagrams of the energy meter panels for Client's approval.

The panels shall be fully wired for the number of circuits/meters and fully equipped with all necessary components and the related accessories.

All panel wiring shall be suitable for power and data signals as appropriate.

All panel wiring shall be:

- Multi-stranded,
- Colour coded according to phase colour (R, Y, B),
- Minimum cross-sectional area of 2.5mm$^2$ for CT, VT and auxiliary supplies circuits,
- Wires shall not be terminated without crimps.

Wires ferrules shall be supplied and approved by NEPCO for all panels.

Factory Test Certificates for all wiring checks, e.g. point-to-point and continuity tests, shall be submitted for Client's approval.

Power and data cables shall be suitably separated inside the cabinet.

All metering panels shall be fully equipped with the following:

- One 13 A power socket (UK type 3 square pins),
- One cooling fan with variable setting temperature-controlled switch,
- Internal lamp suitable for providing adequate light for working conditions, with door activated switch,
- DIN Rail and terminal blocks with appropriate isolation features and test point and earthing facilities; 10% spare terminals to be included,
- MCBs for incoming VT and power isolation with alarm contacts,
- Document/drawing storage pockets on the inside of the rear doors,
- All wiring to be enclosed in trunking with power and data cables separated,
- Engraved circuit labelling above each pair of meters (details to be provided by NEPCO),
- Open/close links for VT circuits and open/close shorting links for CT circuits,
- Earthing bar,
- Other necessary components and accessories.

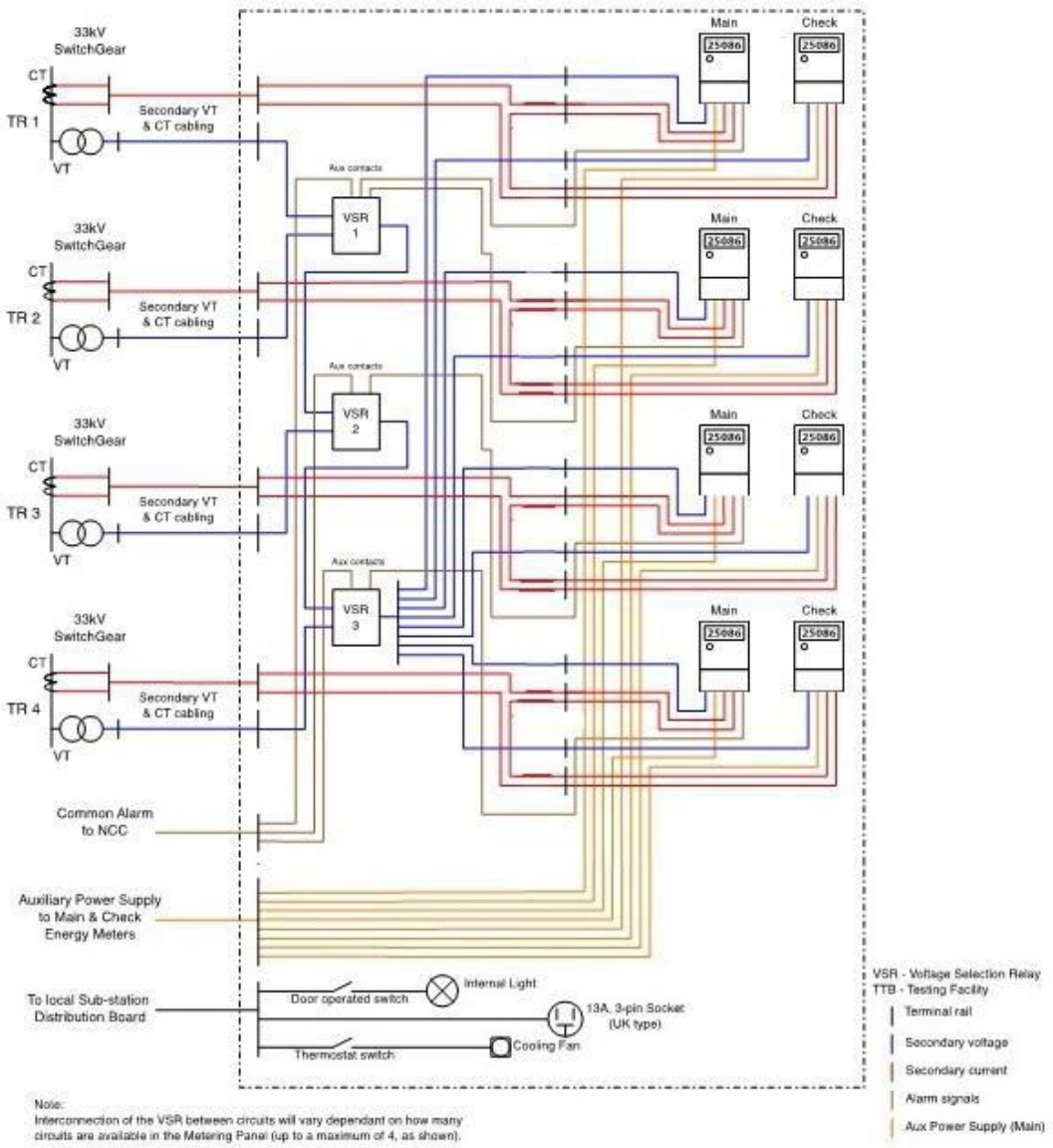
### 4.6.7. Voltage Selection Scheme

In order to prevent the loss of energy measurement due to the failure of a voltage transformer secondary supplying one or more measuring circuits of an energy meter, a voltage selection scheme shall be applied.

Voltage selection scheme shall be configured to switch from the designated voltage transformer secondary circuit to an alternative voltage transformer secondary (typically of a similar, adjacent circuit) should a single, or multiple phase failure occur.

Upon operation of the voltage selection scheme, an auxiliary contact shall be available which can be used as an alarm output and may be used to indicate that a failure has occurred.

Voltage Selection Scheme shall be included within the energy meter panel and shall follow the schematic diagram below.




In addition to the above, the proposed Voltage Selection Scheme shall suit the specific requirements of each substation and shall be a subject of Client's approval.

Discreet auxiliary relays shall not be a acceptable solution for providing voltage selection, and as such shall not be proposed by the Tenderer.

A maximum of four (4) circuits shall be arranged per panel.

Voltage selection relay shall function normally in the following conditions:

- Ambient temperature: -5 °C to 50 °C,
- Storage conditions: between 0 °C and 30 °C,
- Humidity: 75%.

Voltage selection relay shall have the following electrical characteristics:

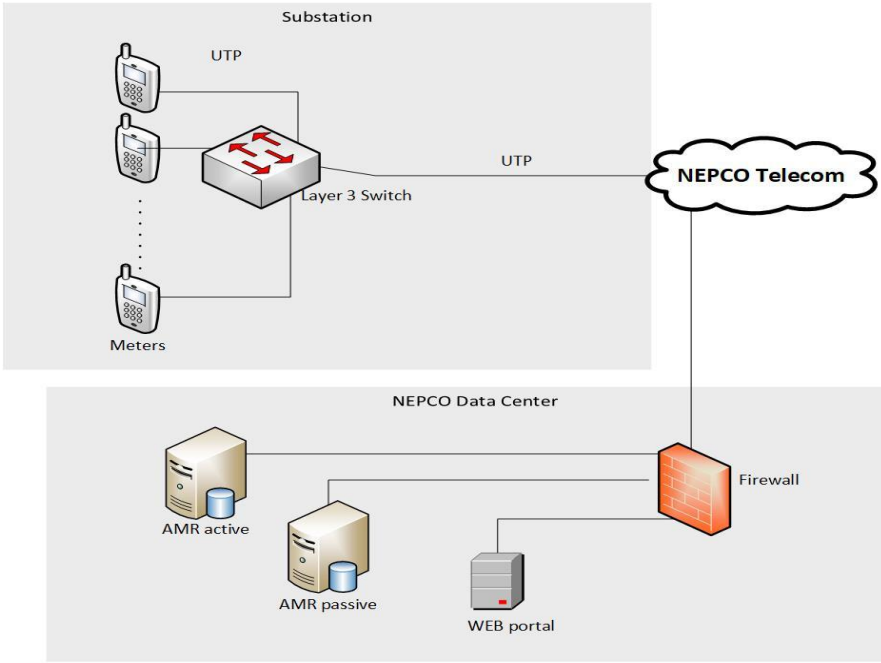
- Insulation class: Class I according to IEC/EN 601010-1,

- Insulation Category (Overvoltage): Category III according to IEC/EN 601010-1,
- Environment: Pollution degree 2 according to IEC/EN 601010-1,
- Product Safety:
  - 72/23/EEC,
  - EN 61010-1: 2001,
  - EN 60950-1: 2002,
- Electrical:
  - From voltage transformer secondary: 110 V AC,
  - System frequency: 50 Hz.

### 4.6.8. Metering System Network

The network is consisted of the following items:

- The Meter itself: each meter should have two communication ports; one of them shall be Fast Ethernet (10/100Mbps) port to be connected to NEPCO AMR network, while the other is to be connected to the billing system of the Facility. The two ports needed for data security and avoid data network interconnection and fully physical separation between the mentioned networks.
- One dedicated high performance Industrial layer 3 switch, the switch will be used to connect meters toward NEPCO AMR network.
- Cisco platforms are preferred to facilitate monitoring and health check tasks.




- In case of the industrial L3 switch is placed in a facility other than NEPCO substation, fibre cabling and termination should be done between NEPCO substation and the facility. At NEPCO side end, the termination should lead to a single RJ45 connector at telecom cabinet.
- The L3 switch should be of a form factor that is either resides in a standard 19” dedicated wall mounted network cabinet or Rail mounted in physically secured cabinet.

- Fiber termination equipment (ODFs, fiber to UTP converters, power converters, etc.) should be industrial grade equipment designed for harsh environment and should also enclosed securely within physically secured cabinet at both side of termination.
- Any fiber transceivers modules (SFPs) or fiber patch cords required to complete the physical connection up to telecom cabinet at NEPCO substation should be also provided.

## 4.7. Cables and Cable Accessories

### 4.7.1. General

The Contractor shall supply all necessary cables for proper functioning of complete substation, including all accessories, such as cable trays, ladders, clamps, fittings, bolts, etc.

The exact characteristics (cross section area, insulation type, etc.) shall be determined in the Contractors Design, which shall be a subject of Client's approval.

The Contractor shall supply the cables and cable accessories necessary for connection of some equipment and systems which are schedule A: scope of supply as well. These include, but are not limited to all necessary cabling for connecting 132 kV Auto transformer to 132 kV GIS, 132kV GIS to 132kV OHL feeders and to Main Transformers, all cables required in schedule A scope of work, cabling between Main Transformers and pertaining Remote Tap-Changer Control (RTCC) panels, , cabling between 33 kV Switchgears and pertaining 33 kV Protection & Control Panels, cabling between Main Transformer and 33kV Switchgear, cabling between Main transformers and Earthing transformers, cabling between 33 kV Switchgears and Capacitor Banks cabling from auto transformer to the 33 kV switch gear at 400 kV side. In order to enable the Contractor to supply these cables and cable accessories, the Client shall submit to the Contractor the necessary documentation and inputs related to these cables and cable accessories that Contractor needs to supply.

### 4.7.2. 132 kV Cables

The Contractor shall provide 132 kV cables for the substations 132/33 kV for connecting 132 kV GIS switchgear to the Main Transformers and 132kV OHTL entering the substations and all cable required in schedule A.

The 132kV cables shall be laid in the concrete cable trenches / cable trough, as shown at the layout SS drawings. One or more current circuits per trench will be laid, each three-phase circuits shall comprise one or more single conductor cables per phase.

Cable circuit shall operate continuously at full capacity (transformer rated current, OHTL ratted current and thus the cables shall be carrying full load current continuously.

The selected 132 kV Cables shall be capable to withstand without any damages, the effects of short circuit currents and for duration as stipulated in Project particular specification.

The following input data for the 132kV cables calculation shall be used in order to design an effective Cable system for a specified route and laying conditions.

- Cable installation – preferable in air in concrete cable trenches.
- Depth of cable trenches - 0.5m (Note: it may be changed according to contractor design)
- Width of cable trenches – 2m (Note: it may be changed according to contractor design)
- Site maximum temperature $50^0$C
- For Transformer bays, the same trench is foreseen for maximum 3 three - phase cable systems/ circuits laying each system carrying **the required ratings.**
- For line bays, the same trench is foreseen for one three - phase cable systems/ circuits laying each system carrying **the required ratings.**

cable formation (trefoil or flat) and spacing between circuits, as well as cable screen bonding arrangement shall be defined by Contractor, to fulfil required rated current per circuits.

**Contractor is responsible to perform necessary design calculation to confirm required current ratings and coordinate cable terminations with cable characteristics.**

Contractor shall supply the final cable length as determined from the drawings and calculations.

The Contractor shall also supply cable terminations, where number and type of cable terminations shall be harmonized with cable design, 132kV GIS and Transformer HV cable boxes design.

The 132 kV cables shall be single core cables with copper conductor and cross-linked polyethylene (XLPE) insulation.

According to the Standard IEC 60840, the maximum temperature of the conductor for such insulated cable, during normal loading shall be 90°C, whereas during the short circuit, in the duration of 5 s, it shall be 250 °C.

The cable shall comprise a copper conductor, bonded semi-conducting screen, extruded solid dielectric insulation with a bonded semi-conducting screen, layers of tape and copper wire or tape screen, or impervious metallic sheath and overall anti-corrosion protection by an extruded HDPE or medium density polyethylene sheath.

The conductor shall be of stranded, plain and high graded electrolytic copper conductor in accordance with IEC 60228. The conductor shall be provided with water sealing to shield from water penetration both in longitude and radial. The sealant shall be made of water swelling type material and comply with IEC 60840.

The conductor screening shall be non-metallic semiconducting compound bonded firmly on the inner circumference of the insulation. The bonding shall not be affected by mechanical and electrical forces that run into the Cable. The contact between the semiconductor screen and insulation shall be free from voids and protrusions.

The core insulation shall be of extruded ultra-clean cross--linked polyethylene (XLPE) cured by a dry process and shall be degassed and free from methane contents. The insulation thickness and dielectric strength shall be adequate and suitable in all respects for the specified highest system voltage in accordance with IEC 60840.

The insulation screen shall be of extruded semi-conducting compound. Water blocking tape(s) shall be applied over the insulation screen to prevent the passage of water in the event of sheath damage.

Core insulation shall be shielded by a layer of extruded semi-conducting material bonded directly over the outer surface of core insulation. The bonding shall not be affected by mechanical and electrical forces that run into the Cable. The contact between the semiconductor screen and insulation shall be free from voids and protrusions.

The metallic screen shall be formed of a number of copper wires applied in helical form together with a copper tape applied in the opposite lay. It shall be capable of carrying without damage the fault current specified in the Schedules for three (3) second based on 200 A/mm$^2$.

The diameter of the wire shall be stated in the Schedules and shall not exceed 0.6 mm.

The thickness of the copper tape shall be stated in the Schedules and shall not be less than 0.1 mm.

A synthetic tape may be applied over the screening wires and copper tape at the option of the manufacturer.

The metal sheath shall be of extruded lead alloy or corrugated aluminium. The cross section of the metal sheath shall be adequate to carry the earth fault current specified. The Contractor/ supplier shall prove by calculation that the metallic sheath and the insulation screen of the cable can withstand not less than system short time current rating specified int the technical data sheets.

Cable metallic sheath shall be bonded sufficiently to the earthing system. Contractor shall provide all necessary equipment and material for cable metallic sheath earthing in accordance with Contractor's cable calculations / design approved by Client.

### 4.7.3. 132kV Outdoor Cable Terminations

The Outdoor cable terminations shall be provided for 132 kV cable connections to OHTL feeders, installed at the steel support structures at the new substation.

Outdoor cable terminations shall be designed in accordance with the requirements of the Standards IEC 60840 and other relevant Standards if not otherwise required in this Specification.

Outdoor cable terminations shall be delivered with complete supporting structures required for erection. The steel structure shall be hot dip galvanized. Cable termination shall be isolated from the steel support structure by means of post insulators which shall be placed between cable termination and steel support.

The pressure-tight composite housing shall be made of a glass fibre reinforced resin (GFR tube) with silicone rubber sheds moulded to the tube.

The fittings and the base plate shall be made of non-corrosive alloy.

To fit the 132-kV cable conductor, mechanical connectors with torque-controlled shear-off bolts or crimp-type connectors shall be used. The connector shall be suitable for 132 kV cable stranded copper conductor. No special tools shall be required to install the connector.

The rated characteristics of outdoor cable terminations are given in schedule A: Scope of Supply & schedule D: Schedule of Technical Data.

### 4.7.4. 132kV GIS Cable Terminations

GIS cable terminations shall be provided for 132 kV cable connections to 132kV GIS switchgear at the substation 132/33 kV.

GIS cable terminations shall be suitable for installation in SF6 gas insulated switchgear (GIS).

GIS cable terminations shall be designed in accordance with the requirements of the Standards IEC 62271-209 and other relevant Standards if not otherwise required in this Specification.

The GIS Cable Terminations shall be based on pre-molded stress-control blocks (silicone or EPDM rubber) and resin molded insulators.

Plug in part shall comprise four components: stress cone made of silicone rubber, cable gland, connection bolt, spring loaded compression device.

The cable termination consists of an epoxy insulator standing on a base made of aluminium alloy. The field controlling component is a stress cone made of rubber. The insulator is filled with synthetic insulating oil. A flange for insulated mounting is integrated in the epoxy insulator.

### 4.7.5. 132 kV Transformer Cable Terminations

132 kV Transformer cable terminations shall be provided for 132 kV cable connections to 132kV side of Main transformer 132 /33 kV and 400/132/33 kV at the substations.

Cable terminations shall be suitable for installation in the Main Transformer HV oil box, complete with support steel structure.

Transformer cable terminations shall be designed in accordance with the requirements of the Standards IEC 60840, EN 50299 and other relevant Standards if not otherwise required in this Specification.

Details of transformer cable terminations, 132kV cables and transformer cable box shall be coordinated, and all equipment & material provided, according to the Contractors Design, Approved by Client.

As transformer shall be provided as part of this contract, and 132 kV cable and accessories and complete substation design will be provided by contractor, transformer manufacturer shall provide all necessary details of HV cable connection box, which shall be the inputs for cable terminations design and supply.

### 4.7.6. Cable Accessories

**Sheath Bonding Cable and Earthing cable**: The sheath bonding cable shall be single core cable 3.3 kV and above grade with 400 Sq.mm (conductor) stranded Copper conductor PVC insulated wire armoured and PVC sheathed. The earthing cable shall be 3.3kV & above grade with 400 Sq.mm stranded copper conductor PVC insulated & PVC sheathed. However, the rating and the size of sheath bonding cable and earthing cable mentioned are indicative and minimum values. The Contractor may quote the actual rating and size of cable offered, to meet the requirement.

**Link boxes at the circuit end**: The lead sheath shall be grounded through suitable disconnecting links at the base of sealing ends. The Contractor shall clearly indicate how the links are to be grounded directly at one end and through SVLs (non-linear resistors) at the other end. The links shall be housed in a weather proof, outdoor, galvanised sheet steel box or cast iron or aluminium alloy box with mounting brackets and provided with 'O' Ring gasketed door. The link box shall conform to IP-66 degree of protection for which the test reports shall be furnished. The Contractor shall furnish a copy of type tests certificates for the link box offered. The cable leads from the sheath to the link box, capable of withstanding 10 kV DC & cable leads from link box to earth shall form a part of the scope of supply of the Contractor. The Contractor shall quote for the same.

All accessories such as copper terminals, cable lugs, connecting links, disconnecting links, washers, gaskets, mounting arrangements, etc., shall be provided to make the system complete.

**Miscellaneous Items**: This includes Power cable and Bonding cable cleat.

### 4.7.7. 33 kV Cables

The 33 kV cables shall be single core cables with copper conductor and cross-linked polyethylene (XLPE) insulation.

The cable shall comprise of compacted circular, oval or shaped conductors, bonded semi conducting screen, extruded solid dielectric insulation with a bonded semi conducting screen, layers of copper tape with a minimum of 15% overlap, curves laid up with polypropylene fillers to produce a circular compactable and held together with a copper woven fabric tape binder, extruded PVC or PE bedding, aluminium or steel wire armour (for 3 cores only) and an extruded HDPE overs-heath.

According to the Standard IEC 60502-2, the maximum temperature of the conductor for such insulated cable, during normal loading shall be 90 °C, whereas during the short circuit, in the duration of 5 s, it shall be 250 °C.

The exact characteristics (cable cross section area, insulation type, number of cables per phase, etc.) shall be determined in the Contractors Design, which shall be a subject of Client's approval.

Contractor shall supply the final cable length as determined from the drawings and calculations. The Contractor shall also supply cable terminations, and accessories. where number and type of cable terminations shall be harmonized with cable design.

### 4.7.8. Multicore, Control and LV AC & DC Power Cables

Cables for power supplies at voltages up to 600/1000 V and for all 240 V AC and DC protection, control, alarm and indication shall have copper conductor with XLPE or PVC insulation and an overall PVC over sheath and galvanized steel wire armour.

The conductors shall be plain annealed copper wire complying with IEC 60228 as applicable or equivalent and all cores shall be clearly identified by printed numbers at regular intervals.

The minimum conductor size shall be not less than seven strands of 0.67 mm diameter wire, or in the case of single wire conductors the minimum cross-sectional area shall be not less than 2.5 $mm^2$. In special cases for light current installations single strand, annealed copper conductors with a cross-section of 1.5 $mm^2$ may be used.

Multicore, control and LV AC & DC power cables shall be protected from rodent attack and other physical damage by a suitable non-corrosive wire armouring.

All sheaths shall be free from defects and impervious to water.

All cores of each multicore cable shall be marked with a unique and indelible identifying number or symbol to easily distinguish one core from another.

Multicore and control cables shall be terminated in accordance with the manufacturers recommendations and the cable cores shall be left long enough to be terminated without the addition of separate tails.

The Contractor shall provide fully detailed wiring diagrams covering all parts of the plant. Detail diagrams shall be cross referenced and shall show multicore cable schedule reference numbers to facilitate cable identification.

The Contractor shall submit full details of all loadings on cables and in the case of interposing current transformer connections, the loop resistance of each circuit.

### 4.7.9. Conductors

Conductors shall be stranded annealed high conductivity copper. The copper wire before shaping shall be smooth, uniform in quality, free from scale, inequalities, spills, splits and other defects.

The term “annealed” signifies that the wire before stranding is capable of at least 15 per cent elongation without fracture, the test piece being not less than 150 mm and not more than 300 mm long.

The annealed copper shall have a conductivity of not less than 100 per cent as defined by the International Annealed Copper Standard (IACS).

When made up from shaped wires the conductor shall be clean and uniform in size and shape and its surface shall be free from sharp edges and unless otherwise approved shall be taped with a layer of conducting or semi-conducting material.

Not more than two joints shall be allowed in any of the single wires forming each length of conductor and no joint shall be within 300 mm of any other joint in the same layer. The jointing of wires shall be by brazing, silver soldering or electrical welding. No joint shall be made in the wire after it has been formed up into the required length.

### 4.7.10. Insulation

XLPE insulation shall be triple extruded solid dielectric which shall be subjected to a dry curing process. The inner semi-conducting layer, solid insulation and outer semi-conducting layer shall be extruded and cured in a single process. Details of the characteristics of the material and the curing process shall be stated in the Schedules.

### 4.7.11. Insulation Thickness

The average thickness of the insulation, when determined by the method described in IEC 60811 shall not be less than the minimum value stated in IEC 60502. The thickness at any place may, however, be less than the specified nominal value provided that the difference does not exceed 10 per cent of the specified nominal value.

The thickness of the semi-conducting screen or any separator on the conductor or over the insulation shall not be included in the thickness of the insulation. Particular attention shall be given to insulation voltage stress with particular reference to installation conditions and ingress and migration of moisture such that a long service life will be ensured.

### 4.7.12. Screen

The insulation screen shall consist of a non-metallic semi-conducting part in combination with a metallic part. The non-metallic part shall be applied directly upon the core insulation and shall consist of an extruded outer layer of semi-conducting material having a minimum thickness of 1.0 mm.

The non-metallic screen shall be of uniform material and shall be applied in a manner ensuring a uniform voltage stress across the insulation along the length of the cable.

The metallic screen shall be formed of a number of copper wires applied in helical form together with a copper tape applied in the opposite lay. MV cable screen short-circuit rating shall be 7 kA for 1 second.

The diameter of the wire shall be stated in the Schedules and shall not exceed 0.6 mm.

The thickness of the copper tape shall be stated in the Schedules and shall not be less than 0.1 mm.

A synthetic tape may be applied over the screening wires and copper tape at the option of the manufacturer.

### 4.7.13. Sheathing

Sheathing of all cable shall consist of new lead or new aluminium both of approved origin and purity applied in the form of a seamless tube. The minimum thickness of the sheath when determined by the method described in the Schedules shall not be less than the appropriate value stated in the Schedules.

The lead sheathing shall consist of lead alloy of the composition stated in the Schedules and shall be free from blow holes and other defects and special care shall be taken to ensure that dross or other impurities are excluded from the lead press when the press is being charged.

The aluminium sheathing shall consist of aluminium of the composition stated in the Schedules and shall be impervious to moisture and free from defects.

If a metallic sheath is applied over the screed core of solid dielectric insulated cables the outer metallic screen may be omitted.

The sheath shall be capable of carrying without damage the fault current specified in the Schedules for one second. The current density in terms of A/mm$^2$ for the type of sheath used shall also be stated in the Schedules.

### 4.7.14. Bedding and Serving Material

The compounds applied over metallic sheaths shall be of such a nature that in the finished cables they do not crack or run at any temperature likely to be attained in transit to the Site, during installation or when the cables are in operation. The compounds used shall have no detrimental effect on the sheath or outer covering.

### 4.7.15. Outer Covering

The outer covering over the metallic screen or impervious metallic sheath shall be extruded black PVC suitable for the operating temperature of the cable.

The minimum average thickness and minimum thickness at a point when measured in accordance with IEC 60811 and IEC 60502 shall not be less than the value stated in the Schedules.

Means shall be provided to prevent adhesion between turns and layers of the cable on the drum and between the cable and the drum or container at such temperatures as may be met with during transit to Site, at Site, before laying or in storage.

The design and efficiency of the coverings shall not be affected by cleating or clamping arrangements supporting the cable and particular care shall be taken to ensure that the outer covering is not damaged in any way.

An outer conducting coating shall be applied to the covering to serve as an electrode for the voltage test on the outer covering.

When an aluminium metallic sheath is used the outer covering shall be sealed to the aluminium sheath to prevent the passage of moisture between the sheath and the covering.

### 4.7.16. Cable Trays and Accessories

The Contractor shall provide cable trays, supports and accessories necessary for proper cables laying.

Cable trays shall be made of bent, perforated, galvanized sheets and shall comply with the requirements of IEC 61537.

In order to avoid unnecessary variety of cable trays, the Contractor shall apply as few types of cable trays as possible.

For horizontal and inclined installation, cable trays shall be assembled on brackets. The brackets shall be made of galvanized steel sheet and shall be sufficiently stiff. The brackets shall be thus positioned as to allow easy assembly and disassembly.

Cable trays shall be assembled:

- On brackets supports by fixing on the ceiling or wall,
- Directly on the wall (with expansion screw holders).

Where appropriate the brackets shall be placed on embedded iron supports.

The length of brackets supports shall be defined in order to enable assembly of all the anticipated cable trays and to provide assembly of a possible additional tray.

Minimum distance between two cable trays, placed one above another, shall be 300 mm. On the upper part of its structure, bracket supports shall be equipped with a straight rod on which trays is to be fixed.

In case the cable trays are vertical, the trays shall be assembled by means of specially manufactured supports.

The cables shall be fixed on cable trays by means of adequate clamps which shall be provided by the Contractor.

During cables laying, strict care shall be taken that the radius of bending should not exceed minimum radius of cables bending.

The Contractor shall submit to the Client for approval drawings showing installation plan for assembling of trays, brackets, shelves, etc.

### 4.7.17. Protection Against Fire

Power cables installed inside substation buildings or in the proximity of oil filled equipment shall be protected externally by a flame-retardant outer covering to IEC 60331 and/or 60332 or by the application of two overlapping silicon impregnated glass fibre tapes.

Where cables pass through holes in floors immediately beneath oil filled switchgear or other oil filled equipment, the Contractor shall be responsible for plugging the holes with approved silicon foam fire seals or other approved materials after the cables have been installed and the cost thereof is deemed to be included in the contract price quoted for the cables.

### 4.7.18. Sealing of Cable Lengths

Immediately after the works tests specified in the Schedules both ends of every length of cable shall be sealed and shall remain sealed until installed in its final position.

The sealing shall be affected by means of a lead cap fitted over each end and plumbed to the metal sheath. The end which is left projecting from the drum for the purpose of tests shall be protected to avoid damage to the sheathing during transport.

Where no metallic sheath is provided sealing shall be affected by means of a plastic cap fitted over each end and sealed to the plastic sheath with a suitable adhesive compound.

### 4.7.19. Identification (Embossing of Over sheath)

The over sheath of all cables shall be embossed with the manufacturer's name and the cable voltage as follows "*NEPCO ELECTRIC CABLE 132 000 VOLTS*" or "*NEPCO ELECTRIC CABLE 33 000 VOLTS*" or other description as appropriate.

The complete legend shall be embossed at any of two or more lines approximately equally spaced around the circumference of the cable.

The embossed letters/figures shall be raised and consist of upright block capitals/figures the size of which shall be not less than 15 per cent of the nominal or specified external diameter of the cable except that in no case shall they be greater than 13 mm.

The maximum gap between the end of one set of embossed lettering and figures as above and the beginning of the next shall be 500 mm.

### 4.7.20. Drumming

The cables with ends suitably sealed shall be supplied on non-returnable drums.

The cable drums shall be arranged to take a round spindle and be lagged with strong closely fitted battens so as to prevent damage to the cable.

Any cable end left projecting from the drum shall be protected against damage.

Each drum shall bear a distinguishing number for identification purposes either branded or neatly chiselled on the outside of the flange. Particulars of the cable, i.e. voltage, length, conductor size, finish, length number, gross and net weights, shall be clearly shown on one flange of the drum.

The direction for rolling shall be indicated by an arrow.

### 4.7.21. Cable Terminations

All cable terminations shall be of approved design and construction and an approved jointing technique shall be adopted.

The terminations shall be designed to restrict the voltage gradients both inside and outside the termination to safe values.

The terminations shall be complete with suitable supporting and lifting arrangements.

The terminations shall be designed to withstand all atmospheric conditions due to weather, ozone, acids, alkalis, dust, sandstorms or rapid changes of temperature under the working conditions existing at Site.

The design shall be such that stresses due to expansion and contraction in each part of the insulator and fittings shall not lead to the development of defects.

The design of all terminations shall be such as to permit easy cleaning.

The terminations shall be filled with oil of an approved type compatible with the main cable insulation if required. The design shall be such as to prevent the formation of air spaces and air pockets during filling. Means shall be provided to ensure that the filling medium is maintained under pressure if required during the termination procedure.

The Contractor will be expected to co-operate directly with the manufacturer of the equipment into which the cables would be terminated as part of the Contract in clarifying the design and manufacture of the cable termination and its enclosure.

Corona shields and arcing rings or horns shall be provided at the top of each open type termination and a horn or ring at the base. The base itself shall be insulated from supporting steelwork by mounting upon porcelain pedestal type insulators.

All terminations shall incorporate sheath gland insulators or insulated glands so that the cable sheath shall remain fully insulated to permit the specified dc high voltage withstand tests to be applied to the anti-corrosion covering.

An earth terminal of adequate dimensions shall be provided on the main metalwork of all termination points.

### 4.7.22. Jointing of Power Cables

Complete description and instructions for the jointing method to be used at Site shall be submitted with the offer. The instructions shall contain information concerning jointing of the core, insulation, core and insulation semi-conducting layers, metallic screen or sheath, sheath covering, bedding and armour, etc and anti-termite outer covering if applicable.

The Contractor shall state if specially constructed jointing bays are required and shall recommend horizontal distance to be maintained between joints of adjacent cables. If such bays are required full details shall be submitted with the offer.

#### 4.7.23. Mechanical Compression Type Glands

All mechanical compression type glands shall be of brass or aluminium. All glands for armoured cables shall be provided with an earth tag, earthing bolt, locking nut or ring and with a threaded armour clamp ring, to clamp the armour wires against a knurled conical section of the gland body. All glands for outdoor installations shall be fitted with waterproof seals.

Each cable gland shall be easily removable without disturbing other glands fixed to the same gland plate.

Cable glands for the various types of solid dielectric and plastic insulated cables to be supplied shall generally be in accordance with the appropriate categories in BS 6121-1 and IEC 62444. The appropriate categories shall include means of sealing the inner and outer sheath. Insulated glands required by the cable system design shall be provided as part of this Contract.

#### 4.7.24. Cable Identification

Cables shall be marked at each end of the run with a marker consisting of a label incorporating up to seven 4 mm characters. The labels shall be attached to the cables with two PVC straps.

#### 4.7.25. Cable Lengths

Unless otherwise approved, each cable shall be manufactured and delivered to Site in single lengths corresponding to the route length.

#### 4.7.26. Supporting Steelwork and Cleats

Supports and other materials supplied or installed by the Contractor shall carry and hold the cables in a neat and orderly manner to prevent undue sagging of any of the cables.

The Contractor shall give special attention when preparing his proposals for the supporting and fixing of any cable crossing any other cables, pipes, ducts or building expansion joints.

When the routes to be followed by the cables have been agreed, the Contractor shall prepare and submit to the Client, drawings showing his proposals for the supporting and fixing of the cables, and the erection of the supports and cleats shall not be proceeded with until the proposals have been approved.

Supports and cleats shall, as far as possible, be arranged on the unit system to facilitate running out, erection and replacement of any individual cable as may be required.

Cleats for single core metal sheathed cables shall be of non-magnetic materials and the arrangements shall be such as to avoid the setting up of a magnetic circuit through any steel or iron work. Single core cables shall, as far as possible, be arranged in a trefoil formation with the cables touching and where departures from the trefoil formation cannot be avoided, approved arrangements shall be employed to minimize sheath currents or other undesirable effects. Cleats shall be insulated from the metal sheath of the single core cables.

The cleating arrangements for single core cables shall be of sufficient strength to withstand the forces set up during short circuit conditions.

All cables on vertical runs or horizontal runs in the vertical plain shall be cleated. Claw type cleats shall be used for cables other than single core lead sheath cables above 50 mm overall diameter.

Cleats for armoured cables shall be of the aluminium claw type and of such a design that they grip the cable sheath firmly but cannot be tightened to such an extent that the sheath is marked or damaged. A range of sizes shall be available to suit all cable sizes required under this Contract.

Cables shall be cleated over the whole of the appropriate section of their length to the satisfaction of the Client before jointing at either end is commenced.

Cables shall not be subject to undue strain or bending during the process of laying on supports.

The maximum spacing of supports for all cables shall be recommended by the Contractor but shall not be more than 1 metre.

All cable supporting steelwork shall be provided under this Contract.

Where cables rise from ground level to terminations adequate protection shall be provided against possible mechanical damage to the cables.

All cable supports, trays or racks shall be galvanized and shall be so constructed or installed in such a manner as to exclude any possibility of electrolytic action between the supports and cable sheath.

All cable supports shall be adequately earthed.

### 4.7.27. Termination Supporting Structure

Supporting structures for all cable terminations shall be provided as part of this Contract.

All steelworks shall be galvanized.

Foundation bolts and plates or steel stubs shall be provided and shall be firmly keyed and grouted into foundation blocks. Complete details of the structures with dimensions and loadings shall be provided to enable foundations to be designed and cast.

# 5. INSPECTION AND TESTS

## 5.1. General

In addition to the general requirements for inspection and tests stated within the General Technical Specifications, the following shall also be applied:

- Tests shall be performed to determine whether the materials and the equipment comply with the technical requirements. All tests shall be performed in the conditions which, as much as possible, correspond to the operating conditions,
- The Contractor shall submit to the Client for approval, the Test Program for all the necessary tests. For each performed test, the Contractor shall prepare the appropriate Test Report and shall submit it to the Client for approval,
- All tests on the equipment, both at the Manufacturer's factory and after completion of installation at the Site, shall be performed in accordance with IEC, BS, and IEEE Standards, unless otherwise agreed with the Client. If IEC, BS, and IEEE Standards are not available for tests, the scope, Standard and procedures to be applied shall be specified by the Contractor and approved by the Client,
- All additional tests, except those specified further below, which might be necessary for confirmation of the quipment guaranteed characteristics, shall be performed at the Clients' request and with no additional cost to the Client,
- Appropriate standard instruments and other measuring equipment, as well as technical personnel, necessary for performance of the Factory Tests shall be provided by the Contractor,
- Appropriate measuring equipment, as well as technical personnel, necessary for performance of the Site Tests and Commissioning of the equipment shall be provided by the Client, while the Contractor shall provide technical Supervision during execution of Site Tests and Commissioning. Exception is 132kV GIS after installation HV site test, where testing equipment and technical personnel shall be provided by Contractor.
- The tests shall not diminish characteristics and reliability of the tested equipment or shorten its lifetime,
- The Detailed Program of the Factory Tests shall be submitted minimum 28 calendar days before commencement of the tests. These tests shall comprise minimum the tests specified in Clause 4.2 of these Particular Technical Specifications. These Detailed Programs shall also comprise the procedures and all details of the procedures and charts of measurements, conditions, and implementation of the testing procedures, as well as the sequence of equipment preparation, the operating procedures to be applied, etc.,
- The Detailed Program of the Factory Tests shall be approved by the Client 21 calendar days after the documents have been submitted,
- The FAT period excluding the travelling days.
- Week means seven calendar days

– The details of the tests are given further below.

## 5.2. Factory Tests

### 5.2.1. General

Factory tests shall be performed in the presence of the Client; however, some tests may be performed in the Client's absence, with his prior consent.

Factory tests shall include tests during manufacture and Factory Acceptance Tests (FAT).

Tests during manufacture shall include routine tests for each type of equipment to be installed.

After satisfactory completion of the witnessed tests at the Factory, the Contractor shall submit Shipping Release request for Client.

No item of equipment shall be dispatched to Site until the Client has given his approval and issued the relevant Shipping Release.

### 5.2.2. Type Tests Certificates

#### *5.2.2.1. General*

It is required that all offered equipment will have type test certificates as required at ITT.

The following Clauses define the minimum requirement for type test certificates.

#### *5.2.2.2. 400 and 132 kV GIS*

At least the following type tests certificates for 400 and 400 and 132 kV GIS (in accordance with IEC 62271-203) shall be submitted:

- Dielectric tests on main circuit - lightning impulse voltage tests, power-frequency voltage withstand tests, partial discharge and radio interference voltage (r.i.v) tests,
- Dielectric test on auxiliary and control circuit,
- Temperature rise test,
- Measurement of the resistance of the main circuit,
- Short-time withstand current and peak withstand current tests,
- Short-circuit making and breaking, out-of-phase making and breaking, critical current and capacitive and inductive (reactor) current switching tests,
- Internal arcing test,
- Mechanical and environmental tests,
- Thermal stability test,
- Electromagnetic compatibility (EMC) tests,
- Verification of the degree of protection,
- Tightness tests,
- Pressure relief device tests.

#### *5.2.2.3. 400 and 132 kV Circuit Breakers*

At least the following type tests certificates for 400 and 132 kV circuit breakers (in accordance with IEC 62271-100) shall be submitted:

Dielectric tests,

- Radio interference voltage test (r.i.v. test),

- Measurement of the resistance of the main circuit,
- Temperature-rise test,
- Short-time withstand current and peak withstand current tests,
- Verification of the degree of protection,
- Tightness tests,
- Electromagnetic compatibility (EMC) tests,
- Mechanical operation test at ambient temperature,
- Extended mechanical endurance tests on circuit breakers for special service conditions,
- High-temperature test,
- Static terminal load test,
- Short-circuit current making and breaking tests,
- Capacitive current switching tests.

#### 5.2.2.4. *400 and 132 kV Disconnectors & Earthing Switches*

At least the following type tests certificates for 400 and 132 kV disconnectors (in accordance with IEC 62271-102) shall be provided:

- Dielectric tests,
- Radio interference voltage test (r.i.v. test),
- Measurement of the resistance of circuits,
- Temperature-rise tests,
- Short-time withstand current and peak withstand current tests,
- Verification of the protection,
- Tightness tests,
- Electromagnetic compatibility (EMC) tests,
- Additional tests on auxiliary and control circuits,
- Tests to prove satisfactory operation and mechanical endurance,
- Tests to prove the short-circuit making performance of earthing switches,
- Tests to prove satisfactory operation at temperature limits,
- Tests to prove the bus-transfer current switching capability of disconnectors,
- Tests to prove the induced current-switching capability of earthing switches.

#### 5.2.2.5. *400 and 132 kV Current Transformers*

At least the following type tests certificates for 400 and 132 kV & 33 kV outdoor current transformers (in accordance with IEC 61869-1&2) shall be provided:

- Temperature-rise test,
- Impulse voltage withstand test on primary terminals,
- Wet test for outdoor type transformers,

- Electromagnetic compatibility (EMC) tests,
- Tests for accuracy,
- Verification of the degree of protection by enclosures,
- Short-time current tests.

#### 5.2.2.6. *400 and 132 kV Voltage Transformers*

At least the following type tests certificates for 400 and 132 kV voltage transformers (in accordance with IEC 61869-1&5) shall be provided:

- Temperature-rise test,
- Chopped impulse voltage withstand test on primary terminals,
- Impulse voltage test on primary terminals,
- Wet test for outdoor type transformers,
- Electromagnetic Compatibility (EMC) tests,
- Tests for accuracy,
- Verification of the degree of protection by enclosures,
- Capacitance and *tan*δ measurement at power-frequency,
- Short- circuit withstand capability test,
- Ferro-resonance test,
- Transient response test.

#### 5.2.2.7. *400 and 132 kV Surge Arresters*

At least the following type test certificates for 400 and 132 kV surge arresters (in accordance with IEC 60099–4) shall be provided:

- Insulation withstand tests on the arrester housing,
- Residual voltage tests,
- Long duration current impulse withstand test,
- Operating duty tests,
- Short-circuit tests,
- Internal partial discharge test,
- Seal leak rate test,
- Bending moment test,
- Environmental tests.

#### 5.2.2.8. *400 and 132 kV & 33 kV Post Insulators*

At least the following type test certificates for 400 and 132 kV & 33 kV post insulators (in accordance with IEC 60168) shall be performed:

- Dielectric tests,
- Mechanical failing load test,

- Radio interference voltage test (r.i.v. test).

#### *5.2.2.9. 400 and 132 kV & 33 kV Connectors*

At least the following type test certificates for 400 and 132 kV & 33 kV connectors shall be provided:

- Chemical analysis of materials,
- Electrical type tests (Heat-run tests with rated current and with rated peak withstand current),
- Mechanical type tests.

#### *5.2.2.10. Neutral Earthing Resistors*

At least the following type test certificates for neutral earthing resistors (according to IEEE Std C57.32) shall be provided:

- Temperature-rise test,
- Lightning impulse voltage test,
- Seismic verification test,
- Verification of the resistor's enclosures degree of mechanical protection.

#### *5.2.2.11. 33 kV Switchgears*

At least the following type test certificates for 33 kV switchgears (according to IEC 62271-200) shall be provided:

- Dielectric tests,
- Measurement of the resistance of circuits,
- Temperature-rise tests,
- Short-time withstand current and peak withstand current tests,
- Verification of the protection,
- Electromagnetic compatibility tests (EMC),
- Tests on auxiliary and control circuits,
- Verification of making and breaking capacities,
- Mechanical operation tests,
- Tests to verify the protection of persons against dangerous electrical effects,
- Internal arc test.

It is also necessary to provide type test certificates for the equipment which shall be installed within the 33 kV switchgears:

- For the circuit breakers, in accordance with the Standard IEC 62271-100,
- For the earthing switches, in accordance with the Standard IEC 62271-102,
- For the current transformers, in accordance with the Standard IEC 61869-1&2,
- For the voltage transformers, in accordance with the Standard IEC 61869-1&3.

#### *5.2.2.12. 33 kV Capacitor Banks*

At least the following type test certificates for 33 kV capacitor banks (according to IEC 60871-1) shall be provided:

- Thermal stability test,

- Measurement of the tangent of the loss angle (*tan*δ) of the capacitor at elevated temperature,
- AC voltage test between terminals and container,
- Lightning impulse voltage test between terminals and container,
- Overvoltage test,
- Short-circuit discharge test,
- Disconnecting test on internal fuses.

#### *5.2.2.13. Protection Equipment*

Type test certificates shall be provided for each type of protection system. Each set of test records shall include a full statement of the performance claims, e.g. performance under reference conditions, effect of influencing the quantities, steady state and dynamic stability for unit protection schemes, current and voltage transformer requirements, etc and full details of tests performed on representative samples of production equipment to demonstrate that the performance claims have been met.

For circulating current protective schemes using high impedance relays, calculation of the predicted performance will be accepted in lieu of type testing of each individual scheme. Type test results must, however, be available for inspection by the Client to show that heavy current conjunctive tests have been performed on a representative scheme to prove the stability and operating time performance.

#### *5.2.2.14. 132 kV Cables*

At least the following type test certificates for 132 kV cables (according to IEC 60840) shall be provided:

- Bending test,
- Measurement of *tan*δ,
- Heating cycle voltage test, followed by a partial discharge test,
- Partial discharge tests:
  - At ambient temperature,
  - At high temperature,
- Lightning impulse voltage test, followed by a power frequency voltage test,
- Measurement of resistivity of semi-conducting screens,
- Measurement of thickness of insulation,
- Non-electrical type tests.

#### *5.2.2.15. 132 kV Cable Termination*

At least the following type test certificates for 132 kV outdoor cable terminations (in accordance with IEC 60840) shall be provided:

- Internal pressure test,
- Cantilever load test.

#### *5.2.2.16. 33 Cables*

At least the following type test certificates for 33 kV cables (according to IEC 60502-2) shall be provided:

- Bending test, followed by a partial discharge test,
- Measurement of *tan*δ,

- Heating cycle test, followed by a partial discharge test,
- Impulse test, followed by a voltage test,
- Voltage test for 4 h,
- Measurement of resistivity of semi-conducting screens,
- Measurement of thickness of insulation,
- Non-electrical type tests.

#### *5.2.2.17. LV Switchgears/Distribution Boards*

At least the following type test certificates for LV switchgears/distribution boards (according to IEC 60439) shall be provided:

- Verification of temperature-rise limits,
- Verification of the dielectric properties,
- Verification of the short-circuit withstand strength,
- Verification of the effectiveness of the protective circuit,
- Verification of clearances and creepage distances,
- Verification of mechanical operation,
- Verification of the degree of protection,
- EMC tests.

#### *5.2.2.18. DC Batteries*

At least the following type test certificates for DC batteries (according to IEC 60623) shall be provided:

- Discharge performance tests,
- Charge retention test,
- Endurance tests,
- Charge acceptance at constant voltage,
- Electrolyte retention test.

#### *5.2.2.19. Battery Charges*

At least the following type test certificates for battery chargers shall be provided:

- Measurement of voltage regulation / AVR regulation,
- Efficiency and power factor measurement test,
- Temperature rise test,
- Measurement of insulation resistance,
- DC voltage current characteristic test,
- High voltage tests,
- Ripple test.

### 5.2.3. Routine Tests

#### 5.2.3.1. *General*

Routine tests shall be performed at the Manufacturer's factory and in the Client's presence, on each part of the equipment foreseen for delivery, for the purpose of detecting failures in the material or in the structure. Tests shall be performed in accordance with the latest edition of the relevant IEC, BS, and IEEE Standards, unless specified otherwise. The test results shall be submitted to the Client for consideration, immediately after completion of the tests.

#### 5.2.3.2. *400 and 132 kV GIS*

At least the following routine tests for 400 and 132 kV GIS (in accordance with IEC 62271-203) shall be performed:

- Dielectric tests on main circuit - power-frequency voltage withstand tests, partial discharge and radio interference voltage (r.i.v) tests,
- Dielectric test on auxiliary and control circuit,
- Measurement of the resistance of the main circuit,
- Tightness test,
- Design and visual checks,
- Pressure tests of enclosures,
- Mechanical operation tests,
- Inspection of the general condition,
- Timing tests of the main contacts and auxiliary switches,
- Complete electrical functioning tests including interlocking,
- Closing and opening check at reduced voltage and other necessary tests and verifications,
- Evidence of quality control of welded assembles by non-destructive testing,
- GIS PD Sensor Test (for Sensitivity & Spectra Range).

#### 5.2.3.3. *400 and 132 kV Circuit Breakers*

At least the following routine tests for 400 and 132 kV circuit breakers (in accordance with IEC 62271-100) shall be performed:

- Dielectric test on the main circuit,
- Dielectric test on auxiliary and control circuits,
- Measurement of the resistance of the main circuit,
- Verification of circuit breaker poles synchronized operation,
- Tightness test,
- Design and visual check,
- Mechanical operating tests.

#### 5.2.3.4. *400 and 132 kV Disconnectors*

At least the following routine tests for 400 and 132 kV disconnectors (in accordance with IEC 62271-102) shall be performed:

- Dielectric test on the main circuit,

- Test on auxiliary and control circuits,
- Measurement of the resistance of the main circuit,
- Tightness test,
- Design and visual check,
- Mechanical operating tests.

#### *5.2.3.5. 400 and 132 kV Current Transformers*

At least the following routine tests for 400 and 132 kV current transformers (in accordance with IEC 61869-1&2) shall be performed:

- Power-frequency voltage withstand tests on primary terminals,
- Partial discharge measurement,
- Power-frequency voltage withstand tests between sections,
- Power-frequency voltage withstand tests on secondary terminals,
- Tests for accuracy,
- Verification of markings,
- Determination of the secondary winding resistance,
- Test for rated knee point e.m.f. (*E*k) and exciting current at *E*k,
- Inter-turn overvoltage test.

#### *5.2.3.6. 400 and 132 kV Voltage Transformers*

At least the following routine tests for 400 and 132 kV voltage transformers (in accordance with IEC 61869-1&5) shall be performed:

- Power-frequency voltage withstand tests on primary terminals,
- Partial discharge measurement,
- Power-frequency voltage withstand tests between sections,
- Power-frequency voltage withstand tests on secondary terminals,
- Tests for accuracy,
- Verification of markings,
- Ferro-resonance check.

#### *5.2.3.7. 400 and 132 kV Surge Arresters*

At least the following routine tests for 400 and 132 kV outdoor surge arresters (in accordance with IEC 60099–4) shall be performed:

- Measurement of reference voltage,
- Residual voltage test,
- Internal partial discharge test,
- Seal leak rate test.

#### *5.2.3.8. 400 and 132 kV & 33 kV Post Insulators*

At least the following routine tests for 400 and 132 kV & 33 kV post insulators (in accordance with IEC 60168) shall be performed:

- Routine visual inspection,
- Routine electrical tests,
- Routine mechanical tests.

#### *5.2.3.9. 400 and 132 kV & 33 kV Connectors*

At least the following routine tests for 400 and 132 kV & 33 kV connectors shall be performed:

- Routine visual check and verification of markings,
- Routine dimensional check.

#### *5.2.3.10. Neutral Earthing Resistors*

At least the following routine tests for neutral earthing resistors (according to IEEE Std C57.32) shall be performed:

- Power-frequency withstand voltage test,
- Measurement of the insulation resistance,
- DC resistance measurement,
- Impedance measurement,
- Verification of the resistor's dimensions.

#### *5.2.3.11. 33 Switchgears*

At least, but not limited to, the following routine tests for 33 kV switchgears (according to IEC 62271-200) shall be performed:

- Dielectric test on the main circuit,
- Tests on auxiliary and control circuits,
- Measurement of the resistance of the main circuit,
- Design and visual checks,
- Partial discharge measurement,
- Mechanical operation tests,
- Tests of auxiliary electrical devices.

It is also necessary to perform the routine tests for the equipment which shall be installed within the 33 kV switchgears:

- For the circuit breakers, in accordance with the Standard IEC 62271-100,
- For the earthing switches, in accordance with the Standard IEC 62271-102,
- For the current transformers, in accordance with the Standard IEC 61869-1&2,
- For the voltage transformers, in accordance with the Standard IEC 61869-1&3.

#### *5.2.3.12. 33 kV Capacitor Banks*

At least the following routine tests for 33 kV capacitor banks (according to IEC 60871-1) shall be performed:

- Capacitance measurement,
- Measurement of the tangent of the loss angle (*tan*δ) of the capacitor,
- Voltage test between terminals,
- AC voltage test between terminals and container,
- Test of internal discharge device,
- Sealing test,
- Discharge test on internal fuses.

#### *5.2.3.13. Control and Indicating Panels, Instruments and Secondary Wiring*

All panels and instruments shall comply with the tests specified in the appropriate Standards.

The wiring on each panel, cubicle, rack and each removable panel or plate of apparatus shall be subjected for one minute to an alternating voltage equal to the test pressure specified for the apparatus to which it is connected. This test shall take place after the complete assembly of the apparatus and wiring on or in the panels, cubicles and racks.

All wiring and apparatus which is, or may become, connected to voltage sources other than the supply for the very low voltage (50 volts and below) apparatus shall be subjected for one minute to an alternating test pressure of 2 000 volts rms to the frame of the panels on which they are accommodated, immediately after which the insulation measured at 6 500 volts dc shall not be less than 20 megohms. Included in these requirements is apparatus and wiring which become connected to voltage or current transformers.

The windings and electrical connections of indicating and recording meters shall be subjected for one minute to a test voltage of 2 000 volts rms to the case or any other metal which is not intended to be insulated from the case when the instrument or meter is in use.

One typical mimic diagram panel shall be erected as in service and the indicating devices operated to the satisfaction of the Client.

#### *5.2.3.14. Protection Equipment*

All relays shall be subjected to routine tests at the Manufacturer's factory to confirm that they comply with the required performance and design limits.

For measuring relays (i.e. relays which have a defined setting of the input and/or characteristic quantity subjected to accuracy requirements, e.g. current, time, etc.) these routine tests shall include as a minimum the following:

- Measurement of the assigned error(s) under reference conditions, i.e. measuring accuracy and operating time characteristics,
- Measurement of the resetting ratios,
- Dielectric tests according to IEC 60255-27, the test voltage being 2 kV rms. All normally open output contacts of all relays shall withstand a test voltage of 1 kV rms.

For all-or-nothing relays, the routine tests shall include a check of relay operation and resetting, together with the dielectric tests described above.

Unless otherwise agreed with the Client, all unit protection schemes using either biased differential, current balance or voltage balance principles shall be subjected to heavy current conjunctive tests using the actual current transformer windings which will be used in service. Tests shall be made to prove operating sensitivity, time of operation and to demonstrate stability of the protection under the worst transient external fault conditions. Tests will only be waived if the manufacturer is able to produce type test results for an identical scheme. In this

case it will be sufficient to prove that individual component characteristics are identical, e.g. current transformers are of the same design, have the same magnetisation characteristics, knee-point voltage and secondary resistance.

For protection schemes including distance protection, phase comparison protection, auto reclosing and automatic switching sequence schemes, etc. routine tests shall be performed on each complete scheme to ensure that all possible operational sequences and features are fully functional. Where necessary, this shall be done using simulation of any ancillary equipment normally used in conjunction with the scheme, e.g. circuit breakers. These routine tests will be performed in addition to the tests normally applied to individual elements of the scheme and details of the proposed test programme shall be submitted to the Client for approval not less than one month before they are to be performed.

If such routine tests are not practicable due to the complexity of the scheme, a scheme type test will be accepted on representative production equipment. The test shall be performed so as to simulate, as nearly as possible, the conditions which will be experienced in service and details of the proposed test programme shall be submitted to the Client for approval not less than one month before they are performed. In those cases where correct operation of the scheme is dependent on measured quantities associated with primary system equipment (e.g. circuit breaker gas pressure), such quantities shall be measured directly during the tests.

Each circulating current protection scheme designed to use high impedance relays shall fulfil the following routine testing requirements:

- Each current transformer, which must be of the low reactance type, shall be individually tested for turns ratio, secondary winding resistance and excitation characteristic up to a secondary voltage equal to 120% of the "knee-point" voltage,
- The VA consumption at operation of current operated relays shall be measured and shall not exceed the maximum value declared by the Manufacturer,
- The operating current of voltage relays shall be measured and shall not exceed the maximum value declared by the Manufacturer.

#### *5.2.3.15. 132 kV Cables*

At least the following routine tests for 132 kV cables (according to IEC 60840) shall be performed:

- Partial discharge test,
- Voltage test,
- Electrical test on oversheath of the cable.

Also, at least the following sample tests for 132 kV cables (according to IEC 60840) shall be performed:

- Conductor examination,
- Measurement of electrical resistance of conductor and of metal screen,
- Measurement of thickness of insulation and oversheath,
- Measurement of thickness of metallic sheath,
- Measurement of diameters,
- Hot set test,
- Measurement of capacitance,
- Measurement of density of HDPE insulation
- Lightning impulse voltage test (for nominal electric conductor stress > 8 kV/mm),
- Water penetration test.

Frequency of sample tests shall be according to IEC 60840.

#### *5.2.3.16. 132 kV Cable Terminations*

At least the following routine tests for 132 kV outdoor cable terminations (in accordance with IEC 60840) shall be performed:

- Partial discharge test,
- Voltage test,
- Visual inspection.

#### *5.2.3.17. 33& 6 kV Cables*

At least the following routine tests for 33 kV cables (according to IEC 60502-2) shall be performed:

- Measurement of the electrical resistance of conductors,
- Partial discharge test,
- Voltage test,
- Electrical test on oversheath of the cable.

Also, at least the following sample tests for 33 kV cables (according to IEC 60502-2) shall be performed:

- Conductor examination,
- Check of dimensions,
- Voltage test,
- Hot set test.

#### *5.2.3.18. LV Switchgears/Distribution Boards*

At least the following routine tests for LV Switchgears/Distribution Boards (according to IEC 60439) shall be performed:

- Inspection of the assembly including inspection of wiring and electrical operation tests,
- Dielectric tests,
- Checking of protective measures and of the electrical continuity of the protective circuit,
- Verification of insulation resistance.

#### *5.2.3.19. DC Batteries*

At least the following routine tests for DC Batteries (according to IEC 60623) shall be performed:

- Routine visual check,
- Battery charging tests,
- Battery charging tests,
- Charge retention test,
- Endurance test,
- Charge acceptance at constant voltage,
- Measurement of battery short circuit and internal resistance,
- Electrolyte retention test.

*5.2.3.20. Battery Chargers*

At least the following routine tests for Battery Chargers shall be performed:

- Dielectric tests,
- Checking of local and remote signalling of chargers in all operating modes,
- Checking the float charging mode,
- Checking the boost charging mode,
- Checking the protection against input voltage failure,
- Checking the protection against low input voltage,
- Checking the protection against excessive input voltage.

### 5.2.4. Factory Acceptance Tests (FAT)

Prior to delivery, all equipment & ancillary equipment specified in tender schedule shall be factory tested.

Cubicles and panels shall be completely assembled in the factory and wired.

Factory Acceptance Tests (FAT) for the following equipment shall be performed at the Manufacturer's factory, in presence of the Client, according to the latest edition of the relevant IEC, BS, and IEEE Standards, unless specified otherwise

Factory Acceptance Tests (FAT) for the remaining equipment shall be also performed and all results shall be submitted to the Client for approval.

The scope of tests shall be in accordance with the Detailed Test Program approved by the Client, but any of the tests performed during manufacturing can be repeated. Reports from tests performed during production shall be available to the Client during the FAT.

For the purpose of FAT tests, the Contractor shall provide all necessary works and conditions needed to conduct all tests, sufficient number of copies of detail Design documentation, Test reports from previously conducted tests, testing protocols and procedures, as well as other required by these Technical Specifications.

The Contractor is obliged, after the conducted tests, to prepare Test Report from FAT tests. Test results shall be submitted to the Client for approval for all equipment specified above. The Test Report shall be signed by all parties involved.

All expenses including economy class air fares, hotel accommodation with meals, local transportation, visa fees, medical insurance, etc. of the Client's personnel during FAT shall be borne by the Contractor. Any costs incurred regarding the re-inspection and re-testing as a result of a failure of the equipment under test, shall be borne by the Contractor.

The contractor shall also give priority to Royal Jordanian Airlines airfreight and transport of personal.

# 6. Documentation

## 6.1. Documentation to be Submitted with the Tender

Together with the Tender, completed with pertaining Schedule of Technical Data duly filled-in, the Tenderer shall submit the following documentation/information:

- Single Line Diagrams for each substation
- Single Line Diagrams for 132kV GIS
- Single Line Diagrams of LV (AC & DC) systems for each substation,

- General arrangement drawings, layout and cross-section drawings of the 132 kV GIS, gas section diagram, 132kV outdoor equipment and ancillary equipment, showing details of all associated equipment and accessories, their overall and lifting dimensions, weights of the complete cubicles and their main components,
- General arrangement drawings of Control and Protection panels,
- Protection diagrams (block schemes),
- Detailed descriptions with characteristics of the proposed 132 kV GIS, 132kV outdoor equipment and ancillary equipment (catalogues, descriptive literature, manufacturing Specifications),
- General arrangement drawings, cross-section drawings of the switchgear/cubicles, showing details of all associated equipment and accessories, their overall and lifting dimensions, weights of the complete cubicles and their main components,
- General arrangement drawings of Control and Protection panels,
- Clear evidence (analysis, end-user certificates, etc.) that the offered SF6 type circuit breaker is suitable for capacitor bank application,
- Protection diagrams (block schemes),
- Detailed descriptions with characteristics of the proposed switchgears and associated equipment (catalogues, descriptive literature, manufacturing Specifications),
- Reference lists for the all proposed equipment,
- Type Test Certificates as required in ITT.
- the End-User Certificates same as required in ITT.

## 6.2. Documentation to be Submitted after Contract Commencement Date

Within the one (1) month upon Contract Commencement Date, the Contractor shall submit the following documentation as a minimum to Client for review and approval:

- Detailed Time Schedule for execution of Works under this Contract (Program of Works), comprising all activities from the design to taking-over,
- List of complete documentation to be submitted under this Contract,
- List of equipment/material samples and models to be submitted under this Contract,
- Type Tests Certificates for the equipment to be supplied under this Contract.

Within the two (2) months upon Contract Commencement Date, the Contractor shall submit the following documentation as a minimum to Client for review and approval:

- Single Line Diagrams for each substation,
- Single Line Diagrams for 132kV GIS
- Single line diagram of the 33 kV switchgears,
- Single line diagram of the 33 kV capacitor banks,
- Single Line Diagrams of LV (AC & DC) systems for each substation,
- Outline drawings of the complete equipment to be supplied under this Contract,
- Outline drawings of the steel structures (apparatus support structures, gantries, etc.),

- Cross section drawing of 132 kV cables in the cable trenches
- Cross section drawing of 33, cables in the cable trenches
- Drawings for the complete route of 132 kV cables in the cable trenches / buried in the ground/ inside cable tunnel and in basement of the rooms …. etc, according to contractor suggestion and design.
- Drawings of the complete route of 33kV cables in the cable trenches / buried in the ground and in basement of the rooms …. etc, according to contractor suggestion and design.
- Drawings of the complete route of cables in the cable trenches / buried in the ground and in basement of the rooms according to contractor suggestion and design.
- Foundation drawings with all necessary details for fixation for the equipment to be supplied under this Contract,
- Detailed technical description of the complete equipment to be supplied under this Contract,
- Detailed protection diagrams including tripping logic/matrix,
- Details (drawings, information, data, etc.) necessary for connection with the equipment which shall be supplied under this Contracts .
- Requirements for civil design related to equipment that shall be procured in this contract , such as ceiling heights, front, rear & lateral clearances for cubicles and panels, cable trenches, cable entry position, battery room requirements (required temperature and other conditions), 132kV GIS requirements, 33kV Switchgear requirements, etc.,
- Necessary calculations, such as:
    - Calculation/Verification of 132 kV and 33 kV apparatuses characteristics,
    - Calculation/Dimensioning of 132 kV bus bars and all conductors for connections between the 132 kV & outdoor 33 kV apparatus in substations,
    - Calculation/Dimensioning of steel supports for 132 kV & 33kV apparatuses and their foundations,
    - Calculation/Dimensioning of tension and suspension insulators,
    - Calculation/Dimensioning of conductors (current carrying capacity, thermal and dynamic stresses, etc.),
    - Calculations necessary to prove the compatibility of instrument transformers to the connected control, protection and metering equipment,
    - Calculations/Dimensioning of 33 kV capacitor bank equipment and connecting material,
    - Study for overvoltage effect on 33 kV busbars due to switching the two (2) capacitor banks (2×10 MVAr),
    - Study to check harmonic and resonance conditions affected by the new capacitor bank installation,
    - All other calculations, necessary for dimensioning/sizing of the switchgears & associated equipment.
    - Calculations/Dimensioning of the 132 kV cables
    - Calculations/Dimensioning of the 33 kV cables,
    - Calculation of LV protection devices including protection selectivity (discrimination) of up-stream & down-stream CBs for each one of the incoming and outgoing feeders,
    - Calculation/Dimensioning of the 110 V DC batteries & battery chargers,

- Calculations/Dimensioning of the LV cables,
- Calculation of substation lightning protection system,
- Calculation of substation earthing system (earthing system resistance, maximum grid potential rise, touch & step voltages, transferred potentials, etc .),
- All other calculations, necessary for dimensioning/sizing of the 132 kV equipment and ancillary equipment.

– All other data that Contractor considers as necessary for submission to the Client.

Within the six (6) months upon Contract Commencement Date, the Contractor shall submit the following documentation as a minimum to Client for review and approval:

– Detailed front view and cross section drawings of the equipment supplied under this Contract, including all dimensions, weights and transport details,

– Detailed layout & cross section drawings of the substations showing equipment and systems which shall be procured in contract (132kV GIS, 132kV outdoor equipment, 132kV control, protection and metering equipment, 33 kV switchgears, 33 kV control, protection & metering equipment, 33 kV capacitor banks, 132 kV and 33 kV cables and transformers) including the existing equipment and systems (for extension and replacement projects),

– Detailed layout & cross section drawings of the substation lightning protection system,

– Detailed layout drawings of the substation earthing system,

– Detailed electrical schematic diagrams, including block-diagrams, single line diagrams, circuit diagrams, I/O signal list, wiring diagrams and connection diagrams. These schematic diagrams shall cover the equipment supplied under this Contract and the equipment to be supplied under other Contracts and existing equipment as well,

– Cable list with defined interconnections of the equipment supplied under this Contract, with connections between the equipment supplied under this Contract and the equipment to be supplied under this Contract and existing equipment as well, Cable laying plan for all cables, including detailed drawings of cable ducts, cable trays and cable racks,

– Protection system functions settings,

– Detailed Program of the Factory Tests,

– Detailed Program of the recommended Site Tests,

– Detailed Erection and Commissioning Program for each substation,

– Instructions for Equipment Installation (review only),

– Operation and Maintenance Manuals (review only),

– Program of Training for the installation, operation, maintenance and testing of the equipment to be delivered,

– All other data that Contractor considers as necessary for submission to the Client.

At least one (1) month prior to shipment, the Contractor shall submit the following documentation as a minimum to Client for review and approval:

– Signed approved Factory Test Reports,

– Clear evidence that all comments during FATs have been corrected,

– Detailed packing lists, transport program and insurance documentation,

- Instructions for loading, unloading, handling and particular safety measures to the applied during storage (review only).

The handbooks and manuals shall cover all of the equipment supplied under this contract including, but not limited to, all of the subjects listed in the Section `Subjects Requiring the Submission of Design Proposals'. The information pertaining to each subject shall form a separate handbook/manual volume or be grouped into a separate section of a volume.

Documentation shall be supplied in electronic format and shall be readable on a standard Microsoft Windows based Personal Computer

Two complete printed sets and two electronic copy of all as-built drawings, schematic drawings (in PDF format and CAD format), test results, operation and maintenance handbooks and manuals shall be provided within three months of acceptance of any system or equipment.