

Specifications

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1. General Technical Requirements

The Equipment Technical Specifications take precedence over any clauses contained in the following General Technical Requirements.

1.1. General Design of Equipment

In complying with the requirements of the Specification, design shall conform to the best current engineering practice. Each component part of the Plant shall be to the maker's standard design provided that this design is in general accordance with the Specification.

The essence of design shall provide simplicity and reliability in order to give long continuous service with high economy and low maintenance costs. Particular attention shall be paid to internal and external access in order to facilitate inspection, cleaning and maintenance.

Type test certificates of all major equipment and major material shall be submitted together with the Tender Documents as stated in the relevant specifications. If necessary type test certificates shall be translated in all aspects to the English language by the issuing test institute. Type test certificates shall be properly issued to the manufacturer and to the manufacturer's factory location.

Type test certificates/ type test reports are subject to the approval of Employer/ Employer's Representative. Type-test certificates/ type test reports shall not be older than ten (10) years at the time of their submittal. Compilation of type test certificates/ type test reports shall be covered by a table of contents, clearly structured by equipment designation, the relevant standards, their sub clauses and designation of the relevant test.

Type tests shall have been performed by an internationally accredited independent testing laboratory not associated with the manufacturers. Also type tests performed at manufacturer's laboratory and witnessed by accordingly accredited independent third party are acceptable. Accreditation to the testing laboratory/ third party shall be given by an according signatory member of International Laboratory Accreditation Cooperation (ILAC).

Upon submission of relevant type test certificates and proof that the equipment and material to be tested is identical to that covered by the test certificates, the Employer/ Employer's Representative may waive the requirements for corresponding type tests called for in this Specification and/ or specified in the Standards.

On request of Employer/ Employer's Representative full type test report/ protocol shall be provided.

The design dimensions and materials of all parts shall be such that they will not suffer damage as a result of stresses under the most severe service conditions.

Fully detailed specifications of the component parts of the Plant shall be submitted describing particularly the materials to be used.

The materials used in the construction of the Plant shall be of the highest quality and selected particularly to meet the duties required of them. Mechanisms shall be constructed to avoid sticking due to rust or corrosion.

Workmanship and general finish shall be of the highest quality throughout.

All similar parts of the Plant shall be interchangeable.

All apparatus shall operate without undue vibration and with the least practicable amount of noise.

All equipment shall be designed to minimise the risk of fire and any damage which may be caused in the event of fire.

All apparatus shall be designed to obviate the risk of accidental short, malfunction or damage due to vermin. The use of materials which may be liable to attack by termites or other insects is to be avoided.

All items of equipment which may have to be lifted for erection or maintenance shall be provided with lifting eyes, jacking pads or alternative handling facilities.

The equipment is to be designed to prevent accidental contact with live parts.

Fixed installed maintenance platforms, where the height of the switchyard equipment necessitates them to perform operation and maintenance, shall be included in the delivery.

1.2. Units of Measurement

In all correspondence, technical schedules and drawings S.I. units (System International Unites) shall be used. On drawings where Imperial or other units have been used the equivalent SI units shall also be shown.

1.3. Erection Marks

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

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

1.4. Cleaning and Painting (Other than Civil Works)

1.4.1. General

All bright metal parts shall be covered before shipment with an approved protective compound and protected adequately during shipment to Site. After erection these parts shall be cleaned with a correct solvent and polished bright where required.

Before testing, all steel pipes shall be thoroughly cleaned by an approved process. Any protective coatings shall be applied after tests have been carried out.

Pipes, valves and other similar parts of the Plant which are subject to hydraulic test and are not readily accessible for drying out are on completion of tests at the manufacturers' works to be drained out by washing with an approved de-watering oil prior to protection for shipment.

All surfaces shall be prepared before coating in accordance with BS 2569.

All iron and steel surfaces shall be protected against corrosion and painted in accordance with BS EN ISO 12944 and shall withstand the site environment for at least 10 years without need for maintenance.

Where painting is carried out at the manufacturers' works and where erection at Site is the responsibility of the Contractor, any damage during delivery or erection at Site shall be made good to the requirements of the Employer/ Employer's Representative including, where deemed necessary, application of a complete finishing coat of an approved colour and quality paint.

Where painting is carried out entirely at Site after erection, the whole of the Plant, including bare pipe surfaces and hand railing, shall be well wire brushed down and cleaned after which all parts shall be given one coat of primer, one undercoat and at least two finishing coat of an approved colour and quality paint.

All paint shall have appropriate standard finish, requiring at least two finishing coats on prepared surfaces properly filled in to provide a smooth finish. The insides of outdoor control cubicles, cabinets, etc., where condensation is liable to occur, shall receive the same number of coats.

1.4.2. Tanks and Accessories

Interiors of oil tanks shall be thoroughly cleaned by shot blasting or other approved methods and, where exposed to corrosion before use, shall be coated with an approved corrosion preventing compound. The internal surfaces of oil tanks that will be exposed to atmosphere in service shall be painted with an epoxy or other approved oil resisting compound.

The exterior shall be thoroughly cleaned by shot blasting or other approved methods and given one coat of primer, two coats of contrasting colour of durable oil and weather resisting paint and a final coat of gloss paint.

1.4.3. Radiators

Radiators shall be thoroughly cleaned and treated externally by phosphating or other approved rust inhibiting process and given, preferably by flood painting. Radiators which are hot dip galvanised to BS EN ISO 1461:2009, shall be given one coat of etch primer followed by one coat of zinc chromate primer followed by the same number and type of paint coatings specified previously.

1.4.4. Steel Structures and Assembly Material

Steel structures are to be understood as substation gantries, equipment supports, with their body and leg extensions, additional crossarms if required, the foundation stubs, and stub setting templates.

Assembly material are to be understood as all bolts, screws, rivets, nuts, washers, locking devices which are necessary for the assembly of the steel structures and their accessories as well as, for the assembling and mounting of the equipment, insulator sets, conductor and earthwire / OPGW accessories.

Steel Structures

Generally, the design and stress calculation shall conform to a consecrated code or standard such as:

IEC 60826 Design criteria of overhead transmission lines

ISO 10721 Steel structures; calculation and construction

EN 1993 Design of steel structures.

The local climatic conditions, load calculation, description of loading cases, as well as the applicable design method and safety factors shall be as specified in these Bidding Documents.

The material to be used for the structures is high tensile - and mild steel sections and plates, according to internationally recognized standards (ISO 630, DIN 17100 or equivalent).

All structural steel shall be protected against corrosion by hot dip galvanizing.

Assembly Material

All necessary bolts, screws, rivets, nuts, washers and locking washers shall be included in the scope of supply of the Contractor with sufficient spare to cover for losses.

Members of lattice steel structures including stub setting templates shall be secured by means of bolts and nuts with approved spring washers and lock washers.

All bolts and nuts shall conform respectively to ISO 898 and/or to DIN 267 and shall have metric screwed threads. Nuts and the heads of bolts shall be of the hexagonal type. Nuts - except lock nuts - shall be full bearing on one side.

Minimum size of bolts for all structural connections shall be 16 mm diameter in mild steel or 12 mm in high tensile steel. The quality of bolts shall not be less than 5.6 according to ISO 898 and/or DIN 267.

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

Where for any type of tower high tensile steel bolts are employed then bolts of this type shall be used for all connections for every type of tower on that line in order to avoid the use of mild steel bolts in error where high tensile

1.5. Rating Plates, Nameplates and Labels

1.5.1. General

All items of plant shall be provided with nameplates or labels designating the service of the particular equipment. Such nameplates or labels shall be of corrosion resistant material with permanent lettering of a contrasting colour or, alternatively, in the case of indoor equipment, of transparent plastic material with suitable lettering engraved on the back.

Items of Plant, such as valves, which are subject to handling, shall be provided with nameplates with permanent inscriptions thereon, specifying also their normal position and use of other positions.

1.5.2. Rating Plate

Each main and auxiliary item of Plant shall have attached to it in a conspicuous position, a rating plate upon which shall be engraved any identifying name, type or serial number, together with details of the loading conditions under which the item of Plant in question has been designed to operate, and such diagram plates as may be required by the Employer/ Employer's Representative, including the short-time rating of switchgear.

1.5.3. Labels

Each item of Plant shall be provided with number plates bearing the equipment number allocated by the Employer/ Employer's Representative according to his standard operational numbering scheme, details of which will be advised during the Contract stage.

The device number shall be displayed in text height 30mm on all operating mechanisms and 60mm or larger in height on principal items of Plant. The same device number shall be displayed on control cubicles in text height 10mm or larger as may be required by the Employer/ Employer's Representative.

The label for the feeder designation shall be provided on middle phase surge arrestor structure. The text height shall be 60mm or larger. Phase identifications with respective color disks shall be provided for the main bus bar as well as incoming line. The material to be used for engraving the labels shall be approved by the Employer/ Employer's Representative. The labels shall be of black color with white writing.

1.6. Nuts, Bolts, Studs and Washers

Nuts and bolts for incorporation in the plant are preferably to conform to ISO metric coarse to BS 3643, BS 3692 and BS 4190. Other sizes or threads are permitted for threaded parts not to be disturbed in normal use or maintenance. Where the Contract includes nuts and bolts of different standards, then the tools to be provided in accordance with this Specification shall include spanners, taps, and dies for these nuts and bolts.

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

On outdoor equipment all bolts, nuts and washers shall be of non-rusting material where they are in contact with non-ferrous parts in conductor clamps and fittings and elsewhere where specifically required by the Employer/ Employer's Representative

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

Where there is risk of corrosion, bolts and studs shall be finished flush with the surface of the nuts.

1.7. Rivets

Rivets shall conform to the appropriate British Standard and for general use pan heads are preferred. Rivets on bearing surfaces shall be flat counter-sunk, driven flush. Whenever practicable, riveting shall be done by hydraulic tools and the rivets must completely fill the holes when closed. If loose, or if the heads are badly formed, cracked or eccentric to the shank or do not bear truly on the plate or bar, such rivets shall be cut out and replaced. All surfaces to be riveted must be in close contact throughout.

1.8. Forgings

All-important forgings shall be jointly examined at the maker's works by the Employer/ Employer's Representative and by a representative of the Contractor during forging and heat treatment and shall be examined by the latest methods for the detection of defects.

1.9. Castings

All castings shall be as free from blowholes, flaws and cracks as is practicable. No welding, filling or plugging of defective parts shall be done without the sanction of the Employer/ Employer's Representative and then only with his approval in writing.

All cast-iron shall be of close-grained quality and shall be corrosion- resistant for those parts in contact with seawater. Cast-iron is not to be used for any part of the equipment which is in tension or which is subject to impact stresses. This clause is not intended to prohibit the use of suitable grades of cast-iron for parts where service experience has shown it to be satisfactory.

1.10. Welding

Where fabrication welds are liable to be highly stressed, the Contractor shall satisfy the Employer/ Employer's Representative before such welding commences, that the welders or welding operators are qualified in accordance with the requirements of the appropriate section of BS 4872 Part 1 or other relevant British Standard Specification.

The Project Manager will inform the Contractor of the stages at which inspection will be required. It will be the Contractor's responsibility to notify the Project Manager when one or more of the inspection stages will be reached and no further work shall be carried out until the specified stage has passed the Project Manager's inspection.

In addition to the above, the Project Manager reserves the right to visit the Contractor's Works at any reasonable time during fabrication of the items of Plant and to familiarise himself with the progress made and the quality of the work to date.

All tests shall be carried out in accordance with the relevant British or other approved Standards. Where required by the Project Manager, non-destructive examination of the finished weld shall be made. If the examinations be by radiograph means, then the recommendations of BS EN 1435 where applicable shall be followed and the resulting negatives shall be made available to the Project Manager.

1.11. Galvanised Work

All iron and steel structures and components intended for use outdoors shall be galvanised.

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

All galvanising shall be done by the hot dip process with spelter, not less than 98% of which must be pure zinc and in accordance with BS EN ISO 1461:2009 or BS EN 10244-2:2009 as applicable. No alternative process shall be used without the approval of the Employer/Employer's Representative. Bolts shall be completely galvanised including the threads, but the threads shall be left un-coated in the case of nuts.

The zinc coating shall be uniform, clean, smooth and as free from spangle as possible.

Galvanised wire shall comply with the requirements of BS 182, and the thickness of the coating and testing thereof shall comply with BS EN 10244-2:2009. Nuts and bolts and small components shall be tested in accordance with BS EN ISO 1461:2009. The Employer/Employer's Representative may select for test as many components to be weighed after pickling and before and after galvanising as he may think fit.

Galvanised steel structures shall be treated after galvanising with Sodium dichromate or other approved solution.

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

Should any emergency arise on Site necessitating drilling, cutting or any other process likely to damage the protective zinc surface, this will be permitted only in extreme circumstances and with the Employer/Employer's Representative's express authority. In such a case, the bared metal will be coated with an approved zinc dust paint or other approved flake metallic compound.

1.12. Chromium Plating

The chromium plating of those components of the Plant where specified and where offered by the Contractor shall comply with the requirements of BS EN 12540.

1.13. Lubrication

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

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

Where lubrication is affected by means of grease, preference will be given to a pressure-gun system with a separate nipple to each point. Where necessary to accessibility, the nipple is to be placed at the end of extension piping, and, when a number of such points can be grouped conveniently, the nipples are to be brought to a battery plate mounted in a convenient position. Nipples shall be of the hexagon headed type complying with BS 1486 Part 1 table 1 type 11B. Where special greases are to be used and where high temperatures are encountered, then 'button' nipples in accordance with BS 1486 are preferably to be used.

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

1.14. Oil Level Indicators

Oil level indicators of approved magnetic type design are to be fitted to all oil containers such as transformer conservators etc.

The indicators are to have a scale of 150mm diameter (minimum) to show the level at all temperatures likely to be experienced in service, are to be marked with the normal level at 25°C clearly visible from normal access levels and are to be easily dismantled for cleaning. In addition, the normal filling level of all removable containers is to be marked on the inside.

1.15. Cubicles

1.15.1. Basic Design and Construction of Cubicles

All cubicles shall be industrially produced, made by reputable manufacturer and internationally approved by independent test laboratories.

The cubicles shall be fully assembled, wired and tested.

Standard designs and models from the Bidder's/ Contractor's manufacturing program are preferred; provided they meet the requirements of this Specification and serve the intended purpose.

Cubicles shall be either of the free and self-standing, floor mounted type or wall mounting type. Transportation shall usually be in vertical position. In some cases, transportation in horizontal position might also be required. All cubicles provided within the same room shall be coordinated particularly with regard to size, doors, plinths, arrangements of plates, lamps and labels, colour, etc. in order to achieve a uniform front design.

Each cubicle shall have a designation label at the top. On the left upper corner there shall be space for manufacturer's logo if applicable. The cubicle naming shall be in the middle and on the right upper corner shall be placed the designation in accordance with DIN 40719 Part 2. The letter height shall be minimum 20 mm. The fixing of the label shall be by screws. The designation label is part of the approval by the Employer/ Employer's Representative.

Generally, all cubicles shall be designed such as to facilitate extension at both side ends.

For wall mounted or structure mounted cubicles and boxes the size shall be selected based on the required number of terminal blocks/ terminals or relays and other protection elements. However, the design of these cubicles shall be basically in conformity with that of the floor mounting cubicles except for the size.

The numbers and size of cubicles shall be selected such as to consider the requirements of maximum allowable heat dissipation by all equipment installed in the cubicle, so as to ensure satisfactory and reliable performance under the specified environmental condition. A written confirmation of cubicle's manufacturer on the same is mandatory.

The cubicles shall be vermin proof and protected against dust and water by protection class IP51 for indoor and IP55 for outdoor, and against external mechanical impacts according to protection code IK06.

Cubicles shall be designed for bottom entry of all cable types and/ or conduit wiring via vermin proof removable gland plates of galvanised sheet steel with at least 3 mm thickness and fire-resistant bushings (if any). The gland plates shall be equipped with suitable cable glands, made of non-corrosive material (e.g. nickel-plated brass or stainless steel) and shall be of metric size. They shall provide protection class of at least IP 67 at 5 bar. They shall be sealed or plugged during transport. Cable screens and armours shall be contacted in a circumferential manner for earthing purpose. Gasket material shall not be exposed to sunlight radiation. If due to any comprehensible reason cubicles may need cable entry from top, this shall be decided together with the Employer/ Employer's Representative. The cubicles shall allow sufficient room for incoming/ outgoing cable cores to be neatly and conveniently channelled to their respective terminals.

The bottom plate shall be suitable to wear a weight of 150 kg without lasting deformation.

The free and self-standing cubicles shall be mounted on base frames. In case of raised floors these frames form part of the raised floor. The base frames need to be designed for the load of the fully assembled cubicles. In case of not floor mounted cubicles (e.g. operating mechanisms) the cubicles shall be properly fixed on steel supporting frames. All cubicles shall be well coordinated in respect to the height of the enclosures plinth and of the base frame.

A tinned copper rope or copper bar shall run along the full length of the cubicle row, connected every five meters to the substation earthing mesh. Each cubicle shall be earthed through two tinned copper earth cables to this copper rope. The dimensioning shall be appropriate to meet the requirements of operational and protective earth, most notably regarding maximum rated short-circuit currents and electromagnetic interference. Outdoor cubicles and stand-alone cubicles shall be directly connected by tinned copper earth cables to the earthing mesh.

The cubicles shall be built-up of high stability profiles with rounded edges. They shall have a format system frame with the required punching in all three planes in accordance with IEC 60917 to allow standardization of cubicle components and system accessories (mounting rails, swing frames, lighting, etc.). Three-dimensional corner pieces shall be preferably welded to each section to guarantee optimum stability.

Side panels shall fit with the design of front doors and back panels. With field-by-field assembly in-stead of two back-to-back side panels between cubicles a partition plate may be used.

The cubicles shall be completely corrosion protected. The outside surfaces shall be preferably electrophoretic dip coat-primed and powder-coated. The inside surfaces shall be varnished as well or sendzimir galvanised, whereas cold galvanisation is restricted to treating of edges and refinish treatment. The thickness of the dry film shall be at least 80 µm; the adhesive strength shall be GT1 or better according to the standard ISO 2409.

The Employer/ Employer's Representative reserves the right to determine the thickness of coating by making appropriate tests. For such tests, the Contractor shall make available the apparatus to be used.

The paint film, under visual examination, must in any case present the appearance of an accurate application and be free of lesions, porosity, cracks or bubbles.

Where sharp edges cannot be avoided by constructional means edge protections shall be applied.

All metallic parts of the cubicles shall be connected with each other in a conductive manner. Varnished parts shall be earthed twice at least on diametrically opposed points.

All built-in equipment in the cubicles shall be fully accessible from the front.

All the material, wires, cables and cable-ducts in the cubicle shall be halogen free and flame retard-ant.

The text on labels for push buttons, selector switches, indicating lamps and other installed equipment shall have a minimum letter height of 5 mm.

The cubicles shall have a seismic withstand capability according to IEC 60068-3-3 of class AG5 with 5 m/s², respectively of the application class III with 15 m/s² for the acceleration of decks.

For seismic withstand capability the complete cubicle shall be qualified according to the requirements of IEEE 693-2005 and shall meet the requirements of the high qualification level. The test report shall be submitted together with the bidding documents.

1.15.2. Doors

The door shall be of 2 mm sheet steel with removable tubular door stiffener frame with holes on a 25 mm DIN pitch pattern, padlocking facilities integrated in door handle and a door opening angle of 170°. Swing-frames or inner panels or doors if applicable shall have an opening angle of at least 150°. They shall be equipped with a door stay hinge.

Doors are to be arranged so that every individual door or frame can be opened without moving doors of adjacent cubicles. Doors shall be equipped with hinges and suitable sealing to satisfy the required protection class. The front door or alternatively one side panel shall be equipped with a rigid and securely fixed steel pocket sufficient to store the concerned circuit diagrams and site commissioning/ test reports.

Separate latch (es) shall be provided within the door, being made of anti-rust material. The latch shall require minimum maintenance and oiling for indefinite period. Doors shall be handled by smooth action locking bars with rollers and security lock system, prepared for insert lengths of 40 or 50 mm. Closing of doors shall be possible with one hand action only.

Glazed front doors shall have tempered security glass with a minimum thickness of 3 mm. Fixture of the glass shall be continuously along the edges by profiles or non-aging, UV-resistant glue. The glass fitting shall be of a width as to allow the electronic equipment to be seen behind. The vertical centre-line of the window cut-out shall be congruent with the one of the 19" rack.

Sufficient space, not less than 1.0 m, to other equipment or switchgear shall be kept free after opening the cubicles door at 90 degrees on the front plane.

Cubicle wiring and wiring on the frames shall be protected against mechanical damage when work is carried out inside the cubicles by facilities allowing easy removal and reinstatement. Each door shall be fitted with two flexible tinned copper strips on top and bottom with a minimum cross-section of 10 sqmm. With covers of boxes flexible earthing conductors having a minimum cross section of 6 sqmm shall be used for connecting any cover to a housing.

1.15.3. Swing frame

All cubicles for bay control units and substation monitoring and control system, protection relays and metering equipment shall be provided with swing frames and a glazed front door.

The swing frames shall be constructed of a rigid steel box section frame and at least triple folded mounting section. It shall be made of galvanised sheet steel and shall be equipped with a swing frame stay hinge. Free access of at least 50 cm width to the terminal blocks at the back of all installed equipment shall be achieved by using hinges of a sturdy design.

The installation kit shall allow an adjustment of the swing frame at any time in order to have it always plumb. Even with a heavy components load, swivelling shall be possible easily with the provision of chassis guides. Closing of swing frames shall be possible with one hand action only.

Swing frames shall have a punching according to IEC 60297 (19" series).

Each swing frame shall be fitted with two flexible tinned copper strips on top and bottom with a minimum cross-section of 10 sqmm.

The 19" racks and accessories, such as sub-racks shall be shock and vibration tested according to IEC 60068.

1.15.4. Mechanical Equipment

The cubicles shall be supplied completely with all locks, cable end boxes, floor fixing kits and anchoring devices, gland plates, bus-bars, internal wiring, terminal boards and accessories, such as wall brackets and angles as well as eye bolts, complete with reinforcement plates and the like. In the case of wall mounting cubicles all fixing accessories shall be provided.

Mounting plates inside the cubicles shall consist of rigid galvanised sheet steel with the edges folded backwards and the assembly systems used shall be of standard design and construction. Rails, brackets etc. shall fit to the pitch system of the basic support frame.

For incoming cables the cubicles shall have cable clamp rails equipped with sufficient cable clamps. Above that, suitable and well accessible earthing bars shall be mounted each providing two 13 mm-holes for the main earth connection to the earthing mesh of the substation. The earthing bars shall be equipped with sufficient number of earthing terminals. The earthing bars shall be mounted on isolators.

1.15.5. Keys and Key Box

Key locked switches as far as applicable shall be provided with an approved lock for locking in the neutral position. A similar lock shall be provided for each selector switch for locking the switch in any of its positions.

Approved means shall be provided for locking the cubicle doors, live terminal shutters, etc.

In general, each lock or padlock used shall be different from the others and shall be supplied with three keys. All keys shall fit to a master key system and six keys to open any lock or padlock shall be supplied.

Each key shall have one identification label attached to it and an identical label shall be fixed above the key hanging hook inside the key box.

The Bidder/ Contractor shall submit for approval a key list and plan/ schedule for the intended system to be provided for securing the electrical operations and interlocking by keys.

A key box shall be provided at the substation control room for storing the keys.

1.15.6. Electrical Equipment

1.15.6.1. General Requirements

All electrical devices and material shall be installed safe from finger-touch (finger safe) according to IEC 61032, if such is not given by the devices or material itself covers must be installed.

The electrical equipment shall be arranged so as to afford as may be necessary:

- Sufficient space for the initial installation and later replacement of individual items of electrical equipment
- Accessibility for operation, inspection and fault detection, testing, maintenance and repair

Care must be taken that all cubicle metering indicators, recorders, lamps, displays and other indicators and control switches are mounted at levels not less than 1.6 meters of the final ground floor level (cable plinth, if any, of enclosures shall be considered).

Operating devices not being installed at the front shall be mounted on the back of the cubicle clearly visible in an easily accessible position at a convenient height from the floor.

Indicating instruments shall be included for the functions listed. Measuring instruments shall be flush-mounted, quadratic switchboard types with 96 mm width and an accuracy class of 1.5 % or better, and with 90° or 270° scales. They shall be installed at approximately eye-height for easy reading by the operators, having anti-glare glasses.

Contacts of switches shall be of the self-cleaning type, mercury contacts are not acceptable.

All supervision circuits shall be in fail safe mode, fail of supply voltage shall result in a faulty status of any supervision.

The labelling of the individual devices shall be clearly visible and readable. Labels of synthetic or of aluminium foil with black letters on clear background shall be provided for all instruments, relays, control switches, push-buttons, lamps, breakers etc. Sticker paper labels are not acceptable.

All equipment is to be connected to the earth bus with individual wires. No looping of earth wires is allowed.

1.15.6.2. Reduction of Electro-Magnetic Interferences

In the secondary circuits the following are the minimum measures to be adopted to reduce EMI:

- Separation of the various circuits connected with devices having different degrees of interference level (power supplies, input and output network circuits, earth connections).
- Galvanic separation of the I/O signal circuits and of the auxiliary supply circuit lines with isolating relays, opto-diodes, transformers, coupling capacitors.
- Screens of cables shall be earthed.

- Screens of cables from the switch bay shall not be laid in the cubicle adjacent to unshielded circuits.
- Coils of relays shall have a protective circuit to limit the voltages, induced on the coil on circuit interruption, to a value that does not pose a danger to any connected electronic devices. The type of protective circuit (e.g. diode) shall be selected according to the intended function, under consideration of the prolongation of the contact switching time due to the protective circuit.
- Switching of loads with inductive component like contactors, solenoid valves, motors, etc.: A protective circuit shall be used to suppress the formation of an arc; the protective circuit shall be implemented directly at the load e.g. at the coil of the contactor; depending on the application the protective circuit shall be a diode, a series connection of diode and zener-diode, a suppressor diode, a varistor or a R/C combination.
- Separation (spacing out or different routes) as far as possible of power circuits from control cables.
- Separate cabling of the low frequency and high frequency circuits
- Twisted pairs or quadruple cables shall be adopted where necessary (i.e. low current circuits and data lines).
- Screen of low resistance, protected of the external high frequency electric and magnetic field from the cables shall be provided.
- Earthing of the screen shall have very low impedance with adequate section minimum length and optimum contact arrangements.

1.15.6.3. Power supply

Generally, signalling and trip circuits, shall be fed by DC. For the particular electrical equipment to be installed reference is made to subsequent articles with special requirements and/or separate part of this specification.

The circuits shall be protected by adequate miniature circuit breakers with alarm contacts suitably wired and integrated in the overall alarm system of the substation. Particular attention shall be given to the selectivity of all MCB's. Fuses will not be accepted.

Completely separate and isolated circuits shall be used for Switchgear control, individual protection relays, redundant tripping, CB-motor, disconnector motors, alarms, interlocking circuit and further individual auxiliary devices.

1.15.6.4. Heating and lighting

Each cubicle shall be illuminated by fluorescent light. The lighting shall be controlled by the cubicle door or by the swing frame through a switch.

Unless otherwise stipulated one 240 V AC socket outlet according to local standard for maintenance purposes shall also be provided inside the cubicle. The outlet shall be protected by RCD (residual current device).

Each cubicle shall be equipped with heater. The heater shall be controlled by humidity and by temperature.

The heater shall be located at a suitable position and its capability shall be as required to maintain the difference in temperature of 5 K above the dew point taking into consideration the specified environmental conditions.

Heating elements shall not be mounted onto the front door; they shall be installed vertically, with minimum all around clearances of 50 mm.

Heating and lighting circuits shall be protected by miniature circuit breakers with the necessary amount of auxiliary contacts for local and remote signalling.

Suitable temperature control to improve the internal convection of the cubicles temperature by a provision of forced air circulation, using internal fans, may be proposed. These fans (if any) shall be fed by the corresponding DC supply used in that particular cubicle.

1.15.7. Wiring

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

All secondary copper wiring within cubicles shall be in accordance with the relevant IEC standards, and shall also be selected to handle the rated nominal and test voltages. Test voltages are 3 kV AC/ 1 min. for current transformer (CT) and voltage transformer (VT) secondary's and 2 kV AC/ 1 min for others.

The colour coding of the wires shall be as per KETRACO standard.

Control wiring shall be of highly flexible stranded copper and must have a cross-sectional area not less than 1.5 sqmm. VT secondary's shall be wired with a cross-sectional area not less than 2.5 sqmm, CT secondary's not less than 4 sqmm.

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

Each end of each wire and cable core shall be permanently marked with a securely fitted, non-combustible, thread-on type marking tag or sleeve. Alternatively imprinted or etched into the conductor insulation in more than one position is also acceptable. The tag/ sleeve/ imprint/ etch must be marked with a non-removable identifying code according to (withdrawn) IEC 391 Figure 11b, dependent local end marking.

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

Conductors shall be laid in halogen free plastic ducts, as far as possible all circuits shall run along the shortest path to their addresses but only in horizontal and vertical planes. Diagonal runs are not acceptable. However, the wire runs shall not block access for testing or removal of any device when needed without disturbing other devices.

Wiring between enclosure and/ or mounting plate to swing frames and doors shall be performed as bundles in flexible cable conduits along with suitable conduit clips, providing conduit fixing, strain relief and cable tie eyelets. Movements of the door/ swing frame shall twist the wiring, a bending or folding of them is not acceptable. Each bundle shall be anchored such that the moving bundle length is the maximum available without loops.

All wires shall be led to terminal blocks for connection according to a connection diagram. Excessive looping between devices in the same cubicle shall be avoided as far as practicable. Direct looping of wires between devices in different cubicles, even if adjacent, will not be permitted.

All power circuits, control and protection wiring and low-level signal wiring shall be physically separated. Separate laying-way shall be provided for power cables, and the working voltage of each power circuit shall be marked on the associated terminals.

The filling degree of the cable ducts of the ready installed cubicle shall be not more than 75 %. This has to be regarded and checked already in the design phase of the project.

All wiring shall be installed such that the likelihood of damage during normal operation, maintenance and fault conditions is minimized. The practice of doubling back wires on themselves to absorb slack is not acceptable.

Separate screened multi-core cables of highly flexible stranded copper wires shall be applied for CT and VT connections. VT secondary circuits shall be equipped with dedicated MCBs in VT junction boxes and also in each cubicle with voltage measuring circuit connection.

Signals with a voltage beneath DC 60 V shall not run outside of a cubicle, and screened cables shall be used inside cubicles, where normal battery voltage used for motors and contactors is prevailing. Connections for indicating instruments and for the telecommunication circuits from transducers, or modem outputs, shall use individually shielded wire pairs together with a separate outer shield, earthed on both ends of the cable.

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

Fibre optic cables shall have a dedicated rigid mechanical protection cover.

1.15.8. Terminals

1.15.8.1. Terminal Arrangement

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

Rows of terminals shall be spaced not less than 100 mm apart. Where plastic channels are used a minimum space of 50 mm shall be left between terminal boards and channel. Terminal boards shall be mounted vertically on TH

35 rails according to IEC 60715 at the sides of the cubicles. Terminal blocks in the rear shall be angled towards the front. The lowermost terminals shall have a minimum clearance of 200 mm to the incoming cable gland plate.

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

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

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

1.15.8.2. Terminal Marking

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

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

1.15.8.3. Terminal Design and Material

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

Terminals for control, trip and signalling circuits shall have isolation and test facilities, i.e. they shall be of type knife disconnect terminal with test socket for insertion of test plugs.

The CT terminal blocks shall have shorting, isolation and coloured insulated injection test facilities whereas VT terminals shall have isolation and coloured insulated injection test facilities. The switching status shall be clearly visible.

- Shorting shall be possible between adjacent terminals by a shorting bridge, being not removable without tool
- Isolation shall be possible by means of links, which can be securely fixed in the open and the closed position

- For injection test two integrated coloured terminal test sockets per terminal shall be available.

Performing of star point shall be realized with fixed bridges and earthing of secondary CT and VT circuits shall be in direction of the CT/ VT.

Connections to the CT circuits second to the star point shall have shorting facility in a phase-wise disconnecting and bypass function.

Terminals for metering purpose shall be covered and lead-sealed.

CT- and VT-terminal design is subject to a separate approval of the Employer/ Employer's Representative.

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

Terminals must be completely of non-corrosive material like copper alloy, corrosion protection is not applicable.

The insulating material of the terminals shall be of moulded, toxic free, non-hygroscopic polyamide (PA), inflammability class V0 acc. to UL 94 respectively IEC 60695-11-10 (-20).

Each individual block design shall have a foot design that ensures a secure fit on the rail and allows removal of individual terminals from the centre of an assembly.

Terminals shall be safe from finger-touch (finger safe) according to IEC 61032. If such is not given by the terminal itself (i.e. only back-of-hand-proof), transparent plastic covers must be installed. It shall be noted that such arrangement will only be allowed in exceptional cases and must be approved by Employer/ Employer's Representative.

1.15.9. Relays

Auxiliary and interposing relays shall have adequate thermal capacity for continuous operation in circuits in which they are used. DC relays shall work with the substations DC voltage considering a voltage range between 80 % and 110 % of the rated voltage. The relays shall be designed for a duty ratio of 100 %. The electrical life time shall be more than 100'000 cycles (full loaded contact operation). The contact material shall be suitable for the intended application (e.g. low voltages and low currents).

1.15.10. Indicating Lamps

Indicating lamps shall be of the panel mounting filament type and low watt consumption. Lamps shall be provided with series resistors, preferably built-in the lamps assembly. The lamps shall have escutcheon plates marked with its function, wherever necessary.

Colour Coding shall follow IEC 60073.

When associated with push buttons, status indication lamps (e.g. OPEN/ CLOSED) shall be directly above the push button.

Lamps shall have translucent lamp-covers.

1.15.11. Control and Selector Switches

1.15.11.1. General

All control and selector switches shall be of the rotary control board type with operating knobs on the front and the operating contact mechanisms on rear. Each switch shall be provided with ample contact stages and suitable arrangement, to perform the function. Contacts of all control and selector switches shall be self-aligning and shall operate with a wiping action. A positive means of maintaining high pressure on closed contacts shall be provided. The covers or plates on the switches shall be readily removable for inspection of the contacts. All control and selector switches shall be designed for an insulation level suitable for the voltage of the circuit to be operated. All such switches shall be capable of satisfactorily withstanding a life test of at least 10'000 operations with rated current flowing in the switch contacts. All switches shall be capable of continuously carrying 20 A without exceeding a temperature rise of 30 °C and shall be capable of interrupting inductive loads of not less than 4 A for 220 V DC or AC.

1.15.11.2. Escutcheons and Name Plates

Each control and selector switch shall be provided with an escutcheon clearly marked to show each operating position. The switch identifications shall be engraved on the escutcheons or on separate nameplates.

1.15.12. Push Buttons

Push buttons shall comply to IEC 60947. The protection degree according to IEC 60529 shall be IP67. The mechanical life time is required as minimum 5'000'000 switching operations. The necessary operating force shall be less than 5 N. The push buttons are to be provided with escutcheons and name-plates adequately describing their function. Where decided during design stage, protective covers are to be installed to prevent inadvertent pressing of the button. The buttons shall be coloured as given by the international standards, e.g. in case of open and close, as per the Employers standard or as decided during the design stage.

1.16. Padlocks and Key Cabinet

Non-ferrous padlocks with stainless steel shanks with different key changes and two keys for each lock and bay-wise submaster as per standard practices of KETRACO shall be provided.

Wall mounted lockable cabinets for the accommodation of padlocks and keys, whilst not in use, shall be provided and labelled in an approved manner so that keys can be easily identified. Duplicate keys shall be mounted in a separate cabinet.

For extensions/modifications to existing substations, the prevailing "master/submaster" system shall be matched. Control room doors and gates of the new substations shall be fitted with locks to suit the master series of existing

substations. New substations shall be provided with key changes to suit the submaster series bay-wise. No grandmaster for each substation is required. Submaster series keys shall be locked off in a separate cabinet. All padlocks and keys shall be engraved with proper identification numbers e.g., circuit number, equipment number, etc. as per KETRACO standard numbering scheme. Locking facilities shall be such that it will accept sizes of padlocks & keys large enough to permit identification numbers, etc. to be embossed on them. Equipment shall be such that it can accept interlocks/scheme identical to that in existing substations.

2. Substation

This specification sets out the general requirements for the design and engineering of new substations and the extension and modifications to existing substations.

2.1. Reference Documents

The substation outdoor equipment shall be supplied in accordance with the detail requirements of this specification and in particular the latest issue of IEC standards. The characteristics of design and construction, ratings and testing procedures are concerned; the outdoor switchgears shall meet the following IEC standards.

The following standards, and all standards quoted therein, shall be applicable:

- IEC 61936-1 – Power installations exceeding 1 kV a.c. – Common rules
- BS 7354 - Code of Practice for Design of High Voltage Open Terminal Substations
- IEC 62271-1 - High voltage switchgear and control gear – Common specifications
- IEC 62271-100 - High voltage alternating current circuit breakers
- IEC 62271-102 - High voltage alternating current disconnectors and earthing switches
- IEC 60099-4 – Metal-oxide surge arresters without gaps for a.c. systems
- IEC 60694 Common specifications of high voltage switchgear
- IEC 60815 Selection and dimensioning of high-voltage insulator intended for use in polluted conditions.
- IEC 60376 Specification of technical grade sulfur hexafluoride (SF6) for use in electrical equipment.
- IEC 60694 AC metal enclosed switchgear and control gear for rated voltage 1kv and up to 52kv
- IEC 62271-200
- IEC 60529 Enclosure Degree of protection
- IEC 60044-2 Voltage transformers
- IEC 60044-1 Current transformers

2.2. General Requirements

2.1.1. Requirements for All Substations

The substation arrangements and layouts shall be as shown on the drawings included in the bid documentation. These drawings are intended to show the basic requirements to be satisfied.

It is the responsibility of the Contractor to prepare a detailed layout showing the manner in which the various items of equipment offered can be accommodated to best advantage within the available area. In preparing the designs, the Contractor shall consider the safety of KETRACO personnel and others employed in the operation and maintenance of the substation, together with the safety of third parties who may approach the extremities of

the substation. The Contractor shall also demonstrate the adequacy of the proposed design by calculation where required.

The arrangement shown on the bid drawings may be modified as necessary to accommodate the various items, provided the basic principles are maintained.

The Contractor is at liberty to offer substation arrangements based on significantly different principles where it is considered that these offer economies or technical advantages. It is emphasised, however, that the bidder's main offer should comply with the principles shown in the bid drawings, other arrangements being submitted solely as alternatives to the main offer.

2.1.2. Compliance with the Laws and Statutes of Kenya

It is the responsibility of the Contractor to ensure that any offer made is compliant with the laws and statutes in force at the time of bidding. Any changes occurring between the date of bid and the date of contract award will be dealt with in post-bid discussions.

2.1.3. Design Life of Substations

The structures, buildings and primary electrical equipment shall have a design life of 40 years. Secondary systems such as protection and control equipment shall have a minimum design life of 15 years.

2.1.4. Environmental

The substation and equipment used therein shall be designed to limit the environmental impact to a minimum and all statutory requirements applicable in the territory shall be complied with. Particular care shall be applied in the design of the substation to prevent the contamination of the ground and watercourses by oil or other liquid contaminants. Where gases are used in equipment or for other purposes care shall be taken to limit the release of "greenhouse" gases to a minimum. In particular SF₆ shall not be deliberately released to the atmosphere during construction, testing or maintenance.

Where equipment contains large amounts of flammable material, care shall be taken to limit the spread of fire to adjacent equipment or buildings. Where specified in the schedules large power transformers and shunt reactors shall be fitted with fire protection systems designed to suppress and extinguish fires in transformer compounds, limit the damage to the transformer/reactor and ensure that adjacent transformers/reactors are protected against the spread of fire. Adjacent transformers/reactors shall be protected from the spread of fire by constructing suitable firewalls. The system proposed shall be suitable for the particular conditions in the territory.

Care shall be exercised in the overall design of the installation and in the selection of plant and equipment to minimise the environmental impact of the substation.

The general information about Substation environment is mentioned below:

a) SITE CONDITIONS		UNIT	DATA	
			Required	Offered
	General Requirement			
1	Climate		Arid	
2	Pollution		Very Heavy	
2.1	Creepage distance (based on Um)	mm/kV	31	
3	Isokeraunic Level	thunderstorm days/year	80	
4	Altitude of Area	m	1850	
5	Seismic Acceleration	g	0.25	
6	Air Temperature			
6.1	- Absolute maximum	°C	40	
6.2	- Absolute minimum	°C	1	
6.3	- max. mean daily	°C	25	
7	Humidity (Maximum average per day)	%	60	
8	Precipitation	Days per year	50	
9	Wind velocity			
9.1	- Normal wind	m/s	20	
9.2	- Gust (design basis)	m/s	40	
10	Maximum Snowy	days per year	10	
11	Ave. annual sum of direct normal irradiation	kWh/m ²	1200	
12	Thickness of ice	mm	5	
13	Average annual rainfall	mm	1000	
14	Minimum factors of safety for switchgear			
14.1	Busbars or other connections based on elastic limit		2.5	
14.2	Complete insulators based on electro-mechanical test		2.5	
14.3	Insulator metal fittings based on elastic limit		2.5	
14.4	Steel structures based on elastic limit of tension members and on crippling loads of compression members		2.5	
14.5	Foundations for structures against overturning or uprooting under maximum simultaneous working loadings		2.5	

2.1.5. Outage Constraints

Unless otherwise agreed by KETRACO the design of the substation shall permit installation, extension, operation and maintenance with one busbar and one circuit only out of service.

2.1.6. Plant and Equipment Identification

It shall be possible to clearly identify any plant, equipment, isolation device and earthing device for operation and maintenance purposes. Within any substation the identification system shall uniquely mark all necessary equipment and shall be consistent with existing identification systems.

The markings used shall be durable and remain legible for the lifetime of the equipment.

The identification system shall include but not be limited to:

- Circuit breaker, disconnecter, earth switch mechanism boxes, busbar sections, current and voltage transformers
- Busbar sections, current transformers and voltage transformers
- Pressure gauges or indicators and associated pipework
- Valves
- Control handles, switches or push buttons
- Points of isolation for secondary systems
- Cabinets, cubicles and kiosks

2.1.7. Access for Substation Operation

It shall be possible to gain safe access to the control point and locking-off point of any device that is used by operations staff during their normal duties without the use of portable access equipment. Road access shall be provided to all outdoor air-conditioning plant for ease of repair and maintenance. All operational access shall be suitable for use by a person working unaccompanied.

2.1.8. Maintenance Requirements

It shall be possible to gain safe access to any device that requires in-situ maintenance by maintenance staff during their normal duties, from ground level by fixed access platforms. Similarly, any device that requires disconnection and removal for off-site maintenance or for replacement shall be readily accessible to both personnel and lifting equipment where required.

Adequate space shall be provided to allow access for maintenance equipment, mobile access platforms, mobile cranes to any substation equipment that may need to be maintained. The substation surfaces provided shall be suitable for movement of such equipment and where heavy plant items need to be moved suitable roads shall be provided. Access roads shall also be provided within the substation from the Main Gate to substation main buildings, relay rooms and outdoor air handling equipment.

2.1.9. Cranes and Lifting Equipment

Fixed cranes are not required for outdoor “Air Insulated” installations but care shall be exercised in the design of the installation to allow access for lifting the largest factory assembled sub-component of any equipment without requiring the shutdown of adjacent circuits.

2.1.10. Interlocking

Electrical and mechanical interlocks shall be provided. Padlocking to the requirements of this specification shall be provided for operational security.

2.1.11. Philosophy

All circuit breakers, disconnecting and earthing devices within the substation shall be interlocked in a manner that ensures that they always operate safely. The system employed shall ensure that unsafe switching actions are prevented. 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 directly driven auxiliary contacts of the main device.

2.1.12. Principles

The following assumptions shall be made:

- a. Disconnectors are capable of switching the capacitive currents of associated connections.
- b. Disconnectors have neither load making nor breaking capacity.
- c. Disconnectors are not capable of making or breaking transformer magnetising current.
- d. It shall not be possible to operate any earth switch unless the point of application is disconnected from all possible sources of supply, and the operating devices of the disconnectors providing the points of isolation are locked in the open position. Where one of the points of isolation is remote, the isolation of that remote supply will be confirmed by other means, e.g. by monitoring the VT secondary output voltage and a suitably inscribed warning label shall be fitted to the earth switch operating device.
- e. It shall not be possible to operate any disconnectors if an associated earth switch is already closed except where special maintenance provisions have been made.
- f. Where the load-breaking device is situated remote from a disconnector and cannot be fully interlocked the disconnector operating mechanism shall carry a suitably inscribed warning notice.

2.1.13. Substation Auxiliary Cabling

Substation auxiliary cables (power and control) between substation buildings, relay rooms, marshalling points and primary equipment shall be installed in cast concrete trenches or cable tunnels on purpose made corrosion

resistant racking. The use of buried cable ducts is acceptable for routes to individual equipment and short lengths of direct buried armoured cable may be acceptable provided the location of such cables is clearly recorded.

Where cables emerge from trenches or ducts, care shall be taken to eliminate tripping hazards and cable trays or racks used above ground shall be designed and installed so as to avoid dangerous edges or projections.

To limit the risk to personnel and equipment from smoke and corrosive fumes all auxiliary cabling shall be of a low fume, zero halogen type.

Spacing between successive cable support brackets within the cable trench shall be maximum 750mm. Extra support brackets shall be provided in case of bends and crossings. Suitable trench covers and their support shall be provided at the bends and crossing of cable trenches. 40% spare space shall be available in individual tiers for laying cables in future. Number of layers in individual tiers shall be decided based on cable capacity calculations and is subject to approval by the Employer/Employer's Representative.

2.1.14. Equipment Ratings

To ensure long-term suitability of equipment and switchgear installations are rated to take into account the projected development of the KETRACO system. The minimum values given are those required after any de-rating factors (from Standard IEC testing conditions) associated with the climatic conditions prevalent in the territory. The contractor shall demonstrate by reference to type test information and calculation or by re-testing at the required ambient temperature that the equipment offered is suitable for the minimum site rating required.

The general information about the Electrical Specification of the system is mentioned below:

a) SITE CONDITIONS		UNIT	DATA	
			400KV	220KV
	General Requirement			
1	Rated voltage	kv	420	245
2	System voltage	kv	400	220
3	Neutral earthing		Effective	Effective
4	Nominal Frequency	Hz	50	50
5	Switching Impulse Withstand Voltage at IEC conditions	kV peak		
5.1	Phase to ground and across open switching device		1050	N.A
5.2	Phase to phase		1575	N.A
5.3	Across isolating distance		900+345	N.A
6	One minute power frequency withstand voltage (at IEC condition)	kV rms		
6.1	Common value (Phase-phase, Phase-ground)		520	460
6.2	Across isolating distance		610	530

a) SITE CONDITIONS		UNIT	DATA	
			400KV	220KV
7	Basic Insulation level (at site condition)	kV peak		
7.1	Common value (Phase-phase, Phase-ground)		1425	1050
7.2	Across the isolating distance		1425+240	1200
8	Pollution		Very Heavy	Very Heavy
8.1	Creepage distance (based on Um)	mm/kV	31	31
	Minimum creepage distance	mm	13020	7595

2.1.15. Voltage Ratings

The required voltage ratings are given in the relevant equipment Schedules of Technical Information.

2.1.16. Rated Short Circuit Withstand Current and Time

The required ratings are given in the relevant equipment Schedules of Technical Information.

2.1.17. Rated Continuous Current

The required continuous current ratings are a function of the circuit application. The values for each application are given in the application documents included in the relevant equipment specifications.

2.1.18. Insulation Coordination Studies

It is in the scope of the contractor to conduct the complete insulation coordination studies, including collection of all the data necessary as input for the studies. The dielectric strength of equipment shall be selected accordingly, but minimum the data as given in Tender Documents shall be fulfilled.

According to IEC, insulation coordination is “the selection of the dielectric strength of equipment in relation to the voltages which can appear on the system for which the equipment is intended and taking into account the service environment and the characteristics of the available protective devices”. It shall be carried out in accordance with the methodology and guidelines outlined in IEEE standard 1313.2-1999, IEC 60071-2, 4 and CIGRE WG 33-04 recommendations and IEEE technical papers presented in various forums.

The procedure for insulation coordination consists of :

- a) Determination of voltage stresses
- b) Selection of the insulation strength to achieve the desired probability of failure.

The voltage stresses can be reduced by the application of surge-protective devices, switching device insertion resistors and controlled closing, shield wires, improved grounding, etc.

The studies shall comprise of three basic steps:

- 12 Determining the Overvoltages in the system, which are temporary Overvoltages, switching Overvoltages and lightning Overvoltages.
- 12 Selecting surge arrester ratings and locations or other mitigation equipment or operating restrictions, to ensure that system-imposed Overvoltages do not exceed the insulation strength of the equipment including appropriate protective margins.
- 12 Deciding the voltage ratings, basic lightning impulse level (BIL), basic switching impulse level (BSL) (wherever appropriate) with required margins or establishing the adequacy of these parameters for equipment by calculating the available protection margins.

The resulting report shall describe the configuration selected for the study, modelling concepts and software used. It shall include lightning stroke current selection, analysis of lightning overvoltage performance for determination of voltage stresses at surge impedance transition points under shielding failure or direct stroke and back flash over conditions and switching surge voltage study for the line energization, line re-energization with trapped charges and also for fault occurrence and fault clearance. The report specifies the selected type, number and location of surge arresters, determines whether the Overvoltages are below the required withstand voltage and the selected BIL and BSL of the substation and indicates the minimum protective ratio for lightning and switching study as per the standard IEEE C62.22-1997.

2.3. Air Insulated Substations

2.3.1. General Design Requirements

The substation design should be such as to limit the number of levels of conductors and to ensure that the consequences of a failure of one set of high level conductors including earth wire conductors are kept to a minimum. All materials and equipment for use in the substation shall be suitably rated to meet the site conditions specified in the schedules.

All gantry type structure supporting conductors shall include facilities for ready access to all insulator sets. There shall be permanently attached climbing devices with guard-rails 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.

Vehicle access to permit the transport of major switchgear equipment shall be provided. This shall be achieved without the need to de-energise adjacent circuits or busbars. Access for vehicles that require the de-energisation of circuits shall be kept to a minimum.

Each substation shall be adequately protected against direct lightning strikes, either by the use of spikes or earth wires located on the substation structures: the use of spikes is preferred. The height, location, and number of spikes or earth wires shall be such as to protect all equipment installed within the substation to a failure rate of shielding from direct lightning strikes of not greater than 0.1 per cent per annum.

Where the connection to the substation is by overhead line, overhead line conductors will be terminated either at the substation gantry structures or to anchor blocks adjacent to the overhead line terminal towers. The overhead line conductors complete with tension insulators, line tee off clamps, and compression fittings (bimetallic where necessary) shall be supplied and erected under a separate contract unless otherwise stated. The substation gantries shall provide the necessary fittings to connect the OHL conductor tension insulators and the earthwire. The conductors from the line tee off clamps to the substation equipment are included in the scope of works.

Where specified, the overhead earth wire will be extended into the substation and the substation gantry structure shall be arranged to receive this. Otherwise the earth conductor will be terminated at the overhead line terminal tower.

Where disconnectors are of the pantograph type, the contact arrangements shall cater for conditions of maximum wind loading coincident with either the maximum or minimum ambient temperature and shall conform to the requirements of IEC 62271-102.

The primary electrical connections in the substation shall be designed to withstand the combinations of atmospheric, geophysical and electromagnetic forces to which it is subjected at the particular location. The insulators, structures and equipment terminals supporting the connections shall not be subject to forces exceeding their design values and all primary connectors used for the attachment or jointing of conductors must be capable of withstanding the forces applied. The effects of short circuits shall be calculated in accordance with the requirements of IEC 60865. The contractor shall declare the combinations of forces used as the basis for design of the connections and their supporting structures.

All type testing shall be performed in line with the requirements of this Specification, in a reputable international third party (and/or witnessed by third party) laboratory certified in line with ISO / IEC Guide 25 / 17025. Accreditation certificate should be included in the Bid. Type tests should be conducted on the same type and make of the equipment, proving ratings and parameters, as required by this Contract and/or other data and information furnished by the Contractor.

2.3.2. Insulation Requirements

All external insulation shall be porcelain, of good quality, dimensionally accurate and rated to suit the application. The external creepage distance shall be based on 31mm/kV of highest phase-to-phase system voltage and the design shall comply with the recommendations of IEC 60815.

2.3.3. Movement of Conductors

The design of the substation shall ensure that the clearances specified are maintained under all conditions of movement of conductors due to wind, short circuit or other external influences. Where necessary additional insulated supports shall be provided to control movement but their influence on substation availability and reliability must be evaluated.

2.3.4. Application of Horizontal Clearance

Wherever possible the appropriate vertical design clearance shall be applied in all directions. In any design where this practice has not been followed, the application of horizontal clearance is to be identified on the drawings submitted for approval.

2.3.5. Conductors Entering the Substation

Where un-insulated conductors cross the substation perimeter fence or wall, care shall be taken to ensure that statutory clearances are not infringed and that care is taken to maintain clearances to street lighting furniture adjacent to the line entry.

2.3.6. Substation Equipment Adjacent to the Perimeter Fence or Wall

Safety working clearance shall be maintained between high voltage equipment and the substation fence (wall).

2.3.7. Insulators and Fittings

The design shall be such that stresses due to expansion and contraction in any part of the insulator shall not lead to the development of defects. Hollow insulators shall comply with IEC 62155 and CENELEC document EN 50062.

Insulating material shall not engage directly with hard metal. Where cement is used as fixing medium, cement thicknesses shall be as small and even as possible and proper care shall be taken to centre and locate the individual parts during cementing.

Each insulator shall be legibly and indelibly marked as required by the appropriate IEC together with such other marks as may assist in the representative selection of batches for the purpose of type tests. For glass insulators these marks may be applied by sand blasting. Marking of ceramic insulation by indentations will not be accepted.

2.3.8. Suspension and Tension insulators

Disc insulators may be of ceramic material or toughened glass, and together with their metal fittings shall comply with the requirements of IEC 60383. Their mechanical characteristics and dimensions shall comply with IEC 60305, whilst the ball and socket couplings, retaining pins and locking devices shall comply with IEC 60120 and IEC 60372. The locking pins shall be of phosphor bronze.

The locking devices shall be formed such that when they are set only extreme deformation of the retaining pin or locking device will allow separation of the insulator units or fittings or cause any risk of the retaining pins or locking devices being accidentally displaced. Their design shall allow easy removal or replacement of the insulator units or fittings. When in position the retaining pins or locking devices shall be independent of the degree of opening applied to the retaining pin or locking device after insertion. A common design of retaining pin or locking device shall be used for each complete insulator set.

All ball and socket joints of insulator sets shall be lightly coated with grease.

2.3.9. Busbars, Connections and Structures

The system of conductors connecting high voltage equipment, including supports, structures, insulators and the high voltage equipment itself shall be designed to withstand the maximum force that may be applied to it during its lifetime.

The design of busbars, connections and structures shall be generally as set out in BS 7354: 1990 Section 3, with parameter values appropriate for the KETRACO system. Alternative methods for the design of busbars connections and structures will be considered by KETRACO where it can be shown that such methods offer a technically compliant design. In all cases, supporting calculations must be provided.

2.3.10. Movement of Vehicles

The design of the substation shall permit the safe movement of vehicles up to 2.4 metres high, within the substation on designated routes. Lockable height barriers shall be installed at all entrances to the substation to prevent uncontrolled access of vehicles exceeding the maximum allowable height.

Adequate ground bearing pressure shall be provided on all designated routes and other locations within the substation where it is necessary for vehicles to be manoeuvred, such that any underground installation is unaffected by such movements.

2.3.11. Earthing of Substation Conductors

Sufficient facilities, designed to permit the application of fixed or fully rated portable earthing devices for the safe maintenance of substation equipment shall be provided. The existing earthing principles shall be applied for the extensions and modifications.

The application of portable earthing equipment shall be considered and where a conductor configuration, angle of approach or size prevents the direct application of a portable earth clamp, a supplementary connection facility shall be provided. Provision shall also be made for the connection of the earth end of the portable earth at each location noting that several leads may be required to achieve a fully rated connection.

2.4. Bay Control Room

For the housing of the diameter's protection, control, metering and fault recorder cubicles, bay control room (BCR) shall be foreseen in-between the diameters. Each BCR use shall accommodate the cubicles for one diameter. The final size and layout of each BCR is depending on the number of cubicles installed in that BCR. A possible location of the BCRs in the switchyard is shown in the layout and section drawings attached with the tender. The substation control building will house all the superior control, protection, metering and fault recorder equipment. From the cubicles in the BCRs to the superordinate equipment in the substation control building fibre optic cables will run. The fibre optic cables shall be properly protected against physical damage and rodents. For that reason, outside of the BCR and control building they shall be installed in suitable galvanised iron heavy duty conduits. Inside of control building and BCR they may also run in suitable cable ducts. In any case fibre optic cables shall be strictly segregated from the power and control cables. The BCRs shall be equipped with raised floor to house the power, control and signal cabling. To reduce the number and cross-section of cables for the AC

and DC power distribution, AC and DC sub-distribution boards shall be installed in the Bay Control Rooms. These sub-distribution boards shall have redundant supply (with automatic switch-over) from the main distribution boards, which are located in the substation control building.

2.5. Testing and Inspection

All type testing shall be performed in line with the requirements of this Specification, in a reputable international third party (and/or witnessed by third party) laboratory certified in line with ISO / IEC Guide 25 / 17025. Accreditation certificate should be included in the Bid. Type tests should be conducted on the same type and make of the equipment, proving ratings and parameters, as required by this Contract and/or other data and information furnished by the Contractor.

2.5.1. Busbar Conductor and Connections

The busbars shall preferably be from standard aluminium conductors in accordance with IEC 60209, supported on porcelain insulators. They shall be suitable for maximum specified short circuit fault rating and for satisfactory continuous operation at the site ambient temperature of +40°C. The busbars shall be arranged so that each busbar can be independently isolated for maintenance.

Satisfactory test evidence to IEC 62271-100 and IEC 62271-1, shall be submitted to confirm the performance of the equipment at all site conditions.

2.5.2. Post Insulators

Where applicable, each type of post insulator being provided shall be type, sample and routine tested in accordance with IEC 60168, IEC 60660 and the following supplementary tests:

2.5.2.1. Radio Influence Voltage Type Test

Each type of post insulator being provided shall be assembled as in service and subjected to radio influence voltage test in accordance with NEMA Publication 107, IEC 60060 and IEC 60437.

2.5.3. Insulator Strings

Where applicable, type and routine tests on insulators of the string type, porcelain or glass, shall be made in accordance with the requirements of IEC 60383 and IEC 60815 and the supplementary type tests stated below.

2.5.3.1. Dielectric Tests

The 50 per cent flashover level as well as withstand shall be determined during the impulse and power frequency tests.

2.5.3.2. Radio Influence Voltage Test

Each type of string insulator shall be assembled as in service and subjected to radio influence voltage tests in accordance with NEMA 107, IEC 60060, IEC 60437 and this Specification.

2.5.4. Large Hollow Porcelains

Where applicable, each type of large hollow porcelain being supplied shall be subjected to the routine and sample tests specified in IEC 62155, modified and supplemented as follows:

2.5.4.1. Routine Pressure Test

Each hollow porcelain being provided shall be subjected to the appropriate routine hydraulic pressure tests in accordance with the requirements of this Specification. The test shall be made on the porcelain complete with irremovable metallic flanges.

2.5.4.2. Temperature Cycle Test

These tests shall be made on the porcelain complete with all irremovable fittings.

2.5.4.3. Routine Bending Test

If the stress expected on the porcelain in service exceeds 20% of the minimum failing load then the following routine test shall be made: -

Each porcelain shall be subjected to a cantilever bending test such that the insulator is fully stressed in all directions, but in the event of a point loading procedure being adopted and the number of points at which the load is applied shall be a minimum of four. The applied bending moment, arrangement for test, and test procedure shall be to the approval of KETRACO.

2.5.4.4. Sample Bending Test

When the porcelain service stress is less than 20 per cent of the minimum failing load then sample bending tests shall be made as specified. Samples shall be selected as specified in IEC 62155.

2.5.4.5. Ultrasonic Tests

Routine tests shall be made on each porcelain insulator being supplied using ultrasonic crack detection techniques. These tests shall be made on the insulator prior to the fitting of metallic flanges.

2.5.5. Structures

Where applicable, a representative sample of each type of support structure being provided shall be assembled prior to despatch to site, and loads applied which simulate the specified design parameters.

Such loads shall be withstood without deformation of any structure member.

2.5.6. Site Tests

After the plant and ancillary equipment have been erected and connected up on site, the Contractor shall carry out to the satisfaction of KETRACO such tests as may be required to prove compliance with the specification, independently of any tests carried out at the manufacturers' works.

Not less than thirteen weeks before any section of the plant is required to enter commercial service, the Contractor shall submit, for the approval of KETRACO, his detailed site test proposals for that section of the plant, together with details of the test equipment and methods that he proposes to use. Subject to approval of the tests, these will be written by KETRACO into an overall programme of tests, which will be issued to all directly concerned prior to the starting date for the tests.

KETRACO shall have the right to witness all tests, and the results must be available to them as the tests proceed. They may recommend waiving of some tests, or may add further tests if considered necessary to prove compliance with the Specification.

Clear records of all tests necessary before the plant can be regarded as ready to be first connected to KETRACO's system shall be maintained by the Contractor and submitted to KETRACO in duplicate. KETRACO requires this information before the plant will be accepted for initial energising.

Initial energising and all subsequent 'live' tests will be directed by KETRACO, and carried out jointly by KETRACO and the Contractor. They will be subject to KETRACO's standard safety procedures, and all operational switching will be carried out by KETRACO according to a detailed programme, which KETRACO will prepare and which will be agreed in advance between both parties.

During these 'live' tests the Contractor shall remain responsible for the performance of his plant. A record of the results of the tests in this category will be made available to KETRACO.

The Contractor shall submit to KETRACO for approval a list of recommended settings for all protection and other types of automatic equipment, not less than thirteen weeks before such equipment is required in commercial service. Where the settings involve discrimination with settings of an existing network or plant supplied under a separate contract, the relevant information will be supplied to the Contractor.

The following is a list of minimum site test requirements for HV power cables, LV power and multicore cables and protection equipment. Further test requirements are specified in the respective chapters.

The programme for system tests will be issued by KETRACO.

2.5.6.1. Tests

For site tests, the following shall be performed in particular:

- Voltage drop tests during commissioning.
- CT polarity check

- Humidity tests of SF₆ gas during commissioning, three months after that, before issuance of FAC, and at each refill operation. Critical dew points are subject to the approval of KETRACO.
- RFI discharge test on complete substation by means of a UHF detection.
- Power frequency voltage test for switchgear and auxiliary circuits. In case of a breakdown, the above-mentioned site tests shall be repeated from the beginning.
- Checks on motors, operating mechanism, closing and tripping devices.
- Time measurement for Circuit breakers; spring charging devices, isolators and earth switches.
- Tests on current transformers and voltage transformers
- Tests on surge arrestors and bushings
- Power transformer tests & shunt reactor tests
- Any other tests as required by KETRACO.

For the above, all test results and calculations evidencing the ratings under site conditions have to be submitted for approval to the satisfaction of KETRACO.

The Contractor shall prove that the HV circuit breakers are capable of interrupting

- The capacitive current, to IEC 62271-100 and
- The inductive currents for switching shunt reactors to IEC 62271-110 under site conditions.

Test evidence shall be submitted to confirm that the highest overvoltage during any switching duty does not exceed 2.5 p.u., by either performing the relevant tests or by submitting the relevant type test reports to the satisfaction of KETRACO.

The Contractor shall furthermore advise and guarantee the minimum number of switching operations for the conditions as mentioned above within the arrangement as designed by him.

2.5.7. Documentation with Bid

The Bid shall contain at least the following information and documents, failure of provision of the mentioned documents will lead to disqualification:

- a. General layout drawings of the substations;
- b. Single line diagrams of the substations;
- c. General arrangement drawings of switchyards;
- d. Manufacturing specification of the main equipment and duly signed schedules of Technical Information;
- e. Catalogues, literature, reference lists of all proposed equipment, sufficiently detailed in such a way that the Employer/ Employer's Representative may have full and complete knowledge of the Plant and equipment offered.
- f. Type test certificates from an independent testing authority or independently witnessed;

- g. Quality Management System Manual and ISO Certificate of the equipment manufacturer.
- h. Verified bid drawings (General SLD, Layout, SLD of LV Supply Systems, PSD, SAS, Telecommunication, Civil and Transmission Line);
- i. List of major components of equal or similar design, size, and/or capacity indicating:
 - Location, Title of the project, Total Contract Price. Time for completion
 - Size, number and major parameter of units supplied;
 - Name and address of the Client including contact person and country;
 - Date of contract award & date of commissioning;
 - Client's letter expressing opinion of the work done.
- j. Experience list for any proposed major sub-contractor in particular civil sub-contractor, if any, indicating his experience in major capital projects of this nature and the high quality of workmanship required.
- k. Major sub-suppliers or sub-contractors
- l. Statement of the Bidder's financial standing (audited statement for last 3 years) including the name and address of his banks and the authorization of Employer to approach Tenderer's bankers for relevant information and comments and audited reports for the last three years.
- m. Project Schedule (Milestones & Gates)
- n. HSE Plan
- o. Risk Register
- p. A detailed program of design, manufacture, shipping, erection, testing & commissioning and the civil works
- q. Methodology and execution plan for completion of construction works within project schedule and put into commercial operation excluding a period for mobilization for each substation.
- r. Additional documents as requested in clause 2.5.1.

2.5.8. Additional Documents to be submitted with the Tender

In addition to the Tender Documents issued for tendering, it is mandatory for the Bidder to provide and properly bind in the Prime Document; the following additional documents shall be submitted in addition.

- a. A copy of each Circular Letter and Addendum, if any, issued by the Internal Tender Committee of Client, appropriately endorsed by the Bidder.
- b. A statement giving the name(s) of the person(s) authorized to sign Agreements on behalf of the Bidder including his (their) specimen signature(s).
- c. The proposed Organization Chart, giving details, numbers and categories of the supervisory and technical staff, their qualifications, previous appointments and experience, together with Curriculum Vitae of the supervisory and technical staff and the estimated labor force to be employed in the Works.
- d. CVs for the Key staff proposed for this project. Also bidder shall submit the current assignments of the proposed key staff associated and status of the project. Moreover, bidder shall declare the proposed key staff will be available for this contract in the event of award.

Bidder must submit with his tender a list of all local and expatriate employees employed in the Company. Giving the name of the employee, job category, and unit rate per month (monthly salary) in the prescribed

forms included in the Bidder's Enclosures. Bidder engaging a high proportion of local employees shall be given preferential consideration.

- e. A list of all major works which the Bidder has completed within the past five years and of all works which are presently under construction, giving the name of the Client, Consultant, location, value, duration and date of completion.
- f. A list of any proposed sub-contractor and suppliers, including local firms, with particulars of the extent of the work, which it is proposed will be undertaken by them.
- g. A statement signifying that a Site inspection has been made and that the Bidder has no doubts or queries regarding the site, ground conditions, access, permits, or permission required concerning the Contract (if site visit to be mandatory in the tender).
- h. A tender Bond as per Part-1, Section II-Bid Data Sheet in ITB 19-1, 20-1 and Form of Bid Security, obtained from a locally registered insurance Company or Bank.
- i. A list of manufacturer's recommended spare parts and special tools giving description, numbers and unit price as required by Specification and Bill of Quantities.
- j. A statement of unresolved doubts regarding the meaning of anything contained within the Tender Documents and the interpretation relied upon by the Bidder.
- k. A statement confirming that the Bidder is fully aware of Kenya Standards and KETRACO's HSE Policy & Procedures.

2.2. Documentation after Award of Contract

All documents required for KETRACO's approval shall be submitted by the Contractor.

3. Open Terminal Switchgear

3.1. General

External parts of the switchgear shall be of porcelain and their profile shed shall be suitable for the worst site conditions.

The switchgear shall be suitable for satisfactory continuous operation at the specified minimum rating, at the maximum site ambient temperature of +40°C, 24 hours a day, 365 days of the year. Satisfactory test evidence shall be submitted to confirm the performance of the equipment at all site conditions.

The switchgear shall be fully type-tested in accordance with IEC 62271-100 and IEC 62271-1. All type tests shall be either carried out by independent testing laboratories not associated with the manufacturers or witnessed by KETRACO Observers. Type-test certificates shall be submitted for approval by KETRACO.

3.2. Circuit Breakers and Operating Mechanisms

3.2.1. Circuit Breakers

The AIS-open terminal SF₆ gas insulated circuit breakers shall be the single-pressure puffer or self-blast or self-blast/rotating arc type, suitable for outdoor installation. They shall be of modern design, reliable and fit for purpose. Pre-insertion resistors to be provided if found necessary as result of the insulation coordination studies that are to be provided.

The circuit breakers shall be designed and fully type tested in accordance with IEC 62271-100, IEC 62271-1, IEC 62271-101, IEC 62271-110, IEC 60270, IEC 60480, IEC 60691 and IEC 60815 and with the requirements of this Specification and shall be suitable for minimum continuous current at an ambient temperature of +40° C.

External parts of the circuit breakers which are under continuous electrical stress shall be of porcelain. The type and the profile of the porcelain insulator shed shall be suitable for the worst environmental conditions specified in the schedules. The creepage and flashover distances of the insulators shall be dimensioned to suit the outdoor service conditions specified in the Schedules.

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 maximum pole scatter during makes shall be less than 3.3ms and during opening shall be less than 3ms.

The inherent 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. The inherent design of these circuit breakers shall be that when switching capacitive (capacitor banks) and inductive (including reactors) currents, they produce very low over voltages. The over voltages produced on any switching duty must be considerably less than (\ll) 2.5p.u.

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

A suitably quantity of 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.

Circuit breakers shall be single-pole SF₆ gas insulated design, suitable for high-speed single phase or three-pole auto-reclose operations. The circuit breakers shall be supplied with a single-pole re-close facility and be equipped with duplicate trip coils. The circuit breakers shall be capable of parallel tripping, when installed in the breaker and a half configuration, without delaying the tripping of either breaker. Circuit breakers shall be electrically and mechanically trip free with either or both of the duplicate trip circuits connected.

The circuit breaker shall be fitted with the open/closed position indicator easily visible from ground level.

The 400kV circuit breakers shall equipped with Point on Wave Switch (POW) to open or close breakers at a pre-determined point on the voltage waveform.

A lock out and tripping feature shall be incorporated to prevent operation of the circuit breaker whenever the gas pressure falls to a value below, which it would be incapable of performing in accordance with its rated duty. Gas monitors shall be temperature compensated.

An alarm feature shall also be incorporated to give an indication of falling gas pressure prior to lockout of the circuit breaker. The rate of gas leakage per annum shall be guaranteed and shall not be greater than 1% for any compartment. The system of gas monitoring shall be temperature compensated and shall be to the approval of KETRACO.

The 400kV circuit breakers shall equipped with online monitoring (OLM) system. The OLM system shall monitor following data (but not limited to):

- Internal temperature
- Power supply voltage and current
- Coil circuit and operating currents
- Motor circuit, operation current and time
- Operating times
- Time between operations
- Monitoring equipment functions (watchdog)

The OLM system shall monitor following functions (but not limited to):

- Status signals (circuit-breaker open or closed)

- Closing operation
- Opening operation
- Close-open operation
- Motor operation

The following parameters should be derived and supervised from the function categories:

- Operating times
- Operating speeds
- Coil armature time
- Coil peak current
- Damping time
- Over travel and rebound
- Counters recording the number of operations and number of motor operations;
- Motor peak current and spring charging time;
- Internal temperature of the operating mechanism;
- Ambient temperature;
- Power supply voltages and currents (OLM and heaters);
- SF6 density, with trend analysis;
- Contact wear (optional);
- Contact stroke and contact position.

OLM of Circuit breaker shall be designed as per working conditions and installation environment prevailing across KENYA. It shall be suitable to work up to ambient temperature of +50°C and RH 95%;

Circuit breaker monitoring system shall provide continuous on line monitoring of the CB by integrating the sensors at the CB and it shall be able to communicate with the central OLM system through the substation OLM data concentrator or otherwise. It shall be able to communicate with available communication protocols at KETRACO and IEC 61850. Contractor shall integrate the same to the KETRACO OLM system.

The software should be delivered with the OLM and it contains a feature for automatic update of the software.

Bidder shall submit specifications / technical details of FO cables, Coaxial cables, fiber optic cables, computers, OLM software, printer and MODEM etc. for approval during detailed engineering stage.

3.2.2. Gas Monitoring and Handling

All circuit breakers shall be filled to the design pressure with Technical Grade SF₆ gas to IEC 60376.

Facilities shall be provided in the gas system for constantly monitoring the gas density. A two-stage low pressure alarm and 'block-trip' system with local and remote indications shall be provided on each circuit breaker in fail-safe-mode. The low pressure/density alarm switches shall instantly provide an indication to the operator, 'block-trip' the circuit breaker and subsequently inhibit their further operation until suitable remedial action has been taken. The local control cubicle shall be adequately labelled to allow easy identification of alarms/indications.

In view of the dependence of system security on the reliability of the SF₆ gas-density relays, the gas density relays 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 circuit breaker shall be checked and handled in accordance with IEC 60480.

3.2.3. Gas Handling Equipment

The mobile gas handling plant for filling, evacuating, and processing the SF₆ gas in the switchgear, to be supplied as part of the Contract to enable any maintenance work to be carried out and shall be as specified in the schedules. The gas handling plant 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 switchgear.

The plants provided 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 a circuit breaker can be evacuated in less than half one hour.

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

It shall be capable of operating satisfactorily to a maximum temperature of +50°C.

3.2.4. 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.

3.2.5. Circuit Breaker Operating Mechanisms

3.2.5.1. General

The circuit breakers shall preferably be fitted with power-spring mechanism but other types of reliable mechanisms such as leak-free hydraulic, spring/hydraulic, and spring/SF₆ gas will also be considered, provided they comply with the above circuit breaker mechanical operations requirement. 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. A pneumatic mechanism is not acceptable.

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. Circuit breakers may be subject to several single shot auto-reclose duty cycles in quick succession upon the occurrence of multiple faults coupled with short reclaim timer settings. 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. The circuit breakers shall be suitable for single phase auto reclose.

Mechanical counters, to record the number of closing operations, shall be provided for each circuit breaker mechanism. Circuit breakers arranged for single-pole operation shall be provided with a counter for each pole. 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 energised or to reclosing 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: -

- a. LOCAL/REMOTE selector switch. The selection of 'local' operation shall inhibit the operation of the breaker from any remote source including the protection scheme.
- b. OPEN/NEUTRAL/CLOSE control switch or open and close push buttons. Where push button controls are provided the selector switch shall have a neutral position.
- c. 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 against 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.

3.2.5.2. Point On Wave Switching relay

Point On Wave Switching relay (or POW relay) that is also known as switching control relay shall be applied to control switching of 400kV circuit breakers for elimination of harmful electrical transients. The contractor shall submit the switching transient study for each line for consultant approval, if it's requested by client. These studies shall be done under manufacturer supervision and if it is necessary, control relay shall be applied for transmission lines.

Controlled energizing and de-energizing of overhead lines shall be considered to minimize the switching transients. Suitable switching control relay shall be considered depending on shunt reactor compensated or uncompensated transmission lines.

Circuit breaker which is selected to apply POW switching relay, shall have stable operating time, which vary only to a limited extent with factors such as ambient temperature and control voltage. The circuit breakers also shall have high and stable dynamic dielectric withstand capability between the contacts, upon making and breaking operations.

Also circuit breakers should have suitable rate of decrease of dielectric strength for closing and rate of rise of dielectric strength for opening.

Closing or opening commands to the circuit breaker shall be adjusted in such a way which making or contact separation shall occur at the optimum time instant related to the phase angle. Therefore by means of switching control relays, both energizing and de-energizing operations shall be controlled with regard to the point-on-wave position, and no harmful transients shall be generated.

Separate output commands shall be given to each pole when a single-pole operated circuit breaker is controlled.

The relay shall be capable of measuring the voltage of both sides of the circuit breaker via voltage transformers.

The reference and control voltage shall be supplied from suitable voltage transformer winding (protection core of current transformer) according to tender drawings.

All switching control relays shall be fully frequency adaptive and shall be designed to work for system frequencies at least between 45 and 55 Hz.

Controller shall have provisions for adaptive input to compensate systematic variations in operating time of the circuit breaker.

Additional predictive compensation sensor inputs e.g. ambient temperature and circuit breaker's control voltage variation shall be considered.

According to high voltage switchgear arrangements of substation, suitable switching control solutions shall be considered and controller arrangements for attaining proper function shall be prepared. In multi circuit Breaker schemes (breaker-and-half, ring arrangement, etc.), special design of control circuits and more than one controller per circuit breaker shall be supplied, as required.

Controller also shall have a data memory that stores information on switching times for condition monitoring of the circuit breaker. For controlled opening (or closing), the contact separation (or touch) instant shall be supervised (and corrected accordingly in the next operation) by detection of voltage onset instant(s), current start

instant(s) or circuit breaker precise auxiliary contacts position in the main circuit. it should be noted that, in later condition, only using precise auxiliary contacts position is acceptable. Adaptation control shall adjust the internally created waiting time when needed.

POW Switching relay shall be coordinated with related circuit breaker characteristics by the circuit breaker's manufacturer. The mechanical operating time and pre-arcing behaviour of circuit breaker settings shall be considered in controller.

Controller shall be equipped with heavy duty and high speed close/open power outputs.

Test, configuration, setting and commissioning of the switch control relay at site shall be done by the contractor under manufacturer supervision.

In substation control and protection circuits, one selector switch in related protection panel for by pass the switch control relay shall be considered.

It is important to arrange all fault tripping commands to by-pass the controller.

In installing trip and close circuit supervision, the POW switching relay shall be considered.

These controllers shall have sufficient facilities for remote communication.

3.2.5.3. Spring Mechanisms

Provision should 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.

- a) 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. A local manual spring release device shall be provided and arranged to prevent inadvertent operations. Provisions shall be made to prevent an operation of the breaker when the springs are in the partially charged condition.
- b) Means shall be provided for hand charging the operating springs and moving direction of handle shall be clearly marked.

3.2.5.4. Hydraulic, Spring/Hydraulic, and Spring/SF6 Mechanisms

Hydraulic and SF₆ gas mechanism shall be leak-free. The hydraulic and SF₆ gas 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.

The SF6 gas should be completely comply with these Standard:

- a) The SF6 gas shall comply with IEC 60376, 60376A and 60376B and shall be suitable in all respects for use in the switchgear` under the operating conditions.
- b) The high-pressure cylinders in which the SF6 gas is shipped and stored at site shall comply with requirements of the relevant standards and regulations
- c) Test: SF6 gas shall be tested for purity, dew point, air, hydrolysable fluorides and water content as per IEC 60376, 60376A and 60376B and test certificates shall be furnished to Employer indicating all the tests as per IEC 60376. Gas bottles should be tested for leakage during receipt at site.

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: -

- a. Trip lockout pressure.
- b. Close lockout pressure.
- c. Auto-reclose lockout pressure.

Alarm contacts shall be provided to indicate conditions a, b and c. 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 running time meter shall be fitted and an alarm shall be provided to indicate excessive running time.

3.2.5.5. Mechanism Housings

Where heaters are provided, these shall be permanently connected. Where two-stage heaters are provided, one stage shall be permanently connected and the other switched.

Means for locking shall be provided for the doors of each mechanism-housing.

Mechanism housings for use outdoors shall have a minimum IP rating of 54.

3.3. Disconnectors and Earth Switches

3.3.1. Disconnectors

The disconnectors shall be constructed and fully type tested in accordance with the requirements of IEC 62271-102 and this Specification. The design shall incorporate features which shall reduce or eliminate very high frequency voltage transients during disconnector operation.

It is preferred that disconnector contacts can be maintained and replaced with the associated earthing switch closed.

The disconnectors shall be provided with power and manually operated mechanisms. The power operation of the disconnectors shall be capable of being controlled from a local or remote point.

Each power-operated disconnector shall be complete with a lockable LOCAL/REMOTE selector switch and OPEN/NEUTRAL/CLOSE control switch or push buttons. 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 this Specification.

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. The design of the NO and NC auxiliary contacts shall allow for equipment intermediate position i.e. a state in which both NO and NC contacts do not make.

The number of the NO and NC contacts shall be as per the schedules of technical information

The auxiliary contacts shall comprise of NO, NC as well as MBB (Make before break) type auxiliary Contacts

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 power-operated disconnectors and the power drive shall be mechanically disconnected during hand operation. It is required that the manual effort to operate the disconnectors or earth switches shall be less than 150N. 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.

Operating motors shall be provided with thermal overload protection and in the case of 3 phase motors, phase unbalanced protection.

All operational interlocks shall function through the electrical bolt interlock circuit. Electrical bolt interference interlocks shall be provided and energised, in the case of hand operation, only when the operating handle of the hand mechanism is brought into the working position or in the case of power operation, when the motor is called upon to operate. A means of overriding the electrical interlock, in the event of loss of auxiliary supplies, shall be provided; the override shall be lockable.

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.

The disconnect switch control circuit shall be designed such that in the event of loss of motor supply (MCB trip at equipment control cubicle, yard marshalling kiosk or DC distribution board) the Control circuit shall not be complete i.e. the open and/or close contactors not to be actuated in the event of loss of motor supply.

3.3.2. Earth Switches and Maintenance Earthing Devices

3.3.2.1. Earth Switches

Earth switches shall comply with IEC 62271-102 and the requirements of this Specification. They shall be fitted with power and manually operated mechanisms. The electrical operations shall be performed from their control cubicles. The position indicators shall be clearly visible from the permanent working platform level.

Earth switches on line circuits shall be capable of interrupting the current induced in the line by a parallel fully loaded line.

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

The earth switch control circuit shall be design such that in the event of loss of motor supply (MCB trip at equipment control cubicle, yard marshalling kiosk or DC distribution board) the Control circuit shall not be complete i.e. the open and/or close contactors not to be actuated in the event of loss of motor supply.

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. The design of the NO and NC auxiliary contacts shall allow for equipment intermediate position i.e. a state in which both NO and NC contacts do not make.

The number of the NO and NC contacts shall be as per the schedules of technical information.

The auxiliary contacts shall comprise of NO, NC as well as MBB (Make before break) type auxiliary Contacts.

Electrical operation of the earth switch shall be enabled only for equipment local level, substation control system and BCU levels. Electrical operation from NCC/RCC shall not be permitted.

3.3.2.2. 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.

3.4. Testing and Inspection

3.4.1. Principal Standards for Type and Routine Tests

All type testing shall be performed in line with the requirements of this Specification, in a reputable international third party (and/or witnessed by third party) laboratory certified in line with ISO / IEC Guide 25 / 17025. Accreditation certificate should be included in the Bid. Type tests should be conducted on the same type and make of the equipment, proving ratings and parameters, as required by this Contract and/or other data and information furnished by the Contractor.

- IEC 62271-100, IEC 62271-1, IEC 62271-207 and IEC 60270 for the switchgear and control gear.
- IEC 62271-100 plus Application Guide, IEC 62271-1, IEC 62271-101, IEC 62215, IEC 60270, IEC 60376, IEC 60691, IEC 60815, IEC 62271-110 and IEC 60480 for the circuit breakers.
- IEC 62271-102, IEC 62271-1 and IEC 62271-100 for HV Disconnectors and Earth Switches.
- IEC 60044-1, IEC 60186, IEC 62271-1, BS 7626 and IEC 60044 for current and voltage transformers.
- IEC 60376 and IEC 60480 for the SF₆ gas.
- IEC 60099-4, IEC 60099-1, IEC 60099-5, IEC 62271-1, IEC 60137 and IEC 60815 for Metal Oxide Surge Arresters and additional tests for the SF₆ encapsulated types when required.
- IEC 60137, IEC 62271-1, IEC 60120, IEC 60305, IEC 60372, IEC 60383, IEC 60383 for bushings and insulators.
- IEC 60060, IEC 60383, IEC 60305, IEC 60044-1 and others, as well as VDE standards, if applicable.

Partial discharge measurements as factory tests are obligatory and to be performed as routine tests.

3.4.2. Type tests

As a minimum, the following Type Tests shall be performed on the switchgear:

- Dielectric test 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 and peak withstand current, Short-circuit making and breaking, out-of-phase making and breaking, critical current and capacitive and inductive (reactor) current switching tests
- Mechanical endurance, environmental operation tests
- Thermal stability and Electromagnetic compatibility (EMC) tests
- Verification of the degree of protection
- Tightness and Pressure relief device tests.

3.4.3. Short circuit tests

Circuit Breaker, Disconnecter and Earth Switch shall be subjected to the Short Circuit tests in accordance with IEC 62271-100, IEC 62271-1 and in the schedule. The over voltages produced on any switching duty must be considerably less than (\ll) 2.5 p.u.

3.4.4. Dielectric tests

Circuit Breaker, Disconnecter and Earth Switch shall be subjected to the dielectric tests in accordance with IEC 62271-100, IEC 62271-1 and in the schedule. There shall be no self-restoring or non-self-restoring disruptive discharges during the fifteen positive and negative impulse test series.

3.4.5. Radio interference voltage tests

Where an external bushing is produced a radio influence voltage measurement shall be made in accordance with NEMA Publication 107. The level shall not exceed that specified in the Schedules and IEC 60137.

3.4.6. Thermal stability tests

All insulating parts of the Switchgear which uses organic material shall be subjected to a thermal stability test, the test procedure being that specified in IEC 60137.

3.4.7. Pressure relief devices

The ability of the devices to relieve pressure in the event of an internal arc shall be demonstrated in accordance with IEC 62271-203.

3.4.8. Verification of the degree of protection

Tests shall be performed on all auxiliary circuits to demonstrate that the degree of protection provided is in line with that specified in the IEC Standards.

3.4.9. Routine tests

As a minimum, the following routine tests shall be performed in accordance with their respective IEC Standards to ensure compliance with this Specification and to provide the necessary operating data:

- Dielectric test 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 circuits
- Mechanical operation tests
- Pressure tests of enclosures
- Gas tightness test
- Design and visual checks.
- 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.
- Chattering time of the arc contact of circuit breaker shall be measured and recorded at no-load operations
- Instrument transformer Core saturation test

The Contractor or his sub-Contractors shall supply to KETRACO, as soon as practicable after works tests, commissioning and site tests have been witnessed, six copies of the relevant test certificates. These shall contain details of each test performed as required by KETRACO - records, results and calculations of all electrical tests.

The subsequent section of this schedule list specific inspections, works and site tests, which KETRACO requires, but this shall not preclude KETRACO's right to call for further tests if it considers these necessary.

After the plant has passed the site tests required under this Contract and has become available for commercial operation, certain additional tests may be carried out in order to investigate the response and recovery of the system during events such as the switching of various items of plant, system faults and load rejection.

3.4.10. Site tests

As a minimum, the following tests after installation on site shall be performed in accordance with their respective IEC Standards:

- Power frequency voltage tests on the main circuits
- Partial discharge measurements and records
- Dielectric tests on auxiliary circuits
- Measurement of the resistance of the main circuits
- Gas tightness tests
- Design and visual checks
- Measurement of gas condition
- Mechanical operation tests
- Complete electrical functioning tests including the function of all interlocks.
- Instrument transformer knee voltage test

3.4.11. Circuit Breakers

3.4.11.1. Type tests

For the purpose of the following tests, the operating pressures for hydraulic operating mechanisms and SF₆ gas circuit breakers of all types shall be as follows:

1. Making and breaking current capacity type tests at minimum operating (lock-out) pressures.
2. Inductive (reactor) current interrupting type test at maximum operating pressures.
3. Capacitive current interrupting type tests at minimum operating (lock-out) pressures.

As a minimum, the following type tests shall be performed in accordance with their respective IEC Standards and cognisance of the subsequent sub-clauses shall be taken:

1. Dielectric test on main circuit - lightning impulse voltage tests, power frequency voltage withstand tests, partial discharge and radio interference voltage (r.i.v) tests
2. Dielectric test on auxiliary and control circuit

3. Temperature rise test
4. Measurement of the resistance of the main circuit
5. Short-time and peak withstand current and Short-circuit making and breaking, terminal fault, short-line fault, out-of-phase making and breaking, critical current and capacitive and inductive (reactor) current switching tests
6. Insulation co-ordination tests
7. Synthetic testing
8. Mechanical endurance, environmental operation tests
9. Thermal stability test
10. Electromagnetic compatibility (EMC) tests
11. Verification of the degree of protection
12. Tightness tests and Pressure relief device tests.

3.4.11.2. Short circuit making and breaking current tests

Each type of circuit breaker being supplied shall be short circuit tested in accordance with the requirements of IEC 62271-100, IEC 62271-1 and IEC 62271-101 and shall include the following: -

1. The type tests shall be made on the full pole [maximum number of making or breaking units in series].
2. The rate of rise and peak value of the inherent recovery voltage applicable to each test duty shall be the values specified in IEC 62271-100 or in the Schedules.
3. Prior to the commencement of any series of short circuit tests, a complete series of no-load timing tests shall be made on the circuit breaker as specified in IEC 62271-100.
4. Test duty 4 make-break [CO] test must be performed at 100 per cent make peak current (C) and symmetrical break (O) at lock-out operating pressure and include longest arc duration.
5. Test duty 5 break test (O) must be performed at 100 per cent asymmetrical break (O) at lock-out operating pressure and include minor loop break and longest arc durations.
6. Test evidence shall be provided to show that one set of contacts and nozzles are capable of successfully interrupting at least twenty times the rated short circuit current.

3.4.11.3. Breaking and making current capacity under out- of- phase conditions

Circuit breakers for operation under out-of-phase conditions shall be rated and tested in accordance with IEC 62271-100.

3.4.11.4. Short time current test

The short time current test shall be carried out in accordance with IEC 62271-100.

3.4.11.5. Capacitive current switching tests

The capacitive current switching duty specified in the Schedules the circuit breaker shall be tested in accordance with IEC 62271-100. Test evidence shall be submitted to confirm that the highest over-voltage during any switching duty does not exceed < 2.5 p.u. The relevant switching type tests shall be to the satisfaction of KETRACO.

3.4.11.6. Low inductive current switching tests

A series of switching tests shall be made to IEC 62271-110 on each type of circuit breaker being supplied in order to demonstrate its performance when switching transformer magnetising currents and reactor currents. Test evidence shall be submitted to confirm that the highest over voltage during any switching duty (including reactor) does not exceed < 2.5 p.u. The relevant switching type tests shall be to the satisfaction of KETRACO.

In addition to the above, additional, low inductive/reactor current switching test evidence of 10, 50, 100 amp currents, in accordance with IEC 62271-110 is required to confirm that the highest over voltage during any switching duty does not exceed < 2.5 p.u. These switching tests under site conditions are required for comparing the performance of different circuit breaker interrupter designs.

These tests shall preferably be made on a complete three phase or single-phase unit, at the rated SF₆ gas pressure, rated control voltage and at maximum operating conditions of the mechanism with the agreement of KETRACO.

3.4.11.7. Synthetic testing

The use of synthetic test circuits shall be in accordance with IEC 62271-101. Tests shall be performed single-phase or three-phase, with maximum arc durations at lockout operating pressures. Test duties with failure in the middle of arcing window shall not be acceptable.

3.4.11.8. Short line fault tests

Each type of circuit breaker shall have satisfactory proven capability of interrupting short-line-faults [SLF90, SLF 75 and SLF 60] to IEC 62271-100.

3.4.11.9. Auto-reclosing tests

When a circuit breaker is intended for auto-reclosing duties, the following supplementary tests shall be made:

- O-t-CO duty cycle at 10% rating and O-t-CO duty cycle at 100% rating

The time interval 't' shall be that specified in IEC 62271-100 and the Schedules for delayed and high speed auto-reclosure.

The TRV shall be as specified in IEC 62271-100. The operating pressure shall be the lockout / 'block-trip' value appropriate to the above duty cycle.

3.4.11.10. Dielectric tests

Each type of circuit breaker being provided shall be assembled complete as in service and subjected to the dielectric type tests specified in IEC 62271-100, IEC 60060 and IEC 62271-1 and in the Schedules and there shall be no self-restoring or non-self-restoring disruptive discharges during the fifteen positive and fifteen negative impulse test series.

3.4.11.11. Insulation co-ordination

Insulation coordination tests on circuit breaker shall be performed in accordance with IEC 60071-1, IEC 60071-2, IEC 60691 and IEC 60815.

3.4.11.12. Radio influence voltage and partial discharge tests

Where applicable, circuit breakers shall be subjected to RIV and PD type tests in accordance with and IEC 62271-1 and the values obtained shall not exceed the value guaranteed in the Schedules.

Test reports covering RIV and PD tests shall give full details of temperature, barometric pressure, humidity and correction factor applied as well as the test values obtained.

3.4.11.13. Mechanical endurance type tests

Mechanical endurance type tests shall be carried to demonstrate that the mechanism fitted to the circuit breaker is suitable for 10,000 satisfactory mechanical operations in accordance with IEC 62271-100.

3.4.11.14. Type test certificate

All type test certificates must stand on the test evidence alone and not require interpretations. It shall include relevant calibration, detailed drawings, construction, necessary dimensions and details of material etc. The contractor or sub-contractor shall supply to KETRACO two complete sets of the type test certificates.

3.4.11.15. Routine tests on works assembled circuit breakers

Each circuit breaker shall be assembled completed with its mechanism box, auxiliary switches and subjected to the routine tests in accordance with IEC 62271-100

and IEC 62271-1 It shall be noted that at least one local control cubicle (LCC) will have to be tested together with the circuit breaker during the factory acceptance tests.

As a minimum, the following routine tests shall be performed and cognisance of the subsequent sub-clauses shall be taken:

1. Dielectric test on main circuit - power frequency voltage withstand tests

2. Voltage withstand tests on auxiliary and control circuits
3. Measurement of the resistance of the main circuits
4. Mechanical operation tests.

3.4.11.16. Site tests

As a minimum, the following tests after installation on site shall be performed:

1. Inspection of general condition
2. Mechanical operation tests
3. Timing tests of the main contacts and auxiliary switches
4. Complete electrical functioning tests
5. Closing and opening check at reduced voltage
6. Contact resistance measurements.

3.4.12. Disconnectors and Earthing Switches

Each type of disconnector and earthing switch being provided shall be subjected strictly to the Type and Routine tests specified in IEC 62271-102, IEC 62271-1 and shall comply fully with the following supplementary type and routine tests.

3.4.12.1. Type tests

In order to demonstrate the insulation co-ordination of the disconnection the critical flashover levels to earth and across the open gap shall be determined in accordance with IEC 60071-102 and IEC 62271-1. The 'up and down' method described in IEC 60060 shall be used for these tests.

As a minimum, the following type tests shall be performed:

1. Dielectric test on main circuit - lightning impulse voltage tests, power frequency voltage withstand tests, partial discharge and radio interference voltage (r.i.v) tests and Dielectric test on auxiliary and control circuit
2. Temperature rise test
3. Measurement of the resistance of the main circuit
4. Short-time and peak withstand current tests and Short-circuit making performance of earthing switches
5. Bus transfer current switching capability tests (If applicable)
6. Insulation co-ordination tests

7. Mechanical endurance, environmental operation tests.

3.4.12.2. Routine tests

Routine tests on the Disconnecter and earthing switch shall be in accordance with IEC 62271-102, IEC 62271-1.

As a minimum, the following routine tests shall be performed:

1. Dielectric test on main circuit - power frequency voltage withstand tests on disconnecter and auxiliary and control circuits
2. Measurement of the resistance of the main circuits
3. Mechanical operation tests.

3.4.12.3. Site tests

As a minimum, the following tests after installation on site shall be performed:

1. Inspection of general condition
2. Operation timing tests
3. Manual and electromechanical closing and opening tests
4. Complete electrical functioning tests including the function of all interlocks
5. Closing and opening tests at reduced voltage.

3.4.12.4. Sulphur Hexafluoride

Samples of SF₆ from each consignment shall be tested and shall comply with the tests specified in IEC 60376 and IEC 60480, before any SF₆ gas is despatched.

Use and handling of SF₆ shall be in accordance with IEC 62271-303

3.5. Special Tools and Equipment

One complete set each of special tools in new condition as needed for operation, maintenance and repairs as well as for changing out components of substations and overhead lines and for storing dismantled parts shall be included in the delivery

- all standard accessories and auxiliary equipment normally belonging to the supplied items or that are required for commissioning of components
- servicing aids for protection systems as required for analysis, configuration and parameterization (hardware and software).

3.6. Spare Parts

The recommended spare parts shall comply with the requirements stated in the relevant Schedules of Technical Information and this Specification and shall be stated in the price schedules.

4. Current Transformers

4.1. Ratings

The current transformers shall be designed and tested in accordance with the requirements of IEC 62271-1 and IEC 61869-1/-2 and any additional requirements of this Specification.

The required quantities, locations, sequence, ratio, rating and class of the current transformers are a function of the circuit application. The requirements for each application are included in the Schedules of Technical Information and bid drawings.

Current transformers shall be of outdoor, oil immersed multi core hermetically sealed type.

The following facilities shall be provided for each current transformer: -

- Visual means of determining the level of oil from the ground level with the transformers; this shall be by means of an internal bellows type oil gauge.
- Oil drain cock and sampling device.
- Earth terminal of adequate dimensions so arranged that the earth connection cannot be inadvertently removed.

If not otherwise stated, the rated extended primary current is 120% of the rated primary current.

Rated output of measuring cores shall be chosen from preferred standard values in such a manner that secondary burden is between 25% and 100% of the rated burden. Preliminary values of rated output for bidding purposes are indicated in the Technical Data Sheets. During design stage the contractor needs to confirm these values by calculation.

Each current transformer secondary winding circuit shall be earthed at only one point. Wherever possible the connection to earth shall be at S2 terminals. Current transformers shall have a secondary terminal, outside the high voltage housing, mounted in suitable accessible, earthed boxes. All secondary leads must be wired to shorting type terminals on the terminal strip in the local control cubicle.

Current transformer secondary shorting and disconnecting links shall be provided in a position secure but readily accessible position for testing purposes.

The static withstand load shall be selected from either load class I or II of IEC 61869-1, based on an assessment of the possible loads under local site conditions.

Changing/selection of current transformer ratio shall be possible only through the secondary circuit. This shall not be implemented at the primary terminal.

4.2. Current Transformers for Tariff Metering

Tariff Metering shall be provided on all overhead lines.

Separate sets of 3-phase CT cores shall be provided, one set for the Main Meter and one set for the Check Meter.

CT cores shall be class 0.2s conforming to IEC 61869-2 and have a minimum burden of 5VA. Preliminary values of rated output for bidding purposes are indicated in the Technical Data Sheets. CT dimensioning calculation shall be provided to demonstrate the supplied burden is adequate and will operate within the accuracy parameters defined in IEC 61869-2.

The secondary current shall be 1A.

Wiring terminations shall be provided with integral earthing, isolation and shorting links to facilitate maintenance and testing.

4.3. Special Tools and Equipment

One complete set each of special tools in new condition as needed for operation, maintenance and repairs as well as for changing out components of substations and overhead lines and for storing dismantled parts shall be included in the delivery

- all standard accessories and auxiliary equipment normally belonging to the supplied items or that are required for commissioning of components
- servicing aids for protection systems as required for analysis, configuration and parameterization (hardware and software).

4.4. Spare Parts

The recommended spare parts shall comply with the requirements stated in the relevant Schedules of Technical Information and this Specification and shall be stated in the price schedules.

4.5. Type tests

In order to demonstrate that all transformers made to the same specification comply with the requirements, the type tests in accordance with IEC 61869-1/-2 shall be performed.

As a minimum, the following type tests shall be performed:

- Short time current tests
- Temperature rise tests
- Lightning impulse test
- Switching impulse test

- Wet test for outdoor type of transformer
- Determination of errors

4.6. Routine tests

Routine tests on the current transformers shall be in accordance with IEC 61869-1/-2.

As a minimum, the following routine tests shall be performed:

- Verification of terminal marking
- Power frequency withstand test on primary winding
- Partial discharge measurement
- Power frequency withstand test on secondary winding
- Inter-turn overvoltage test
- Determination of errors

4.7. Site tests

As a minimum, the following tests after installation on site shall be performed in accordance with their respective IEC Standards:

- Inspection of general condition (supporting structure, secondary wiring, earthing, primary connection, oil level & leakage test etc)
- Primary test - Ratio test with primary injection
- Secondary injection & excitation curves of CT for each core
- Winding resistance measurement for each core
- Isolation (Megger test) with applied voltage of 1000V dc
- Polarity check
- CT loop resistance measurement

5. Capacitive Voltage transformers

5.1. Ratings

The capacitive voltage transformers shall be designed and tested in accordance with the requirements of IEC 62271-1 and IEC 61869-1/-5 and any additional requirements of this Specification.

The required quantities, locations, sequence, ratio, rating and class of the voltage transformers are a function of the circuit application. The requirements for each application are included in the Schedules of Technical Information and bid drawings.

Rated output shall be chosen from preferred standard values in such a manner that the secondary burden is between 25% and 100% of the rated burden. Preliminary values of rated output for bidding purposes are indicated in the Technical Data Sheets. During design stage the contractor needs to confirm these values by calculation.

The secondary circuits shall be earthed at one point only. A separate earth link shall be provided to each secondary winding.

The secondary terminals must be located in an accessible, earthed weatherproof terminal box located on the base of the voltage transformer. The secondary connections must be protected with MCB and wired on the terminal strip in the local control cubicle.

The static withstand load shall be selected from 'Voltage terminals' or 'Through current terminals' Load Class I or II of IEC 61869-2 and IEC 61869-5 depending on an assessment of the connections and possible loads under local site conditions.

5.2. Capacitor Type Voltage Transformers

These voltage transformers shall be designed to operate devices which require a potential source of approximately constant voltage ratio and negligible phase shift with respect to the high-voltage circuit.

The voltage transformers shall be high capacitance type.

The capacitor unit shall be hermetically sealed.

A bushing shall be provided to enable a high frequency signal to be coupled to the capacitor unit. The bushing shall be fully protected against rain and vermin when in use so as to avoid the possibility of being shorted to earth.

5.3. Voltage Transformers for Tariff Metering

The voltage transformer may be of the wound or capacitive design principle.

The VT shall provide separate secondary windings for connection to main and check metering.

The VT secondary shall be of class 0.2 conforming to IEC 61869-3 for a wound VT and IEC 61869-5 for a capacitive voltage transformer. VT dimensioning calculation shall be provided to demonstrate the supplied burden is adequate and will operate within the accuracy parameters defined in IEC 61869.

The secondary voltage shall be $110V/\sqrt{3}$.

VT secondary winding-1 shall connect to the Main Meter and secondary winding-2 to the Check Meter.

Wiring terminations shall be provided with integral earthing and isolation links to facilitate maintenance and testing.

The VT shall be protected by a suitably rated MCB with an auxiliary contact. This contact shall be wired out to a terminal block and raise upon operation "Metering VT MCB trip" alarm.

5.4. Special Tools and Equipment

One complete set each of special tools in new condition as needed for operation, maintenance and repairs as well as for changing out components of substations and overhead lines and for storing dismantled parts shall be included in the delivery

- all standard accessories and auxiliary equipment normally belonging to the supplied items or that are required for commissioning of components
- Servicing aids for protection systems as required for analysis, configuration and parameterization (hardware and software).

5.5. Spare Parts

The recommended spare parts shall comply with the requirements stated in the relevant Schedules of Technical Information and this Specification and shall be stated in the price schedules.

5.6. Type tests

In order to demonstrate that all voltage transformers made to the same specification comply with the requirements, the type tests in accordance with IEC 61869 shall be performed.

As a minimum, the following type tests shall be performed:

- Accuracy check
- Temperature rise tests
- Capacitance and $\tan\delta$ measurement at power frequency
- Short circuit withstand capability
- Lightning impulse test
- Wet test for outdoor type of transformer

- Ferro-resonance test
- Accuracy test

5.7. Routine Tests

Routine tests on the current transformers shall be in accordance with IEC 61869:

As a minimum, the following routine tests shall be performed:

- Tightness of capacitor voltage divider
- Capacitance and $\tan\delta$ measurement at power frequency
- Power frequency withstand test
- Partial discharge measurement
- Verification of terminal marking
- Power frequency withstand test on the electromagnetic unit
- Power frequency withstand test on secondary winding
- Ferro-resonance check
- Accuracy check determination

5.8. Site Tests

As a minimum, the following tests after installation on site shall be performed in accordance with their respective IEC Standards:

- Inspection of general condition (supporting structure, secondary wiring, earthing, primary connection, oil level & leakage check etc.)
- Ratio test
- Winding resistance measurement for each core
- Isolation (Megger test) with applied voltage of 1000V dc for secondary winding
- Polarity check

6. Substation Auxiliary Transformers

6.1. Ratings

The substation service auxiliary transformers shall be designed and tested in accordance with the requirements of IEC 61689-1&3, IEC 60076 or IEEE C57.13, C57.13.8 and C57.12 and any additional requirements of this Specification.

The required quantities, locations, sequence, ratio and rating of the transformers are a function of the application. The requirements for each application are included in the Schedules of Technical Information and bid drawings.

Preliminary values of rated output for bidding purposes are indicated in the Schedules of Technical Information. During design stage the contractor needs to confirm these values by calculation.

The secondary terminals must be located in an accessible, earthed weatherproof box located on the base of the transformer. The secondary connections must be protected with MCB and wired on the terminal strip in the local control cubicle.

The auxiliary transformer shall withstand seismic requirement according to the IEEE 693.

The bushing shall be fully protected against rain and vermin when in use so as to avoid the possibility of being shorted to earth.

Transformer dimensioning calculation shall be provided to demonstrate the supplied burden is adequate and will operate within the parameters defined in IEC 61869.

The secondary voltage shall be $415V/\sqrt{3}$.

6.2. Construction

The standard Station Auxiliary Transformer (power only) has two (2) isolated secondary power windings that can be parallel connected for different voltage output. The construction and general requirements of the substation Auxiliary Transformer shall be in accordance with that specified for 2-winding transformers with ratings up to 500KVA of the power transformer in this specification and includes but is not limited to the following features:

- ONAN cooling
- Protection pressure relief valve
- HV connections shall be an air-bushing connection.
- The LV (auxiliary) terminals of the transformer shall be brought out into a weatherproof cable box fitted with a lockable, hinged lockable door. The cable box shall incorporate an adequately rated fuse-switch unit suitable for cable connections.

- The installation of protective current transformers (CTs) in primary and secondary neutrals is required.
- Oil preservation system: May be conservator with Buchholz and dehydrating breather or sealed type (gas cushion or corrugated tank). Where corrugated type is offered, the manufacturer shall provide adequate reinforcement to prevent damage during transport, installation and service. Off-circuit tap-changer with $\pm 5\%$ voltage variation in 4 equal steps
- The transformers shall be able to supply its full output in a cooling mode with a temperature rise of 80°C and with an indoor ambient temperature of 40°C .

6.3. Special Tools and Equipment

One complete set each of special tools in new condition as needed for operation, maintenance and repairs as well as for changing out components of substations and overhead lines and for storing dismantled parts shall be included in the delivery

- all standard accessories and auxiliary equipment normally belonging to the supplied items or that are required for commissioning of components
- Servicing aids for protection systems as required for analysis, configuration and parameterization (hardware and software).

6.4. Spare Parts

The recommended spare parts shall comply with the requirements stated in the relevant Schedules of Technical Information and this Specification and shall be stated in the price schedules.

6.5. Testing

Routine and Type tests shall be generally in accordance with the requirements of IEC 60076-1 and IEC 60076-3, appropriate to the voltage class of the transformer under consideration. Additionally, some tests in the class identified as 'Special' in IEC 60076 are included, which may in practice be effectively a Routine or Type Test, as appropriate.

6.5.1. Routine Tests

The following routine tests shall be performed:

- Measurement of winding resistances at all tap positions
- Capacitance and $\tan\delta$ measurement at power frequency
- Measurement of voltage ratio and check of voltage vector relationship
- Measurement of impedance voltage (principal tapping) short-circuits impedance and load loss.

- Measurement of no-load losses and no-load current at rated frequency and nominal voltage.
- Induced-voltage test with partial discharge measurement.
- Short Duration AC (ACSD)
- Separate source voltage test.
- Oil test and function tests.
- Measurement of insulation of core.
- Measurement of insulation resistance (R15, R60, R600) at 2500 V DC. The polarisation index R10min: R1min shall not be less than 1.1.
- Measurement of ratio and polarity check of current transformers
- Lightning impulse (LI) withstand test: Transformers with HV $U_m > 72.5$ kV.
- Switching Impulse (SI) withstand test: Transformers with HV $U_m \geq 245$ kV
- Long Duration AC (ACLD): $U_m \geq 245$ kV

The test steps U_1 (withstand level) and U_2 (PD measurement level) will be at the enhanced values of $1.8 U_m$ and $1.6 U_m$ respectively. The test sequence and PD limits shall be as given in IEC 60076-3. The phase to ground test values for transformers with HV windings rated at 220 kV and 400 kV are given in the following table.

HV U_r (kV)	HV U_m (kV)	U_1 (kV)	U_2 (kV)	PD test duration (minutes)	Max PD (pC)
220	245	255	226	30	500
400	420	436	388	60	500

6.5.2. Type Tests

The following type tests shall be performed:

Temperature Rise Test: This test shall be carried out with the transformer at tap positions giving highest losses. The temperature rise qualification of the SSVT transformers shall be in accordance with IEC 60076-2, at the auxiliary rating when the temperature rises of the main and auxiliary windings will be measured.

Lightning Impulse (LI) test for $U_m \leq 72.5$ kV: This test shall be carried out in accordance with IEC 60076-3 on the HV and neutral terminals. Tap-changers shall be in the position of minimum, principal and maximum tap as each phase is tested in turn (A-B-C).

In-lieu evidence from demonstrably similar units and/or mechanical and thermal calculations shall be provided to demonstrate clear margins of short-circuit current withstand at system fault levels for all transformers. All tests and calculations shall be in accordance with IEC 60076-5.

6.5.3. Special Tests

The following 'special' category tests shall be performed when specified the Schedules of Technical Information and may be on each unit (equivalent to a routine test) or on one unit (equivalent to a type test) as indicated:

- Determination of sound levels to IEC 60076-10: (Type test).
- Measurement of the harmonics of the no-load current: (Routine test).

6.5.4. Site Tests

As a minimum, the following tests after installation on site shall be performed in accordance with their respective IEC Standards:

- Inspection of general condition (supporting structure, secondary wiring, earthing, primary connection, oil level & leakage check etc.)
- Ratio test
- Winding resistance measurement for each core
- Isolation (Megger test) with applied voltage of 1000V dc for secondary winding
- Polarity check

6.6. Documentation

6.6.1. Documentation with Bid

The Bid shall contain at least the following information and documents, failure of provision of the mentioned documents will lead to disqualification:

1. General arrangement drawings;
2. Manufacturing specification of the proposed types of transformer;
3. Catalogues, literature and reference lists of proposed equipment;
4. Type test certificates from an independent testing authority or independently witnessed;
5. Quality Management System Manual and ISO Certificate of the equipment manufacturer.

6.6.2. Documentation after Award of Contract

All documents required for KETRACO's approval shall be submitted by the Contractor.

7. Surge Arresters

7.1. General

Surge arresters shall be of the metal-oxide, gapless type (MOAs). Suitable outdoor type surge arresters shall be offered. The application and rating of surge arresters shall be determined by insulation co-ordination studies.

The design of the surge arresters shall be in accordance with the requirements of IEC 60099-1, IEC 60099-4, IEC 60099-5, IEC 62271-1, IEC 60137, IEC 60815 and any additional requirements of this Specification. Each pressure vessel for housing the metal-oxide discs shall comply with the requirements of the appropriate CENELEC Document and European standard. The testing of the equipment shall be in accordance with the requirements of IEC 60099, (IEC 60099-1, IEC 60099-4, IEC 60099-5), IEC 62271-1, IEC 60060 and IEC 60270.

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, and under such sudden variation of voltage as may be met with under working conditions on the system.

The creepage distance shall be as specified in the Technical Data Sheet and surge arresters shall be equipped with a grading ring.

The surge arresters form part of the overall contract for the engineering of the substations and the supply of equipment, therefore they shall be positioned as near to the equipment to be protected so that they can provide maximum protection in accordance with IEC 60099.

7.2. Surge Counters and Leakage Current Meters

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.

Internal parts shall be unaffected by atmospheric conditions on Site. Alternatively, a weatherproof housing to IP65 shall be provided as part of the Contract and this shall be designed to allow the recording device to be read without exposing the internal parts to the atmosphere.

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 shall be provided for installation in the earth connection of the surge arresters and shall be designed for continuous operation. The internal parts shall be weatherproofed to IP65 with a transparent cover to provide an unobstructed view of the ammeter.

7.3. Testing and Inspection

7.3.1. Type Test

Type, routine and standard acceptance tests on metal oxide surge arresters shall be carried out in accordance with the IEC 60099-4 and IEC 60099-1. Type test certificates will be accepted subject to KETRACO approval.

As a minimum, the following type tests shall be performed:

1. Dielectric test on main circuit - lightning impulse voltage tests, power frequency voltage withstand tests and internal partial discharge tests
2. Active part withstand tests
3. Residual voltage tests
4. Long duration current impulse withstand tests
5. Operating duty tests
6. Short-circuit tests
7. Current distribution test.

7.3.2. Routine Tests

As a minimum, the following routine tests shall be performed:

1. Measurement of reference voltage
2. Residual voltage tests
3. Internal partial discharge test
4. Current distribution test.

7.3.3. Standard Acceptance Tests

As a minimum, the following standard acceptance tests shall be performed:

1. Power frequency voltage test on the complete arrester
2. Lightning impulse residual voltage test on the complete arrester
3. Internal partial discharge test
4. Thermal stability test.

7.3.4. Tests on Surge Counters

7.3.4.1. Minimum Current Operation Tests

The rated minimum operating current of the counter, stated in the schedules, shall be passed ten times and the counter shall correctly register these operations.

7.3.4.2. Maximum Current Withstand Tests

The maximum rated current stated in the schedules with an 8/20 μ sec wave shape shall be applied to the counter ten times without any cooling periods and the counter shall register and withstand without distress.

7.3.5. Site Tests

The site tests of surge arrestors shall be mainly based on visual inspection of the surge arrestors, in order to ensure that all components are mechanically assembled and installed properly and that there are no imperfections that shall be performed.

The following site test to be conducted:

- Tests of insulation resistance
- Tests of surge counting device and leakage current meter
- Measurement of AC leakage current at rated system voltage & maximum continuous operating voltage
- Measurement of DC leakage current at the voltage equivalent to the peak of rated system voltage & maximum continuous operating voltage
- Tests of Watt loss (10 kV AC) & Test on insulation power factor (10 kV AC)

8. Control, Protection and Indication System

8.1. Protection Equipment and Auxiliary Relays

8.1.1. General Requirements for Protection Relays

This section contains the general requirements applicable to all protection relays.

Each element of the main plant, transmission and distribution systems shall be provided with high-speed discriminative protection (main protection), capable of detecting all "credible" faults and issuing tripping commands to the associated circuit breakers within the prescribed time. "Credible" faults shall include all faults whether phase/phase or phase/earth irrespective of whether maximum or minimum plant is connected, account being taken of the fault impedance. "Non-credible" faults are those involving a second order plant failure, for example, a broken conductor lying on high resistance ground and for which extended fault clearance time may be acceptable.

There shall be two sets of main protection such that the loss of one set or the failure of one set to clear a fault will not result in time delayed tripping for an electrical fault. Redundant auxiliary supplies shall be used and there shall be redundant tripping systems. For distribution level this is named as Main and Backup protections.

High-speed discriminative protection systems shall be engineered as complete schemes, with due account being taken of current and/or voltage transformer performance. 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-energise any part of the network.

In the event of an uncleared external fault or any other abnormal operating condition which may cause damage to plant, time delayed tripping shall be initiated as a back-up action to prevent plant damage.

With reference to the above the protection systems must therefore be designed, manufactured, applied, set and commissioned to offer the highest level of security against incorrect operation for faults beyond the protected circuit or during disturbances or temporary overload conditions from which the power system should recover.

The diameters protection cubicles shall be arranged in Bay Control Rooms. The houses shall be installed beside of each diameter with each house accommodating the protection cubicles for two adjoining bays. The substation control building shall house the busbar protection central units and the superior substation automation system, to which the protection relays shall be connected with fibre optic cables.

8.1.2. Protection Technology

All relays performing a measuring function shall be of numerical design with continuous self-monitoring. Auxiliary relays, repeat relays, trip relays and any other simple auxiliary or contact multiplication function may be based on standard attracted armature or other electromechanical techniques.

In order to maximise the cost-benefit of the protection in all groups and to reduce lifetime costs, all protection relays shall be of numerical design wherever practical. The main numerical relays shall offer instrumentation, disturbance recording and event logging functions in addition to providing protection. Periodic routine test requirements shall be limited to basic function testing only, through the provision of comprehensive, continuous self-monitoring with alarm and diagnostic functions.

Numerical relays and schemes provided shall all be suitable for connection to a local communication network (either interfaced directly to the substation LAN or to the local BCU) to allow the complete relay scheme to be interfaced to a central computer work station (engineering workstation). The communication bus, necessary switches and interface units and all associated software shall be provided as part of the contract. With the resulting system it shall be possible to interrogate all numerical relays and schemes to monitor and extract recorded data (including settings, measurement parameters and disturbance records). It shall also be possible to enable remote adjustment of relay settings if required.

Numerical relays shall also be provided with a local communications port to allow direct interfacing to a laptop PC, to facilitate local interrogation, setting-up and recorded data extraction. Individual protection units shall be provided with an integral user interface to facilitate setting changes and observation of indications without the use of remote communications. The interface cables for communication with the relays through a laptop PC shall be provided.

Protection relays shall be from approved suppliers and they shall be type-tested according to relevant sections of the current IEC 60255 standards and copies of type test certificates shall be provided. Relays shall be CE-marked in accordance with European Union requirements related to Electromagnetic Compatibility and Low Voltage Equipment safety. Equipment complying with other national standards may be accepted at KETRACO's discretion and where the vendor provides copies of the relevant standards.

Protection relays shall have a minimum of two year's satisfactory service history in similar applications with at least 5 utilities. The history is to be supported by reference lists and supporting letters from the utilities.

Relays must be offered on the basis of a minimum service life of 15 years. Statements must be obtained from the relay manufacturer(s) to this effect, with confirmation that a spares and repairs service will be available for the stated minimum service life.

8.1.3. Protection Discrimination

On the occurrence of an electrical fault on the power systems, the high speed discriminating protection systems (main protection) shall rapidly detect the fault and initiate the opening of only those circuit breakers which are necessary to disconnect the faulted plant or circuit from the network. Protection equipment associated with adjacent plant or circuits may detect the fault, but there must be discrimination between this protection and that of the faulted plant or circuit. Time delayed tripping is not permitted except where main protection has failed to clear a fault or where plant damage would otherwise occur.

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 electrical system.

8.1.4. Protection Settings

A protection setting study shall be performed as part of the contract and a list of the settings to be applied to all protection equipment, together with all associated calculations (e.g. load flow, short-circuit) and relay co-ordination curves on log paper, shall be provided for review and approval not less than 3 months prior to the first programme date for commissioning. Any limitations imposed on the power system operation as a result of the settings proposed shall be explicitly stated. In the absence of system data required for calculation purposes, assumptions may be made, providing these are clearly identified as such in the relevant calculations.

Copies of all data files used for the studies shall be submitted for approval on suitable media to be agreed with the Employer's Representative on completion of the study work, together with the report detailing the study results. The studies shall include, amongst others:

- Magnitude of secondary ARC current and associated recovery voltage
- Level during single pole auto reclosure operation (SPAR)
- Time required for arc extension during SPAR operation
- Insulation coordination
- Switching overvoltage during line energization
- Switching overvoltage during SPAR operation

Based on these studies the contractor shall confirm that adequate protective margin exists between the calculated switching overvoltage and the short duration power frequency withstand voltage. The required dead time during SPAR shall also be provided.

8.1.5. Constructional Requirements

8.1.5.1. General

Means shall be provided to positively lock each withdrawable module, circuit board or unit in the "service" position within the relay case. It shall not be possible to withdraw the analogue input module from its case before short-circuiting the current transformer connections.

All relay cases shall be earthed except where insulated cases are provided for special requirements.

A list of all of the protection and control equipment being offered under the contract shall be provided together with a list of all of the test and ancillary equipment required for commissioning and routine testing of all protection and control equipment.

8.1.5.2. Equipment Accommodation

Protection and control cubicles shall be front access, swing-rack design. Cubicles with front and rear access are acceptable for extensions to existing substation where this is the present arrangement. However, there should not be a mixture of both cubicle types in the same substation control/relay room.

8.1.5.3. Operator Interface

All numerical protection systems shall be provided with an integral local user interface, 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 user interface. No exceptions to this requirement shall be permitted.

Relay serial communication facilities shall allow all information, which is available locally at the relay front panel, to be accessed remotely. It shall also be possible to carry out bulk transfer of settings and fault record information using appropriate PC based software. The necessary software for communication with each relay type shall be provided as part of the contract.

Each protection relay shall also comply with the following requirements.

8.1.5.4. Identification and LCD Display

Each protection relay shall have a unique identifier that is clearly visible. The software reference and issue level shall be identified. The marking of all relays shall comply with Clause 12 of IEC 60255-6 (1988).

Each protection relay shall be provided with an LCD display facilities on which shall be shown:

1. The current transformer ratio (if applicable), including all ratios of multi-ratio transformers and the ratio selected.
2. Voltage transformer ratio (if applicable).

The display shall allow for indication of measurement data, fault data and setting values. Buttons shall be available to navigate through the menus and to enter setting parameters. LEDs are showing important alarms (e.g. trip indication) and the status of the numerical relay (power on, alarm, out of service).

8.1.5.5. Settings

Each protection relay shall provide a means by which the user can easily apply the required settings, which is also secure from inadvertent operation. A display of the selected settings shall be provided on the protection relay.

8.1.5.6. Indications

Each relay or protection scheme shall be provided with an adequate number of LED indications to ensure that the appropriate faulted phase, zone, operated element, etc. can be easily identified after a fault condition. Each indicator shall be visible and capable of being reset without removing the relay cover. It shall not be possible to operate the relay when resetting the indication. Unless otherwise approved, indications shall only be given by the protection(s) causing the relay to trip.

Numerical relays shall include continuous self-monitoring and supervision of all parts of the relay hardware, firmware and software and any failure shall be annunciated via the relay and any remote control facility. An alarm contact shall close for any detected failure.

The record of relay indications shall be maintained following any DC auxiliary supply interruption and the status of the DC power supplies shall be permanently indicated.

8.1.5.7. Output Contacts

All protection relays shall be provided with an adequate number of contacts of suitable rating to perform the required tripping functions, alarm indications, fault recorder functions and such supplementary signalling functions as may be necessary for initiation of automatic switching control, inter-tripping etc. In all cases contacts intended for tripping duty shall be designed such that:

- a. They cannot inadvertently interrupt trip coil current.
- b. They initiate the circuit breaker trip coil directly without the interposition of auxiliary relays or reinforcing contacts.

8.1.5.8. Test and Isolation Facilities

Each functional protection relay 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 scheme to enable the protection and control equipment to be tested from the front of the protection equipment panel with the primary circuit(s) in service. The test points shall be clearly identified and labelled. The type of test terminal block shall be SIEMENS type 7XG22 or similar. The test terminal blocks shall be provided including the test plugs.

Adequate facilities shall be provided, preferably at the front of each protection equipment panel, to isolate all DC and AC incoming and outgoing circuits so that work may be carried out on the equipment with complete safety for personnel and without loss of security in the operation of the switching station. The isolation points shall be clearly identified and labelled. The labels on the isolation points shall either describe the function or be uniquely numbered.

8.1.6. Service Life and Service Support

The protection systems shall be designed for a service life of 15 years, allowing for only routine testing that is limited to basic functional testing in accordance with manufacturers recommendations.

The service life of the protection system equipment in relation to that of the main HV plant and apparatus shall be stated so that the cost of any replacement during the life of the substation can be assessed.

The period for which lifetime support will be provided for the protection system equipment shall be stated. Recommendations for the provision of spare parts are required.

Circuit diagrams for each protection system and the associated tripping system(s) shall be supplied. The diagrams shall provide sufficient information to enable fault finding and maintenance to be carried out and shall not consist solely of information used for equipment manufacture.

A service to enable any faulty item of protection equipment to be rectified or replaced within a stated period after the fault being reported shall be provided. The repair/ replacement period shall be defined.

Training for the Employer's personnel in the operation and maintenance of the protection equipment shall be offered.

8.1.7. Protection Testing

8.1.7.1. Type Tests

A type test certificate shall be provided for each relay type, which shall confirm compliance of the protection relay with the requirements of the relevant sections of IEC 60255 as detailed in this specification. Any areas of non-compliance shall specifically be identified. It shall be stated whether the protection relay has been approved by any independent approval bodies or users.

Should the certificates be invalid or unacceptable to KETRACO, the type tests shall be performed by a recognised and KETRACO approved independent laboratory, at the expense of the contractor.

8.1.7.2. Routine Tests

A routine testing programme shall be determined between the Employer/ Employer's Representative and the Contractor before the tests are undertaken at the premises of the equipment supplier. Notwithstanding, the routine testing shall comprise, as a minimum, of the following tests being performed on one tenth of each relay type, but minimum one: -

- 1) Functional tests.
- 2) Dielectric Test (a.c. power frequency high voltage test) with 2 kV, 50Hz for 1 min as per IEC-60255-5.
- 3) Electrical disturbance test (for static relays only) to IEC 60255-22.

The tests shall be conducted in the presence of KETRACO or their representative.

The Contractor shall submit a report to the Employer/ Employer's Representative detailing the routine tests and the test results.

Inspection and taking over in the factory do not relieve the Contractor from his obligations as per the contract documents and guarantee of performance.

8.1.7.3. Site Tests

The Contractor shall perform the following site tests on the protection relays: -

- 1) Relay auxiliary D.C. supply checks
- 2) CTs and associated secondary wiring tests

- 3) VTs and associated secondary wiring tests
- 4) Application of relay settings as determined in the Protection Setting Report
- 5) Secondary injection testing to determine relay settings and operation within manufacturers stated parameters.
- 6) Primary injection tests where appropriate
- 7) Checks of all alarm circuits
- 8) Functional testing of all relays. This includes testing protection relays, aided by secondary as necessary, a scheme operation of relevant CBs
- 9) Signal-test together with the substation control system

The Contractor shall submit for approval a Commissioning Programme prior to the tests being performed. The Commissioning Programme shall include, as a minimum, the following: -

- 1) List of the site test for all protection systems/relays and associated power equipment (CTs/VTs etc.)
- 2) Procedures and methods for each commissioning test including those to be performed on-load.
- 3) Testing equipment and instruments necessary for performing of each test
- 4) Format of site test reports for each test.
- 5) Installation, operation and maintenance manuals

Each site test shall be witnessed and signed off by a KETRACO Engineer or their representative.

One month before the site tests and commissioning start the Contractor shall submit to KETRACO the approved Protection Setting Report.

Commissioning will be deemed complete when all relevant equipment is energised, loaded and all necessary on-load tests, measurements and checks are complete and signed for by the Employer/ Employer's Representative .

8.1.8. Environmental Requirements

8.1.8.1. Atmospheric Environment

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:

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

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

Relative humidity:

The protection system shall operate correctly with a relative humidity of 93 % and shall be tested to IEC Publication 60068-2-3 with severity class 56 days.

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 Contractor shall provide a cubicle to classification IP50 to accommodate the relay.

8.1.8.2. Mechanical Environment

Vibration:

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

Shock and bump:

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

Seismic:

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

8.1.8.3. Electrical Environment

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 150 V.

Numerical protection systems shall meet the requirements of IEC Publication 60255-11 with interruptions to the DC auxiliary energising quantity of 20 ms.

Frequency:

The rated frequency shall be 50 Hz. The nominal range of operating frequency shall be -5 % to +5 % of nominal.

Thermal rating:

Relay equipment intended to perform a current measurement function shall be capable of continuous operation at a current of not less than 2.4 times the nominal rating or 2 times the setting value, whichever is the more onerous.

Relay equipment intended for use in a normally quiescent mode and having a short time rating - for example, high impedance differential protection - shall be rated in accordance with the intended function and taking account of such inherent protective devices as may be incorporated in the design.

The short time rating for all protection relaying schemes shall be 100 times the nominal relay rating for a duration of 1 s.

Voltage sensitive equipment intended for use on effectively earthed networks shall have a continuous withstand of not less than 1.2 times nominal voltage and a short duration withstand of not less than 1.5 times nominal phase-to-ground voltage for 30 s.

Insulation:

- 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.

- Dielectric Tests:

The protection system shall comply with the dielectric test requirements of IEC Publication 60255-5. The test voltage shall be selected according to the rated insulation voltage of the circuits being tested from Series C of Table 1 of IEC Publication 60255-5.

- Impulse Voltage:

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

8.1.8.4. Electromagnetic Compatibility

The requirements of this section of the specification are applicable to electronic protection systems whether these are based on analogue digital or numerical design techniques. The requirements may also be applied to electromechanical relays that may radiate electromagnetic interference during their operation.

- 1 MHz Burst Disturbance:

The protection system shall comply with the requirements of IEC Publication 60255-22-1 with severity Class III.

- Electrostatic Discharge

The protection system shall comply with the requirements of IEC Publication 60255-22-2 with severity Class III.

- Radiated Electromagnetic Field Disturbance:

The protection system shall comply with the requirements of IEC Publication 60255-22-3 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

- Electromagnetic Emissions:

The protection system shall comply with the requirements of IEC Publication 60255-25.

- Fast Transient Disturbance:

The protection system shall comply with the requirements of IEC Publication 60255-22-4 with severity level IV.

8.2. Protection System Particular Requirements

8.2.1. Transmission Systems (400kV, 220kV and 132kV)

8.2.1.1. Protection Performance Requirements

a. Protection redundancy

The protection systems for the transmission systems must provide fast and highly dependable clearance of any electrical fault in order to minimise the duration of severe voltage dips to a large number of customers and to avoid loss of transmission system capacity due to back-up tripping of any other circuits. A forced shutdown of a transmission circuit for any single item of protection equipment failure shall not be required. For a limited period, it shall be possible to operate a transmission circuit with only one group of protection in service, while the other group is out of service for testing or while it is awaiting repair. During this period any fault must still be cleared quickly and the plant must still be protected against damage if exposed to abnormal operating conditions. To meet

these dependability and redundancy requirements, all transmission plant and circuits shall be provided with two fully independent, high-speed protection systems for detecting and clearing electrical faults.

Unless otherwise specified, each independent protection group shall also be driven from independent current transformers and independent VT secondary circuits.

b. Protection clearance time

Each main protection scheme shall independently clear any credible fault within 100ms from fault inception.

c. Provision of back-up protection

Back-up protection (e.g. inverse-time overcurrent and earth fault protection or thermal overload protection) shall be provided to trip protected plant and circuits in the event of a sustained external fault condition or of a sustained power system abnormality that would otherwise damage or significantly reduce the life expectancy of the protected plant.

Where applicable, each set of feeder protection shall include “Zone 2” under impedance remote back-up protection for busbars to ensure that, in the event of busbar protection failure, a remote-end busbar fault will be cleared within the switchgear internal arcing fault withstand time.

d. Circuit breaker failure

Each protection system includes the circuit breaker(s). Beyond the circuit breaker trip coils, the duplication of the protection system ends. Circuit breaker fail protection shall be provided to cater for the possibility of a single circuit breaker failing to clear fault current when commanded to do so, by either of the two main protection systems. The breaker fail protection shall initiate a first stage CB re-trip followed by a second stage rapid back-trip/intertrip of adjacent circuit breakers, as necessary, and within KETRACO's required transmission breaker failure fault clearance time of 260 ms.

e. Auxiliary DC supplies

The auxiliary power and tripping supplies for each independent protection group shall be derived from independent DC auxiliary supply systems comprising two separate batteries and battery chargers as detailed in LV Service Equipment specification. This is in line with the existing KETRACO practice at substations where the upper voltage level is transmission.

f. Protection supply and trip circuit supervision

The protection systems shall continuously supervise the DC auxiliary supplies and the integrity of all circuit breaker tripping circuits with the CB in the closed or open state. The circuit shall be arranged so, that any failure of the supervising relay coil (short or open circuit or earth-fault) will not prevent a trip signal opening the breaker or cause inadvertent opening of the circuit breaker. Resistors, if needed, shall be located close to the circuit breaker auxiliary contacts. The trip circuit supervision relay shall operate when the trip supply fails or the circuit breaker trip coil or trip circuit becomes open circuited. Operation shall occur after a settable time delay. The design of the supervision must allow for latched contacts (from lock-out-relay). The trip circuit supervision functionality shall be realized by separate supervision relays, independent from the protection relays. All

protection relays shall incorporate comprehensive continuous self-monitoring and diagnostic facilities. All supervision relays shall provide an alarm signal into the SCS/SAS system.

g. High speed tripping relays

With immunity to operation with DC wiring capacitance discharge currents, high-speed tripping relays shall be used to interface protection relay trip contacts to circuit breaker trip circuits. These are to ensure that output contacts within the protection relays will not be damaged in the event of the circuit breaker failing to interrupt its trip coil current before the protection relay contact(s) open (e.g. in the event of fault clearance by breaker fail protection). They will also form a single point of interfacing between the protection schemes and the circuit breaker. The tripping relays shall either be of the self-reset type or of the latching type, with circuit breaker lockout contacts, according to protection scheme requirements. Lockout relays shall be electrically resettable, locally and from SAS.

h. Protection trip, alarm and disturbance records

The protection systems shall provide comprehensive records for trip and alarm conditions, with local indications of which element has initiated a trip or alarm and of voltage and current vector parameters at the time of trip initiation.

Voltage and current waveform disturbance recording and event-logging shall be included as part of the protection system.

i. Test facilities

The protection systems shall include comprehensive maintenance isolation and test facilities. SIEMENS type 7XG22 or equivalent. test and associated terminal blocks and shall be provided.

8.2.1.2. New Overhead Line Feeders

a. Protection arrangements

The protection and control arrangements are illustrated in the single line schematic diagrams in Part 2-D.

The circuit protection shall be housed in relay panels as defined in the Protection General Requirements.

The illustrated control arrangement is one Bay Control Unit (BCU) per CB and shall be located in a dedicated panel per diameter basis. The contractor may propose alternative BCU configurations.

Busbar protection bay module (including breaker-fail protection) shall be located within a dedicated suite of busbar protection relay panels.

b. Bay control and monitoring

The BCU associated with the CB adjacent to the busbar shall be configured to control the circuit disconnect and earth switch. For mid diameter circuits having no busbar CB then one BCU of the associated CBs shall control the circuit disconnect and earth switch. The contractor may propose alternative BCU configurations.

BCU shall provide mid-diameter CB failure functionality.

The BCUs shall perform the check synchronisation function and shall provide 3ph voltage signals to the SAS pertaining to each busbar and each mid-diameter section. The appropriate busbar and circuit VT secondary voltages shall be supplied to the BCU via a diameter voltage selection scheme according to the status of the AIS switchgear.

BCU shall also provide fault recording functions however the separate Fault Recorder is the principle system.

For communication purposes, all numerical protection devices shall be capable of being connected to the substation LAN via protocol IEC 61850. In exceptional cases, provided the approval of KETRACO, single numerical protection devices can be connected via a serial link to the BCU, using a protocol different from IEC 61850, but this shall only be the case if no comparable device with IEC 61850 is available on the market.

The BCU shall normally be powered from DC1 auxiliary supply and upon loss of this supply automatic changeover to DC2 shall occur within the tolerable BCU dc interruptions ride through time.

Bay control unit requirements are fully detailed in the SAS specification.

It shall be possible to confirm the operation of a primary plant switchgear equipment before the operation i.e. the BCU shall have the “Confirm before execute” functionality same as the SAS HMI system.

c. Main protection

The new overhead line feeder circuits shall be provided with fully duplicated main protection systems that comprise:

Main 1 - one set of numerical distance protection operating in BLOCKED, POTT, PUTT or other tele protection mode, whichever is the most applicable signalling scheme and final mode to be decided at design review meeting. The Main 1 distance relay shall also incorporate Directional Earth Fault protection which shall operate in blocked mode. Upon opening of the line disconnector the distance protection function shall be blocked and a stub protection function integral to the main protection relay shall be invoked. The Contractor shall ensure the OHL feeder is adequately protected by high speed main protection at the remote terminal should it be energised from the remote terminal up to the local line disconnector. The line distance protection relays shall communicate via the telecommunication multiplexer equipment i.e. direct relay to relay communication between distance protection relays at opposite substations shall not be permitted.

Main 1 - one set of optical fibre current differential protection, with integral distance protection elements to provide Zone-2 remote busbar back-up protection and Zone-3 remote circuit back-up protection (if required). Zone 1 of the impedance protection shall be deactivated whenever the line differential protection function is active/communication link is active. This zone shall be activated whenever a communication failure appears or deactivation of the line differential protection function. The operate time for the impedance zones shall be delayed by 80ms as compared to operate times for the similar zones in the Main 1 protection relay. The current differential protections shall remain stable during charging current inrush and with the presence of steady-state charging current. For current differential protection via fibre optic pilots, upon opening of the feeder disconnector the current differential function shall be blocked and a stub protection function integral to the main protection relay shall be invoked. This will also block the remote end terminal differential function and in this respect the

Contractor shall ensure the feeder is adequately protected by high speed protection should the feeder be energised from the remote terminal up to the local line disconnector.

Main 2 - one set of optical fibre current differential protection, with integral distance protection elements to provide Zone-2 remote busbar back-up protection and Zone-3 remote circuit back-up protection (if required). Zone 1 of the impedance protection shall be deactivated whenever the line differential protection function is active/communication link is active. This zone shall be activated whenever a communication failure appears or deactivation of the line differential protection function. The operate time for the impedance zones shall be delayed by 80ms as compared to operate times for the similar zones in the Main 1 protection relay. The current differential protections shall remain stable during charging current inrush and with the presence of steady-state charging current. For current differential protection via fibre optic pilots, upon opening of the feeder disconnector the current differential function shall be blocked and a stub protection function integral to the main protection relay shall be invoked. This will also block the remote end terminal differential function and in this respect the Contractor shall ensure the feeder is adequately protected by high speed protection should the feeder be energised from the remote terminal up to the local line disconnector. For each line the contractor shall match the differential relays at both ends.

The contractor shall ensure that he matches for Main 2 protection the existing line differential relays that are in use in the terminal substation as the station will be the remote end for the transmission lines.

Main 1 and Main 2 protections shall be provided by different manufacturers. Each main protection shall be located in its own panel.

Reference to be made to the schedules of technical information for detailed description of the protection system.

d. Back-up protection

The fully redundant protection systems applied at transmission present a negligible probability of the OHL short-time withstand limit being exceeded but in order to provide additional security back-up, the protection scheme design shall include directional overcurrent (67), directional earth fault (67N), time-delayed overcurrent (51), overvoltage (59), undervoltage (27) and thermal overload (49) protection. The back-up protection functions shall be provided as stand-alone protection relays. There shall be one back up protection relay for each main protection panel. The overvoltage protection shall be configured with three stages as per KETRACO's practice.

e. Distance Protection Signalling

Distance tele-protection signalling shall be via a digital tele-protection signalling unit or Multiplexer. Direct Signalling between distance protection relays shall not be installed.

For Multiplexer schemes a separate intertrip channel shall be provided via dedicated intertripping equipment

f. Current Differential Protection Signalling

Current differential protection signalling shall be via a digital tele-protection signalling unit or Multiplexer. For remote substations with identical differential relays (including firmware) then direct fibre signalling may be proposed.

For Multiplexer schemes a separate intertrip channel shall be provided via dedicated intertripping equipment. For direct fibre connections the current differential protection shall be provided with an integral, two-way, high-speed, high-security intertripping channel where the energisation of an intertrip send opto-input of one relay will cause dedicated intertrip receive contacts of the remote relay to operate.

In the case of relay fibre optic direct connection, the OPGW (if available) shall provide a pair of fibres plus a pair of spares for each main protection.

g. Intertrip signalling

Intertrip signals to and from the remote terminal shall be blocked upon opening of the local OHL disconnector.

Upon receipt of the intertrip signal, intertrip receive relays shall trip and lockout the circuit breakers. There shall be one intertrip receive relay per signalling channel that individually trips each circuit breaker trip coil.

h. Auto Reclose

Faults occurring on an overhead line feeder are mostly transient and following a short delay after tripping the line can reclose and the supply of power re-established. The majority of transient faults on overhead line feeders are earth faults that are usually the result of lightning strikes, vegetation or animal contact. Following the initial fault, the insulation of the line is re-established once arc products have dispersed and the line can be re-energised.

The KETRACO transmission network OHL feeders principally use single pole AIS circuit-breakers configured to provide single phase auto-reclose.

Earth faults are statistically the most common fault and in this respect single pole auto-reclose is beneficial in respect to less interruption and maintaining of synchronism between two systems via the healthy phases. The disadvantages are increased complexity of protection and control circuitry as well and protection setting considerations for the period when the faulted phase is open.

Single-pole auto reclose is the standard operational mode however the option of choosing three phase auto-reclose shall be provided by means of a selector switch. The Auto-reclose selector switch shall provide the following auto-reclose modes:

1. 1ph AR
2. 1+3ph AR
3. 3ph AR
4. OFF

The auto-reclose relay shall operate in a single phase auto-reclose mode (unless selected otherwise) for all line faults detected in the protected zone with respect to current differential protection and instantaneous elements of the distance protection.

The auto reclose relay shall be a separate stand-alone relay, i.e. not integrated in the main or back-up protection relays.

For 1+1/2 (and 1+1/3) CB substation arrangements it is necessary to control two CBs hence a separate numerical auto-reclose relay is required. A separate auto reclose relay allows for either main protection to be out of service without affecting the auto-reclose availability and avoids complex race issue between systems. It may not be desirable for the network to operate with auto-reclose in service if one of the main protections is out of service. In this case the network operators can switch the auto reclose relay out of service if required. IN/OUT switching shall be available both locally at the relay panel and by remote operation via the SAS system.

The Auto reclose scheme shall be one shot only and shall trip 3ph and go to lockout mode if a second fault occurs within the reclaim time following the first shot reclose.

The Auto reclose sequence shall be blocked by distance protection time delayed impedance zones, operation of main protection Switch-onto-fault (SOTF) function, operation of busbar protection and circuit breaker failure protection. Auto-reclose shall also be blocked when the line disconnecter is open and/or the stub protection is invoked.

Circuit breaker low stored energy signals shall inhibit the auto-reclose sequence until the elapse of a timer resulting in AR lockout. Should the stored energy recover before the elapse of the timer then auto reclose sequence will continue.

In the case of three phase auto-reclose sequence, there is a possibility that the power system may be split and one part of the system may lose synchronism with respect to the other part. Any resulting CB auto reclose, without a check synchronism reference may result in an out of synchronism closure that damages the power system both electrically and mechanically. The severity of the damage depends on the degree of out of synchronism at the instant of closure. For these reasons all three-phase auto-reclose shall be performed with a check synchronism.

For existing substation where a central check synchronism relay is used, the availability of a signal from this scheme shall be investigated and if practical be utilised. Alternatively, if the central check synchronisation scheme cannot provide the necessary signals, then an auto reclose relay with an integral check synchronism function shall be provided.

An intertrip receive signal shall inhibit the AR sequence until either the intertrip signal is reset or a persistent intertrip timer elapses and the AR relay goes to lockout.

The circuit breaker at the line end that recloses first shall upon detection of a permanent fault issue a persistent intertrip that prevents the remote end CB from reclosing onto the fault.

The auto reclose relay shall be provided with a manual close inhibit feature that prevents AR for a settable period of time following manual CB closure e.g. following CB maintenance.

The Auto-reclose relay shall provide CB maintenance alarm and lockout functionality.

The auto-reclose relay shall be provided with indications and alarms for: -

- In/out of service

- Auto reclose relay healthy
- Auto reclose in progress
- Auto reclose lockout
- Auto reclose complete

The alarms shall be available locally on the relay and via the SCS.

i. Circuit breaker failure

This shall be configured with two stages/timers. Stage 1 shall be re-trip stage with stage 2 being the back-up trip stage.

For CBs adjacent to the busbars, the breaker fail protection shall be integral to the busbar protection scheme and so arranged to trip the mid diameter and intertrip the circuit remote terminal CB.

For the mid diameter CB (Tie CB), separate breaker fail protection shall be provided and the appropriate trip and intertrip scheme designed to open all adjacent CBs upon stage-2 operation. This may be implemented in the BCU for the Tie CB.

j. Trip Relays

In order to permit auto-reclose functionality on OHL circuits, self-resetting trip relays shall be provided for each trip coil and for each phase.

k. Fault recording

For new build substations a standalone substation fault recorder shall be provided and all appropriate feeder analogue and digital signals shall be extended to this device. Additional fault recording shall be provided by the numerical protection relays. All fault records shall be retrieved via the SAS Engineering Workstation.

For existing substations, where practical, the existing fault recorder shall be adopted for the new circuits.

8.2.1.3. Modifications of Existing Overhead Line Feeders due to LILOs

a. Protection arrangements

The existing protection panels shall be maintained. The relays' settings shall be upgraded and protection panels shall be renamed accordingly for each bay.

b. Bay control and monitoring

The existing control scheme shall be maintained in the Existing substations. However, any modification of the control system resulting from renaming of the OHL bays and change of the line protection system shall be included the Contractor's scope.

c. Main protection

The existing system is composed of line distance and line differential protection. In this scope the contractor will implement main A and main B of line differential protection. The contractor will maintain the existing differential protection and replace the existing distance protection and panels with a new differential protection scheme and panels.

The existing distance protection and panels shall be decommissioned and handed over to KETRACO.

d. Back-up protection

The existing back-up protection functions shall be maintained in the Existing substations. However any modification of the back-up protection resulting from renaming of the OHL bays and change of the line protection system shall be included the Contractor's scope.

e. Distance Protection Signalling

This will be decommissioned for the line distance protection that will be decommissioned.

f. Current Differential Protection Signalling

This current differential signalling shall be reconfigured accordingly for the existing and new line differential protection to be implemented.

g. Intertrip signalling

The existing intertrip signalling shall be reconfigured accordingly since the remote ends for the OHL have changed to ensure the new remote ends are correctly captured.

h. Auto Reclose

This scheme shall be maintained in the Existing substations. However, any modification of the auto-reclose scheme resulting from renaming of the OHL bays and change of the line protection system shall be included the Contractor's scope.

i. Circuit breaker failure

This scheme shall be maintained in the Existing substations. However, any modification of the circuit breaker failure scheme resulting from renaming of the OHL bays and change of the line protection system shall be included the Contractor's scope.

j. Trip Relays

This scheme shall be maintained in the Existing substations. However, any modification of the trip relays scheme resulting from renaming of the OHL bays and change of the line protection system shall be included the Contractor's scope.

k. Fault recording

This shall be modified to incorporate the changes.

8.2.1.4. Power Transformers (Primary side)

a. Protection arrangements

The protection and control arrangements are illustrated in the single line schematic diagram in Part 2-D, for transformer circuits.

The circuit protection shall be housed in relay panels as defined in the Protection General Requirements.

The illustrated control arrangement is one Bay Control Unit (BCU) per CB and shall be located in a dedicated panel per diameter basis. The Contractor may provide alternative BCU arrangements.

Busbar protection bay module (including breaker-fail protection) shall be located within a dedicated suite of busbar protection relay panels.

b. Bay control and monitoring

The BCU associated with the CB adjacent to the Busbar shall be configured to control the circuit disconnect and earth switch. For mid diameter circuits with no busbar CB then one BCU of the associated CBs shall control the circuit disconnect and earth switch. The contractor may propose alternative BCU configurations.

BCU shall provide mid-diameter CB failure functionality.

The BCUs shall perform the check synchronisation function and shall provide 3ph voltage signals from each busbar and each mid-diameter section to the SCS. The appropriate busbar and circuit VT secondary voltages shall be supplied to the BCU via a diameter voltage selection scheme according to the status of the AIS switchgear.

For communication purposes, all numerical protection devices shall be capable of being connected to the substation LAN via protocol IEC 61850. In exceptional cases, provided the approval of KETRACO, single numerical protection devices can be connected via a serial link to the BCU, using a protocol different from IEC 61850, but this shall only be the case if no comparable device with IEC 61850 is available on the market.

The BCU shall normally be supplied from DC1 auxiliary supply and upon loss of this supply automatic changeover to DC2 shall occur within the tolerable BCU dc interruptions ride through time.

Bay control unit requirements are fully detailed in the SAS specification.

c. Transformer protection

The transformers shall be provided with a single numerical main protection system.

The transformer is protected by the main protection transformer biased differential and restricted earth fault protection featuring magnetising inrush restraint and inhibition of current differential operation upon transient over fluxing.

The Main protection is to be located within the primary side transformer protection panel. Operation of the main protection relay shall operate separate primary side and secondary side trip relays on each protection channel.

The main protection shall be complemented with thermal overload and overflux protection functions.

d. Primary side connections protection

The transformer HV connections shall be provided with two sets of numerical main protection systems connected to two sets of current transformers.

Primary side connections-1 shall comprise current differential protection of either the low or high impedance principle. For low impedance protection, the protection relays shall provide separate CT inputs to ensure a bias characteristic across all CT inputs. Upon opening of the HV transformer disconnecter the connection protection shall be blocked from tripping the LV side CB's. This protection relay inherently provides stub-protection-1 function.

Primary side connections-2 shall be provided by a second protection arrangement as specified for HV connections-1 above.

The primary side connection protection is to be located within the primary side transformer protection panel. Operation of a connection protection relay shall operate separate primary side and secondary side trip relays on each protection channel except when the Transformer HV side disconnecter is open.

e. Back-up protection

Primary side back-up protection shall include inverse-time through fault overcurrent protection to ensure that the transformer will not be operated beyond its short-time withstand limits. Back-up protection may also provide stub-protection when the primary side disconnecter is open.

A transformer neutral connected standby earth fault relay shall provide system back-up earth fault protection and provided tertiary winding protection (subject to tertiary phase connection to main winding neutral).

f. Transformer auxiliary (mechanical) protection

Each transformer shall be fitted with a range of auxiliary protection and alarm devices as illustrated in the protection single line diagrams. The auxiliary protection trips shall be integrated into the transformer protection tripping scheme. The auxiliary protection trips shall be wired to trip the CBs directly from trip relay contacts as well as through protection relay trip binary outputs. The operation of these devices shall be logged by the SCS.

g. Circuit breaker failure

For CBs adjacent to the busbars, the breaker fail protection shall be integral to the busbar protection scheme and so arranged to trip the mid diameter CB and intertrip the circuit remote terminal CB.

For the mid diameter CB's, separate breaker fail protection shall be provided and the appropriate trip and intertrip scheme designed to open all adjacent CBs upon stage-2 operation.

h. Trip Relays

Dual trip lockout relays (86) shall be provided with each separately operating CB trip-coil 1 and trip-coil 2. These relays shall be electrically resettable, locally and via the SCS.

i. Fault recording

For new build substations a standalone substation fault recorder shall be provided and all appropriate primary side feeder analogue and digital signals shall be extended to this device. Additional fault recording shall be provided by the numerical protection relays. All fault records shall be retrieved via the SAS Engineering Workstation.

For existing substations, where practical, the existing fault recorder shall be adopted for the new circuits.

8.2.1.5. Power Transformers (Secondary side)**a. Protection arrangements**

The protection and control arrangements are illustrated in the single line schematic diagram in Part 2-D.

The circuit protection shall be housed in relay panels as defined in the Protection General Requirements.

The illustrated control arrangement is one Bay Control Unit (BCU) per CB and shall be located in a dedicated panel per diameter basis. The Contractor may provide alternative BCU arrangements.

Busbar protection bay module (including breaker-fail protection) shall be located within a dedicated suite of busbar protection relay panels.

b. Bay control and monitoring

The BCU associated with the CB adjacent to the Busbar shall be configured to control the circuit disconnecter and earth switch. For mid diameter circuits with no busbar CB then one BCU of the associated CBs shall control the circuit disconnecter and earth switch. The contractor may propose alternative BCU configurations.

BCU shall provide mid-diameter CB failure functionality.

The BCUs shall perform the check synchronisation function and shall provide 3ph voltage signals from each busbar and each mid-diameter section to the SCS. The appropriate busbar and circuit VT secondary voltages shall be supplied to the BCU via a diameter voltage selection scheme according to the status of the AIS switchgear.

For communication purposes, all numerical protection devices shall be capable of being connected to the substation LAN via protocol IEC 61850. In exceptional cases, provided the approval of KETRACO, single numerical protection devices can be connected via a serial link to the BCU, using a protocol different from IEC 61850, but this shall only be the case if no comparable device with IEC 61850 is available on the market.

The BCU shall normally be supplied from DC1 auxiliary supply and upon loss of this supply automatic changeover to DC2 shall occur within the tolerable BCU dc interruptions ride through time.

Bay control unit requirements are fully detailed in the SAS specification.

c. Transformer protection

The transformers shall be provided with one numerical main protection systems.

Main protection schemes are detailed in the primary side particular requirements specification and are to be located in the primary side protection cubicle.

Operation of the main protection relay shall operate separate secondary side and primary side trip relays on each protection channel.

d. Back-up protection

Secondary side back-up protection shall include inverse-time through fault overcurrent protection to ensure that the transformer will not be operated beyond its short-time withstand limits. Back-up protection may also provide stub-protection when the secondary side disconnector is open.

e. LV Connections protection

The transformer LV connections (Secondary side) shall be provided with two sets of numerical main protection systems connected to one set of current transformers.

LV (Secondary side) connections-1 shall comprise current differential protection of either the low or high impedance principle. For low impedance protection, the protection relays shall provide separate CT inputs to ensure a bias characteristic across all CT inputs. Upon opening of the LV circuit disconnector the connection protection shall be blocked from tripping the HV CB's. This protection relay inherently provides LV stub-protection-1 function.

LV (Secondary side) connections-2 shall be provided by a second protection arrangement as specified for LV connections-1 above.

The Secondary side connection protection is to be located within the Secondary side transformer protection panel. Operation of a connection protection relay shall operate separately the Primary side trip relay and secondary side trip relay each on the associated protection channel except when the circuit disconnector is open.

f. Circuit breaker failure

For CBs adjacent to the busbars, the breaker fail protection shall be integral to the busbar protection scheme and so arranged to trip the mid diameter CB and intertrip the circuit remote terminal CB.

For the mid diameter CB's, separate breaker fail protection shall be provided and the appropriate trip and intertrip scheme designed to open all adjacent CBs upon stage-2 operation.

g. Tertiary Winding protection

The 11kV Tertiary winding is connected to a primary side earthing transformer that supplies the LV services switchboard. The protection comprises the following: -

- Tertiary 3-phase overcurrent and earth fault relay.
- Earthing Transformer 11kV side restricted earth fault protection.
- 11kV side standby earth fault protection

- Earthing Transformer Auxiliary protections (if any).

All tertiary and LV protections trip both the 400kV and secondary side CBs.

j. Automatic Voltage Regulator

Automatic Voltage Regulation (AVR) shall be provided by a dedicated numerical relay provided solely for control of the transformer On-Load Tap-Changer (OLTC). The AVR shall provide selectable local/remote, manual/automatic, parallel/independent and selectable Master/follower control. The AVR shall be connected via IEC 61850 to the substation LAN.

See separate Transformer and SCS specifications for further AVR details.

h. Trip Relays

Dual trip lockout relays (86) shall be provided with each separately operating CB trip-coil 1 and trip-coil 2. These relays shall be electrically resettable, locally and via the SAS.

i. Fault recording

For new build substations a standalone substation fault recorder shall be provided and all appropriate secondary side feeder analogue and digital signals shall be extended to this device. Additional fault recording shall be provided by the numerical protection relays. All fault records shall be retrieved via the SAS Engineering Workstation.

8.2.1.6. Transmission level Busbar Protection

The busbar protection arrangements are illustrated in the individual transmission circuit single line schematic diagrams.

The busbar protection scheme shall be current differential protection of numerical design of distributed principle. The bay units shall be installed in the OHL or power transformer protection cubicles, which are located in the Bay Control Rooms. The central units are to be installed in the substation control building having fibre optic connection to all bay units. Each busbar shall have its own central unit protection cubicle.

The central module shall be powered from two station DC auxiliary supplies, via dual power supply units, such that failure of one power supply unit will not result in loss of busbar protection. There shall be a high degree of continuous self-supervision, where the failure of any bay module, communication link or loss of auxiliary supply to a bay module will be alarmed and will not result in any incorrect tripping.

The bay modules shall acquire the appropriate current signals and shall monitor the position of the busbar disconnect switch auxiliary contacts for each diameter. The disconnect switch MBB type (Make before break) contacts shall be utilised for bus bar protection. The bay module shall also provide the breaker fail protection functionality for each busbar CB.

Existing substations having separate breaker fail protection shall maintain that design arrangement.

Check zone functionality shall be integral to the numerical busbar protection scheme and hence a separate relay providing check zone functionality is not required.

The busbar protection shall include checking techniques to detect analogue input errors that might provoke an incorrect trip under load. In addition, the sensitivity of the busbar protection shall be settable such that it cannot trip for any current measuring error under load conditions whilst still providing adequate sensitivity under minimum plant conditions.

Provision shall be made for future substation extension by including in the delivery two spare bay units per busbar, to ensure there will be no future problems with software versions.

Dual trip lockout relays (86) shall be provided with each separately operating CB trip-coil 1 and trip-coil 2. These relays shall be electrically resettable, locally and via the SCS.

The bidder shall include in his bid a detailed description about his proposed way of reliable and effective testing of the busbar protection against the background that central units and bay units are not installed in the same place and bay units are located in different Bay Control Rooms.

8.2.2. Distribution Systems (33kV)

8.2.2.1. Protection Performance Requirements

8.2.2.1.1. Protection redundancy

The requirements for protection system redundancy are less stringent than those applied to the higher voltage systems. A single set of main protection shall be applied to each new circuit with separate local back-up protection. Remote back-up protection should be provided by protection relays of other circuits.

Each protection group shall also be driven from separate current transformers and independent VT secondary circuits.

8.2.2.1.2. Provision of back-up protection

Back-up protection (e.g. inverse-time overcurrent and earth fault protection or thermal overload protection) shall be provided to trip protected plant and circuits in the event of a sustained external fault condition or of a sustained power system abnormality that would otherwise damage or significantly reduce the life expectancy of the protected plant.

Where applicable, each set of feeder protection shall include “Zone-2” under impedance remote backup protection for busbars to ensure that, in the event of busbar protection failure, a remote-end busbar fault will be cleared within the switchgear internal arcing fault withstand time.

8.2.2.1.3. Circuit breaker failure (if required)

The provision of numerical busbar protection (if any) enables the inherent application of circuit breaker fail protection and shall cater for the possibility of a single circuit breaker failing to clear fault current when

commanded to do so, by either of the main protection systems. The breaker fail protection shall initiate a first stage circuit breaker re-trip followed by a second stage rapid back-trip/intertrip of adjacent

circuit breakers, as necessary, and within KETRACO's required breaker failure fault clearance time of 300ms.

8.2.2.1.4. Auxiliary DC supplies

The auxiliary power and tripping supplies for each separate protection group shall be derived from a single DC auxiliary supply systems.

8.2.2.1.5. Protection supply and trip circuit supervision

The protection systems shall continuously supervise the DC auxiliary supplies and the integrity of all circuit breaker tripping circuits with the circuit breaker in the closed or open state. All protection relays shall incorporate comprehensive continuous self-monitoring and diagnostic facilities. All supervision relays shall provide an alarm signal into the SAS system.

8.2.2.1.6. High speed tripping relays

With immunity to operation with DC wiring capacitance discharge currents, high-speed tripping relays should be used to interface protection relay trip contacts to circuit breaker trip circuits. These are to ensure that output contacts within the protection relays will not be damaged in the event of the circuit breaker failing to interrupt its trip coil current before the protection relay contact(s) open (e.g. in the event of fault clearance by breaker fail protection). They will also form a single point of interfacing between the protection schemes and the circuit breaker. The tripping relays shall either be of the self reset type or of the latching type, with circuit breaker lockout contacts, according to protection scheme requirements.

8.2.2.1.7. Protection trip, alarm and disturbance records

The protection systems shall provide comprehensive records for trip and alarm conditions, with local indications of which element has initiated a trip or alarm and of voltage and current vector parameters at the time of trip initiation.

Voltage and current waveform disturbance recording and event-logging shall be included as part of the protection system.

8.2.2.1.8. Test facilities

The protection systems shall include comprehensive maintenance isolation and test facilities.

OHL Feeders

OHL feeders shall be provided with a single main protection and a separate back-up protection system.

The bay protection and control equipment shall be located within a dedicated relay panel, as indicated in the respective diagram.

For the communication purposes, all numerical protection devices shall be capable of connection to the Bay control unit or substation LAN.

The BCUs shall perform the check synchronization function and shall provide 3-phase voltage signals to the SAS. The appropriate busbar voltages shall be supplied to the BCU via a voltage selection scheme functions according to the monitored status of the bus disconnector switches. BCU shall also provide fault recording functions.

Logic shall be provided within the Bay Control Units and the hard wired logic scheme such that operator open and protection trip signals to the Bus Coupler and Bus Section circuit breaker are blocked when any bay is undergoing load transfer until the transfer process is complete.

The BCU shall have a main DC supply and a standby dc supply automatically connected should the main DC supply be lost. Change-over should occur within the tolerable BCU dc interruptions ride through time.

Bay control unit requirements are fully detailed in the SAS specification.

8.2.2.1.9. Main protection

The new overhead line feeder circuits between the existing substation and the new substation shall be provided with a single main protection system that comprise one set of numerical 3-Zone distance protection operating in “Blocked mode”. The Main 1 distance relay shall also incorporate Directional Earth Fault protection and shall operate in blocked mode.

- **Main Protection Signalling**

Where the length of the OHL permits, main distance protection shall be designed for direct interfacing to a pair of optical fibres for teleprotection communication. Should there be no OPGW or separate fiber conductor in the line construction then a digital teleprotection signalling unit (Multiplexer) shall provide the necessary teleprotection communications between circuit-end relays. For direct fibre or multiplexer based communications, the distance protection should preferably be provided with an integral, two-way, high-speed, high-security intertripping channel, where energization of an intertrip send optical isolator of one relay will cause dedicated intertrip receive contacts of the remote relay to operate.

8.2.2.1.10. Auto-reclose

OHL circuits shall be equipped with a single auto-reclose relay per circuit. The auto reclose sequence shall be initiated from the main protection relays and shall preferably be integral to the BCU which provides integral check synch.

The circuit breakers are 3-phase tripping only and hence all auto-reclose sequences shall be 3-phase. The number of auto-reclose shots shall be confirmed. Typically, an auto-reclose sequence is one shot and lock-out if a second fault occurs within the reclaim time.

The auto-reclose sequence shall be blocked by distance protection time delayed impedance zones, operation of main protection Switch-onto-fault (SOTF) function, operation of busbar protection and circuit breaker failure protection.

Circuit breaker low stored energy signals shall inhibit the auto-reclose sequence until the elapse of a timer resulting in auto-reclose lockout. Should the stored energy recover before the elapse of the timer then auto-reclose

sequence will continue For 3-phase auto-reclose sequence, there is a possibility that the power system may be split and one part of the system may lose synchronism with respect to the other part. Any resulting circuit breaker auto reclose, without a check synchronism reference may result in an out of synchronism closure that damages the power system both electrically and mechanically. The severity of the damage depends on the degree of out of synchronism at the instant of closure.

For these reasons 3-phase auto-reclose shall be performed with check synchronism.

For existing substation where a central check synchronism relay is used, the availability of a signal from this scheme shall be investigated and if practical utilized. Alternatively, if the central check synchronisation scheme cannot provide the necessary signals then an auto reclose relay with an integral check synchronism feature can be provided and connected to busbar and line voltage transformers.

An intertrip receive signal shall inhibit the auto-reclose sequence until either the intertrip signal is reset or a persistent intertrip timer elapses and the auto-reclose relay goes to lockout.

The circuit breaker at the line end that recloses first shall upon detection of a permanent fault issue a persistent intertrip that prevents the remote end circuit breaker from reclosing onto the fault.

The auto-reclose relay shall be provided with a manual close inhibit feature that prevents auto-reclose for a settable period of time following manual circuit breaker closure e.g. following circuit breaker maintenance.

The auto-reclose relay shall provide circuit breaker maintenance alarm and lockout functionality.

The auto-reclose relay shall be provided with indications and alarms for:

- In/out of service
- Auto-reclose relay healthy
- Auto-reclose in progress
- Auto-reclose lockout
- Auto-reclose complete

The alarms shall be available locally on the relay and via the SAS.

8.2.2.1.11. Circuit breaker failure

For circuit breakers adjacent to the busbars, the breaker fail protection shall be integral to the busbar protection scheme and so arranged to trip adjacent circuit breaker s connected to the same busbar and intertrip the circuit remote terminal circuit breaker.

8.2.2.1.12. Back-up protection

Back-up overcurrent and earth fault protection shall be provided separate to the main protection relay.

Back-up shall also include sensitive earth fault (SEF) and broken conductor (BC) protection

functionality and shall be provided by the Bay Control Unit.

8.2.2.1.13. Trip relays

In order to permit auto-reclose functionality on OHL circuits, self resetting trip relays shall be provided for each trip coil and for each phase.

8.2.2.1.14. Fault recording

For new build substations, fault recording (waveforms and events) facilities should be integral to the numerical protection and control relays and retrievable via the substation automation and control system.

8.2.2.2. Power Transformer Protection (Primary Side)**8.2.2.3. Protection arrangements**

The bay protection and control equipment shall be located within a dedicated relay panel, as indicated in the respective diagram.

8.2.2.3.1. Bay control and monitoring

For the communication purposes, all numerical protection devices shall be capable of connection to the Bay control unit or substation LAN.

Synch check will not be required at Primary side, since the tripping logic for each transformer shall ensure that the secondary side circuit breaker is tripped whenever the Primary side circuit breaker is open. Each transformer should always be first energized from the Primary side. The secondary side circuit breaker close circuit shall be interlocked with a voltage monitoring function such that circuit breaker closure is prevented when the secondary side circuit is de-energized.

The BCUs shall perform the check synchronisation function and shall provide 3-phase voltage signals to the SAS. The appropriate busbar voltages shall be supplied to the BCU via a voltage selection scheme functions according to the monitored status of the bus disconnect switches. BCU shall also provide fault recording functions and may provide the back-up protection functions.

Logic shall be provide within the Bay Control Units and the hard wired logic scheme such that

operator open and protection trip signals to the Bus Coupler and Bus Section circuit breaker are blocked when any bay is undergoing load transfer until the transfer process is complete. For double busbar configurations with two Bus Couplers and one or more Bus Sections, the Bus Section tripping shall not be blocked if the circuit undergoing on-load transfer and the Bus Coupler being used to provide the “parallel path” are on the same section of busbar. Where the Bus Section is included in the “parallel path” the tripping shall be inhibited.

The BCU shall have a main DC supply and a standby dc supply automatically connected should the main DC supply be lost. Change-over should occur within the tolerable BCU DC interruptions ride through time. Bay control unit requirements are fully detailed in the SACS specification.

8.2.2.3.2. Main transformer protection

The transformer and secondary side circuit is protected by the main protection transformer biased differential and separate HV and LV restricted earth fault protection. The Main protection and HV REF protection is located within the primary side protection panel and the LV REF protection located in the secondary side protection panel.

8.2.2.3.3. Back-up protection

Within the protection panels, directional overcurrent back-up protection and secondary side winding starpoint standby earth fault protection shall be provided. The directional protection shall be set to coordinate with the primary side inverse time overcurrent protection and secondary side standby earth fault protection of the parallel transformer(s). The standby earth fault protection shall be co-ordinated with the buscoupler and bus-section earth fault elements and shall trip both the primary and secondary side circuit breakers in one stage.

Back-up protection shall be integral to the BCU.

8.2.2.3.4. Transformer auxiliary protection

Protections are detailed in the specification for the transmission level.

8.2.2.3.5. Protection trip relays

The primary and secondary protection schemes for each transformer shall include latching, multi-contact, tripping/lockout relays. These relays shall be capable of being electrically reset either locally or via the SAS.

8.2.2.4. Bus Section**8.2.2.4.1. Protection arrangements**

The bay protection and control equipment shall be located within a dedicated relay panel, as indicated in the respective diagram.

8.2.2.4.2. Bay control and monitoring

For the communication purposes, all numerical protection devices shall be capable of connection to the Bay control unit or substation LAN.

The BCUs shall perform the check synchronisation function and shall provide 3-phase voltage signals to the SACS. The appropriate busbar voltages shall be supplied to the BCU via a voltage selection scheme functions according to the monitored status of the bus disconnector switches. BCU shall also provide fault recording functions.

Logic shall be provide within the Bay Control Units and the hard wired logic scheme such that

operator open, and protection trip signals, to the Bus Coupler and Bus Section circuit breaker are blocked when any bay is undergoing load transfer until the transfer process is complete.

For double busbar configurations with two Bus Couplers and one or more Bus Sections, the Bus Section tripping shall not be blocked if the circuit undergoing on-load transfer and the Bus Coupler being used to provide the

“parallel path” are on the same section of busbar. Where the Bus Section is included in the “parallel path” the tripping shall be inhibited.

The BCU shall have a main DC supply and a standby DC supply automatically connected should the main DC supply be lost. Change-over should occur within the tolerable BCU DC interruptions ride through time.

Bay control unit requirements are fully detailed in the SACS specification.

8.2.2.4.3. Back-up protection

Inverse-time overcurrent and earth fault protection shall be provided to safeguard against sustained overloading of a bus section circuit breaker as a result of operator error or of a power system break up.

8.2.2.5. Busbar protection (if required)

The protection arrangements are illustrated in the 66kV circuits' single line diagrams.

The busbar protection scheme shall be current differential protection, of numerical design of centralised principle.

The relay shall be powered from two station DC auxiliary supplies, via dual power supply units, such that failure of one power supply unit will not result in loss of busbar protection.

There shall be a high degree of continuous self supervision, where the failure of any bay module, communications link or loss of auxiliary supply to a bay module will be alarmed and will not result in any incorrect tripping.

The bay units shall acquire the necessary current signals and they shall monitor the position of the busbar selector switch auxiliary contacts for each diameter, as necessary. They shall also provide the breaker fail protection functionality for each busbar adjacent circuit breaker.

Provision shall be made for future substation extension by ensuring the busbar protection scheme is installed with bay modules for two future “spare” diameters to ensure there will be no future problems with software versions.

The busbar protection shall include checking techniques to detect analogue input errors that might provoke an incorrect trip under load. In addition, the sensitivity of the busbar protection should be settable such that it cannot trip for any current measuring error under load conditions whilst still providing adequate sensitivity under minimum plant conditions.

Check zone functionality shall be integral to the numerical busbar protection scheme and hence a separate relay providing check zone functionality is not required

8.2.3. Substation Optical Cables and Termination

The main optical fibre cables are supplied under the overhead line contracts and are to be terminated at a termination block (TB) supplied by the overhead line contractors. The OPGW TB is to be mounted on either the line landing gantry or terminal tower and the substation Contractor will continue the FO into the substation.

Once in the substation, the main optical fibre cables are to be terminated at an optical termination block (OTB). The main OTB may be housed within a termination panel or telecommunication cubicles. The substation Contractor shall supply and install the optic fibre cable between the main OTB and the OTB located in the applicable protection panel. The optical characteristics of the substation optical fibres shall be the same as those specified in the overhead line contracts. Patch cords shall connect the protection relays to the panel OTB. A pair of spare optical fibres shall also be available in each substation optical fibre cable running from the OTB to the main protection panels and these shall be terminated at each end with the appropriate connectors.

The substation Contractor shall undertake a loss budget analysis and provide multiplexers if necessary for satisfactory transmission of signals between the substations.

8.2.4. Instrument Transformer Requirements

CTs and VTs ratio, class and accuracy limitation factor have been defined elsewhere in the substation specification. In addition, CTs and VTs are indicated on each protection single line drawing. The Contractor shall ensure that the CT and VT characteristics (VA burden or V_k) are calculated to meet at least the minimum protection and instrumentation manufacturer's requirements.

Current transformer requirements shall be determined to ensure high protection performance. The Contractor shall submit a comprehensive technical report that includes the required CT ratio and burden, the selected accuracy class and the Accuracy Limit Factor and knee point voltage calculations. The report shall confirm that CTs are designed to guarantee an excitation of the protection functions during all possible short-circuit and earth-fault conditions. For that purpose, ratio has to be selected accordingly, taking into account accuracy limits given by the measured current in relation to the rated current and by the connected burden. Furthermore, CTs shall ensure a saturation-free performance under both transient and steady state fault conditions, taking due account of system X/R ratios, system fault levels and remanent flux conditions in the CT core. Saturation of current transformers during short-circuit conditions can lead to mal-operation of protection relays and to unselective tripping. Especially distance and differential protection functions do have high requirements. In this regard it has to be considered that fault currents during transient conditions consist of a symmetrical a.c. component and a d.c. component, that rapidly saturates the core. A connected burden lower than the rated burden may help in this regard as far as the current transformer will be able to transmit higher currents without saturation. The calculation shall take into account the specific protection relay requirements. Modern protection relays do have, as an integral part, saturation detectors that reduce the time in which the relays need to be supplied with an unsaturated current. A corresponding evidence shall be based on the related manufacturer specific relay formulas. Furthermore, it has to be taken into account, that protection relays do have limits in which short circuit currents can be measured without endangering the current inputs of the protection relays. That means that having a low actual burden can also lead to secondary currents that can damage the current inputs of the relays. This has also to be verified.

The calculation shall be done for each typical core, typical in respect of the core data and the protection relay(s) connected to the core.

Typical X/R ratios of power systems shall be considered. The bus fault levels shall correspond to the respective switchgear ratings, unless specified otherwise.

Furthermore, the report shall show that selected rated burdens of CT measuring cores fit to the requirements of measuring instruments and meters. In this matter IEC definitions regarding burden limits for guaranteed accuracy class shall be considered. Additionally, it has to be considered, that the rated instrument security factor (FS) is effective at rated burden and that a connected burden lower than the rated burden results in higher amplitude of current that measuring instruments and meters need to withstand during short circuit conditions.

A burden calculation for VT windings shall show that the selected rated burdens fulfil the requirements of the protection relays, measuring instruments and meters. Furthermore, IEC definitions regarding burden limits for guaranteed accuracy class shall be considered. It shall also be considered that in case of short-circuit in the secondary circuit of the VT the tripping of the protective mini circuit breakers must be guaranteed.

Summarizing above statements, the CT and VT calculation document shall be structured accordingly in:

- General explanations describing what is calculated and how.
- Calculation per feeder/ CT(VT)/ core(winding) with
- Feeder single line diagram showing the CT cores respectively VT windings and the connected protection relays, measuring instruments and meters.
- Indication of:
 - General feeder data (short circuit current, voltage, power etc.)
 - Data of the CT core respectively VT winding
 - Data of the connected protection relays, measuring instruments and meters (burden etc.)
- Calculation of maximum possible primary current and selection of rated primary current accordingly
- Indication of the requirements of the protection relays, measuring instruments, meters etc. (a reference shall be made to the correspondent documents of the protection re-lays e.g. the chapters of the related manual)
- Calculation of the complete burden connected to the CT core respectively VT winding.
- Calculation to verify that the requirements are fulfilled.
- Conclusion
- Reference documents (e.g. relevant pages from the manuals)

The Technical Data Sheets include tentative data for CTs (ratio, rated output, accuracy limit factor) and VTs (rated output). The final data results from the calculation performed by the Contractor. Necessary changes of the data due to the calculation results do not permit the Contractor to ask for additional costs.

In case of capacitive voltage transformers (CVT) the relay system shall operate correctly and with high speed and shall have correct directional sensing in the presence of severe CVT transients produced in accordance with ANSI standard C93.2 or IEC equivalent. The CVT transient requirement shall include the conditions of relaying accuracy with the rated burden of the CVT connected.

The voltage circuit shall be divided into separate groups for each protection relay or other equipment to be connected. All subdivisions into groups shall be carried out in the junction box nearest to the voltage transformer, where the various groups shall also be individually protected against short circuits with miniature circuit breakers.

In each relay panel incoming voltage circuits (from the junction boxes or other relay panels) shall be first wired to miniature circuit breakers, before connecting the circuits to the relays.

The miniature circuit breakers shall be provided with electromagnetic and thermal protection elements and shall have potential free contacts for blocking purpose and signalling. Auxiliary contacts for voltage blocking need to be designed for this special purpose (short tripping times).

Where voltage inputs to protection relays are required, these shall be monitored continuously. Any open phase shall be detected on high speed and shall prevent mal-operation of the affected protective relays. Unbalanced conditions in the current circuits due to defective connections should also be monitored. Auxiliary contacts of mini circuit breakers need to be designed for this purpose.

8.3. Documentation

The Contractor shall provide all necessary drawings, design specifications, design details, operation and maintenance manuals.

8.3.1. Documentation with Bid

The Tender shall contain at least the following information and documents, failure of provision of the mentioned documents will lead to disqualification:

- Protection and indication single line diagrams of the substation(s);
- General arrangement drawings of the protection and indication panels;
- Manufacturing specification of the protection and indication equipment;
- Catalogues, literature and reference lists of proposed equipment;
- A comprehensive set of documentation shall be provided for all protection relays covering, as a minimum, the following topics:
 - Detailed description of protection relay including coverage of self-monitoring facilities, if applicable.
 - Range of features provided as standard.
 - Range of optional features.
 - Range of settings provided for all features, both standard and optional.
 - Details of all of the operating time characteristics for the protection relay.

- Statement of performance under reference conditions.
 - Variation of performance with departure from reference conditions.
 - Effects of interruptions to dc auxiliary power supply.
 - Current transformer requirements.
 - Voltage transformer requirements.
- Pre-energisation and commissioning;
 - Details of all necessary pre- energisation and commissioning tests shall be submitted for approval prior to the tests being performed, together with any supporting explanatory documentation such as “Installation, Operation and Maintenance manuals”. An opportunity shall be provided for KETRACO to witness site tests.
 - Type test certificates from an independent testing authority or independently witnessed;
 - A type test certificate shall be provided for each relay type, which shall confirm compliance of the protection relay with the requirements of the relevant sections of IEC 60255. Any areas of non-compliance shall specifically be identified. It shall be stated whether the protection relay has been approved by any independent approval bodies or users.
 - Quality Management System Manual and ISO Certificate of the equipment manufacturer.

8.3.2. Documentation after Award of Contract

All documents required for KETRACO's approval shall be submitted by the Contractor.

9. Telecommunication System

1.1. General requirements

The new telecommunication systems to be provided at the substations shall be designed to transmit and receive data, voice and teleprotection signals according to this specification. The objectives of the telecommunication systems are to provide the relevant communication facilities and interfaces at the new substations and to integrate into the existing telecommunication network. All necessary hardware and software shall be provided to enable full integration to be achieved.

Complete Substation Telecommunication System to be implemented as per Grid code and KETRACO Technical specification and SCADA policy. Moreover, it should be considered remote end modification for SCADA based on existing design philosophy.

It is envisaged that the new telecommunication equipment shall be based on synchronous digital hierarchy (SDH) technology operating at STM-1/4/16 transmission level. All necessary optical boosters and pre-amplifiers shall be provided to enable satisfactory communications between substations without using intermediate repeaters or regenerators. The operating wavelength of the SDH network shall be 1310 nm or 1550 nm as appropriate. The multiplexer shall be able to be linked to the backbone telecommunication network and shall maintain redundancy with all other multiplexer in opposite sites.

The SDH network shall be designed for digital transmission using single mode optical fibres and shall conform to relevant ITU-T recommendations for the specified transmission bit rates. A minimum of 4 fibre pairs (i.e. 8 single fibres) shall be made available for use by the telecommunication system. Firewall shall also be implemented to eliminate unwanted communication and malicious attacks through SDH network.

The existing telecommunication network backbone is based on fibre optic via OPGW fitted to overhead lines. The Contractor shall be responsible for ensuring the supplied equipment is capable of interfacing with the existing telecommunication equipment. Should the bidder have any additional requirements he should state these in the Tender.

The SDH multiplexers shall be capable of being upgraded to the next hierarchy level, by exchanging appropriate modules at a later stage, to provide a higher transmission rate using the same optical fibres. The maximum transmission capacity that the proposed SDH network can achieve and whether the upgrading can be carried out whilst the system is carrying live traffic shall be stated in the offer.

The Contractor shall be fully responsible for the design of the telecommunication system and the provision of necessary items and works required for proper operation of the telecommunication system under the Contract. The telecommunication system shall provide, as a minimum, the following communication facilities:

- a. V.24/V.28 (RS232C) asynchronous data channels with speed up to 9.6 kb/s.
- b. High speed data channels (n x 64 kb/s).
- c. 2 Mb/s transport service.

- d. Voice channels.
- e. Teleprotection signalling channels.
- f. Gigabit Ethernet Interfaces 1000 Base-X/T
- g. Common LAN – 10/100 Base-T interfaces (RJ45) for connection of gateway computers of substation control system.
- g. Other non-critical operational and administrative data communication services using TCP/IP.

The Contractor shall be responsible for any modifications and re-allocations of existing channel assignment required to ensure that the telecommunication system can be developed and existing facilities are fully migrated to the new network with minimal disruption to power system operation.

A diagram showing the bidder's proposed telecommunication system and a detailed description on the functionality provided shall be submitted with the Tender.

The new telecommunication equipment shall conform to the latest editions of the International Electrotechnical Commission (IEC) Specifications, ISO Standards, IEEE Standards, and International Telecommunication Union (ITU) Specifications.

Details of the existing telecommunication system and OPGW cable can be found in Part 2G of the Bid Document.

VHF mobile radio system and network shall be provided in each new substation including a station set, at least 4 portable handsets, battery and battery charger, suitable antenna with all required accessories e.g. RG, Heliac cabling, AC & DC cabling, indication lamp and supported tower with suitable height (details as per clause No. 10 and 11).

9.2. Design and Operational Philosophy

The design philosophy of the new telecommunication system is that failure of any single component shall not cause failure of critical function. In addition, the telecommunication system shall be capable of providing a fully resilient network in which all speech, data and teleprotection signalling channels can be automatically re-routed in the event of a trunk/node failure and/or traffic congestion occurring anywhere on the network.

Cross-connection design criteria of channels shall be as follows:

- a. Transmission of teleprotection channels over physically separated multiplex equipment.
- b. Transmission of “main” and “standby/backup” channels over physically separated multiplex equipment as much as possible.

Telecommunication equipment supplied shall be equipped with dual redundant hot-standby control modules and power supply units. The equipment shall preserve configuration data during power failure and all modules shall be capable of hot swappable.

Appropriate number of 2 Mb/s tributaries on the STM-1/4/16 system will be utilised to provide voice, data and teleprotection signalling connectivity using first order multiplexing equipment. The 2 Mb/s transmission system will interconnect the following end-user facilities:

- a. High speed (64 kb/s) data channels according to ITU-T G.703.
- b. Low speed data channels (up to 9.6 kb/s asynchronous according to ITU-T V.24/V.28).
- c. Voice channels (E&M 2/4 wire).
- d. Remote subscriber channels.
- e. Gigabit Ethernet Interfaces 1000 Base-X/T
- f. Common LAN – 10/100 Base-T interfaces (RJ45) for connection of gateway computers of substation control system.

The telecommunication system shall also have provision for an engineering order wire (EOW) facility capable of providing a dedicated telephone communication system for commissioning/maintenance purposes between nodes.

Major communication equipment malfunction alarms shall be transmitted to the appropriate Control Centre via the SCADA system, to alert the system operators of the operational status of the telecommunication system. In addition, it is envisaged that remote supervision and monitoring of the new communication equipment will be via the existing telecommunication network management systems. All necessary hardware and software interfaces to enable integration with the existing telecommunication network management systems shall be provided under the Contract. Full details showing how this is achieved shall be submitted in the Tender.

9.3. Expansion and upgrade capability

The telecommunication system supplied by the Contractor shall employ open standard concept in the design and shall offer greatest flexibility for future expansion and upgrade of the system and facilities.

System expansions and upgrades carried out at a later stage shall be possible by means of minor modifications and/or by the addition of extra equipment modules to the telecommunications system. The following future upgrade options shall be possible:

- a. Single fibre operation.
- b. Dense wavelength division multiplexing (DWDM).
- c. TCP/IP Ethernet networking.
- d. Tele-Protection over Multi-Protocol Label Switching Network (MPLS-TP)

The telecommunication system shall be supplied already equipped with a minimum of 20 per cent spare capacity including interface modules for each type of communication circuit. A minimum of 50 per cent system expansion capability shall be provided over and above the capacity/channel requirements that are needed for the new telecommunication system.

Details of system expansion and upgrade capability shall be submitted with the Tender.

9.4. Teleprotection signalling

The Contractor shall provide the necessary teleprotection signalling equipment including all necessary ancillary equipment so that teleprotection signalling commands such as blocking, permissive tripping and direct tripping can be transmitted via the new fibre optic link.

It is envisaged that at least 4 simultaneous teleprotection signalling commands shall be required per circuit. The Bidder shall include details of the proposed teleprotection signalling system in the Tender.

9.5. Telephony

For tendering purpose, the telecommunication system shall be capable of supporting:

- 3 simultaneous voice channels at each substation.

Telephone handsets shall be of modern design and equipped with push buttons for call selection and shall be suitable for desktop or wall mounted installation.

The final design and colour of the telephone handsets shall be subject to the approval of the Employer/ Employer's Representative.

9.6. Power supply

A 48 Vdc power supply system shall be provided at each new substation for powering the telecommunication systems. The 48 Vdc power supply system shall consist of duplicated 100% float/boost chargers and two sets of storage battery. In the case of mains failure, the autonomy of the system shall be 10 hours. Power supply system operating in so called full float regime shall be used. The batteries and the chargers shall be sized to support the full load and 50 per cent spare capacity over and above the required loading requirements.

The 48V DC distribution shall be independent and supplied by separate main distribution panel(s) adjacent to the battery (ies) for communication equipment. Sub-circuit protection shall be in the particular panels, using MCBs. Any change-over and transfer facilities shall be located at these panels. Multiple grounding or earth return system is not permissible.

The battery capacity shall then be optimized to the minimum obtainable temperature of 10°C inside the powerhouse. Final battery capacity shall include a minimum 15% design margin in the calculated value to allow for aging and temperature effects on the battery. Aging factor shall be considered 25%.

If more than one system is specified, manual or automatic transfer facilities which will be fully interlocked to prevent loss of output voltage shall be provided. Manual or automatic transfer system shall be considered of make-before-break type.

To the automatic operations, the following requirements shall also be met with the selector switch in the 'Auto' position:

- On an automatic transfer, the breakers shall operate in such a way to prevent an interruption of power to the loads being transferred. Paralleling of supply systems will occur momentarily during this transfer. It shall not be possible to parallel the supply systems under any other circumstances.
- Individual control of each one of the supply and bus section breakers by means of their local control switches shall be blocked.
- The under voltage transfer control shall be blocked if any of the supply or bus section breakers are withdrawn from their 'connected' position.
- The automatic under voltage transfer control shall be blocked if either of the supply breakers are tripped due to an over current condition, or if there is a complete AC failure to both battery chargers.

In the manual mode, it shall not be possible to parallel supply systems. The following requirement shall also be met with the selector switch in the 'Man' position:

- Individual control of each of the supply and bus section breakers shall be possible by means of their local manual control switches. This shall apply whether the breakers are in the 'connected' or 'test' positions - The automatic under voltage transfer control shall be blocked.

The system shall continue its normal operation in case of a fault on one feeder or section of the system without affecting the DC supply to other section. The system is required to continue its normal operation with a single ground fault but an alarm shall be initiated. The system will interrupt DC supply if ground fault current increases to a predetermined level or there are two ground faults.

9.7. Interfaces with other systems/equipment

The telecommunication system shall be equipped with the necessary hardware including interconnection cabling and software to enable interfaces and full compatibility with the following systems to be made:

- a. Existing telecommunication systems.
- b. Existing telecommunication network management systems.

The Contractor shall be responsible for resolving and co-ordinating with other contractors or Authorities to ensure that the interfaces and the final installation between the telecommunication systems and other systems are fully compatible both physically and operationally. Failure to co-ordinate or delay in providing or timely requisition of the necessary interfacing information/ requirements shall be at the risk of the Contractor and the Contractor shall bear any costs which may arise as a result thereof for the provision of modification to other works which are involved with or subject to another contract.

9.8. Fibre optic communication system

9.8.1. General requirements

9.8.1.1. Introduction

The SDH system shall be designed for digital transmission using single mode optical fibres and shall conform to the ITU-T recommendations G.703, G.704, G.707, G.783 and G.957.

The multiplexing structure of the proposed SDH system shall allow existing PDH signals to be carried over the synchronous network and shall permit the extraction of individual circuits from high capacity systems without having to demultiplex the whole system. Cross connect facilities shall be provided to enable interconnections between different channels and network components.

The fibre optic communication system shall be provided with direct software control of network functions and in-service provision, and comprehensive network management and distributed bandwidth on demand facilities. In addition, remote test control and centralised alarm gathering and reporting features shall also be provided.

All electrical and electronic equipment supplied shall be properly grounded and shielded to protect the equipment and operating personnel from effects of induced currents and voltages. The equipment shall be rack mounted and be of modular design construction and be housed in approved equipment enclosures. The enclosures shall be provided with lockable doors.

The equipment shall not generate any type of electromagnetic interference at a level which could be detrimental to the performance of other equipment or which could cause annoyance or discomfort to personnel. Details of electromagnetic emission levels shall be included in the Tender. Where the performance of the equipment could be susceptible to interference, the Contractor shall state the maximum level of such interference, which will not cause equipment malfunctioning.

Built-in test and self-monitoring facilities shall be provided to enable maintenance personnel to break-in and/or make bridging measurements without degradation or interruption of service.

In order to maximise the benefit of the communication network and to facilitate the operation and maintenance of the SDH and PDH equipment, the system shall include network management capability so as to facilitate system performance monitoring, alarm and fault monitoring, system configuration, bandwidth management, dynamic allocation, automatic re-routing, prioritising of channels, testing and maintenance facilities etc.

A redundant configuration for ensuring minimum down time in case of equipment failure shall be provided by installing two physically separated SDH – multiplexers. Any failure shall produce automatic switch-over to the back-up unit and initiation of an alarm. Bidders shall provide detailed design philosophies for equipment and routing redundancy.

The fibre optic communication equipment shall be capable of providing proper performance for at least 25 years.

9.8.1.2. Loss budget calculations

The Contractor shall carry out loss budget calculations for each transmission link to ensure the SDH system meets the requirements of this Specification. The calculations shall include both a 'worst case' and a 'typical' loss budget calculation, using the respective maximum and average attenuation predicted for each component in the system.

The optical power budget calculation shall take into account of the following parameters:

- a. Mean launch power.
- b. Receiver sensitivity.
- c. System design penalties.
- d. Margin for age degradation and temperature.
- e. Connector losses.
- f. Maximum installed cable loss.

System performance calculations shall include a minimum safety margin of 3 dB.

Preliminary loss budget calculations shall be included in the Tender. Detailed calculations shall be submitted during the detail design stage for the approval of the Employer/ Employer's Representative.

9.8.1.3. Safety

The SDH and PDH equipment will be situated in high voltage electricity substations which are subject to rises in earth potential at times of system faults. Precautions shall be taken to prevent damage occurring to the equipment.

The system shall incorporate all reasonable precautions and provision for the safety shut-off of the optical source to prevent exposure to laser light during installation, maintenance and repair work. The possibility of automatic laser shut down adjustment through the network management system should be supported. Laser products shall comply with the requirements of IEC 60825 specification.

All metal parts, metal cable sheaths and equipment housings shall be bonded to earth. Details of the earthing arrangements shall be submitted to the Employer/ Employer's Representative for approval.

9.8.2.Functional requirements

9.8.2.1. General

The SDH system shall have the following features:

- a. High operational security and reliability.
- b. High quality transmission in accordance with ITU-T recommendations.
- c. Flexibility for adaptation to the desired transmission capacity.

- d. Integrated monitoring facilities.
- e. Comprehensive operation and fault diagnosis.
- f. Redundancy capability where required.
- g. Direct and easy access to the transmitted base band signal.
- h. Direct connection to multiplexing equipment employing pulse code modulation (PCM) techniques.
- i. Capability of routing TCP/IP traffic.
- j. Support Q3 interface in accordance with ITU-T G.773.

As far as practicable all fibre optic communication equipment shall self-diagnose internal fault conditions and separately alarm their occurrence. The designs shall also include diagnostic test facilities to allow step-by-step checking of the performance of the equipment.

9.8.2.2. System capacity and performance

The system shall be capable of being upgraded to the next STM hierarchy level by exchanging appropriate modules at a later stage, to provide a higher transmission rate using the same optical fibres and repeater locations, if any.

The overall mean equivalent bit error rate (BER) of the SDH system between any two end terminals shall not be worse than 10^{-9} under normal operating conditions. The typical error rate for each traffic path shall be stated. End to end error performance shall be in accordance with the requirements of ITU-T recommendation G.826.

The automatic switch-over to standby transmitter criterion shall be $BER > 10^{-9}$. Switching shall also be possible manually for maintenance purposes. The switchover shall be transparent to the data stream.

Jitter performance on STM-1/4/16 interfaces shall be in compliance with ITU-T recommendations G.813 and G.825.

The SDH system shall include provision for overcoming impairments caused by transmission delays. Details of the performance of the proposed SDH system shall be included in the Tender.

The SDH system shall preserve configuration data during power failure or management connection failure. During power or management connection failure alarm logs and performance monitoring statistics shall be preserved.

Signal synchronising facilities are required to enable the system to be implemented effectively, and facilities for connection of unused multiplexer inputs to appropriate signals as specified by the manufacturer shall be provided. In addition, details of how the Bidder intends to perform synchronisation across the fibre optic communication network shall be included in the Tender. The existing synchronization scheme applied in the system shall be followed.

9.8.2.3. Service channels

Each SDH terminal equipment shall provide at least two analogue and four digital service channels for voice communications and testing purposes between any two terminal stations exclusively for the use of installation and servicing personnel.

The 64 kb/s digital service channels shall be suitable for any data transmission requirements.

Each SDH terminal equipment shall have a handset for voice communications.

9.8.3.SDH equipment

9.8.3.1. General

The SDH equipment shall perform both multiplexing and optical line terminating functions and must be able to expansion and upgrade capability to Include MPLS TP. The aggregate ports of the SDH equipment shall be duplicated and shall be capable of operating in a '1 + 1' protected mode as part of a point to point link, or as an 'east/west' mode when used in a drop and insert chain in a ring. All features and functions of the SDH equipment shall be readily software configurable to suit operational requirements of the SDH system.

The SDH equipment shall be capable of being configured as a hub, cross connection, repeater, add/drop multiplexer or terminal multiplexer.

The SDH equipment shall be equipped with a range of plug-in tributary interfaces to support a comprehensive range of plesiochronous and synchronous tributaries including 2 Mb/s, 34 Mb/s, 140 Mb/s, and from STM-16 operation. Cross connection levels shall include 64 kb/s, VC-12, VC-3 and VC-4. Further common LAN interfaces and Gigabit Ethernet interface on tributary side shall be present.

Each SDH equipment shall comprise, but not be limited to, the following functional elements:

- a. Optical line interface.
- b. Electrical line interface.
- c. Tributary module.
- d. Switching unit.
- e. Control and alarm functions.
- f. Engineering order wire (service telephone) unit.
- g. Service data interface.
- h. Ethernet interface.

9.8.3.2. Optical line interface

The SDH equipment shall be capable of supporting the following optical interfaces:

- a. S-1.1, L1.1 and L-1.2 STM-1 interfaces in accordance with ITU-T G.957.
- b. S-4.1, L-4.1 L-4.2 and X-4.2 STM-4 interfaces in accordance with ITU-T G.957
- c. S-16.1, L16.1 and L-16.2 STM-16 interfaces in accordance with ITU-T G.957.

The optical interface shall carry out the parallel to serial conversion of traffic from the switch unit into a STM-16 2.5 Gb/s or STM-4 622 Mb/s and STM-1 155 Mb/s stream. The optical section shall convert electrical signals into an optical signal for transmission over an optical fibre and perform a reciprocal function on the receive side. Each optical line system shall be suitable for duplex operation at optical wavelength of 1550 nm over 2 optical fibres.

The electro-optic converter shall have a power output suited to the requirements of the fibre optic links and shall be suitable for transmission length of at least 180 km without the use of intermediate repeaters. All necessary optical boosters and pre-amplifiers shall be provided to suit the optical performance requirements of the fibre optic link.

The optical source shall have minimum life of at least 50 000 hours at an ambient temperature of +50°C. The transmitter shall have internal diode current and output power monitoring, which will provide status indications.

The design of the transmitter shall be in a way that under fault conditions, the launch power shall be significantly reduced to a safe level. It is preferable that the optical transmit and receive equipment are interconnected in such a way that a broken fibre will automatically switch off the optical transmitters at both ends of the section.

Transmitters which output optical power of sufficient intensity to cause hazard to health shall have mechanical interlocks to isolate the diode supply current during the installation or maintenance of the equipment. Sign warning of possible hazard shall be permanently fixed at all appropriate points.

Transmitters shall provide the continuous transmission of data timing information.

The optical receiver equipment shall have a bit error rate performance suited to the requirements of the network.

The receiver shall automatically accommodate signal level changes due to temperature effects and ageing of the system. Where necessary, receiver optical attenuators shall be provided to optimise link performance.

It shall be possible to use an optical line interface unit as a tributary module to enable STM-1/4/16 signals to be terminated when the equipment is configured as an 'Add/Drop' multiplexer.

The SDH equipment shall support FC/PC type optical connectors or similar.

9.8.3.3. Electrical line interface

The equipment shall support standard electrical tributary interfaces in accordance with ITU-T recommendation G.703. The electrical interface shall perform the same electrical functions as the optical interface unit. STM-1 electrical line signals shall be in accordance with ITU-T recommendation G.709.

It shall be possible to use an electrical interface unit as a tributary module to enable STM-1 signals to be terminated when the equipment is configured as an 'Add/Drop' multiplexer. A 10/100 Mb/s Ethernet LAN interface shall also be supported.

9.8.3.4. Tributary module

The tributary module shall perform the selective extraction/insertion of tributaries to and from the STM-1/4/16 signal whilst enabling other traffic to pass through without interruption.

The tributary module shall be capable of supporting tributary data rates of 2 Mb/s, 8 Mb/s, 34 Mb/s & 140 Mb/s.

The data from each tributary shall be mapped into virtual containers and tributary units in accordance with ITU-T recommendation G.774 which shall make up the SDH payload before being sent to the switch unit.

9.8.3.5. Switching unit

A switching unit shall be provided to allow traffic from any line interface unit to be connected to any tributary port or any other line port. In addition, it shall allow full cross connections between tributaries.

The switching unit shall provide the changeover facility from faulty units to the standby units to achieve 1+1 protection.

9.8.3.6. Control and alarms functions

Comprehensive control and alarm functions shall be included to provide performance monitoring, alarm and fault monitoring, system configuration, bandwidth management, dynamic allocation, automatic re-routing, prioritising of channels, testing and maintenance facilities etc. These functions shall interface to the telecommunication network management system to allow the control and alarm monitoring of the equipment to be carried out locally and remotely.

The equipment shall be provided with a fault location and supervisory system to monitor the status and alarms of the SDH equipment. The fault location and supervision system shall provide in-service bit error monitoring facilities.

The following alarms shall be provided on the SDH equipment as a minimum:

- a. Loss of incoming signal or loss of frame alignment.
- b. Optical transmit power low.
- c. Laser current high.
- d. Bit error rate (BER) threshold high.
- e. Optical receive level low.
- f. Multiplex input fail.

- g. Loss of clock signal.
- h. Distance alarms.
- i. Power supply fail or out of limits.

An alarm monitoring system shall be provided to monitor and display the locally derived alarms and if applicable adjacent repeater station alarms, showing the location of each alarm displayed. The system shall be capable of providing details of origin, date and time of the occurrence of alarms. It shall be possible to change alarm severity and threshold levels manually.

Alarm indications shall be clearly displayed through LEDs on the front panel of the module. It shall also be possible to remotely display some of the alarms locally at that site via voltage free contacts.

The alarm monitoring system shall form an integral part of the network management system. The alarm concept shall conform to ITU-T recommendation G.784. Test points shall be available on each unit to help in failure diagnosis.

Digital data streams shall be monitored at all levels. Equipment power supplies shall be monitored and a fuse alarm indication shall be provided for each cabinet or rack.

9.8.3.7. Engineer order wire

An engineer order wire (EOW) telephone system shall be provided at each SDH terminal site. The system shall operate on a service channel in the STM-1/4/16 -bit stream. The system shall be configured as an omnibus circuit, with a telephone handset, selective calling to reach any station along the route and an audible alert provided at each terminal.

9.8.3.8. Service data interface

Means shall be provided for accessing auxiliary channels using spare bytes in the SDH 'overhead' bit stream to enable management signals from additional equipment such as primary access multiplexers to be transmitted over the fibre optic communication system.

The number, bit rate and type interfaces available shall be stated by the Bidder.

9.8.3.9. Ethernet interface

The SDH equipment shall be capable of supporting 10/100 Mb/s BaseT interfaces complying with IEEE standard 802. Interfaces on the multiplexers tributary side shall be modular and provide up to four 10/100 Base T interfaces per –card slot.

9.8.4.Primary access multiplexing equipment

9.8.4.1. General

Primary access multiplexing equipment shall be provided as necessary and shall comply with the relevant ITU-T recommendations. The digital interface of the multiplexing equipment shall be of a time division multiplex signal conforming to the ITU-T recommendation G.703 to enable direct connection to the SDH optical multiplexing equipment.

All primary access multiplexing, de-multiplexing and signal processing and conditioning equipment shall be provided to interconnect SCADA, teleprotection and telecommunication equipment to the fibre optic communication system. It shall be the Contractors responsibility to ensure that the types and quantities of primary multiplexing equipment provided shall be capable of meeting the required number of communication channels specified, including redundancy requirements.

All equipment shall be wired for their maximum capacity. Future extension shall be possible by simple field installation of appropriate modules.

9.8.4.2. Multiplexer

The primary digital multiplexing equipment shall be capable of combining timeslots into a digital 2048 kb/s data stream conforming to the ITU-T recommendation G.703.

The multiplexing equipment shall have the following features:

- a. Sample rate for each channel shall be 8 kHz with maximum deviation of ± 50 parts per million, with 8 coding bits per sample, giving 256 quantisation levels, resulting in a 64 kb/s rate for each channel.
- b. Encoding law shall be in accordance with the requirements of ITU-T G.771.
- c. Jitter characteristics shall be equal to or better than ITU-T G.703.
- d. The 2 Mb/s interface shall be 2048 kb/s ± 50 parts per million with a HDB3 line code conforming to the ITU-T G.703.

Signal synchronising facilities are required to enable the system to be implemented effectively, and facilities for connection of unused multiplexer inputs to appropriate signals as specified by the manufacturer shall be provided. The existing synchronization scheme shall be applied.

Communications interfaces shall be capable of being made available by means of insertion of appropriate plug-in cards into the multiplexer rack to support the following user interfaces:

- a. 4-wire to 4-wire voice frequency.
- b. 2-wire to 2-wire voice frequency.
- c. 2-wire E&M signalling.

- d. 4-wire E&M signalling.
- e. 2-wire with ring down suitable for a remote subscriber telephone connection.
- f. 2-wire loop disconnect signalling.
- g. 4-wire to 4-wire voice frequency with FSK modem and channel fail detection.
- h. Data interface suitable for multirate synchronous/asynchronous data signalling.
- i. 64 kb/s data channel according to ITU-T G.703.
- j. 2 Mb/s data interface according to ITU-T G.703.
- k. Alarm collection interface.

The types and quantities of the cards for the 30 PCM channels (64 kb/s) shall be supplied so as to meet the requirements of the project.

9.8.4.3. Alarm indications

The PCM multiplexing equipment shall have extensive alarm monitoring facilities. In the event of failure, appropriate alarm indications shall be initiated. Alarm indications shall be clearly displayed through LEDs on the front panel of the module. It shall also be possible to remotely display some of the alarms locally at that site via voltage free contacts.

9.8.4.4. User interfaces

User interfaces shall be provided by the Contractor to accommodate various voice frequency (VF) and data channels requirements. The user interfaces shall allow direct connection to SCADA, teleprotection and other communication equipment.

Any special interfaces which are considered necessary for the provision of a full and complete installation of the communication system shall be included in the offer and full details shall be supplied with the Tender.

a. Telephony interface

4-wire voice frequency channel interfaces shall comprise 600 ohm balanced circuits with a bandwidth of 300 Hz to 3400 Hz. VF signal levels shall be adjustable within the range:

Input: -16 to +1 dBm
Output: -7 to +7 dBm

E & M signalling interfaces shall be provided on each 4-wire VF channel.

2-wire analogue subscriber interfaces shall permit direct connection of subscriber sets to the telephone exchange equipment. Interfaces shall comprise balanced circuits with E & M signalling and recall facilities and shall be suitable for both standard telephone instruments and telephone consoles using dual tone multi-frequency (DTMF) signalling. Telephone ringing supplies shall form part of the interface equipment.

Signalling (E & M) channel interfaces shall be suitable for a maximum signalling rate of 300 baud. The interface shall be capable of operating from an external power supply with either positive or negative polarity grounding and a maximum potential of 100 V. The E-lead shall be capable of switching currents up to 100 mA.

The external connections of both VF and E & M circuits shall be isolated from the associated board circuits. Where modems are connected to communication cables, barrier transformers shall be supplied for protection against induced over-voltages.

b. Data interface

Data interfaces of the following types shall be capable of being made available by insertion of appropriate cards into the multiplexer rack for direct connection to computer systems. The following data interfaces shall be supported as a minimum:

- a. 64 kb/s data interface according to ITU-T recommendation G.703.
- b. Multirate 0.6 to 64 kb/s data interface according to ITU-T recommendations X.21/V.11.
- c. Multirate 0 to 19.2 kb/s data interface according to ITU-T recommendations V.24/V.28.
- d. nx64 kb/s data interface according to ITU-T recommendation V.35.
- e. 2 Mb/s HDB3 coded signals on line interfaces conforming to ITU-T recommendation G.703 using 120 ohms balanced impedance, with co-directional interface synchronisation.
- f. Gigabit Ethernet Interfaces 1000 Base-X/T
- g. Common LAN – 10/100 Base-T interfaces (RJ45) for connection of gateway computers of substation control system.

Sub-multiplexing up to 8 low speed (0 to 1 200 baud) asynchronous data inputs over a single 64 kb/s communication channel shall be possible.

c. Teleprotection signalling interface

The fibre optic communication system shall be capable of facilitating the transmission of teleprotection signalling commands associated with the power transmission network. Provision shall be made by the Contractor to enable direct connection to the teleprotection equipment for transmission of remote protection signalling/tripping commands. The transmission of protection signalling commands shall preferably be utilising a complete 2Mbit/s channel according to ITU-T G.703 or transmitting N times 64 kbps on an optical fiber according to IEEE C37.94.

The protection channel interface units shall operate regular loop tests to ensure their readiness for operation. In the event of a fault being detected an alarm shall be raised and the protection command inhibited.

The maximum signal transmission time of the fibre optic communication system over any fibre optic links shall not exceed 2 milliseconds. This signal transmission time shall exclude any delay times of the teleprotection equipment.

The Contractor shall ensure that the routing and rerouting of the SDH transmission network do not compromise the operating time of the protection signalling equipment.

9.8.4.5. Cross connection equipment

Cross connection equipment shall be provided as necessary to enable interconnections between different channels and network components be made.

Cross connection functions available shall include pass through, broadcast, add/drop and loopback.

9.8.4.6. Power supply requirements

The fibre optic communication equipment shall be designed to operate from a 48 Vdc (positively earthed) supply. The equipment shall have protection against transient voltages and operate without degradation in performance for a supply voltage variation stipulated in the Technical Schedules.

All interconnection cabling from the equipment to power source and any necessary devices to protect the fibre optic communication equipment from damage in the event of overload shall be provided.

The power supply input to individual items of equipment comprising the fibre optic communication system shall be individually fused.

9.8.4.7. Optical fibre distribution frames

Optical fibre distribution frames shall be provided as necessary by the Contractor to facilitate the termination of fibres, testing and isolation of both the optical fibre cable and fibre optic terminal equipment, and to provide interface and/or cross-connect facilities between the digital multiplex equipment. Sufficient space shall be available on the frame to allow ease of access and minimise the possibility of interference or damage to fibres carrying traffic during maintenance testing on the back-up or spare fibres.

Optical fibres shall be terminated by detachable connectors, complying with the requirements of IEC 60874, at the optical fibre distribution frame and shall be properly labelled with fibre identity, destination or source, go or return. It shall be possible to connect each optical fibre to the appropriate point on any terminating equipment. Fixed couplers shall be provided for each fibre comprising a link.

The following basic functions of the fibre distribution frame are required:

- a. Circuit re-routing/jumpering.
- b. Circuit disconnection.
- c. Patching and test connections.
- d. Bridging measurements.

Plug-in connection shall be used, and the transmit and received direction of the transmission shall be segregated. The optical fibre tail cables and connections shall be substantially protected from possibility of damage due to maintenance or installation activity.

The capacity of the fibre distribution frame shall be chosen to accommodate the maximum capacity of the fibre optic communication system plus 50 per cent spare capacity to cater for any future expansions. All fibre distribution frames shall have an earth connection provided, and shall be protected from corrosion by painting or galvanising.

9.9. Teleprotection signalling equipment

9.9.1. General requirements

The teleprotection signalling equipment shall be suitable for transmission of teleprotection commands in the high voltage networks and shall be capable of being used for blocking, permissive and direct tripping commands without any additional equipment. The teleprotection signalling equipment shall, in addition, be capable of direct transfer tripping, special switching functions and digital current comparison protection.

The teleprotection signalling equipment shall be designed and manufactured in such a way that disturbances on the transmission path shall not lead to false operation or cause undue delay in the transmission of the tripping command.

The teleprotection signalling equipment and signal transmission shall not be affected by switching operations, atmospheric conditions and other sources of interference.

The teleprotection signalling equipment shall employ state-of-the-art components together with the digital signal processing technique to provide programming facilities for flexible adaptation to various requirements of teleprotection signal transmission.

The selection of transmission time, dependability and security to suit the different operating modes shall be possible by means of programming using either a plug-in handheld terminal or programming switches on the equipment.

The teleprotection signalling equipment is required to operate over fibre optic links. It shall therefore be of a modular design so that it can be readily for direct connection to the SDH fibre optic equipment by insertion of a plug in interface module. Teleprotection signalling equipment that is an integral part of the SDH equipment without via multiplexing equipment is preferred. The type of teleprotection signalling equipment proposed shall be clearly stated in the Tender.

The equipment should be able to selectively disconnect the faulty part of the system in the event of faults in high voltage installations within the shortest possible time.

Technical descriptions detailing the teleprotection signalling equipment performance and equipment configuration shall be provided in the Tender.

The protection signalling equipment shall be capable of providing reliable performance throughout the 15-year life expectancy of the system.

The teleprotection signalling equipment shall be designed for ease of maintenance and shall include a variety of built-in alarms associated with vital operating parameters and a loop test facility.

9.9.2.Functional requirements

The teleprotection signalling equipment shall have the following features:

- a. High equipment reliability.
- b. Integral monitoring facilities.
- c. Simple operation and fault diagnosis.
- d. Direct integration to existing telecommunication systems.
- e. Wide selection of user interfaces.
- f. Easy programming for optimum setting of signal processing time, security and dependability.
- g. Permanent self-supervision.
- h. Automatic loop checking.

9.9.3.System capacity

The protection signalling system shall be designed with a minimum of 4 diverse teleprotection command channels operating in full duplex mode.

9.9.4.System performance

The protection signalling system performance shall be in accordance with the requirements of IEC 60834 specification.

9.9.5.Interfaces

The teleprotection signalling equipment shall provide suitable interfaces for the direct connection to fibre optic communication equipment.

9.9.6.Alarms indications

The teleprotection signalling equipment shall have extensive alarm and operational monitoring facilities. In the event of failure, appropriate alarm indications shall be initiated. Alarms and monitoring indication shall be clearly displayed through coloured LEDs on the front panel of the module. It shall also be possible to transmit alarms to other systems such as the existing SCADA systems via voltage free contacts with a maximum operation time of 1.5 ms.

The equipment shall be equipped with alarm circuits to detect at least the following:

- a. Error rate of guard or tripping signal codes too high.
- b. Loss of synchronisation.
- c. Alarm indication signal response.
- d. Bit error rate above the set level.
- e. Components failure.
- f. Response of an internal test routine.
- g. Receive signal low level.
- h. Loss of guard signal.

The LED alarm displays shall be capable of being reset from the equipment.

9.9.7. Power supply requirements

The teleprotection signalling equipment shall be designed to operate from a 48 Vdc (positively earthed) supply. The equipment shall have protection against transient voltages and operate without degradation in performance for a supply voltage variation stipulated in the Technical Schedules.

All interconnection cabling from the equipment to power source and any necessary devices to protect the teleprotection signalling equipment from damage in the event of overload shall be provided as part of this contract.

The power supply input to individual items of equipment comprising the teleprotection signalling equipment shall be individually fused.

9.10. 48 VDC power supply system

9.10.1. Introduction

The 48 Vdc battery and charger system shall be used for powering the telecommunication equipment and shall comprise 2 x 100% rated duty Nickel-Cadmium (Ni-Cd) type battery units, 2 x 100% rated battery float/boost chargers and duplicated distribution panels.

The system shall be designed for ease of maintenance and shall include a variety of built-in alarms associated with vital operating parameters.

A preliminary single line diagram of the 48V DC system is attached in Part 2-D.

9.10.2. Functional requirements

9.10.2.1. General

The Contractor shall be responsible for the design and provision of a 48V DC system.

The chargers shall be sized to ensure that one charger alone can supply the total normal consumption of the two distribution panels. During normal operation both rectifiers shall be in operation, and they shall be able to operate in parallel.

The system shall have, as a minimum, the following features:

- a. High operational security and reliability.
- b. Alarm monitoring facilities.
- c. Simple operation and fault diagnosis.

The output of the battery and charger system shall be 48 volts (positive earth) and shall continuously supply the power requirements of the load. There shall be no power interruption to the load during mains power failure or when the mains power is restored.

9.10.2.2. System capacity and performance

The ampere capacity of the batteries shall be adequate when fully charged to maintain the stated load in normal operation within its stated voltage limits for a period of at least 10 hours:

The batteries shall normally be kept charged by a dual battery charger unit, each charger comprising a float charger with manual boost charge facilities.

The rating of each charger shall be sufficient to carry the specified maximum load including the spare capacity, whilst maintaining the battery in a fully charged condition.

The boost charger shall be rated to restore the fully discharged battery to the fully charged condition within 12 hours, without interrupting supplies to the equipment.

When the battery is connected to the charger, the psophometric noise level at the output, for loads between 0 per cent and 100 per cent, shall not exceed the equivalent of 2 mV at a frequency of 800 Hz after weighting as specified by ITU-T recommendations for any operational condition.

Automatic control of the output dc voltage is required. Variation shall not exceed 0.5 V from 20 per cent to 100 per cent full load current.

9.10.2.3. Alarm indications

The battery and charger system shall be provided with efficient built-in self-monitoring and alarm facilities. An alarm shall be activated when a fault is detected. Alarm conditions shall be displayed locally. Voltage free contacts wired to cabling terminals shall also be provided to enable remote indication of each alarm.

As a minimum the following remote signals shall be provided for connection to the Substation Control System:

- a. AC supply fail.
- b. Battery voltage high.
- c. Battery voltage low.
- d. Charger fail indication.
- e. Battery earth fault.
- f. DC supply fail.
- g. Output dc MCB Trip (Common for all MCBs).

Sufficient alarm initiation outputs shall be provided to allow each alarm of the 48 Vdc power supply system to be displayed at up to three remote locations.

9.10.3. Battery and charger equipment

9.10.3.1. Batteries

The batteries shall provide power supply for the telecommunication equipment demand and be designed to give at least 10 years life from the date of installation.

The batteries shall operate in floating service, i.e. they shall be continuously connected to load and to the charging rectifiers.

The 48 Vdc batteries shall be housed in the battery room and shall be mounted on heavy-duty epoxy coated metal racks suitably protected against corrosion and attack by the battery electrolyte. The battery shall be spaced so as to permit sufficient access to all individual cells to allow replacement of cells and/or checking cell voltages and connections. Racks shall be assembled clear of walls to permit access on all four sides of the battery bank.

Battery trays shall be factory treated with an electrolyte corrosion resistance coating.

The positive and negative terminals of each cell shall be clearly marked and permanently indicated. The positive and negative terminals of each complete battery shall be indicated by red and black markings respectively in an approved form. Each cell shall be identified by a number formed in a non-corrodible material and fixed to the cells to be visible when installed on the racks.

The Contractor, shall select the Ah capacity according to the load requirements of telecommunication and control equipment, taking into consideration the following:

- a. The 100% spare capacity.
- b. The standby time required.
- c. The service voltage required shall not drop below recommended figures (permitted voltage tolerances of the individual loads).
- d. The voltage fluctuations caused by power consumption of various loads shall be kept within permitted limits.

Cells shall be formed into a sub-assembly by mounting in groups, in robust containers. Taping together of cells will not be accepted. Stainless steel containers shall be insulated one from the other.

Cells utilizing plastic containers shall be constructed so that the plates are rigidly held so as to avoid the possibility of distortion and short-circuiting of the plates. Each cell container shall be equipped with an electrolyte level indicator and the electrolyte capacity shall be sufficient to ensure long intervals between topping-up.

The battery unit, located in a battery room, shall be connected to the distribution board and battery charger by halogen free insulated copper cables. A fuse box, located outside the battery room, shall be provided for the battery. The positive and negative fuses shall be arranged in pairs and shall be fully segregated from each other by an insulating barrier. The fuses shall be of the high breaking capacity type in accordance with IEC 60269.

The Contractor shall submit a calculation of battery capacity.

9.10.3.2. Battery chargers

The batteries shall normally be kept fully charged by a dual battery charger unit. Each battery charger shall be capable of simultaneously supplying the full load and trickle charging the batteries. Under normal condition, each battery charger shall support half the load. In the event of a failure of one of the battery chargers, the healthy charger shall automatically take-over the full load current without supply interruption. Manual change-over of chargers shall also be possible.

The battery charger shall be of the solid state static thyristor or switch-mode rectifier type suitable for dc power supply and charging of the associated storage battery. The rated output and current of rectifier shall correspond to the requirements of system load and battery charging. The operation of the rectifier shall be fully automatic.

The output voltage shall be maintained constant and just sufficiently above the open circuit voltage of battery to keep the battery in a fully charged condition, independent of load variations or variations of ac input voltage within the specified limits. Provisions shall be made to adjust the charging voltage for a fully charged battery with an accuracy of at least 1%, and to move the setting point within a range of $\pm 10\%$.

The rectifiers shall be fed from the LVAC main switchgear. Double wound transformers shall be provided at the input side of rectifier to prevent galvanic connection between the dc and ac system.

The charging rectifier shall normally operate in the float charge mode. It shall be possible to select the charger to 'Boost charge' mode. When selected to 'Boost charge' mode, the battery condition shall be monitored and on achieving a fully charged condition, the rectifier shall automatically regulate the charging current and change over to the 'Trickle charge mode'. In addition to Boost and Float Charge modes, the charger shall also be equipped with manual equalizing mode for initial conditioning and periodical maintenance of batteries. Irrespective of the mode of operation the load voltage will be maintained to nominal level by the automatic introduction of suitable dropping diodes.

When an ac supply failure occurs which lasts for more than five minutes, the rectifier shall automatically select the 'Boost charge' mode immediately on restoration of the ac supply.

Each mode shall be signalled on the front of the rectifier cubicle. Manual or automatic switchover from one mode to the other shall be possible. No break in voltage shall occur during such switchover.

Rectifier ratings in all modes of operation shall be adequately adjustable to deliver the optimum charging rate recommended by the battery manufacturer while also supplying the normal steady state loads. The Contractor shall submit a calculation of rectifier load.

The rectifiers shall be equipped with automatic current limiting devices to make them short-circuit proof. Current limitation shall be 100% of rated output current. Each rectifier shall be designed to carry 110% of rated output current for an indefinite time.

All fuses shall be equipped with a flag, enabling an easily visible detection of any blown fuse. Battery fuse shall be equipped with signalling contact.

The charging rectifiers shall be of approved construction and shall be equipped with all necessary fuses, protective devices, indicating instruments, switches, lamps, etc. and shall be suitable for automatic and manual control. All voltmeter instruments shall be connected via fuses to the busbars, feeders, batteries, etc.

The mains supply voltages available to the chargers will be 415 Vac, 50 Hz three phase.

Internal cooling of the charger shall be by natural ventilation. If forced ventilation is unavoidable then 100 per cent redundant fans shall be provided.

The output dc voltage control range shall be adjustable and the range of voltage shall be stated in the Tender.

The dual battery charger unit shall be housed in the LVAC room or in the telecommunication room. Final location to be decided and agreed by the Engineer.

9.10.3.3. Control and instrumentation

The battery and charger system shall have a local control panel to show the status of the key parameters and mode of operation of the system. A mimic diagram shall be mounted on the front panel and shall clearly display the main circuit in relation to the various switching equipment.

Each of the two rectifier cubicles shall contain at least the following indications/meters:

- a. AC input voltmeter
- b. Ammeters for AC input current
- c. DC output voltmeter.
- d. Ammeters for charger current output & battery current.
- e. LED indications for:
 - Charger on.
 - Float mode.
 - Boost mode.
 - Under voltage.
 - Over voltage.
 - Current limit.
 - Charger fail.
- f. Circuit breakers for rectifiers shall be electrically operated with provision to be controlled:
 - Individually, from the board.
 - Remotely.

9.10.3.4. Construction

The cubicles shall be completely self-supporting, made of a required number of standardized, prefabricated, vertical sections bolted together to form indoor metal clad, dust-proof rigid unit, degree of protection IP51. The cubicles shall be free standing, equipped with bottom frames suitable for bolting to the floor. Sheet steel thickness shall not be less than 2 mm. The switchboard and charger cubicles shall be vermin and termite proof.

Hinged doors shall be provided to provide easy access to equipment contained within the cubicle. The hinged doors shall be of the lift-off type, secured with integral handles provided with locks and shall be flush fitting and sealed with a gasket made of rubber or other approved material to prevent the ingress of dust. Cubicles and doors shall be structurally stiff and braced to withstand twisting without distortion.

The cubicle shall be designed for cable entry from the bottom rear and equipped with glands suitable for all incoming and outgoing cables. Adequate working clearance shall be maintained inside the cubicles.

The main switchgear and distribution board shall be provided with a copper earth bus of the size not less than 100 mm² and in cases where two or more cubicles are installed adjacent to each other this earth bar shall be continuous.

A light suitably positioned to ensure even illumination of the entire panel shall be provided inside each cubicle as well as 1-phase, 10 A, socket-outlet of the same type as other outlets in the installation.

9.10.3.5. 48V DC distribution board

The 48 Vdc distribution boards shall supply power to telecommunications equipment. The board shall be composed of standard cubicle of approved construction.

The busbars shall be made of copper painted with suitable paint while all connection points shall be tin-plated. The busbars shall be supported by insulators having high mechanical and electrical strength, sufficient creepage distance and shall be able to withstand all short-circuit conditions without damage. To ensure maximum safety to personnel, the busbars shall be completely insulated at the front.

The busbar shall be supervised by an under voltage relay to be set at 80% of rated voltage with time delay between 0-5 seconds.

Switching of the outgoing feeders shall be effected by two pole, manually operated miniature circuit breakers.

The miniature circuit breakers shall be equipped with an adjustable, temperature compensated thermal overload and an adjustable magnetic instantaneous over current release for automatic tripping. The short circuit rating shall be adequate to protect each circuit against the effects of a fault at the outgoing terminal of the unit.

Auxiliary contacts shall be provided on each circuit breaker for signalling circuits.

The Contractor shall submit a calculation of selectivity between all protective devices in a circuit for all 48 Vdc feeders to the Employer/ Employer's Representative for approval. Time delayed releases shall be used wherever necessary in order to provide proper selectivity between circuit breakers of a circuit. Resetting shall also be provided.

The above-mentioned protective devices shall withstand the specified short currents. Auxiliary contacts shall be provided on each circuit breaker for signalling circuits.

9.11. Documentation

The Contractor shall provide all necessary drawings, design specifications, design details, operation and maintenance manuals.

9.11.1. Documentation with Bid

The Bid shall contain at least the following information and documents, failure of provision of the mentioned documents will lead to disqualification:

1. Type test certificates
2. Technical bulletin of the equipment to be used
3. Front views of cubicles if applicable with arrangement of offered equipment
4. List of references for the different equipment

5. List of applicable quality assurance, environmental, EMI, SWC and electrical standards
6. Quality Management System Manual and ISO Certificate of the equipment manufacturer.
7. Proposed training courses/ sessions

9.11.2. Documentation after Award of Contract

All documents required for KETRACO's approval shall be submitted by the Contractor.

9.12. IP PABX and Telephone Equipment

9.12.1. General Information

This part of the Specifications covers the design, manufacture, factory testing, transport, delivery, erection, unloading and storage at site, commissioning and handing over in satisfactory operating condition of IP-PABX equipment.

The IP telephony equipment shall be designed and arranged in full compliance with all applicable Sections, Articles and Drawings of these Specifications as below.

9.12.1.1. International Telecommunication Unit

- ITU-T Recommendations of Q-Series
- ITU-T Recommendations of V-Series
- ITU-T Recommendations of G-Series

9.12.1.2. Internet Society (ISOC)

- RFC 3261 - SIP
- RFC 3265 - SIP Extension: Specific Event Notification
- RFC 3515 - SIP Update: SIP Refer Method
- RFC 3665 - SIP Basic Call Flow Examples
- RFC 3851 - SIP Update: Symmetric Response Routing
- RFC 3853 - SIP Update: Usage of AES instead of 3DES
- RFC 4320 - SIP Update: Issues with the SIP Non-INVITE Transaction
- RFC 4916 - Connected Identity in the Session Initiation Protocol

Supplementary standards are the international standards ISO, the German standards DIN and VDE, the European standards EN (CENELEC), the British standards BS, the American standards (ANSI, IEEE and ASTM) or specific national standards in the above mentioned sequence, if there are no relevant IEC-standards existing or if there is no sufficient information available in the IEC-standards and/or if explicitly asked for in these Tender Documents.

The Bidder shall submit with his offer a list of similar IP based telephony systems already delivered by the manufacturer proposed. In addition, the Bidder shall submit with his offer valid certificates proving that the proposed manufacturers are certified by ISO 9001. Manufacturers not having sufficient experience in manufacturing and testing of similar equipment like those as specified and/or not being certified by ISO 9001 will not be accepted.

Contractors are held responsible to carry out the erection and pre-commissioning work for all IP telephony equipment under supervision of the IP telephony system manufacturer according to the manufacturer's instruction.

Each item which is obviously necessary for proper function and completion of the work, whether especially specified in the Tender Documents or not, is to be included in the Tender and Contract price.

Furthermore, the equipment shall comply with the stipulations of the following Articles.

9.12.2. Common Requirements

Within the frame of the assignment a new IP-PABX system shall be provided for installation in each new substation. The IP-PABX to be installed shall be capable to deal with an overall amount of 300 utility internal remote subscribers (substations and offices). For substation internal telephony a total amount of 25 subscribers shall be considered. The total amount of subscribers managed by the IP-PABX shall be extendable in case of need.

The design shall be based on site and service conditions as specified elsewhere.

Neutral points shall be brought out by suitable means and shall be grounded as required.

The required equipment shall have been already working successfully in telecommunication network operated by power utilities. Therefore, it shall be suitable for operation in harsh environment with electromagnetic interference and shall provide a high reliability and security.

9.12.2.1. Transmission Media

The IP telephony equipment shall use the following transmission media:

- The local area network (LAN) within the substation
- FO infrastructure for the connection to remote locations / substations
- 2 wire twisted pair cable for the connection to the public switched telephone network (PSTN)

9.12.2.2. Hardware Requirements

The IP-PABX system shall consist at least of the following basic elements:

- The IP telephony exchange server
- The IP Gateway
- The subscriber handsets (IP Telephones)
- The necessary cabling and accessories

9.12.2.3. IP telephony exchange server

The IP telephony exchange server shall be located in the telecommunication room of the control building along with other communication equipment. The final location shall be approved by KETRACO.

The exchange shall be of modular construction with provision for expansion. Printed circuit cards shall be supported by insulating guides, terminated on multi-contact connectors and properly secured to the frame. Means shall be provided to extract cards easily for maintenance and installation (hot swap). Interconnection between cards shall be made by use of multi-conductor cables terminated by compatible connectors. All hardware components shall be treated against corrosion and fungus caused by humidity or moisture. Exchange enclosure shall cover the entire equipment and protect it against dust and insects. Means shall be taken to prevent overheating and moisture in equipment. Where necessary, a small heating element and thermostat shall be provided.

It shall be possible to enable or disable any shelf, plug-in unit, including common equipment where spares are provided, without affecting other parts of the system. It shall be possible to remove or insert any peripheral circuit pack without degrading service to any other part of the system. It must not be necessary to remove any components in order to access and / or test other components or connectors. The circuit packs shall be clearly labelled and visible from the front as to the functions of the card. Furthermore, it shall be possible to read serial numbers, if used, without removing the cards. A 10 years guarantee must be given to assure availability of spare parts and assistance in case of maintenance.

Enclosure shall allow access to interior from the front or back by means of doors or removable panels.

Along with exchange, a multiterminal distributor shall be supplied where all lines (trunks + extension) will terminate. Multiconductors interconnection cables (5 meters length minimum) will be fitted at one end to the exchange by means of a plug-in connector and at the other end to the distributor terminals. The distributor shall come in a suitable junction box to protect against dust and insects. Provision shall be taken to avoid moisture and fungus. All external cables in the exchange enclosure shall enter through bottom plate.

The IP exchange shall be powered from the 48V source of the power supply.

9.12.2.4. The VoIP Gateway

The VoIP gateway shall be a standard industrial gateway which has been successfully in service in at least 5 different locations during the last 3 years. The major task is the conversion of IP packages into DSS1-protocol and vice versa.

The gateway shall be able to handle common VoIP protocols as for instance SIP, H.323, and/or MGCP and MeGaCo as well as ISDN protocol.

9.12.2.5. VoIP handsets

The VoIP handsets shall be provided for desk and wall mounting, equipped with signalling push buttons and function push buttons for automatic call back, automatic redialling, call forwarding and speed calling. There shall be provision for eleven (15) indoor handsets.

One (2) standard wall type telephone sets shall be installed in outdoor areas. The telephones shall be designed to withstand mechanical stress, a corrosive atmosphere and extreme moisture. In hazardous areas the casing shall be

pressure-tight and of integrated cast iron. Alternatively, standard outdoor wall phones may be used when there is a possibility to connect them through the VoIP gateway to the call server.

9.12.2.6. Cables and Accessories

The cables shall be Cat-5 and therefore fulfil the requirements stated in EIA/TIA-568. Sockets, connectors and terminations have to fit the requested standards to avoid quality loss.

Additionally, a patch field shall be installed in the respective 19-inch cabinet where all extensions shall be cabled to. From there patch cords shall connect to the router installed in the same location.

9.12.2.7. Software Requirements

The IP telephony equipment shall fulfil the following software-based requirements:

The IP PABX equipment shall be able to be integrated into an existing network structure and to be interfaced with 3rd party equipment without any need of customisation.

Alarm monitoring shall be possible from the rack itself, the outside of the cabinet and the network management system.

The equipment shall be using common standard protocols (e.g. SIP, H.323, H.248, MGCP etc.) for the VoIP as well as for the PSTN side.

The numbering plan of the IP PABX shall be in compliance with the existing dialling plan.

Call priority: can be assigned to certain extensions or Network Tie Lines as a fixed attribute. Calls originated by these extensions or on these lines will always have priority over routine calls. Alternatively, extensions may be given a Service Class which allows them to obtain Priority on a call-by-call basis when needed. During the application of priority, priority intrusion is used to intrude upon an established call when congestion is encountered upon initiating a call to another extension. The function may be inhibited either manually or automatically.

Hot-line Extension: This type of extension shall have the facility to automatically call a pre-designated number by only lifting the handset.

Call Diversion on Busy: Calls to an extension are diverted to a predefined directory number when the extension is busy.

Call Diversion on No Answer: Calls to the extension are diverted to a predefined Directory Number (DN) when the call is not answered within a specified period of time (default duration of ten seconds).

Call Transfer: Allows an extension user on any two party call to Hold the existing call, originate a call to a third party and then transfer the call to a third party. The station user can then consult privately with the third party before completing the transfer, or can return to the original caller.

Call Forward: All incoming calls to a station user can be automatically forwarded to another pre-selected destination within or outside the PABX to which the station user is connected.

Call Waiting: Alerts the station user busy with an established call of additional calls waiting to be transferred to the station user.

Ring Again: Allows a station user, on encountering a busy connection, to be alerted when a called party or trunk route becomes free. The system will then automatically redial the desired destination.

Call Pick-up: Enables the definition/ programming of specific call pick-up groups whereby a station can pick up an incoming call for another station his call pick up group by lifting his handset and dialling a pre-designating call pick up code. In case of the dispatcher console, the lifting of handset will not be required and the code will be dialled while on-hook.

Conference: Allows a station user to establish a conference without the attendant console's assistance. Conferences may be inside or outside the local PABX to which the station user is connected.

On-hook Dialling: This feature enables a user to originate a call without lifting the handset.

Privacy: When a station user is engaged in a two party conversation, no other party can enter the conversation.

Authorisation Code: For the purpose of overriding the access restrictions, a specific two to three-digit pre-programmed code is dialled by a designated station, to enable him to gain free access to the network. Dial tone is returned to the station user after dialling the code and he is able to call the destination without restriction.

Night Service: This feature allows the routing of all incoming calls to a pre-programmed night number, outside normal working hours. It shall be possible to set and adjust the exact night service hours by programming of the system and it shall not be possible for a station user or night service number to alter/ modify these parameters.

9.12.2.8. Scope of Supply

As a general rule, the supplier is liable to include all material for full operation of IP telephony equipment including:

IP-PABX for substation internal / external telephony incl. the described amount of indoor and outdoor telephone sets.

Cabinets: all accessories for proper installation and connection with transmission equipment (i.e. SDH/PDH equipment etc.) incl. cabling and installation material.

Software and interface for PC programming and setting.

Documentation as hard and softcopy.

9.12.3. System Design

The supply shall comprise the system design leading to a firm guaranty by the supplier of the operation of the system. Essentially, without limiting the scope of work, the services shall include:

- a) Gathering of site data
- b) Site survey including remote site inspection (if necessary).
- c) System design to establish network topology, equipment location and characteristics.
- d) The system design Report shall be submitted to KETRACO's approval not later than two months after contract signature.
It shall be written in English and include Supplier's recommendations for each site and all relevant information leading to these recommendations such as maps, topology, contingency analysis, attenuation, error rate analysis, equipment losses and gains, etc.
- e) IP PABX component layout and wiring diagram showing dimension of frame, modular rack, position of each card or component, wiring between components and outgoing cable to distributor. These drawings shall include outline dimensions of
- f) Software user manual with a detailed description of each feature, and step-by-step instructions for programming of the IP PABX.
- g) Detailed description of operation and maintenance software including troubleshooting guide showing procedure to locate and detect failure.
- h) Proposal of adaptation of the existing numbering plan to the new equipment.

9.12.3.1. Modular extendibility

The system shall be extendable on the basis of "n" card positions for analogue or digital peripheral circuit cards per rack. Extendibility shall also be provided by additional cabinets with racks for further I/O cards.

9.12.3.2. Flexibility

The system and customer data shall be software parameter driven and controlled via a telephone set, the operator position or from a PC application program. User friendly programming tool shall be available to generate HW/SW configuration.

9.12.3.3. Maintenance

Cards shall be exchangeable without a major disturbance of telephone traffic. Input/output of maintenance data shall be performed via ITU-T language.

9.12.3.4. System Assurance

System maintenance standard test routines shall be available for: fault detection, localisation, isolation and reporting.

9.12.3.5. Analogue Subscriber Interfaces

Analogue line cards shall be available with DTMF / decadic dialling.

9.12.3.6. Digital Line Interface

Following digital line interfaces shall be available:

Ethernet interface for the connection of the IP handsets

Data transmission speed up shall be a minimum of 64 kbit/s synchronous and 19.2 kbit/s asynchronous

9.12.3.7. Caller Number Identification

The PABX equipment shall incorporate the capability of transferring the caller number identification throughout the network to enable the appearance of this information (on a per call basis) on the dispatcher consoles at the Load Despatch Centre. The display of this information shall facilitate the efficient working of the dispatcher as it shall alert the dispatcher about the originating and terminating station and calling or called directory number.

9.12.4. Factory Acceptance Test

Before the installation of the equipment a Factory Acceptance Test (FAT) shall be carried out during which all components of the IP telephony equipment shall be tested.

The test shall be prepared to set up a complete fibre optic link (test system at end A, transmission media, test equipment at end B), simulating a lossy conductor with attenuation in between end A and end B.

The tests shall include, but not be limited to, the testing of the different interfaces (G.703, X.21, V.24 etc. with BER test) as well as each possible set-up and signal to be transmitted. Also the functionality of indication lamps and alarms shall be tested.

9.12.5. Field Installation

The field installation shall consist of:

- a) Provide liaison equipment to coordinate the works
- b) Unpack equipment, verify content against shop bill of material and condition
- c) IP PABX and remote handset installation
- d) Interconnect equipment
- e) Connection to fibre optic cable
- f) Carry out functional test

Substation Control System

10.1 General

This section details the supply (hardware and software), data engineering, erection, testing and commissioning of the systems for control and monitoring of the new Substations and interfaces to other associated substations. A new Substation Control/Automation System (SCS/SAS) shall be installed at each substation. In the event of having hard wired mimic control board at existing substation, this shall be updated accordingly. The required modification of SCS in the associated SS shall also be included to carry out renaming and updating the SLD and to integrate the extension to the central SCADA/EMS system at the National Control Center (NCC) and Regional Control Center (RCC) and National System Control Center (NSCC). KPLC operates the electricity network from the NCC.

Details of the equipment to be controlled and monitored at each substation site are indicated in the individual substation sections of this technical specification.

The diameters control cubicles shall be arranged in Bay Control Rooms. The houses shall be installed in-between the diameters with each house accommodating the control cubicles for two adjoining bays. The substation control building shall house the cubicle with the common bay control unit for auxiliary and building services, the superior substation automation system with Human Machine Interfaces, gateways to national and regional control center, GPS and the telecommunication equipment. The bay control units shall be connected via fibre optic cables to the superior automation system.

10.2 Scope of Works

The supply and services to be performed by the Contractor shall comprise the design, manufacture, shop testing, packing, transport, insurance, unloading, storage on Site, construction works and erection, corrosion protection, site testing, submission of documentation, commissioning, training of KETRACO's personnel and warranty of the works.

The Contractor is bound to provide complete works, even if the equipment or services to be provided are not specifically mentioned in the specification.

10.1.1. Substation Works

The scope of work consists of:

- Works at new and existing substation(s) incorporating high voltage switchyards, transformer connections, protection, control, SCS and related civil works.
- The design, engineering, supply, delivery, installation and testing of SCADA and EMS database modifications at the NCC, NSCC and the RCC, for the control and monitoring of the new and existing substations.

The drawings referred to below are to aid the description of the SCS functionality and requirements. Bidders may submit alternate configurations that provide the same functionality and other requirements such as availability and performance.

10.1.2. Modifications at the NCC/RCC

The following works are required at the NCC/RCC:

1. Update of NCC databases to incorporate new substations and modified existing substations and data received from the RCC
2. Reconfiguration of NCC/RCC applications, as necessary, to utilise the updated database data
3. Update of the Geographic Map
4. Update of NCC/RCC Operator displays to incorporate new / modified line diagrams.
5. Update of NCC/RCC Mimic board to incorporate new / modified circuits
6. End to end testing of new controls, indications, analogue and alarms from the substation to both the NCC/RCC.

10.1.3. Scope of Work for SCS

10.1.3.1. Overview

The proposed distributed control systems for the above work shall offer at least the following functionality: -

- Full operational control, reporting, alarm and indication facilities for the substation from the NCC/RCC (Supervisory level).
- Full operational control, alarm and indication facilities for the substation from Human Machine interface (HMI) workstations in the substation control room (Substation Level).
- Operational control of each circuit/bay using the bay control unit LCD display (Bay level).
- Control of each item of plant from the Local Control Cubicle (LCC) (Local Level)
- The control facilities from each control point are to be interlocked (hardwired and software) to prevent operation of any device simultaneously from more than one control point.
- At least one fully operational control point shall remain available in the event of a single equipment or communications failure.
- Complete facilities must exist for the proper lockout and maintenance tagging of circuits and plant items to ensure the safety of personnel and the security of the system
- The new control systems shall use IEC 61850 communication protocols and be readily interfaced with third part devices operating on IEC 61850 or other open protocols. The

Bidder shall describe such interfaces and provide an experience list of devices with which the offered control system has previously been interfaced.

Protocol converters are required in case of mismatch between SAS protocol and protocol required by NCC and RCC.

10.1.3.2. New Substation Scope of Work

For each substation the contractor shall provide the following:

- Provision of all hardware and software necessary to control and monitor the entire substation both locally and remotely from the NCC and RCC.
- Complete Substation Control System (SCS).
- Incorporate new substation into the SCADA/EMS System at the NCC/RCC.

10.2. SCS Specification

10.2.1. Introduction

The following sections describe the distributed control system requirements for new substations SCS.

This specification describes standard terms and equipment typically associated with SCS. Alternate configurations may be considered so long as the overall functionality and redundancy required by this specification is maintained or improved.

10.2.2. Overview

A computer based SCS shall be provided for monitoring and control. The SCS shall be designed to provide the following four control levels:

1. Supervisory Control (NCC/RCC)
2. Station level through a HMI
3. Bay level, using a Bay Control Unit (BCU) with LCD mimic
4. Local, directly from the Local Control Cubicle (LCC).

The entire substation shall be monitored and controlled from Substation Control Room through two independent substation computers and associated HMI(s), while individual circuit bays shall be monitored and controlled from processor based Bay Control Units (BCU) located in a separate BCU suite of panels. The SCS shall typically include:

Station Level:

- 2 independent Gateways (Main and Hot-standby) for external communications to the NCC/RCC.
- 2 independent Station computers (Main and Hot-standby)
- 2 independent Operator Workstation(s)/HMI, and the complete workplace (desk, chair). The design of the desk and chair shall be subject to Employer/ Employer's Representative approval.
- 1 independent Engineering Workstation/HMI, and the complete workplace (desk, chair). The design of the desk and chair shall be subject to Employer/ Employer's Representative approval.
- Event printer.
- Operator log printer
- Hard copy colour printer.
- Common bay control unit, for monitoring AC/DC system supply and all other equipment on S/S level (telemetry, telecommunication, HVAC, fire protection etc.) The fire protection signal shall be communicated to NCC/RCC.
- Satellite clock, complete with GPS Receiver, Antenna and necessary time synchronization ports.
- Interface for laptop computer for maintenance, information transfer and emergency HMI
- UPS system for SCS as specified under LV Service Equipment. (This shall as well supply the online monitoring devices for reactor bank and auto transformer and fire protection panel.)
- Communication network equipment [station (system) LAN, Field Communication Network, Various optical couplers, etc.].

Bay Level:

- Bay control units (BCU) for each individual circuit/bay with a LCD mimic and user interface for control and monitoring of the circuit/bay
- Interface for protection devices that cannot directly interface with the substation LAN
- Interface for laptop computer for maintenance, information transfer and emergency HMI

10.3. System Functions

SCS shall include the following functions:

- Control of all switching devices *
- Real time indication of status, alarms and devices
- Display of measured values, high/low limit checking.
- Indication of real and historical values
- Data Archiving
- Disturbance Monitoring and analysis
- Trend display facilities
- Protection device information
- Remote access to SCS from the NCC using TCP/IP link
- Remote communications
- Indication of automatic tap changer relay status
- Manual local and remote setting of tap changer relay
- Check sync control
- Interlocking of primary plant
- Substation Monitoring System functions (Parameter of digital protection relays – protection setting, service values, trip values, etc.)
- Time synchronisation.
- Operator action monitoring (in case of any inappropriate action taken, a mal-operation message is displayed)
- Self-check & diagnostic: These functions are essential for system operation Safety and easy maintenance.
- Manual data setting (can be performed by the operator) using the following functions:
 - Device status setting
 - Analogue data setting
 - Control inhibit setting
 - Alarm inhibit setting
 - Maintenance tag setting
 - High/Low limit setting
 - Protection relay parameter setting, etc.
- Bay Control from bay control units (BCU) using LCD mimic

- Bay indications, alarms and events from bay control units (BCU) using LCD mimic

Also, all required signals related to the control, status indications and monitoring of the switchgear, power transformers, LV AC/DC switchgears and other relevant equipment shall be provided to the SCS.

* It shall be possible to independently select individual Switch bay Control point (e.g. NCC/RCC/SCS/BCU/LCC) irrespective of overall substation control authorisation.

10.3.1. Data Scope

The data scope required for SCS will be determined at design phase in accordance with actually contracted equipment. 10% spare capacity, for each type of I/O module and system function shall be added after the finalisation of the lists of Alarms/Signals.

Typical alarms/signals are presented below but the Contractor shall include all alarms, indications and measurements of each item of plant and the SCS system. These alarms may then be grouped according to KETRACO's requirements for signals to the NCC/RCC. The final signals list shall be submitted by the Contractor for review and approval by KETRACO.

Fire protection signal and fault locator signal shall be communicated to NCC/RCC.

All bay control units shall have direct analogue inputs for secondary CT and VT measurements. Power system measurements including real and reactive power shall be an internal calculation within the bay control unit. The MW and MVar values shall be displayed on each bay and busbars on the overview screen.

Signal lists shall be worked out per substation. The lists shall include the signals of the complete substation including all other works as e.g. building facilities, auxiliary supply. The signal lists shall include as minimum the following columns:

- Signal text including designation of the equipment
- Originator of the signal including designation
- DI/DO designation or internally generated signal
- Status Text (e.g. OPEN, CLOSED)
- Alarm Hierarchy (EVENT, ALARM Priority 1 etc.)
- IEC 61850 Reference
- Transmission to NCC/RCC
- Signal address for NCC/RCC

10.3.2. Transformer Bays

Control functions shall comprise:

- Bay level control
- Data acquisition
- Bay level interlocking
- Bay level supervision
- Station wide interlocking between BCUs

Measuring functions shall comprise:

- Amps
- Volts and Frequency
- MW
- MVAr
- Transformer oil and winding temperature

Position indication and alarms shall comprise at least, final list of signals to be agreed during design stage:

- CB open indication
- CB closed indication
- Tap changer position
- Maintenance earth switches close indication
- Maintenance earth switches open indication
- Diameter/Bus Disconnecter open indication *
- Diameter/Bus Disconnecter close indication *
- Circuit Disconnecter open indication *
- Circuit Disconnecter close indication *
- Local/Remote Control Selection indication
- CB Drive fail indication
- CB fault indication
- Protection operated
- Transformer Buchholz alarm
- Transformer Buchholz trip

- Transformer Oil High Temperature alarm
- Transformer Oil High temperature trip
- Transformer Winding High Temperature alarm
- Transformer Winding High Temperature trip
- Pressure relief valve operated
- Oil level low
- Cooling fans on
- Cooling System Faulty
- OLTC Buchholz alarm
- OLTC Buchholz trip
- OLTC Pressure relief valve operated
- OLTC Oil Low Level alarm
- All status and alarms from the Tap changer/AVC relay
- Trip circuit faulty
- VT fail/Out of service
- AC Aux. Supply failure
- DC supply failure
- All other relevant alarms such as biased differential protection – trip, restricted earth fault trip for HV and LV, standby earth fault, over current trip, SF₆ alarms etc.

Note: All relevant alarms for Earthing Transformers shall also be included.

* Disconnecter status signals as per the substation primary arrangement.

10.3.3. OHL Bays

Control functions shall comprise at least, final list of signals to be agreed during design stage:

- Bay level control
- Data acquisition
- Bay level interlocking
- Bay level supervision
- Station wide interlocking between BCUs.

Measuring functions shall comprise:

- Amps

- Volts and Frequency
- MW
- MVA_r

Position indications and alarms shall comprise:

- CB open indication
- CB close indication
- Maintenance earth switches close indication
- Maintenance earth switches open indication
- Diameter/Bus Disconnecter open indication *
- Diameter/Bus Disconnecter close indication *
- Line Disconnecter open indication
- Line Disconnecter close indication
- Line earth switch close indication
- Line earth switch open indication
- Status local/remote control selection indication
- CB fault indication
- CB drive fail indication
- Protection operated
- VT fail/Out of service
- Trip circuit faulty
- Inter-trip send and receive
- AC aux. Supply failure
- DC supply failure and
- All other relevant alarms such as Line Differential Protection Trip, Distance Protection Trip, O/C Protection Trip, SF₆ alarms etc.

Note: * Disconnecter status signals as per the substation primary arrangement.

10.3.4. Mid Diameter

Control functions shall comprise at least, final list of signals to be agreed during design stage:

- Bay level control
- Data acquisition

- Bay level interlocking
- Bay level supervision
- Station wide interlocking between BCUs.

Measuring functions shall comprise:

- Amps
- Volts
- MW
- MVA_r

Position indications and alarms shall comprise:

- CB open indication
- CB close indication
- Maintenance earth switches close indication
- Maintenance earth switches open indication
- Diameter Disconnecter open indication *
- Diameter Disconnecter close indication *
- Status local/remote control selection indication
- CB fault indication
- CB drive fail indication
- Circuit Breaker Failure Protection operated
- Trip circuit faulty
- AC aux. Supply failure
- DC supply failure and
- All other relevant alarms such as SF₆ alarms etc.

Note: * Disconnecter status signals as per the substation primary arrangement.

10.3.5. Bus Section Bay (if applicable)

Control functions shall comprise at least, final list of signals to be agreed during design stage:

- Bay level control
- Data acquisition
- Bay level interlocking

- Bay level supervision
- Station wide interlocking between BCUs.

Measuring functions shall comprise:

- Amps
- Volts
- MW
- MVar

Position indications and alarms shall comprise at least, final list of signals to be agreed during design stage:

- CB open indication
- CB close indication
- Maintenance earth switches close indication
- Maintenance earth switches open indication
- Bus Disconnecter open indication
- Bus Disconnecter close indication
- Status local/remote control selection indication
- CB fault indication
- CB drive fail indication
- Protection operated
- VT fail/Out of service
- Trip circuit faulty
- Inter-trip send and receive
- AC aux. Supply failure
- DC supply failure and
- All other relevant alarms such as Cable Protection, O/C Trip, SF₆ alarms etc.

10.3.6. Bus Coupler Bay (if applicable)

Control functions shall comprise at least, final list of signals to be agreed during design stage:

- Bay level control
- Data acquisition
- Bay level interlocking

- Bay level supervision
- Station wide interlocking between BCUs.

Measuring functions shall comprise:

- Amps
- Volts
- MW
- MVar

Position indications and alarms shall comprise:

- CB open indication
- CB close indication
- Maintenance earth switches close indication
- Maintenance earth switches open indication
- Bus Disconnecter open indication
- Bus Disconnecter close indication
- Status local/remote control selection indication
- CB fault indication
- CB drive fail indication
- Protection operated
- VT fail/Out of service
- Trip circuit faulty
- Inter-trip send and receive
- AC aux. Supply failure
- DC supply failure and
- All other relevant alarms such as O/C Trip, SF₆ alarms etc.

10.3.7. Common alarms

All relevant alarms including, but not limited to, the following

- 400kV & 220kV Busbar protection
- LVAC Switchgear
- 110 V DC switchgear

- 48V DC switchgear
- Batteries, chargers (110V & 48V)
- Telecom/Telemetry
- UPS
- GPS Clock
- Fire Protection System
- HVAC system
- Substation Security

10.4. Equipment Requirements

10.4.1. General

The control system shall be designed for easy modification of hardware and software and for easy extension of the substation either from the substation HMI or each of the control centres. Maintenance, modification or extension of components shall not require a shutdown of the whole SCS. The control equipment shall comply with the latest revisions of the IEC publications, except where otherwise stated.

There shall be no single point of failure of the SCS at the substation level that will cause a loss of control and monitoring functionality of the substation. The bidder shall state how this is achieved.

Failure of any component of the SCS at bay control level shall not result in more than one feeder / circuit being out of control by the system. The bidder shall state how this is achieved.

The main process information shall be distributed to databases in different bay terminals. The system shall include the concept of a Distributed Data Base approach for safety reasons.

Special attention shall be paid to the issue of cyber security. The SCS shall provide security capabilities as intrusion protection and protection against virus attacks. The security capabilities shall be described in detail in the bid documentation.

“Operational Technology Cyber Security”, “Telecom & SCADA Cyber Security requirement for new substation projects”, and also “SCADA System Security management policy” for substation shall be provided based on the KETRACO regulations. Any required coordination with adjacent Substations or dispatching Centers shall be considered. (if any)

10.4.2. Environmental Requirements

The bidder shall ensure that all equipment is fit for purpose and housed appropriately for the substation environment. The following requirements reflect the fact that the Bay Control Units are typically based on numerical protection relay devices.

The station level equipment (station computer, gateway, LAN) shall so far as possible also meet the following requirements but may be housed in a IP50, force cooled cubicle. Failure of the cooling fan shall not result in system failure. Any deviation from the specifications shall be highlighted.

The operator's desk and HMI, typically housing a desktop computer, shall be suitably designed to reduce the effects of dust.

Bay Control Unit's shall comply with the following environmental requirements: -

- Atmospheric Environment
- Mechanical Environment
- Electrical Environment
- Electromagnetic Compatibility

which are defined within the General Protection Specification.

10.4.3. SCS Architecture

The architecture of the SCS shall be such that it provides the same overall division of operational responsibility as exists between the NCC and RCC. To this end, it is envisaged that each gateway shall have two communication channels. One for connection to the NCC and one for connection to the RCC as follows;

Gateway 1:	Communication Port 1 – NCC Main
	Communication Port 2 – RCC Back-up
Gateway 2:	Communication Port 1 – RCC Main
	Communication Port 2 – NCC Back-up

Enforcement of the division of operational responsibility at the substation and bay levels shall be through the configuration of 'permissions' within the SCS. It should be considered that architecture for 400 and 220 kv substations shall be based on PRP protocol.

Load shedding is initiated by the NCC and requires the tripping of selected feeder circuits at multiple substations. It shall be possible to send the trip commands directly to the substations from the NCC.

10.4.4. Substation Level Equipment

10.4.4.1. General

The design of all SCS hardware shall be such as to ensure satisfactory operation in an electrically hostile environment typical of high voltage electrical installations. In order to prevent incorrect functioning or damage to the equipment when subjected to interference arising from power system switching, fault currents and lightning, all SCS input and output circuits and power supply circuits shall be provided with isolation and/or immunity to electrical interference. The bidder shall state how this is achieved and the international standards to which the SCS has been tested.

There shall be no single point of failure on the Substation level equipment that will cause a loss of SCS functionality.

The Substation level equipment shall typically consist of the following:

- Substation computers
- Communication gateways
- Substation Local Area Network(s)
- Human Machine interface
- System Clock
- Printers
- Audible Alarm
- External Data storage system

Alternate configurations of hardware shall be considered so long as the functional and separation requirements are met.

10.4.4.2. Substation Computer

The substation computer coordinates the operation of the SCS. The functionality shall include:

- Event Logging
- SCS Management software

The substation master control shall be capable of automatic restart in the event of power failure without loss of functionality or local database. It shall be readily possible to update the substation computer software to alter or extend the SCS functionality. The bidder shall state how this is achieved.

10.4.4.3. Communications Gateway

The SCS shall be able to communicate with the NCC and RCC on separate communication channels using a variety of open protocols. The gateway shall be connected to the communication equipment. IEC 60870-5-104 communication protocol shall be used for data transmission to the NCC and RCC on the main and alternate routes. The selection of main or alternative route will be made by the respective control centre master station and the gateways shall respond via whichever route it receives communication from the master station. In the event of route failure, fallover to the alternate route will be managed by the respective master station.

The NCC shall be capable of remote access to the SCS over a TCP/IP link. This link shall be used for downloading of fault waveforms, sequence of events records and similar data. The bidder shall state the functionality available through such a link. Down loading of information to or from the SCS to the NCC shall not have any impact on SCS performance including alarm response times.

10.4.4.4. Substation Local Area Network

Local substation communications shall use an optical fibre LAN to connect the components of the SCS using IEC 61850 protocol. The LAN may be of star-coupler configuration or a fibre ring configuration. No single point of failure of the substation LAN shall result in any loss of substation control functionality. It should be considered that architecture for 400kV and 220 kV substations shall be based on PRP protocol.

10.4.4.5. Operator Workstation

The Operator workstations / HMIs shall consist of high performance computer and monitor with computer desk. It shall be fully integrated into the SCS on the substation LAN. The proposed HMI shall be based on the latest PC technology available on the market at the time of offering. The operator desk and chair shall be of high quality construction, appropriate to continuous use by the operator.

10.4.4.6. Printers

Three high performance printers shall be provided, each capable of connection to the substation LAN.

- 2 off Matrix Printer Logger (or equivalent for use with fan fold paper), one for events and one for operator log.
- 1 off Colour Printer to print screen shots or other information

10.4.4.7. Satellite Clock

The Satellite GPS Clock shall be provided for time synchronization and event time tagging with resolution of at least 1 ms. The GPS Clock requirements are as following:

- GPS C/A code receiver
- TCXO-HQ Timebase
- Single board computer with Linux operating system/Windows, supporting the following protocols:
 - NTP/SNTP v4, Time protocol (RFC 868),
 - Daytime protocol (RFC 867),
 - SNMP v1,2,3, SNMP Traps, SSH v2,

- IP v4, IP v6, DHCP client, HTTP(S),
- Email, FTP, Telnet, Syslog
- Power supply: 100-240 VAC(or different DC variants)
- Metal 19" modular chassis, 1U/84HP, slimline (483 mm wide x 43 mm high x 285 mm deep)1 x RS232 front panel interface , 9pin D-Sub male connector for initial setup and configuration
- 1 x USB (Rev. 1.1) front panel interface to:
 - install firmware upgrades
 - backup and restore configuration files
 - copy security keys
 - lock/unlock front panel keys
- 3 x Bicolor LEDs: Ref. time (e.g. GPS),
- Time Synchronization Service (NTP) and Network-Link status
- 1 x Red alarm LED (configurable)
- 1 x LC Display, 40 character x 2 rows
- 2 x LAN interface, RJ45 connector, status LEDs for link, activity, speed (10/100 Mbit)
- 2 x RS232 interface, independent, 9pin D-Sub female connector, with following data formats:
 - Standard-Telegram, SAT,
 - NMEA0183 (RMC),
 - Uni Erlangen (NTP), COMPUTIME,
 - SYSPLEX-1, SPA, RACAL
- 1 x Pulse Per Second (PPS), TTL into 50 ohm, pulse duration 200 msec, active high, female BNC connector
- 1 x Standard Frequency 10 MHz, TTL into 50 ohm, female BNC connector
- 1 x Alarm relay output, change-over contact, 3pin DFK connector

10.4.4.8. Audible Alarm

One common sounder shall be provided to give at least two distinct audible alarms in case of alarms/faults or events. The sounder shall be configurable according to the event type and to the control status of the SCS (Local/Remote). An auto-silencing scheme shall be provided for the alarm and the sounder shall be controlled by distinctly labelled "Audible alarm ON/OFF" control switch. The complete unit shall be mounted in suitable relay/control panel.

10.4.4.9. Common Bay Unit

The Common Bay Unit (CBU) shall be provided for monitoring of the common services (AC/DC system supply) and all other equipment on the S/S level (telemetry, telecommunication, HVAC, fire protection etc.). The CBU shall be located in the Control/Relay Room.

10.4.4.10. CCTV

Integrated Closed Circuit Television (CCTV) System to be provided for the substation buildings and outdoor area, including:

- Control room
- Warehouse
- Telecom collocation room
- Generator room
- Storage yard

- Switchyard area
- Gates and corridors
- Guard house
- Boundary wall (chain-link fence) and site area

The Contractor is responsible for the integration of all necessary controls, indication and alarms as KETRACO requirements.

The contractor shall provide and install minimum ten (10) CCTV cameras along as follows:

1. Minimum Six (6) 360 degrees CCTV PTZ cameras
2. Minimum Four (4) fixed angle CCTV Entrance camera for viewing the entrance.

The location of the different cameras shall be defined during detailed design stage. The CCTV system shall be installed both at the switchyard and within the main Control building. The CCTV system shall have the possibility for remote access at KETRACO Headquarters and at the National and Regional Control Centers.

Two (2) 24" LED monitor shall be mounted in the central control room for viewing live and recording footages of the CCTV cameras.

One (1) PC with a 22" LED Display shall be mounted in the guardhouse for viewing live of both CCTV cameras.

The PTZ camera should be such that it can be controlled with a joystick from the control room.

The network video recorder and switches shall be located inside the Control room secured in a 9u cabinet and shall have a 2 extra channel license to allow expansion of cameras at the facility. Depending on the storage requirement, the minimum storage capacity it will house is 2 TB.

They shall be IP based with several ports for future integration to a central system.

The source of supply shall be from a UPS based system.

The cameras shall have the following specifications:

- **IP Dome cameras – Internal and External**
 - i. Be a vandal resistant IP/Network Mini-dome camera.
 - ii. Be designed to provide support for H.264 and MPEG-4 video, and support resolutions up to 1280x960 pixels using a 1.3MP CCD sensor with Wide Dynamic Range (WDR) Capabilities.
 - iii. Be designed to provide two individually configured simultaneous video streams to total 30/25 frames per second in all resolutions up to 1280x960 pixels in H.264 or MPEG4 in any combination.
 - iv. Have a Vari-focal electronically controlled zoom lens that can be set and adjusted via the NVMS software.
 - v. Operate on an open source; Linux-based platform, and including a built-in web server.

- vi. Make use of a modular design allowing for interchangeable parts (bubble, housing, electronic assembly, etc) enabling the unit to be serviced, maintained, or upgraded to new technologies without removal of the physical housing.
- vii. Be equipped with a built-in mechanical IR cut filter to provide IR sensitivity for Day/Night functionality.
- viii. Built in PoE
- ix. Supports both IPv4 and IPv6
- x. Digital PTZ
- xi. IP66, IP67 and NEMA 4X ratings

- **Analytics PTZ camera**

Video Motion Detection (VMD) and Non-Motion Detection (NMD) which includes multiple trip-wire detection rules, multiple video detection zones, unattended object and illegally parked vehicle detection.

The NVMS Analytics camera shall support as minimum:

- i. Video Analytics for people and car counting
- ii. Video Analytics Behaviour recognition including tailgating detection, loitering, detection and grouping detection (group can be defined to be up to five people)
- iii. Video Analytics for Crowd detection package (crowd is defined by percentage of area covered)
- iv. Video Analytics Object removal detection
- v. Video Analytics PTZ Camera Control - PTZ camera control for object tracking
- i. Video Analytics VMD Detection over PTZ Camera Pre-sets

- **180 Degree cameras**

- vi. 2 x 2MP CMOS sensors
- vii. 1600 x 1200-pixel array for each sensor
- viii. 1/2" optical format
- ix. Sensitivity 0.2 Lux at F1.2
- x. Dynamic range 61Db
- xi. Maximum SNR 50 dB
- xii. Moonlight mode – Extended exposure
- xiii. Compression H264, MJPEG, 21 quality levels
- xiv. 22fps 1600 x 1200
- xv. Capable of PoE

Technical Specifications

Specification	Requirements	Proposal
Audio	Audio/Video Output	

Zoom	Optical Zoom: 35 X Digital Zoom: 10 X	
Video	Video Compression: MPEG 4/H.264 Part 10 Max Video Resolution: 704 x 480 / NTSC Light Sensitivity: 1 Lux Frames Per Second: Up to 30 Video Source: Embedded CCD/CMOS/PIXIM Image Sensor: 1/4 inch colour CCD image sensor Shutter Speed: 1/60 ~ 1/120,000 second NTSC Automatic Electronic Shutter (AES) Automatic Gain Control (AGC) Automatic White Balancing (AWB) Flip Image Mirror Image Colour Images at daytime and b/w at night Min. Illumination (day) Colour (day) 0.1 lux f1.4 Min. Illumination (night) B/W (night) 0 lux f1.4	
Software	Drivers Recording Software Installation Utilities	
Event Operations	Motion Detection FTP Snapshots Email Snapshots Schedule Snapshots Event Snapshots	
Dimensions	Length: 155.0 mm Width: 155.0 mm Height: 125.0 mm Weight: Net 4000g All measurements are +/-25% margin	
Protocols	Protocols: TCP/IP, HTTP, SMTP, FTP, Telnet, NTP, DNS, DDNS, UPnP, DHCP,	
Safety	Certifications: CE, FCC in addition to referenced standards must be intrinsically safe	
Lens	Auto Iris Lens Type: 35 x Optical Zoom Lens	
Environment	Temperature: 0 to 50° C Humidity: 90% Outdoor: Hazardous and Potentially explosive	
Pan/Tilt	Pan Tilt Pan Range: 180° at minimum, up to 360° Tilt Range: 90° at minimum Auto Panning Auto Patrol	
Power	Consumption: Maximum 12W Output: 12V DC, 1.5A Input: 100 ~ 240V AC, 50/60 Hz, 0.4 A	
Security	Access Restrictions Number of Simultaneous Logged-in Users: 10	

System	Compatible Operating System: Windows 7, Windows Vista Compatible Browsers: MS Internet Explorer, Google Chrome, Mozilla Firefox Viewing Protocols: Active.	
Infra-red imaging	Thermal imagery to enable night viewing	
Storage	2TB	
Warranty	1 Year	

10.4.5. Bay Level Equipment

10.4.5.1. Bay Control Unit

Bay level control, status monitoring, interlocking, synch check, instrumentation and fault recording functions shall be achieved at all voltage levels through the deployment of a Bay Control Unit (BCU). The BCU deployment shall be based on the requirements of the substation primary plant arrangement and shall have at least one BCU per switch-bay. For Breaker and ½ switchgear arrangements, including variants, BCUs shall be assigned one per CB, however, alternative proposals will be considered.

A BCU shall provide a serial communications interface for any numerical protection relays that cannot be interfaced directly to the substation LAN. Information from such protection relays shall be available to the SCS.

Requirements for the BCU that are secondary functions of protection devices such as fault waveform capture may be removed from the BCU requirements so long as the data is fully accessible through the BCU / Substation LAN to the SCS. Such features must be clearly listed and detailed by the bidder.

The BCUs from a hardware and software point of view shall be independent of each other and shall enable operation of the bay even if a fault occurs at the station level equipment or local communication network.

The BCU local control shall incorporate a LCD mimic on which it shall be possible to view the BCU setup parameters, bay plant status and measurements such as current, voltage and power. If a bay protection device housed in the same cubicle as the BCU is fitted with a LCD display, measurements and alarms associated with the bay protection device may be presented on its own LCD display.

The BCU shall be equipped with a serial port for connecting a laptop computer by which it shall be possible to undertake local control at bay level even if the station level processor is not available for any reason.

Each BCU shall be supplied with standard Application software, including as a minimum the following functions:

- Apparatus control
- Interlocking
- Measurement presentation
- Events time tagging module
- Synchronizing module etc.

The main requirements for protection functions are described in Protection and Control Specification.

The control output of the BCU shall be used to control various power system devices such as circuit breaker trip/close coils. They shall use a select and check-before-execute command sequence between the BCU and the NCC/RCC Master Station. The sequence shall include, as a minimum, the following functional capabilities:

1. The Master Station shall transmit a control selection message addressing the proper SCS and control point within the BCU, and indicate the control action desired.
2. The SCS shall initialise its control logic, reassemble the control selection message received in (a) above, and transmit the reassembled message back to the Master Station.
3. The information in the message sent to the master station shall be generated by the SCS point-selection logic and indicate the point and control function selected.

The 'check back' message shall not be a simple repeat of the message received in the transmission from the Master Station but shall be a reconstruction of the message as interpreted by the SCS from the received message. The master station will verify the returned message with the message sent in (a) and, if valid, shall issue an execute control message to the SCS.

The SCS shall only operate the control point selected in the BCU after the check-before-execute sequence above has been performed without error or interruption by any other messages. The SCS shall reset its control logic upon any error in the sequence or if the execute message is not received within a user defined preset time after the initial command message is received at the SCS.

The design of the command circuit shall ensure that no single hardware failure of the module can result in an incorrect operation of any command output.

An on-board watchdog circuit shall be provided to monitor correct software operation of the control module in the BCU. Should a watchdog time-out occur, then all outputs shall be inhibited and an alarm generated.

10.4.5.2. Operator Interface

10.4.5.2.1. Overview

This section defines the facilities that shall be available at the SCS operator interface to allow the operator to monitor the status of plant items and perform control operations securely and efficiently. The operator interface shall be a computer terminal / workstation typically described as a Human Machine Interface (HMI).

The main functions of the HMI are to:

- View plant status information and to acknowledge alarms.
- Perform primary and secondary plant switching and other control operations, associated to the substation, securely and efficiently
- View sequence of event logs, alarm logs and access protection relay information

The facilities available at the HMI shall include those needed to allow it to function as a substation control point (SCP), acting as a backup control point, in the event of a failure of either the NCC or RCC.

10.4.5.2.2. Basic Requirements

The SCS HMI shall comprise of a number of linked displays that provide the following:

- Substation Overview
- Individual Busbar Groups
- Detailed views of the individual circuits
- Automatic tap change control (ATCC) relay overview
- Common Facilities
- Communication Status
- Alarm List
- Event List
- Trend displays (real-time and historical)
- Report displays
- Input Suppression Status
- Protection Relay configuration
- Power disturbance analysis
- SCS System status

The substation line diagrams shall be completely user configurable, the final representation shall be agreed in the design phase with KETRACO. Point and click links shall be provided at the top of all user screens to allow the operator to navigate to selected screens quickly (Alarms, events, Substation Overview, ATCC, etc.).

The main operator interface to the HMI for line diagram navigation, control selection and alarm acknowledgement, etc., shall be through a multi-button pointing device such as a mouse or tracker-ball. A keyboard shall be used for password entry, applying notes to plant and similar functions. The SCS functionality available to the operator shall be password controlled to at least 3 levels, system view, system control, system modification.

10.4.5.2.3. Substation Overview

The substation overview display shall provide the Operator with the electrical topology of the substation and will display the current status of plant items including maintenance tags. Depending on the size of the substation and to aid the clarity of presentation the overview may be split between two or more screens.

The AC/DC system single line diagrams indicating the actual equipment status shall be represented on the station HMI. It shall be possible to operate the incomer ACBs and bus coupler ACB of the 415VAC board from the station HMI.

The following plant items should be displayed on the Overview screen.

- Busbars
- Circuit breakers
- Diameter/Busbar Disconnectors
- Line disconnectors
- Bus section disconnectors
- Transformers
- Shunt Reactors
- Capacitor banks
- Other AVC equipment
- Control Point

Colour shall be used to identify different voltage levels. Circuit, circuit breaker and busbar names shall be displayed on the overview screen. Real time frequency and busbar voltages shall also be displayed.

Dynamic busbar colouring shall be configured for different status of the busbar i.e. live, dead and earthed.

The switchgear equipment symbols to be used on the HMI shall be subject to KETRACO's approval.

The upper and lower colour alarm limits for all bay measurements for voltages and frequency shall be implemented. These limits shall be provided by KETRACO.

Selection between the hierarchical operating levels shall be via software i.e. selection between NCC/STATION level for the SCS system.

10.4.5.2.4. Individual Busbar Groups

The individual busbar group screen shall provide a single screen view of each voltage level in the substation. The following plant items should be displayed on the individual busbar groups.

- Busbars
- Circuit breakers
- Diameter/Busbar Disconnectors
- Line disconnectors
- Bus section disconnectors

- Transformers
- Earth switches
- Shunt Reactors
- Capacitor banks
- Other AVC equipment
- Control Point

The alignment of the plant on the individual busbar group screen shall match that of the overview screen. The detailed screen shall include the following information:

- Name of substation
- Name of circuit
- Name of plant
- Plant status
- Plant Measurements
 - o Amps
 - o Volts
 - o Active and Reactive Power, including direction of flow
 - o Frequency

10.4.5.2.5. Detailed View

Detailed views of each circuit shall be available by selecting the circuit from the overview screen or Individual Busbar Groups. Control of the plant shall only be available from the detailed view. The following plant items, where present on a circuit, shall be represented on the detailed views.

- Busbars
- Circuit breakers
- Busbar disconnectors
- Line disconnectors
- Bus section disconnectors
- Transformers
- Earth Switches
- Shunt Reactors
- Capacitor banks
- Other AVC equipment

The alignment of the plant on the detailed screen shall match that of the overview screen. The detailed screen shall include the following information:

- Name of substation
- Name of circuit
- Name of plant
- Plant status
- Load shedding Group (11kV Feeders)
- Plant Measurements
 - o Amps
 - o Volts
 - o Active and Reactive Power, including direction of flow
 - o Frequency
- Transformer Measurements
 - o Actual Voltage
 - o ATCC function In/Out
- Control Point

Where a transformer has an ATCC function there shall be a link between the detailed circuit screen and the ATCC Overview screen.

10.4.5.2.6. ATCC Overview

The ATCC view shall detail all the plant associated with the ATCC functions, provide control selection of target voltage and display the following information:

- Actual Voltage
- Target Voltage
- Tap Position
- Amps
- ATCC Function In/Out
- Target Voltage Selection
- Control mode (Master/Follower)

A separate ATCC Overview screen shall be provided for each ATCC voltage level.

10.4.5.2.7. Amps / Power Summary

The Amps/Power summary screen shall detail all the circuit power flows, magnitude and direction, in tabular format, and provide a zero summation check.

10.4.5.2.8. Common Facilities

The Common Facilities screen shall provide substation control of all common site systems such as local/remote control, alarm klaxon and floodlights.

10.4.5.2.9. Plant Representation

The representation of the plant (static and dynamic) shall be finalised during the design stage. The bidder shall provide sample screen layouts using international symbols for the plant.

The single line diagrams shall have the following colours for each voltage level (to BS 381C:1996), final representation will be fixed during design stage:

- | | |
|-----------|-----------------------|
| ○ 400kV | To be associated |
| ○ 220kV | Light Violet (No 797) |
| ○ 132kV | Black |
| ○ 66kV | Green (No. 221) |
| ○ 11kV | Red (No. 537) |
| ○ 0.415kV | Blue (No. 166) |
| ○ Earth | Black |

For bidding purposes, dynamic plant shall be represented as follows:

- Closed Busbar: Colour according to voltage level
- Open: White
- Discrepancy: Orange flashing
- Running: White flashing

Running shall be indicated for a pre-defined time. Once time out has happened the plant shall be considered as a discrepancy.

10.4.5.2.10. Hand Dressed Plant

The HMI shall have the facility to hand dress Plant which is not monitored through the SCS. This facility shall only be available through the detailed screen and shall be reflected in the overview screen where appropriate.

10.4.5.2.11. Maintenance Tagging

The HMI shall have the facility of tagging selected plant items as being out for maintenance. This shall restrict the control of the plant item and provide a text box for explanation to other operators. All items of plant with a tagged message shall be highlighted as such on all screen displays.

- Red Tag Prevent closing and opening operation
- Yellow Tag Prevent closing operation only
- Green Tag Prevent opening operation only
- White Tag Will not prevent operation but tag information shall be read by the operator prior to operation

10.4.5.2.12. Alarm and Event Screen

The HMI shall present both an Event screen and an Alarm Screen. Indication of new or unacknowledged alarms shall be presented to the operator on all screens. All alarms shall appear on the event screen. Each item on the event / alarm screen shall be time tagged. Items on the alarm screen shall be displayed in one of the following three groups:

- Unacknowledged Alarms, Inverse Red Text
- Acknowledged Alarms, Red Text
- Cleared Alarms, Green Text

10.4.5.2.13. Trend displays

Trend displays shall allow the operator to view real time and historical trends. The requirements of this feature will be developed during the design phase.

10.4.5.2.14. Report displays

Report displays shall allow the operator to generate pre-defined reports. The requirements of this feature will be developed during the design phase.

10.4.5.2.15. Control from Substation

The following steps shall be required for the control of any item of plant through the SCS HMI:

- Operator enters password through HMI
- System verifies password and unlocks appropriate level of authorisation
- The Operator selects the circuit to be operated from the Overview screen
- The Operator selects the plant item to be controlled from the detailed view
- The Operator selects the required action such as Open / Close / Raise / Lower etc.

- The SCS executes the control request

Messages shall be displayed on screen during the control steps to allow the Operator to monitor the control progress and cancel the operation at any point. The control operation shall have a time out facility to return the system to a safe state should the time be exceeded.

10.5. Database Management System

Each SCS shall be provided with a database management system. The database management system shall present the information via a user interface such that any individual database is transparent to the user. The database management system shall provide a means of verifying the database in order to check consistency and completeness of the database. The SCS database shall be fully tested prior to uploading on the SCS or NCC/RCC to ensure errors are reduced to a minimum.

The database modifications shall all be documented. The contents of a database shall not be lost if the power supply fails. After a power failure, the SCS shall start and load its database automatically. The SCS shall allow the user to configure the database on site or from the NCC or RCC, respective to the associated SCS operational responsibilities. The NCC/RCC database shall be kept updated with the current configuration data for each SCS. Bidders shall state how this is achieved.

10.6. Configuration and Maintenance

The SCS shall perform continuous self-diagnostics to monitor its own operational capability. Any detected fault or abnormality which could affect the SCS performance or operational capability shall be indicated to the respective control centre, NCC or RCC, and locally at the HMI.

A laptop computer based configuration and maintenance facility shall be provided along with all database and software interfaces required for the maintenance and configuration of the SCS, e.g. SCS diagnostics, database compiler, software listings, SCS configuration listings, etc.

The laptop computer shall have diagnostics for the BCU processor(s), memory, I/O ports, and any other functional areas of the BCU. The laptop computer shall also be used to monitor and test the BCUs operation and communication interfaces and shall be capable of emulating both the SCS and the NCC/RCC.

10.7. Performance Requirements

10.7.1. Overview

The performance of the SCS shall be based on a standard circuit which consists of at least the following controllable items, indications and measurements:

Controls:

- 7 primary plant items, including 1 circuit breaker with synchronising.

- 4 secondary plant items and associated indication.

Automatic tap change control:

- 1 Transformer for every 5 circuit breakers, with each transformer having a minimum of 21 tap positions.

Analogues:

- 6 analogues

Single point status:

- at least 50 points

The standard circuit shall meet the following performance requirements where:

1. Normal Activity for a standard circuit is defined as:
 - One primary plant alarm every 30s
 - One control action every 60s
 - Different display request every 60s
 - 20% of analogues require processing every 1s
2. High Activity for a standard circuit is defined as:
 - One primary plant alarm every 2s
 - One control action every 15s
 - Different display request every 30s
 - 40% of analogues require processing every 1s

10.7.2. System Loading and Utilisation

Description	Normal Activity	High Activity
Utilisation of any processor	30%	70%
Utilisation of any memory device	30%	70%
Utilisation of any communication device of network bus	40%	80%

10.7.3. Response Times

Description	Normal Activity	High Activity
Display appearance	< 1s	< 2s
Presentation of binary changes	< 1s	< 2s
Presentation of analogue changes	< 2s	< 4s
From order to process output	< 1s	< 2s
From order to update of display	< 2s	< 3s

10.8. Inspection and Testing

10.8.1. General

10.8.1.1. Test Principles

The principle of testing shall be that, at stages throughout the work, formal tests shall be performed and recorded against written test specifications to provide a high level of confidence to both the Contractor and KETRACO that the Works meet the specified requirements such that subsequent stages of the Works may proceed.

The testing philosophy for the SCS shall ensure that the System hardware and software equipment functionality is thoroughly exercised and validated at the Contractor's premises before delivery and commissioning. The test methodology shall complement the design methodology and the two shall be developed in parallel.

This document does not constitute a Test Specification or Test Procedure for any part of the system but rather it sets out the stages at which tests are required and the subjects, locations and purpose of the testing at each stage.

The Contractor shall be responsible for specifying, conducting and recording all tests and the test documentation for all tests shall be written by the Contractor and submitted to KETRACO for approval in accord with the requirements for document submission. The degree to which KETRACO intervenes in the testing process will depend upon the level of confidence built up during the project.

Inspection of incoming goods and components, and subassembly testing, shall be undertaken by the Contractor in accordance with the procedures set out in the Contractor's own Quality Plan and are not described here.

This Specification covers the higher levels of complexity, namely:

- Type testing
- Subsystem testing
- System testing.

Type testing is required to verify that the equipment meets with the specified environmental conditions. For purpose built equipment such as BCU, station computer, terminals and connectors test certification shall be provided or tests shall be carried out to verify compliance with the required standards. However, for proprietary equipment such as printers, VDUs and keyboards, it shall suffice to provide test certification that shows the equipment is suitable for the intended environment.

'Subsystems' are defined as single items or small groups of closely related equipment (including software) such as printers, workstations, operator consoles, etc., that may be installed as an organisational entity.

The 'System' is defined as the interconnection of all Subsystems and any other equipment that will eventually comprise all of the equipment supplied under this Contract (with the exception of spares) along with the communications and network media and interface equipment supplied by others.

10.8.1.2. Responsibilities

The Contractor's responsibilities shall include but not be limited to requirements to:

- Produce written test plans, schedules, procedures, method statements, test record sheets and procedures for fault reporting, for all tests.
- Submit all test documentation associated with any subsystem or system test for approval by KETRACO within the required time scales.
- Ensure that all test documentation associated with any testing has been approved by KETRACO prior to the commencement of the corresponding testing.
- Provide the equipment, test equipment, test software, personnel and facilities to conduct the testing.
- Successfully carry out internal acceptance testing using the approved test procedures and correct any errors found in either the test procedures or the subsystem/system being tested prior to the commencement of the witnessed acceptance tests.
- Provide facilities for KETRACO and/or their Representatives to witness any Factory tests.
- Produce permanent records of all test progress and results in a formal systematic manner.
- Carry out all remedial work and re-testing necessary for the equipment to pass the tests.

Each of the above responsibilities shall be discharged to the satisfaction of KETRACO, but approval by KETRACO shall not imply any diminution of the Contractor's responsibilities. It is expressly the responsibility of the Contractor to satisfy himself that items 'supplied by others' are in a satisfactory condition for the Contractor's tests to be conducted.

10.8.1.3. Test Equipment and Facilities

The Contractor shall provide all equipment and services required for testing, including, but not limited to:

- Laboratory test instruments
- Special test equipment, emulators, simulators and test software, to permit full testing of System functions and performance
- Other items of the System, specified elsewhere as being part of the Contractor's supply, even if not part of the Subsystem under test
- Consumables required to prepare for and perform the tests.

All test instruments shall be subject to routine inspection, testing and calibration by the Contractor. All test instruments shall be subject to approval by KETRACO and, if required by KETRACO, shall be calibrated at the expense of the Contractor by an approved standards laboratory.

All test software shall be subject to formal quality assurance requirements stipulated elsewhere in the Specification.

10.8.1.4. Testing Stages

Inspection of incoming goods and components, and subassembly tests, shall be performed in accordance with the Contractor's Quality Plan. The formal stages of testing to be performed fall into the following three categories:

- | | |
|-----------------------------------|---|
| a) Type Tests | Equipment shall pass these tests in order to be accepted for use under this Contract |
| b) Factory Acceptance Tests (FAT) | Systems shall pass these tests before they may be shipped to site |
| c) Site Acceptance Tests (SAT) | Systems shall pass these tests before they may be put into operation and before they are Taken Over |

The acceptance testing includes the elements of testing outlined in **Error! Reference source not found.** and **Error! Reference source not found.**

Table -1 Factory Acceptance Tests

Testing Stage	Purpose	Results
Internal Acceptance Testing	Tests to be performed by the Contractor prior to witnessed testing as a 'dress rehearsal' for all test procedures and to ensure there are no faults pre-existing at the commencement of the witnessed tests.	The test results shall be sent to KETRACO for review to them to assess the readiness of the System for witnessed testing.

Table -1 Factory Acceptance Tests

Testing Stage	Purpose	Results
Subsystem Factory Acceptance Testing	<p>To prove the design of a Subsystem prior to the Subsystem being used in the System FAT.</p> <p>In the case of subsystems or auxiliary equipment, not required to be tested as part of an integrated System FAT (e.g. UPS); to prove the subsystem/equipment before despatch to site.</p>	<p>Subsystem tests shall be completed to the satisfaction of KETRACO before the System FAT can commence.</p> <p>Subsystem tests shall be completed to the satisfaction of KETRACO before despatch to site.</p>
System FAT	To prove that the complete System being supplied under the Contract performs in accordance with the Contract requirements.	Tests shall be completed to the satisfaction of KETRACO before despatch to site.

Table -2 Site Acceptance Tests

Testing Stage	Purpose	Comments
Installation Tests	To ensure that the installed subsystem/system is functioning as specified after installation.	Tests shall be completed to the satisfaction of KETRACO.
Point-to-point Testing	To verify correct correlation and operation between Master Station Database and plant.	Tests shall be completed to the satisfaction of KETRACO.
Subsystem Acceptance	To check the operation of a Subsystem in the field.	Tests shall be completed to the satisfaction of KETRACO.
System Acceptance	To check that the totality of the equipment and functionality supplied under the Contract performs in accordance with the Contract requirements and interacts correctly with equipment supplied by others and interfacing to the Works.	Tests shall be completed to the satisfaction of KETRACO.
System Performance	To verify the performance of the System.	Tests shall be completed to the satisfaction of KETRACO.
Tests on completion	To ensure the Subsystem or System are ready to be put into operational use	Tests shall be completed to the satisfaction of KETRACO.

10.8.1.5. Notice & Witnessing of Tests

The Contractor shall provide, as part of the Programme of Work documentation, a master plan showing the scheduled dates of testing and shall provide updates to this plan, when any changes are known, at least six weeks in advance of the tests.

The Contractor shall advise KETRACO in writing of the actual date of commencement of every test covered by Clause **Error! Reference source not found.** (c), at least 15 working days before the commencement. Notice of Factory Acceptance Tests shall be given as defined in the general part of this specification.

KETRACO shall have the right to witness any tests whether conducted at the Contractor's premises or elsewhere. Records of every test, whether witnessed or not, shall be taken by the Contractor and copies sent to KETRACO within three weeks of completion of the tests.

10.8.1.6. Test Procedures and Result Sheets

The Contractor shall prepare test procedures and result sheets for all tests. The Contractor shall also prepare a cross reference listing that clearly shows function by function and clause by clause, where the test for each of the respective function/requirement Functional Design Specification have been included in the tests.

Separate test procedures and result sheets shall be provided for factory and site acceptance tests. All test procedures and result sheets will be subject to review and approval by KETRACO.

Test result sheets will be retained as part of the permanent QA record for the SCS.

10.8.1.7. Contractor's Prior Tests

The Contractor shall successfully complete a prior run of all tests, using the test procedures and result sheets described above before the commencement of the formal tests.

Any revisions to the test documents found necessary as a result of the prior tests shall be made before the commencement of formal tests.

Test results from the prior tests shall be made available to KETRACO on request, to indicate the readiness of the equipment for tests to commence.

10.8.1.8. Conduct of the Tests

The Contractor shall conduct the tests in accordance with the approved test procedures, and shall enter the results in the result sheets.

For each test, KETRACO will determine whether the test has passed or failed. In general, the test will be considered to have failed if either:

- The result of the test is not in accordance with the expected result described in the test procedure,

or

- The result of the test is in accordance with the expected result described in the test procedure, but some other unexpected or unexplained event occurred which KETRACO considers to be a fault.

Full use shall be made during the tests of operator manuals and other documentation provided by the Contractor, to provide a series of tests of their accuracy.

10.8.1.9. Failures

The Contractor shall correct all faults found during testing, and shall arrange for the test to be repeated. The test shall only be repeated when the fault has been remedied and the equipment demonstrated to function correctly.

Where remedial measures involve significant modifications that might, in KETRACO's opinion, affect the validity of earlier tests then the Contractor shall repeat the earlier tests and obtain satisfactory results before repeating the test in which the fault was first identified.

KETRACO shall have the right to order the repeat or abandonment of any test in the event that results demonstrate that the equipment is significantly non-compliant with the Contract requirements.

KETRACO shall have the right to suspend any test in the event that errors or failures have become unacceptable. KETRACO shall also have the right to suspend any test in the event of a fault being detected by the Contractor but not reported to KETRACO within 24 hours. In this event, the suspension shall remain in effect until reporting has been brought up to date to the satisfaction of KETRACO.

10.8.1.10. Fault Categories

KETRACO will allocate a category to each fault, which shall determine the future conduct of test. Test categories shall be as defined in [Error! Reference source not found.](#).

10.8.1.11. Repeat Tests

The Contractor shall correct and re-test every fault detected during the tests.

Time spent by KETRACO and/or KETRACO's representatives witnessing re-tests, or waiting at the Contractor's premises or the test site while corrections are made prior to re-test, shall be charged to the Contractor at the standard hourly rate for the personnel concerned. All other costs incurred by KETRACO and/or KETRACO's representatives as a result of such re-tests, including accommodation, subsistence and travel charges, will be charged to the Contractor at cost.

If KETRACO and/or KETRACO's representatives is required to return to the Contractor's premises or the test site to witness such re-tests then time spent by the personnel concerned in travelling to the site of and witnessing such re-tests, and all charges incurred by them in so doing, will be charged to the Contractor.

10.8.1.12. Fault Log

The Contractor shall maintain a fault log throughout each series of tests. Every fault detected during the tests will be entered in the log, together with the actions taken to clear and re-test the fault.

The fault log will be retained as part of the permanent QA record for the SCADA/EMS System.

10.8.1.13. Hardware Failure Reports

For each hardware failure that occurs at any stage of testing, the Contractor shall investigate the failure and prepare a report on its cause(s) and design implications. The report shall clearly show:

- The most likely cause of the failure
- An analysis of any stress that may have been caused to other components of the equipment being tested as a result of the failure
- Whether the failure is a result of any component operating outside its design range
- Whether any design changes should be made to avoid further failures.

All such reports will be retained as part of the permanent QA record for the SCADA/EMS System.

10.8.1.14. Software Failure Reports

For each software failure that occurs, once the software has been approved for inclusion into the system and is subject to configuration control, the Contractor shall generate a software failure report. The report shall clearly show:

- The observed symptoms
- The likely cause
- The fault category (from Table below)
- The report shall also clearly show the following information that shall be entered when the failure has been investigated:
 - The actual cause of the failure
 - The corrective action taken
 - All software modules affected

All such reports will be retained as part of the permanent QA record for the SCADA/EMS system.

Table -3 Fault Categories	
Category	Definition
0	An item recorded as a fault during testing, and subsequently considered to be a normal acceptable occurrence. Testing may continue.
1	Minor fault. An event not affecting the functionality being tested in that session; testing may continue.
2	Repeatable fault not affecting the functionality being tested in the session. Testing may continue at the discretion of KETRACO.
3	Repeatable fault affecting the functionality being tested in the session. The fault must be rectified before retest of the affected test sessions or sessions. Testing may proceed on other sessions if permitted by KETRACO.
4	Major fault affecting the functionality being tested in the session. The fault must be rectified before recommencing testing.
5	Non-repeatable fault affecting functionality being tested in the session. The action taken will depend on the severity of the fault. Discussion is needed to establish the most appropriate course of action.
6	Documentation error or deficiency. The error will usually be amended during the test and the test will continue. The documentation shall be corrected before the tests are considered complete.
7	Deficiency in the ability of the test or test equipment to demonstrate the function being tested in the session. Discussion is needed to establish the most appropriate action.
8	Other fault not covered above, but requiring explanation and, in some cases, correction.

10.8.1.15. Type Tests

Full details of type tests performed on equipment identical to that being offered shall be submitted with the offer, accompanied by a proposed schedule of tests to be performed for each item of equipment. If the submitted type test results are satisfactory then the type tests specified may, at the discretion of KETRACO, be waived.

In general, type test results shall show that the equipment being proposed for this Contract will perform in accordance with its design specification in the environments to which it will be subject in its application under this Contract. The environmental factors include climatic (temperature, humidity, wind, rain, etc.), electromagnetic (radiated and conducted), mechanical (transport vibration, handling knocks, operational ruggedness, earthquake stresses) and chemical (salt laden atmosphere).

Where appropriate, the type tests shall also demonstrate that the equipment does not exceed accepted standards in terms of its impact on the environment (e.g. noise, harmonic emissions into the mains, etc.).

10.8.1.16. Factory Acceptance Tests

Subsystem FAT

A Subsystem Factory Acceptance Test shall include the inspection, hardware test and software test of any clearly identifiable Subsystem, prior to use as a component in a System test. The test shall prove that the Subsystem meets its particular physical, functional and performance specification. All corresponding inspection, and component and subassembly test documentation shall be complete and available for inspection prior to the commencement of a subsystem FAT. The tests shall be carried out at the Contractor's premises.

System FAT

The System FAT shall combine all Subsystems and shall include other equipment that shall represent, emulate or simulate those parts of the "System" to be eventually provided. The System FAT shall commence only if all associated subsystems have successfully completed their individual FATs to the satisfaction of KETRACO. The Contractor shall have completed his own internal system integration tests prior to commencement of the System FAT.

The System shall be inspected to ensure that all interfaces mate correctly and that the System is complete. The System shall then be tested as a whole to prove that it meets the Specification in all aspects of function, performance, capacity, maintainability and operability.

It is required that the results of the test shall demonstrate System reliability and availability consistent with the values specified and those guaranteed by the Contractor. The test shall be carried out at the Contractor's premises. Upon satisfactory completion of the test, the System will be ready for delivery to site.

The FAT shall not commence until all documentation associated with the FAT including Test Plan, Cross-reference Document, Test Specifications, Test Procedures and Test Record Sheets have achieved Category I approval. The System equipment will not be allowed on site until the FAT has been successfully completed and the corresponding test records have been reviewed by KETRACO.

Partial shipment may take place, by agreement with KETRACO, of equipment that has been successfully factory tested (and the corresponding test records have been reviewed by KETRACO) and is not required to form part of the System FAT.

General FAT Requirements

It is the responsibility of the Contractor to produce the Test Documentation for the FATs to the satisfaction of KETRACO. Coverage shall include, but not be limited to, the following:

- **Order of Tests** Tests shall be conducted to prove the integrated functioning of the system as a whole and shall include (but not be limited to) the following:
 - a. Hardware inspection

- b. Hardware functionality including firmware and operating system level software tests on CPU, disks, I/O interfaces etc. (The extent of this testing will be dependent on the extent and nature of the subsystem tests)
 - c. Integrated system tests to prove the functionality of all applications software in the context of the complete integrated system, equipment and software configuration
 - d. System performance tests to demonstrate that the integrated system can achieve the guaranteed levels of response and to determine the limits of the response envelope
 - e. System performance in the face of various contingencies
 - f. Soak test to give an indication of system reliability, stability and robustness.
- **Inspection** Prior to commencement of the tests, the equipment shall be inspected to ensure:
 - a. Correct standards of workmanship and quality
 - b. Correct identification labels, cabling, tagging, housing and mounting etc.
 - c. Adequate accessibility
 - d. Compliance with the Specification and reviewed drawings (including compliance with fire safety and materials requirements)
 - e. Verification of model numbers, quantities of items etc.
 - **Test Conditions** The conditions of the tests shall be no less rigorous than:
 - a. All subsystem components shall have been successfully inspected and tested, as necessary, and all corresponding documentation shall be complete and available for inspection.
 - b. All necessary maintenance and adjustments shall be carried out before commencement of the test so that the tests can continue uninterrupted by routine operations.
 - c. The equipment shall be complete at the start of the tests and no interchange of modules or equipment shall be allowed.
 - d. All parts subject to wear, such as electromechanical peripherals, may be omitted from the tests if agreed by KETRACO. The printing and recording equipment needed for conducting the test shall be run throughout the test.
 - e. Each subsystem and/or each module shall be tested cyclically at least once per hour whilst all other parts are functioning normally.
 - f. No repairs or adjustments shall be carried out during the test period unless agreed by both parties.
 - g. The test shall run for at least 200 hours continuously. It need not be permanently manned throughout this period provided that a comprehensive log of operations tested and faults occurring is printed.

- h. Where there is redundancy in the equipment the test period shall be divided equally between the redundant parts. All modules must remain powered up for the duration of the test.
 - i. Test equipment and test software shall be provided to load the equipment to a greater extent than the worst case predicted for the complete system. Online loading and all functions shall be tested under these worst case conditions. Sufficient hardware (e.g. remote terminals) and/or simulation devices shall be provided by the Contractor to ensure that the Design System Loading conditions can be achieved and System performance demonstrated to the satisfaction of KETRACO.
 - j. The tests shall be carried out at the prevailing ambient conditions of temperature and humidity, no special conditioning is required.
- **Computer Equipment** The Contractor shall provide all the software necessary to carry out the tests. Tests shall include:
 - a. CPU tests
 - b. RAM write/read tests
 - c. Disc write/read tests
 - d. Data highway loading tests
 - e. Peripheral tests
 - f. Workstation equipment test.

Tests shall exercise communication ports and shall overload ports so that queuing of messages occurs. The tests shall use a simulated network, or where practical, a real network.

- **Communications** Tests shall include, where appropriate:
 - a. Data integrity in the presence of noise
 - b. Loss of Link procedures
 - c. Demonstrate that communication systems do not interfere with each other (e.g. cross-talk) or with other systems
 - d. Demonstration of network management functions
 - e. Programming, control and configuration of the network.
 - f. The tests shall use a simulated network or, where practical, a real network.
- **Soak Test**

Each subsystem soak test shall be carried out over a period of time sufficient to fully prove the correct functioning of the equipment comprising the subsystem. The initial System soak test shall have a minimum duration of 100 hours. The time shall be calculated as the number of hours continuously connected and running. All errors or problems shall be printed out. Messages shall also be output

periodically indicating continuing successful operation. The equipment shall perform successfully without errors or failures that are inconsistent with the reliability and availability criteria of the System design.

- **Functional Tests**

During the functional tests, every function specified for the system in the Functional Design Specification shall be thoroughly tested. Both positive and negative tests shall be carried out.

Before commencement of the functional tests, all software for which source code is supplied under the Contract shall be reassembled and/or recompiled from source. The resulting object code shall be re-linked and used for the tests.

Similarly, all configurable databases, screen displays and reports shall be regenerated from source. All of these activities shall use compilers, assemblers, linkers and generation/startup utilities identical to any of those supplied under the Contract.

- **Performance Tests**

The performance tests shall demonstrate that the performance and response times of the equipment are in accordance with the specified requirements.

- **Unstructured Tests**

In addition to the structured tests described above, all factory acceptance tests shall include a 48-hour period of unstructured testing, during which KETRACO and/or KETRACO shall be at liberty to instruct the Contractor to carry out such additional tests as may be required to test the reliability and robustness of the system.

10.8.1.17. Site Acceptance Testing

After equipment has been erected and connected up on site, the Contractor shall carry out to the satisfaction of KETRACO such tests as may be required to prove compliance with the Specification, independent of any factory tests.

In support of the Site testing activities, the Contractor shall prepare an overall test plan that covers all testing to be carried out on Site. The test plan shall indicate test precedence and dependencies and should be co-ordinated with the Contractor's general programme of work. It shall conform to the relevant requirements for test documentation. The test plan will be subject to the approval of KETRACO and should be closely co-ordinated with KETRACO in terms of the availability of plant for testing and the timely provision of the associated permits to work.

KETRACO shall have the right to waive some tests and require additional tests to be carried out if findings on Site indicate additional or alternative tests are required to properly demonstrate that the works comply with the requirements of the Contract.

The general requirements for testing and factory testing set out in preceding clauses of this section are applicable to Site testing.

Subsystem SAT

A Subsystem SAT shall be conducted to prove that the Subsystem has not been damaged during packaging, delivery and installation on site. The test shall prove that the Subsystem is operating correctly and interfaces correctly to equipment and services on that site. On completion of the test, the Subsystem shall be ready for use in the System SAT.

The scheduling of Subsystem SATs shall be subject to coordination with the installation and testing schedules of equipment of other suppliers, to which the Subsystem is designed to interface.

System SAT

The System SAT shall be conducted on all the interconnected equipment forming the Contractor's scope of supply, together with equipment of other suppliers to which the System is designed to interface.

The System SAT shall be conducted after all the various elements of the System have been installed in the field and have all successfully completed their individual Subsystem SATs. The System SAT shall be performed with equipment in the locations in which they will eventually operate.

This test shall demonstrate that the overall design of the System meets the functional and performance requirements of the Specification in the field, using the actual communications network and including equipment supplied by others, to which the System is designed to interface.

The Contractor shall satisfy himself by testing and other necessary means that the physical communication links between terminations supplied by others meets the Contractor's requirements. Any deficiencies in such equipment shall be reported fully in writing by the Contractor to KETRACO upon their discovery, to allow prompt remedial action to be instigated. The correction of deficiencies in such equipment shall not be the responsibility of the Contractor, provided that the deficiencies have not resulted from inadequate definition and specification of requirements on the part of the Contractor.

General SAT Requirements

It must be emphasised that all testing that requires an interface to operational equipment must only be carried out after prior agreement with KETRACO and adequate advance notice shall be given to KETRACO by the Contractor of their intent to conduct testing involving operational equipment.

The end to end testing shall require coordination by the Contractor. The Contractor shall provide a detailed commissioning plan for the end to end testing for review and approval by KETRACO. This shall be followed by joint meetings by the Contractor and KETRACO to finalize the responsibilities of the contractor.

It is the responsibility of the Contractor to produce the Test Documentation for the SATs to the satisfaction of KETRACO. They shall meet the appropriate requirements for the Factory Acceptance Test specified in General FAT Requirements. In addition, the following requirements shall be met:

- Commissioning

It shall be the Contractor's responsibility, within the scope of definite work, to fully commission the System in such a manner as to enable trained operators to use the System.

In the event of necessitated shutdowns at key installations within the grid to facilitate the commissioning of the substation, the duration for such an activity shall be depended on the availability and reliability of the grid as advised by the National Control Center (NCC) currently managed by KPLC.

The Contractor shall submit for review/approval by KETRACO the CVs/Resumes of the commissioning personnel. The employer reserves the right to request for changes in composition of the commissioning team as deems appropriate.

The commissioning tests shall be carried out by the Contractor taking into consideration KETRACO's standard practice for substation commissioning. The Contractor shall submit for review/approval the substation pre-commissioning and commissioning test plans and methodology for KETRACO's approval. Detailed consultative meeting shall be held between Contractor, KETRACO and employer's representative shall be held to discuss and agree on the testing and commissioning methodology and protocols.

The Contractor shall budget for a commissioning duration of two months per substation.

For the final end to end testing and commissioning of the substations, the Contractor shall be bound by the requirements and constraints of Kenyan National grid as advised by the National Control Center NCC managed by KPLC

In the end to end testing between the new substation and existing substation shall be planned for every Sunday of the week depending on the grid system constraints as advised by NCC

- Duration and Downtime

Each Subsystem SAT and the System SAT shall be carried out over a period of time sufficient to fully prove the correct functioning of the equipment. All errors or problems shall be printed out. Messages shall also be output periodically indicating continuing successful operation. The equipment shall perform successfully without errors or failures that are inconsistent with the reliability and availability criteria of the System design.

- Testing to Plant

Initial setting to work and all subsequent 'live' tests will be directed by KETRACO, and carried out jointly by KETRACO and the Contractor. Tests shall be subject to KETRACO's standard safety procedures, and

all operational switching will be carried out by KETRACO according to a programme that will be prepared and agreed in advance between KETRACO and the Contractor.

10.8.1.18. Specific Site Test Requirements

Installation Tests

Following despatch from the factory and arrival at site, the Contractor shall ensure that the location for the system or subsystem is fully prepared to proceed with installation. Of completion of installation the Contractor shall set the equipment working and carry out the necessary tests and diagnostic to verify that the system or subsystem is functioning according to the requirements. When completed the results of the diagnostic and verification tests shall be submitted to KETRACO. Following this and subject to the tests being approved, the Installation Tests shall be conducted by the Contractor. On successful completion of these tests the EMS/SCADA system/subsystem shall be made available for the point to point testing and verification of the database.

Point To Point Testing

Site acceptance test procedures for the new SCS equipment shall ensure that the SCS database and displays are correctly mapped onto the BCU input output connections to the plant. The process of testing this mapping may take up to 1 month to complete. Therefore, the Contractor shall establish, to the satisfaction of KETRACO, quality procedures that ensure the validity of the results of previous testing are systematically reviewed following subsequent changes in the database, displays and or the system code. These procedures should identify when previous test results may no longer be valid due to subsequent changes on the system. If test results are invalidated by subsequent actions, then re-testing will be necessary. The scope of the re-testing shall be agreed with KETRACO on a case by case basis.

Readiness to Commence Tests On Completion

When KETRACO is satisfied that the Site acceptance testing has shown that the works as a whole comply with the specification and that:

- a. All test documentation and records are complete in order and signed off by the Contractor's test engineers;
- b. The spare parts and test equipment are complete, in working order and available for use;
- c. The initial issue of technical documentation and copies of marked as built drawings have been provided;
- d. Training has been completed as required by the Contract;
- e. And the arrangements for support during the warranty period have been agreed;

The Contractor may apply to commence the Tests On Completion.

System Acceptance

The System will be accepted by KETRACO if both:

- The System and all items of equipment have successfully completed all the specified tests
- All failures, problems and reservations noted during the tests have been corrected to the satisfaction of KETRACO.

If either of these conditions has not been complied with, then the necessary corrective action shall be agreed between the Contractor and KETRACO.

10.9. Spare Parts

In order to assist in the ordering of spare parts, the bidder is required to recommend spares holding to cover the first five (5) years, following the end of the Defects Liability Period, and to provide a cost breakdown. The Contractor shall not have access to spares held by KETRACO during the Defects Liability Period.

The maintenance philosophy which will be adopted will generally be for fault finding to card level and module replacement, with the faulty modules being either scrapped, if damaged beyond repair, or returned to the Contractor for repair, as appropriate. The Contractor shall operate a module repair and replacement scheme, details of which shall be provided with the Tender, including turnaround times.

The bidder shall base the list of recommended spare parts on the above maintenance philosophy. This list shall be submitted as an optional price and shall include a cost breakdown. Prices for the supply of spares shall include all associated charges and shall remain valid for orders placed within the term of the Defects Liability Period. KETRACO shall be at liberty to order quantities of spare parts at variance with those listed by the bidder. The prices shall remain valid for any such variation of quantities, unless stated otherwise in the Tender.

The cost of spare parts shall not be used to calculate the cost of any variations to the Contract.

The spare parts recommended shall be identical functionally, electrically and mechanically, to the corresponding parts in the equipment supplied under the Contract and shall be suitably packed and clearly marked, ready for reception at KETRACO's stores. Any special handling instructions shall be clearly marked on the packages.

The Contractor shall supply equipment lists of the recommended spare parts which include the names and addresses of the individual manufacturers of the listed items.

The recommended spares holding shall be quoted on a unit basis, as an option, for selection by KETRACO at any time up until the end of the Defects Liability Period.

The availability of spare parts to KETRACO, at a reasonable cost, shall be guaranteed by the Contractor as follows:

The Contractor shall maintain an adequate stock of spare parts for a minimum period of ten years (or until the end of the equipment's specified life) after the product has been removed from quantity production, declared obsolete or officially removed from sale

Where a component, which is not under the Contractor's control, has become unavailable, it is the responsibility of the Contractor to offer a compatible alternative at reasonable cost

Design improvements or changes made to a product during its production run shall be carefully assessed such that component interchangeability shall not be affected.

This requirement shall apply to equipment manufactured by the Contractor and also to equipment purchased from other suppliers.

10.10. Documentation with Tender

The Tender shall contain at least the following information and documents:

- 1) General arrangement drawings of the SCS;
- 2) Overall structure of the SCS;
- 3) Detailed description of the SCS;
- 4) Manufacturing specification of the SCS;
- 5) Catalogues, literature and reference lists of proposed equipment;
- 6) Type test certificates from an independent testing authority or independently witnessed;

Quality Management System Manual and ISO Certificate of the equipment manufacturer.

11. LV Service Equipment

11.1. General requirements

This Specification provides for the design, manufacture, factory testing, delivery and commissioning of the complete LV (AC and DC) service equipment, Solar PV System and includes all auxiliary equipment necessary for complete installation.

All materials and equipment shall be provided as required to make a complete, properly functioning installation and shall conform to the highest standards of engineering design and workmanship.

The LV service equipment shall comply with this Specification and the latest revisions of the respective IEC publications.

The 415/240 V AC, three phase, five wire (3~, N, PE) solidly earthed supply system shall comprise two 11/0.415kV earthing/ auxiliary transformers supplied from the transformer tertiary winding.

Each incoming supply connected to the LVAC switchgear defined in this specification is to provide a highly reliable and safe auxiliary power supply within the substation. The switchboard shall provide feeds to the substation outdoor and indoor lighting sub distribution board (the outdoor & indoor lighting shall be primarily supplied via the Solar PV System), substation equipment as defined by the single line diagrams and additional spare feeds for future diameters' requirements. The LVAC arrangements are illustrated in the single line schematic diagrams in the tender drawings (Part 2-D).

The auxiliary transformers shall constitute the main auxiliary LVAC supply for all loads except outdoor and indoor lighting where Solar PV System shall be the primary/main supply. The Solar PV System complete with a Battery Storage System, Inverter(s), Charge Controller(s), PV modules and other accessories shall be the main supply for the indoor and outdoor lighting loads. At least two (2) days of autonomy shall be considered. The indoor and outdoor lighting will be primarily served by the Solar PV System with automatic load transfer capability to main 415 V bus supply (auxiliary or Gen set supplied bus) once the battery reaches its discharging threshold or if there is a fault on the Solar PV System. The Solar PV system arrangements are illustrated in the single schematic diagrams in the tender drawings (Part 2-D).

The 110V DC supply system shall comprise 2 x 50% rated duty, Nickel-Cadmium (Ni-Cd) type battery units, 2 x 100% rated battery float/boost chargers and a separate DC distribution switchboard configured to provide duplicated supplies as defined by the single line diagrams and additional spare feeds for future diameters' requirements. The 110V DC arrangements are illustrated in the single line schematic diagrams in the tender drawings (Part 2-D).

The 415V AC uninterruptible power supply (UPS) system shall be supplied and installed to feed:

- Substation control system equipment whose power supply is not available with 110V DC

- Fire protection panel
- Online monitoring systems

The UPS shall comprise dual independently operating units, arranged to share the load, incorporating static switches, manual bypass switch and a distribution switchboard.

11.2. Scope of Works

The supply and services to be performed by the Contractor shall comprise the design, manufacture, shop testing, packing, transport, insurance, unloading, storage on site, construction works and erection, corrosion protection, site testing, submission of documentation, commissioning, training of KETRACO's personnel and warranty of the works.

The Contractor is bound to provide complete works, even if the equipment or services to be provided are not specifically mentioned in the specification.

Typically, each new build substation Low Voltage Services will include:

1. 415/240 LVAC Switchgear:

1 – Main distribution board to be installed in the substation control building with two sections, fully metal enclosed design, draw-out type, comprising two incoming cubicles, one bus-section cubicle, one Emergency Diesel Generator/temporary commissioning supply cubicle, and separate cubicles with the required number of outgoing feeders equipped with MCCBs, including spares, completely wired and tested, complete with all other devices and accessories including automatic changeover scheme.

X – Sub distribution boards to be installed in the substation control building as specified/required by KETRACO, fully metal enclosed design, incoming feeders equipped with MCCBs, with the required number of outgoing feeders, including spares, completely wired and tested, complete with all other devices and accessories including automatic changeover scheme, if redundant incoming feeders present.

1 – Sub distribution board to be installed in each Bay Control Room (if any), fully metal enclosed design, redundant incoming feeders equipped with MCCBs, with the required number of outgoing feeders, including spares, completely wired and tested, complete with all other devices and accessories including automatic changeover scheme.

2. 110V DC System for Substation power supplies comprising:

2 - Nickel-Cadmium (Ni-Cd) Batteries 110V DC, minimum Ah (10h) rated as stipulated in the Technical Data Sheets, to be installed in the substation control building.

2 - Battery Chargers 415V AC/110V DC, minimum 250 Ah rated, thyristor controlled, suitable for parallel operation with each other sharing the load, complete with all the accessories, to be installed in the substation control building

1 - 110V DC Switchboard with two sections, fully metal enclosed design, draw-out type, comprising two incomers and one bus-section equipped with MCCBs of the required rating, with the required number of outgoing feeders, including spares, completely wired and tested and complete with all the devices and accessories, including automatic changeover scheme, to be installed in the substation control building

3. 1 – Sub distribution board to be installed in each Bay Control Room, fully metal enclosed design, redundant incoming feeders equipped with MCCBs, with the required number of outgoing feeders, including spares, completely wired and tested, complete with all other devices and accessories including automatic changeover scheme.
4. **UPS** 110V DC/415V AC, appropriately sized (6000 VA minimum) consisting of dual independently operation units complete with all accessories. The Contractor shall provide sizing calculations for the UPS loading. The UPS supply shall power the fire protection panel within the control building as well as the reactor bank and auto transformer online monitoring devices.
5. **48V DC system** consists of separate DC distribution board, batteries (Nickel Cadmium type) and chargers as per tender SLDs & KETRACO Standard Specification. DC system shall be designed based on future requirement and shall be sized for the final number of bays including all non-equipped spare bays.

5. Solar PV System:

1 – Sub distribution board to be installed in the substation control building with one (1) section fully metal enclosed design, with 2 incoming feeders (from Solar PV system and 415V main bus) equipped with MCCBs, with the required number of outgoing lighting feeders, including spares, completely wired and tested, complete with all other devices and accessories including automatic changeover scheme.

The tender drawings provided as the conceptual design and the Contractor is responsible to provide detail design together with required calculations. The following items shall be considered:

Space provision and facility for future extensions shall be considered.

All the modifications at existing Substations (/remote end Substations) shall be considered.

Relay panels which shall house all main1, main2 & CB protection relays together with connection and all accessories. It shall be emphasized that protection relays specifications at both ends should be matched and in

accordance with KETRACO Protection policy and standards. However, any required modification on remote end Relay & Control panels (including supply, installation, and modification of relays, control equipment & circuits, and etc.), in case of necessity, falls into Contractor's scope of work and responsibilities.

Bus bar protection panels including protection relays (low Impedance Bus-bar protection schemes), auxiliary relays, etc. as required together with connection and all accessories.

Configuration and quantity of protection panels shall be finalized during detail design stage subject to the approval of Client/Consultant.

Protection system shall be supplied and implemented as per tender drawings & KETRACO Standard Specifications.

Relay setting calculations to be implemented for all protection relays. Relay setting calculation for local and all remote ends shall be carried out including relay configuration changes.

Protection, control and metering, for all equipment to be provided as indicated in single line diagram.

Contractor shall check and review the interlocking scheme at remote ends and carry out modifications based on operational requirement.

Metering equipment shall be in line with per Metering and Data Exchange Code, Grid Code and KETRACO standards (Main and Check Tariff Metering) on Overhead Line Feeders. Meter pulses are to be made available to Master SCADA through SCS/RTU control system. Proposed meters shall be of class 0.2s and be equipped with Ethernet ports.

Online Condition Monitoring (OLCM) shall be considered as per Transformers and 400kV CBs Standard Specifications.

OLTC and RTCC shall be considered as per Standard Specification.

LV power, control, lighting, Solar PV System, Earthing, instrumentation, telecommunication cables for complete project under the scope of this project including cable supporting system and accessories as per KETRACO Standard Specification.

LV Cable and Accessories within substation and related services to be implemented, including but not limited to:

- Interconnection between Earthing/Auxiliary transformer and 415VAC main distribution board including cable supporting system from EAT transformers.
- Connection between 415VAC main distribution board and Sub-Distribution Board.
- Interconnection between 415VAC busses.

- All other LV power, control, lighting, Solar PV System, Earthing, instrumentation and telecommunication cables including cable supporting system and accessories.

Note: Tentative cable routes shall be as per equipment layout. However final lengths and sizes shall be estimated by the Contractor. Contractor shall also carry out adequacy checks for the selected cable sizes as per tender SLDs.

11.3. Equipment Requirements

11.3.1. LVAC Service Equipment

11.3.1.1. General Design Requirements

The LV AC switchgear shall be designed as an indoor switchgear installation and shall be of metal-clad design with fully insulated busbars. The free-standing switchgear shall be mounted directly above the cable trench and shall have both front and rear access for maintenance. The switchgear shall be purpose built to meet the requirements of the Specification.

The switchgear shall be supplied from either substation earthing transformers or auxiliary transformers by cables. The switchboard shall be equipped with outgoing 3-phase, four wire, 415/240 V circuits to cater for station services including secondary supply (backup) to the outdoor and indoor lighting sub distribution board. The nominal rating of all outgoing feeders shall be selected according to the respective load.

The AC switchgear shall be of a single busbar arrangement. The main fully insulated busbars shall be divided into two independent sections with a bus section circuit breaker. The incoming feeder circuit breakers and the bus section circuit breaker shall be provided with automatic, high-speed changeover facilities and also, shall be interlocked such that only two of three circuit breakers can be closed at one time. Auto changeover facility shall be provided in case one out of two breakers opens/trips.

All electrical components shall be incorporated into the withdrawable portion and shall be capable of complete withdrawal without removing any termination.

The incoming circuit breaker shall be interlocked with the earthing switches of the respective 11 kV transformer circuits. Incoming circuit breakers shall also be interlocked with the EDG/Commissioning temporary supply circuit breaker to prevent parallel operation.

In the event of outage of the air-conditioning system in the LV Services room, the switchgear installation shall remain operational at full load, and at the ambient temperature of 50°C. Switchgear shall be provided with humidity controlled anti-condensation heaters with isolation facilities.

The complete switchgear shall be capable of carrying rated load current without a temperature rise of any part exceeding 65°C. Parts that may be touched by operating personnel shall not exceed a temperature of 70°C.

11.3.1.2. Switchgear

The switchgear shall consist of cubicles and shall be erected in a single row. The switchboard shall be provided with lifting lugs. The height of the switchgear shall not exceed 2250 mm and operating handles of all equipment shall be within the reach of a person standing at ground level.

The switchgear shall comply with IEC 61439-2 and other relevant IEC Standards and local standards if not otherwise stated. The switchgear shall be of draw-out design. The switchgear shall be designed to comply with the degree of protection of IP51 and shall be vermin and termite proof.

The switchboards shall be type-tested including arc fault containment (IEC 61641, criteria 1 to 7 to be fulfilled).

The fully insulated busbars shall be located in the rear upper part of the cubicle. The connections from the busbars to the equipment contacts shall be isolated from the incoming or outgoing connections.

The cross sectional area of the busbars may be graded according to the current rating, but shall remain capable of the short time current rating stated in the Schedules. All busbars and connections shall be made of copper and encapsulated.

All separately mounted metallic parts that are not normally energised shall be earthed. To this end they shall be equipped individually with terminals for the connection of the earth conductor. The switchboard shall be provided with an earth bar incorporating terminals for the connection of earth conductors, directly connected to the earthing system at both ends. All metallic parts that are to be earthed for safety reasons shall be connected to this bar in the factory and form part of the wiring system. The cross section of this earth wiring shall be adequate for the short-circuit current.

Hinged doors shall be provided at the rear for easy access to equipment contained within the cubicle. The hinged doors shall be of the lift-off type, secured with integral handles provided with locks, and duplicate keys to an approved change system and shall be flush fitting and sealed with a gasket of rubber or other approved material to prevent the ingress of dust. Cubicles and doors shall be structurally stiff and braced to withstand twisting without distortion.

Each cubicle shall be equipped with a cable compartment, isolated against other compartments of the cubicle, and glands suitable for all incoming and outgoing cables. The cubicle shall be designed for cable entry from the bottom rear. Armoured cables shall be equipped with armour clamps for connection to the earth bar.

It must be possible to work within each cubicle with the equipment withdrawn whilst the incoming contacts are energized. The minimum requirements for protection shall be:

- Insulating barriers installed between phases within the cubicle
- Automatically operated metallic shutters provided to cover busbar and feeder spouts

On the front of the switchgear cubicle of each incoming feeder a coloured mimic diagram shall be provided, with the necessary switch position indicators, symbols and signal lamps.

All equipment installed on the front panel of the cubicle shall be flush mounted.

Each incoming feeder unit, including the emergency diesel generator/commissioning supply incomer, shall be fitted with an indicating voltmeter with selector switch and one ammeter with a selector switch. Each busbar section shall be fitted with an indicating voltmeter.

Outgoing feeders of 250A or more and feeders to rectifiers shall also be fitted with an ammeter.

The indicating instruments shall be connected to earthed cases and shall comply with IEC 60051.

Cast-resin insulated, corona-free current transformers shall be provided for protection and measurement as per single line diagram. The current transformers shall be of the single or three pole, multi-ratio type for indoor installation and shall comply in all respects with the requirements of IEC IEC 61869-1. The current transformers shall be mounted at the withdrawable units or in case of incoming feeders current transformers shall be mounted in the circuit breaker compartments. The current transformers must withstand the dynamic and thermal short circuit stress resulting from system faults.

Earthing transformer LV side restrictive earth fault protection shall be provided. On the incoming circuits, overcurrent and earth fault protection as well as for overvoltage / undervoltage protection shall be provided. LV side restrictive earth fault protection shall trip both the LV incomer and main transformer circuit breakers.

Each outgoing circuit from the switchgear shall be controlled and protected by moulded case circuit breakers of a design type that provides a means to readily remove it from the installation and their short circuit rating being adequate to protect each circuit against the effects of a fault at the outgoing terminal of the unit.

Switchgear provision shall be made for an Emergency Diesel Generator connection that additionally provides a temporary diesel generator supply for construction and commissioning purposes. The connection shall be arranged to ensure that the Emergency Diesel Generator cannot be connected in parallel with incoming supplies from the earthing / auxiliary transformers. The connection point for the diesel generator shall be positioned to permit a convenient and speedy connection, preferably close to the substation entrance.

All cubicles shall be supplied complete, including protection, instrumentation, all internal wiring, terminal blocks, etc.

Suitably rated LV surge arresters shall be installed to protect the system against overvoltage impulses. The surge arresters shall be equipped with remote signalling contact, the alarm to be transmitted to the substations control system.

Proof of selectivity for the feeders with regard to the grading shall be provided and the Contractor shall submit the respective calculations for approval.

11.3.1.3. Circuit Breakers

The circuit breakers shall be of the air break type in accordance with IEC 60947, be modularly sized, of draw out design and suitably rated to handle the relevant capacities at their installation location.

Circuit breakers shall be fitted with 110V DC electric motor wound spring operated mechanisms. Means shall be provided for hand-charging the operation springs.

Circuit breakers shall have a test position, in which their main contacts are separated (with automatic metallic shutters closed), but the mechanism stays fully operational and the auxiliary contacts are still connected. The draw out operation from the service to the test position shall only be possible with the circuit breaker in its off position. In addition, it shall not be possible to put back a closed circuit breaker into its service position. The circuit breaker compartments shall be provided with an adequate number of auxiliary contacts signalling the circuit breaker position.

The main contacts shall be generously dimensioned and shall be silver-plated or equivalent, and arcing contacts shall be fitted. Direct acting overcurrent release shall be provided for protection against short-circuit currents, and shall be adjustable to a multiple of the normal current. These devices must ensure selectivity with the fuses and/or circuit breakers below. The circuit breakers shall further protect the transformers against overload.

An adequate number of auxiliary contacts shall be available for each circuit breaker. A trip alarm contact shall be provided for signalling any involuntary tripping of the circuit breaker. All contacts shall be easily convertible from close to open and vice versa. All contacts shall be wired onto the cubicles terminal blocks.

The circuit breaker shall be supplied with an appropriately rated integral protection (control) module that shall provide Long time, Short time, Instantaneous (LSI) and Ground (G) protection functions. Separate neutral protection is not required.

The circuit breaker shall be completed with the following:

- Manual charging lever for the closing spring
- Manual On green push button (to be placed behind sliding covers which serve to pre-vent unintentional actuation)
- Manual Off red push button (to be placed behind sliding covers which serve to prevent unintentional actuation)
- Handling truck

The circuit breaker shall have following flag indicators.

- On/ Off indicator
- Spring charged/ uncharged
- Position indicator for fully inserted, test, isolated position

Each circuit breaker shall be equipped with two tripping coils.

11.3.1.4. Miniature and Moulded Case Circuit Breakers

Each outgoing feeder shall be controlled and protected by a withdrawable moulded case circuit breaker.

All MCCB's shall be of instantaneous type and shall be designed and constructed to have short circuit breaking capacity as required. The rated service short-circuit breaking capacity shall fulfil the values of the prospective short-circuit current at the location. This guarantees, that the shut down time, after a breaking of short-circuit current, is as short as possible, due to the fact that the circuit breaker keeps to be serviceable.

The MCCB's shall be designed to provide positive trip-free operation on abnormal overloads and short-circuit, with quick break contacts for both manual and automatic operation. Adequate protection for the stationary and movable contacts shall be provided with effective and rapid arc interrupting devices, in particular limiting the value of the specific let-through energy I^2t and the current peak. All MCCB's shall be fitted with thermos-magnetic trip unit, opening the breaker automatically in case of abnormal overload or short-circuit. The thresholds for the thermal device (bimetal) and the magnetic device shall be adjustable. The MCCB's shall have an operating lever for manual operation. The position of the operating lever shall correspond definitely with that of the power contacts (positive operation), thereby guaranteeing safe and reliable signals, in compliance with the prescriptions of the relevant IEC standards. The operating lever shall indicate:

- MCCB closed
- MCCB open
- MCCB open due to protection trip

The circuit-breaker operating mechanism shall have free release regardless of the pressure on the lever and the speed of the operation. Protection tripping automatically opens the power contacts. To close them again, the operating mechanism shall have to be reset by pushing the operating lever from the intermediate position into the lowest open position.

The MCCB's shall have double insulation between the live power parts and the front parts of the apparatus. Each electrical accessory shall be completely segregated from the power circuit, thereby preventing any risk of contact with live parts, and, in particular, the operating mechanism shall be completely insulated in relation to the powered circuits.

It shall not be possible to open the board door when the circuit breaker is in 'CLOSED' position.

The MCCB's shall be delivered with padlocking facility to prevent the lever closing operation.

The MCCB's shall be provided with under voltage release wherever necessary according to the supplied consumer.

All Mini Circuit Breakers (MCBs) shall be of high performance, rapid interrupting, current limiting type designed and type tested. They shall be of type B characteristic for all general lighting and small power circuits, and of type C characteristic for circuits supplying pumps, air-conditioning units, street lighting etc. The category of duty shall be selected adequately, the necessity of back-up protection to be considered thoroughly.

The MCBs shall be of single or three pole type, depending on the consumer to be supplied. The MCBs shall be equipped with auxiliary trip contacts as required for signalling. The MCBs shall be equipped with real contact position indication, directly connected to the moving contact. Padlocking facilities shall be provided and included in the delivery.

Each distribution board shall provide MCBs as spare for future, completely wired in respect to connection to busbar and auxiliary contact remote signalling. In each distribution board 20 % spare MCBs of each installed type (type in regard to characteristic and rated current) shall be furnished, but minimum three spare MCBs of each type.

In addition to the overcurrent and short circuit protection afforded by MCBs every circuit supply-ing socket outlets, water heater, water cooler, cooker unit, wet area and etc. shall be equipped with a Residual Current Circuit Breaker (RCCBs) to provide protection against shock and earth leakages. The sensitivity of these units shall be 30 mA.

11.3.2. Solar PV Equipment

11.3.2.1. General Design Requirements

The guidelines given herein are preliminary; the Contractor shall be responsible for the design, testing, installation and commissioning of the complete Solar PV System, its accessories and its integration with the LVAC main distribution board.

Solar PV System shall be the primary source of supply to indoor and outdoor lighting loads. The Solar PV System shall monitor the battery voltage, charge and discharge current, stored energy and time to discharge threshold. It shall have the capability to automatically transfer the entire lighting load to the Control Building's main LVAC supply source until the Solar PV battery is fully recharged.

Outdoor lighting operation shall have two modes: manual and automatic. Automatic switching shall be implemented via photocell(s) and complemented by digital timer(s). The digital timer(s) shall be powered by a 240V AC supply and shall have a rechargeable battery. The automated system shall switch on batches of various lighting circuits in sequences spaced out in 5 minutes interval. Every batch shall consist of seven (7) or less lighting circuits. The entire outdoor lighting circuits must, however, be all ON within 15 minutes when the sequence begins. For manual operation, this shall also employ the automatic switching of the lights in batches and all lights circuit should not come on at the same time. There shall be provision for wall mounted ON/OFF switches clearly labelled and mounted to a height of no more than 1400mm above the finished floor level.

For Control Building indoors, the lighting system will incorporate occupancy sensors in select rooms such as the store, battery room, AC/DC room, communication room, archive, relay room, washrooms and corridors with the option for reverting to manual operation (by-passing the occupancy sensor system) for each room.

The Solar PV switchgear shall be designed as an indoor switchgear installation and shall be of metal-clad design with fully insulated busbars. The free-standing switchgear shall be mounted directly above the cable trench and shall have both front and rear access for maintenance. The switchgear shall be purpose built to meet the requirements of the Specification.

The switchgear shall be supplied from the 415V main distribution board and the Solar PV inverter(s) output by cables. The switchboard shall be equipped with outgoing 3-phase, four wire, 415/240 V circuits to cater for the substation's indoor and outdoor lighting circuits. The nominal rating of all outgoing feeders shall be selected according to the respective load.

The AC switchgear shall be of a single busbar arrangement. The main fully insulated busbars shall consist of one section, with 2 incomers. The incoming feeder circuit breakers shall be provided with powered automatic, high-speed changeover facilities and also, shall be interlocked such that only **one of two** circuit breakers can be closed at one time. Incoming feeder from the Solar PV inverter(s) 415 V output shall be the primary source of the Solar PV System sub distribution board. Incoming feeder from the 415V main distribution board shall be the secondary/ backup source of the Solar PV System sub distribution board.

All electrical components shall be incorporated into the withdrawable portion and shall be capable of complete withdrawal without removing any termination.

Incoming circuit breakers shall also be interlocked to prevent parallel operation.

In the event of outage of the air-conditioning system in the LV Services room, the switchgear installation shall remain operational at full load, and at the ambient temperature of 50°C. Switchgear shall be provided with humidity controlled anti-condensation heaters with isolation facilities.

The complete switchgear shall be capable of carrying rated load current without a temperature rise of any part exceeding 65°C. Parts that may be touched by operating personnel shall not exceed a temperature of 70°C.

The Contractor shall provide a breakdown of the entire approximate substation auxiliary load out of which the indoor & outdoor lighting load shall be clearly indicated, and appropriate adequate design proposed.

The Contractor shall be responsible for the shade analysis, study of the direction of the sun in relation to the Solar PV installation location, determination of the effective sun hours, calculating favorable tilt angles and effective irradiance.

The Contractor shall submit the complete design and sizing calculations of the Solar PV System. The Contractor shall state any assumptions made in the design and calculations of the proposed Solar PV System and provide datasheets of key Solar PV Components (i.e., PV modules, MPPT Solar Charge Controller(s), Hybrid Inverter(s), Batteries).

Thirty (30) years lifespan shall be expected from the proposed Solar PV System. The Solar PV System shall be designed with lightning protection scheme to insulate the installed electrical equipment from damages caused by lightning and induction of HV surges. Efficient grounding shall be provided for the Solar PV System.

The Contractor shall ensure that the personnel who shall design, install, test, commission, maintain and repair the Solar PV System are licensed by the Energy and Petroleum Regulatory Authority of Kenya (EPRA) and all works carried out in line with the standards set by EPRA. The said personnel shall have authority to design, install, test, commission, maintain, and repair Solar PV Systems of any capacity.

The Contractor shall be responsible for acquisition of a valid license to import, manufacture or install Solar PV Systems or Solar PV components.

Routine and site tests shall be carried out on the key components of the Solar PV System (PV modules, MPPT Solar Charge Controller, Hybrid Inverter & Battery). All tests on material and equipment shall be done in accordance with IEC Standards if not otherwise specified. Routine tests shall be performed on each piece of the key components to be supplied for the purpose of revealing faults in material or construction. They shall not impair the properties and reliability of any part being tested or reduce its lifetime.

The Contractor shall be required to maintain the entire Solar PV System until the end of defects liability period.

11.3.2.2. Switchgear

The switchgear shall consist of cubicles and shall be erected in a single row. The switchboard shall be provided with lifting lugs. The height of the switchgear shall not exceed 2250 mm and operating handles of all equipment shall be within the reach of a person standing at ground level.

The switchgear shall comply with IEC 61439-2 and other relevant IEC Standards and local standards if not otherwise stated. The switchgear shall be of draw-out design. The switchgear shall be designed to comply with the degree of protection of IP51 and shall be vermin and termite proof.

The switchboards shall be type-tested including arc fault containment (IEC 61641, criteria 1 to 7 to be fulfilled).

The fully insulated busbars shall be located in the rear upper part of the cubicle. The connections from the busbars to the equipment contacts shall be isolated from the incoming or outgoing connections.

All busbars and connections shall be made of copper and encapsulated.

All separately mounted metallic parts that are not normally energised shall be earthed. To this end they shall be equipped individually with terminals for the connection of the earth conductor. The switchboard shall be provided with an earth bar incorporating terminals for the connection of earth conductors, directly connected to the earthing system at both ends. All metallic parts that are to be earthed for safety reasons shall be connected to this bar in the factory and form part of the wiring system. The cross section of this earth wiring shall be adequate for the short-circuit current.

Hinged doors shall be provided at the rear for easy access to equipment contained within the cubicle. The hinged doors shall be of the lift-off type, secured with integral handles provided with locks, and duplicate keys to an approved change system and shall be flush fitting and sealed with a gasket of rubber or other approved material to prevent the ingress of dust. Cubicles and doors shall be structurally stiff and braced to withstand twisting without distortion.

Each cubicle shall be equipped with a cable compartment, isolated against other compartments of the cubicle, and glands suitable for all incoming and outgoing cables. The cubicle shall be designed for cable entry from the bottom rear. Armoured cables shall be equipped with armour clamps for connection to the earth bar.

It must be possible to work within each cubicle with the equipment withdrawn whilst the incoming contacts are energized. The minimum requirements for protection shall be:

- Insulating barriers installed between phases within the cubicle
- Automatically operated metallic shutters provided to cover busbar and feeder spouts

On the front of the switchgear cubicle of each incoming feeder a coloured mimic diagram shall be provided, with the necessary switch position indicators, symbols and signal lamps.

All equipment installed on the front panel of the cubicle shall be flush mounted.

Each incoming feeder unit, Solar PV Inverter(s) 415V output feeder and the 415V main distribution board outdoor and indoor lighting feeder, shall be fitted with an indicating voltmeter with selector switch and one ammeter with a selector switch. Each busbar section shall be fitted with an indicating voltmeter.

The indicating instruments shall be connected to earthed cases and shall comply with IEC 60051.

Cast-resin insulated, corona-free current transformers shall be provided for measurement. The current transformers shall be of the single or three pole, multi-ratio type for indoor installation and shall comply in all respects with the requirements of IEC IEC 61869-1. The current transformers shall be mounted at the withdrawable units or in case of incoming feeders, current transformers shall be mounted in the circuit breaker compartments. The current transformers must withstand the dynamic and thermal short circuit stress resulting from system faults.

Each incomer feeder to the sub distribution board shall be controlled and protected by moulded case circuit breakers of a design type that provides a means to readily remove it from the installation and their short circuit rating being adequate to protect each feeder against the effects of a fault at the incoming terminal of the unit. The incomer circuit breakers shall have integral overcurrent and short circuit protection

Each outgoing lighting circuits from the switchgear shall be controlled and protected by moulded case circuit breakers of a design type that provides a means to readily remove it from the installation and their short circuit rating being adequate to protect each circuit against the effects of a fault at the outgoing terminal of the unit.

All cubicles shall be supplied complete, including protection, instrumentation, all internal wiring, terminal blocks, etc.

Suitably rated LV surge arresters shall be installed to protect the Solar PV System against overvoltage impulses.

11.3.2.3. Solar PV Modules

The Contractor shall be responsible for the design of the PV arrays of the Solar PV System. All direct current component ratings (cables, isolators/disconnectors, switches, connectors, etc.,) of the Solar PV System shall be derived from the maximum voltage and current of the PV array. This must take into account system voltage/ currents of the series and parallel connected PV modules making up the array. It must also take into account the maximum output of the individual PV modules.

Strings of solar panels shall be paralleled in the combiner that includes breakers. There shall be a separate overcurrent interrupter for each string.

A means/mechanism to separate out individual strings making up the PV array shall be incorporated to allow for testing and tracing faults. Suitable removable string fuses or blocking diodes may be considered for this purpose.

A means to manually electrically isolate the entire PV array for maintenance and repairs shall be provided. If a dc switch is used, it must be double pole to effectively isolate both PV array positive and negative terminals/ connections. The dc switch must be load-break rated.

The PV array/ strings performance tests shall be carried out during installation to check for any faulty modules. Any faulty PV module shall be replaced before the Solar PV System is commissioned.

The Contractor shall ensure that the maximum electric shock voltage that may be encountered during installation is that of one individual PV module.

11.3.2.4. Solar PV Batteries

Heavy duty battery, preferably Lithium-Iron type, with a depth of discharge of 80% or more shall be supplied for the Solar PV System. Generally, the battery size shall be guided by the principle:

$$\text{Battery Capacity (AH)} = \frac{((\text{Loads wattage}) * (\text{Hours of Use}))}{(\text{Battery Loss Factor} * \text{Depth of Discharge} * \text{Nominal Battery Voltage})}$$

Battery banks of the Solar PV System shall be housed in such a way that access can be restricted to authorized personnel, adequate containment is assured, and appropriate temperature control can be maintained.

The Contractor shall ensure that the proposed Solar PV System battery shall store sufficient energy to operate the entire indoor and outdoor lighting system at night and on cloudy days and handle the peak demand with at least two (2) days of autonomy. The Contractor shall clearly indicate the PV technology they intend to use for the PV modules and the battery.

Solar PV battery banks shall be installed in the battery room of the Control Building.

11.3.2.5. Solar Charge Controller

The Contractor shall ensure that the MPPT Solar Charge Controller is designed/ selected in such a way that it will regulate voltage and current from the Solar Arrays (PV modules), charges the battery, prevent the battery from overcharging and prevent over discharging.

An overcurrent device shall be installed in all active (non-earthed) conductors between the battery and the solar charge controller. The overcurrent device shall have a trip value as specified within the charge controller manual, be rated for operation at direct current at 125% of the nominal battery voltage and have an interrupt rating greater than the potential battery short-circuit current.

A means of manual isolation shall be provided between the charge controller and the battery, either combined with the overcurrent device or as a separate unit. The isolator shall be double poles, dc rated and with a load break capability. The length of the cable between the isolator and the battery shall be as short as practicable.

11.3.2.6. Hybrid Inverter

The Inverter technology used in the Solar PV System shall be capable of detecting low and high battery voltage, passing it via audible and visual alarm and relays for remote signaling. The Solar PV inverter(s) shall be programmed such that the automatic protection system operates at:

- i. Operating voltage greater than 264V phase to neutral
- ii. Operating voltage less than 207V phase to neutral
- iii. Operating frequency greater than 50.5 Hz
- iv. Operating frequency less than 47.5 Hz

The Solar PV Inverter(s) shall have output meter(s) that as a minimum shall display and record the energy delivered by the Solar PV system (kwh), the instantaneous power output (kW) and the output voltage values. The meter(s) shall be located at a position and height where it can easily be read.

In particular, since the Solar PV inverter(s) shall be connected to the lighting sub distribution board, supply signs shall be installed in prominent positions on the main switchboard and all intermediate distribution boards. This is to ensure that personnel working on other parts of the electrical installation will be aware that the system has multiple supplies, and how to isolate parts of the system safely.

11.3.2.7. Solar PV Accessories

Provisions shall be made for direct current disconnect switch at the point where the cables from the solar array enter the control building.

Cables of the Solar PV System shall be sized such that the overall voltage drop at standard test conditions between the PV array and the inverter is less than 3%. Cables routed behind a PV array must be rated for a minimum temperature of 80°C. The cables shall be well supported, especially those cables exposed to the wind. The cables shall be routed in prescribed zones or within mechanical protection. The cables shall also be protected from sharp edges.

Direct current junction boxes must be labelled as 'PV array direct current junction box', and labelled with 'Danger, contains live parts during daylight'. All labels must be clear, legible, located to be easily visible, and durably constructed and affixed to last.

Cables used in the Solar PV System shall have a current rating above that of the relevant overcurrent device nearest downstream (fuse/ breaker). The cable current ratings are to be adjusted using standard correction factors for installation method, temperature, grouping and frequency to BS 7671.

On arrival at the site and during and after completion of installation, the complete Solar PV System including the accessories shall be inspected and tested in order to check quality, correct operation and correct installation of the equipment. The performance acceptance test to verify that the complete system is fully operational and 'Fit for Purpose', meeting all the standards and functional requirements shall be carried out by the Contractor in the presence of KETRACO and Employer's Representative personnel, who will certify the acceptance of the system on a test-by-test basis

11.3.3. 110V DC Service Equipment

11.3.3.1. General Design Requirements

The 110V DC service equipment shall be designed, supplied and installed to provide high availability, reliable and safe supply for control, protection, alarm and indication devices, tripping and closing circuits, emergency power and emergency lighting.

The 110 V battery system shall comprise 2 x 1000% rated duty Nickel-Cadmium (Ni-Cd) type battery units and 2 x 100% rated duty float/boost charger units. These shall be arranged such that under normal conditions both float chargers are operating to supply the specified DC load via two busbars operated independently and at the same time each automatically float charging its associated battery to keep it fully charged within the specified voltage limit for the correct operation of equipment.

It shall be possible to switch either charger out of service leaving the remaining charger and batteries to carry the full DC load requirement and at the same time provide the full battery float charge requirements. It shall not be possible to switch off more than one charger at one time.

It shall also be possible to switch either battery out of service leaving the remaining chargers and batteries to carry the full DC load requirement and at the same time provide the full battery float charge requirements. In this case the normally independent DC supply busbars shall be coupled through a bus section switch.

The system shall be such that either battery may be connected to the chargers through changeover contactors, which shall be mounted in the DC Switchboard.

Under boost charge conditions the charger shall be capable of supplying the full boost charge requirement, taking care not to exceed the maximum permissible battery voltage. Only one battery unit (100% of total battery capacity) shall be on boost charge at any one time and means shall be provided to automatically limit the voltage applied to the loads connected to the DC bus during the boost charge period to a value no greater than the float charge value.

In case of loss of AC supply during boost charging, the charger shall return automatically to the float charge position upon restoration of AC supply and the battery automatically reconnect to the DC busbar. The charger shall continue to operate in float charge mode unless manually re-selected to boost charge.

The second 100% charger shall continue to operate normally in float charge mode with the second battery and continue to supply its own DC load requirement.

Selection of the boost charge shall be by manual means. Each charger shall be rated to be capable of boost recharging each battery from the discharge condition to 100% of fully charged capacity in a time not exceeding 8 hours. The control of the boost charge condition shall be such that the charging rate is reduced as the battery approaches full charge to avoid excessive gassing.

When selected to "Boost charge" mode, the battery condition shall be monitored and on achieving a fully charged condition, the rectifier shall automatically regulate the charging current and change over to the float charge mode. The maximum period of boost charging shall be controlled automatically by a preset timing switch which will return the charger to float mode.

The 110-volt battery system shall be centre point earthed through a limiting resistance to limit earth fault D.C. current to maximum 10 mA. A suitable D.C. centre zero milli-ammeter shall be provided for the detection and clearing of 110 volts D.C. faults. A suitable battery earth fault scheme shall be provided, which shall be capable of detecting, in the event of an earth fault, whether the positive or negative pole is earthed. Earth-fault alarm shall be initiated locally and remotely via the SCS.

11.3.3.2. 110 V Battery Units

The battery units shall be Nickel-Cadmium (Ni-Cd) type. The batteries shall comply with IEC 60623 and other relevant Standards if not otherwise stated.

The battery shall be mounted on heavy-duty epoxy coated metal racks suitably protected against corrosion and attack by the battery electrolyte. The battery shall be spaced so as to permit sufficient access to all individual cells to allow replacement of cells and/or checking cell voltages and connections. Racks shall be assembled clear of walls to permit access on all four sides of the battery bank.

Battery trays shall be factory treated with an electrolyte corrosion resistance coating.

The cell container shall be made for non-flame propagating "transparent" shock resistant and leak-proof plastics.

Positive and negative terminals of each cell shall be clearly and permanently indicated. Intercell connections shall be silver plated. Each terminal connector shall be stamped with the associated battery numbers.

The float voltage of the battery shall be the optimum required. It shall not exceed the maximum voltage rating of the equipment being supplied.

The discharge capacity of the battery shall be sufficient to supply loads during a discharge time of 10 hours and maintain at least 90% rated voltage. The battery shall be capable of supplying normal standing load for the full discharge period at the minimum stated ambient temperature, emergency lighting load for a period of three hours and also be capable of sequentially closing and simultaneous tripping the most distant group of circuit breakers when the battery is at the end of its discharge period. (The 'most-distant group' is defined as that group of circuit breakers which may be tripped simultaneously by a single protection operation and which has the highest impedance in the dc supply system). Furthermore, random load at the most critical time of the duty cycle shall be verified.

The capacities of batteries selected shall be justified by calculation using the principles laid down in IEEE 1115 - Recommended Practice for Sizing Nickel-Cadmium batteries for stationary Applications. The minimum ambient temperature relevant for the calculation of the normal standing load must be 0°C. The battery capacity shall include a design margin of 1.3 to accommodate any future substation expansion and an aging factor of 1.25. The calculation shall consider the voltage drop between battery and consumer. The consumer currents shall be calculated during the complete discharge time using the final discharge voltage. For the calculation of the consumer load the final configuration of the substation shall be considered.

At the end of the rated discharge period the voltage available at the terminals of the equipment being controlled shall not be less than the minimum operating voltage of the equipment being supplied.

Protective relays that need non-standard DC voltages shall be supplied with DC/DC converters.

The battery units shall be located in a battery room and shall be connected to the distribution board and battery charger by halogen free insulated copper cables. A fuse box, located in the battery room, shall be provided for each battery. The positive and negative fuses for each battery shall be arranged in pairs and shall be fully segregated from each other by an insulating barrier. The fuses shall be of the high breaking capacity type in accordance with IEC 60269 and shall have auxiliary contacts for remote supervision.

Sufficient electrolyte shall be provided to permit the first filling of each cell and 5% spare electrolyte in solid form shall be provided for topping up during commissioning and another 5% spare electrolyte in solid form shall be delivered to KETRACO Stores.

After first filling of the battery cells the contractor shall carry out the initial charging. Everything needed for this shall be in the responsibility of the contractor. Furthermore, it is in the contractor's responsibility that the batteries remain charged.

The following information shall be indelibly marked on outside of each cell of the batteries:

- Manufacturers name and trade mark

- Country and year of manufacture
- Ah capacity
- Upper and lower electrolyte level

One set of tools comprising two syringe hydrometers, one voltmeter, ten cell-bridging connectors, one electrolyte-pouring funnels, two electrolyte thermometers, battery instruction card for wall mounting, electrolyte airtight containers, labels, other items necessary for the erection and correct functioning and maintenance of the battery shall be provided with the battery.

11.3.3.3. Battery Charging Equipment

The battery chargers shall be thyristor controlled devices and shall operate fully automatically.

The battery charger output voltage shall be maintained constant and just sufficiently above the open circuit voltage of the battery to keep the battery in a fully charged condition, independent of load variations or variation of the AC input voltage.

Drop of the battery charger output voltage on float charge position shall be such that the failure of a single cell shall not lead to cascading of the bank on excessive charging.

The DC output of each charger unit shall remain within ± 2 per cent under any of the following conditions:

- System frequency ± 5 per cent;
- Rated voltage input ± 10 per cent;
- Output between 5 - 100 per cent of rated output.

The chargers shall be equipped with an automatic current limiting device to make them short-circuit proof. Current limitation shall be at 110% of rated output current. Each charger shall be designed to carry 110% of rated output current for an indefinite time.

The charger shall be equipped with fuses, protective devices, indication instruments, switches, lamps and other necessary equipment.

Rectifier stacks shall comply with the requirements of IEC 60119 and IEC 60146 as appropriate.

Rectifier transformers shall be of the air-cooled type, rated in accordance with the requirements of the Schedules and comply with BS EN 61558 as appropriate. They shall be capable of withstanding the "let through" energy of the fuse controlling the AC supply to the transformer.

The rectifiers shall be fed from the LVAC switchgear.

Rectifier transformer shall be double wound to prevent galvanic connection between the DC and LVAC systems.

11.3.3.4. Switchboard and Charger Cubicles

The DC switchboard and charger cubicles shall be designed for indoor mounting and shall be of fully metal enclosed design. The free-standing switchboard and charger cubicles shall be mounted directly above the cable trench and shall have both front and rear access for maintenance. Battery charger cubicles shall be of single tier construction and a separate DC distribution panel shall be incorporated.

The switchboard shall consist of cubicle(s) and shall be erected in a single row. Each charger shall be arranged in a metallic cubicle that shall match the switchboard cubicles in height and other dimensions. The height of the cubicles shall not exceed 2250 mm and operating handles of all equipment shall be within the reach of a person standing at ground level.

The switchboard shall comply with IEC 61439-2 and other relevant IEC Standards if not otherwise stated. The switchboard shall be of draw out design.

The switchboard and charger cubicles shall be designed with a degree of protection IP51 and shall be vermin and termite proof.

Hinged doors shall be provided to provide easy access to equipment contained within the cubicle. The hinged doors shall be of the lift-off type, secured with integral handles provided with locks and shall be flush fitting and sealed with a gasket made of rubber or other approved material to prevent the ingress of dust. Cubicles and doors shall be structurally stiff and braced to withstand twisting without distortion.

The cubicle shall be designed for cable entry from the bottom rear and equipped with glands suitable for all incoming and outgoing cables. Adequate working clearance shall be maintained inside the cubicles.

The main DC switchboard shall be designed with a single busbar system containing two sections with a moulded case circuit breaker (MCCB), similar to the MCCBs used on the LVDC incomer circuits, in between and each section shall be supervised by undervoltage, overvoltage and earth fault relays. The main busbar shall be installed in the rear upper part of the distribution panel and shall be fed by battery/charger units.

The incoming circuits to the main busbars shall be controlled and protected by two-pole type MCCBs suitable for use on battery backed 110V DC circuits.

Outgoing circuits shall be controlled and protected by DC miniature circuit breakers, their short circuit rating being adequate to protect each circuit against the effects of a fault at the outgoing terminal of the unit. Sufficient number of two pole MCBs for outgoing circuits including spare unused feeders shall be provided.

Coloured mimic diagrams shall be provided on the front of the DC equipment cubicles with the necessary switch position indicators, device symbols and alarm lamps. The colour and format of the mimic shall be approved by KETRACO

For individual cubicles the necessary instruments, control switches and switch operating devices shall be installed on the front panel.

Ammeters shall be provided to indicate battery output current. Voltmeters shall be provided for measuring battery and charger volts. Voltmeter shall be connected via miniature circuit breakers to the busbar. The indicating instruments shall be provided with connections from the back side and in accordance with IEC 60051.

The following local alarms shall be provided by means of indicator lamps, together with facility for remote indication and audible alarm:

- AC Supply Fail;
- Battery - High Voltage;
- Battery - Low Voltage;
- Charger Fail Indication;
- Battery Earth Fault;
- DC Supply Fail.
- Float Charger On;
- Boost Charger On;
- Output DC MCB Trip (Common)

Means shall be provided to provide separate initiations to remote systems for each alarm generated in the 110 V DC power supply system.

In the event of outage of the air-conditioning system in the LVAC/DC room the switchgear installation shall remain operational at full load and at the ambient temperature of 50°C. Switchgear cubicles shall be provided with humidity controlled anti-condensation heaters with isolation facilities.

Cubicle wiring and terminals shall be in accordance with the General Technical Requirements.

11.3.3.5. Miniature and Moulded Case Circuit Breakers

All MCCB's shall be of instantaneous type and shall be designed and constructed to have short circuit breaking capacity as required. The rated service short-circuit breaking capacity shall fulfil the values of the prospective short-circuit current at the location. This guarantees, that the shut down time, after a breaking of short-circuit current, is as short as possible, due to the fact that the circuit breaker keeps to be serviceable.

The MCCB's shall be designed to provide positive trip-free operation on abnormal overloads and short-circuit, with quick break contacts for both manual and automatic operation. Adequate protection for the stationary and movable contacts shall be provided with effective and rapid arc interrupting devices, in particular limiting the value of the specific let-through energy I^2t and the current peak. All MCCB's shall be fitted with thermo magnetic trip unit, opening the breaker automatically in case of abnormal overload or short-circuit. The thresholds for the thermal device (bimetal) and the magnetic device shall be adjustable. The MCCB's shall have an operating lever for manual operation. The position of the operating lever shall correspond definitely with that of the power

contacts (positive operation), thereby guaranteeing safe and reliable signals, in compliance with the prescriptions of the relevant IEC standards. The operating lever shall indicate:

- MCCB closed
- MCCB open
- MCCB open due to protection trip

The circuit-breaker operating mechanism shall have free release regardless of the pressure on the lever and the speed of the operation. Protection tripping automatically opens the power contacts. To close them again, the operating mechanism shall have to be reset by pushing the operating lever from the intermediate position into the lowest open position.

The MCCB's shall have double insulation between the live power parts and the front parts of the apparatus. Each electrical accessory shall be completely segregated from the power circuit, thereby preventing any risk of contact with live parts, and, in particular, the operating mechanism shall be completely insulated in relation to the powered circuits.

It shall not be possible to open the board door when the circuit breaker is in 'CLOSED' position.

The MCCB's shall be delivered with padlocking facility to prevent the lever closing operation.

All Mini Circuit Breakers (MCBs) shall be of high performance, rapid interrupting, current limiting type designed and type tested. The category of duty shall be selected adequately, the necessity of back-up protection to be considered thoroughly.

The MCBs shall be of two pole type. The MCBs shall be equipped with auxiliary trip contacts as required for signalling. The MCBs shall be equipped with real contact position indication, directly connected to the moving contact. Padlocking facilities shall be provided and included in the delivery.

Each switchboard shall provide MCBs as spare for future, completely wired in respect to connection to busbar and auxiliary contact remote signalling. In each switchboard 20 % spare MCBs of each installed type (type in regard to characteristic and rated current) shall be furnished, but minimum three spare MCBs of each type.

11.3.4. 415 V AC Uninterruptible Power Supply

11.3.4.1. General Design Requirements

The uninterruptible power supply (UPS) system shall supply continuously regulated AC power as required for substation operation. The UPS shall also power the online monitoring system for the reactor bank and autotransformer and fire protection panel. The UPS system shall consist of dual independently operating units

working as sharing the load method with all necessary control, static switches, manual bypass switch, etc. necessary for the reliable operation of UPS system under all operating conditions of the substation.

The UPS system shall comprise but not be limited to the following major items:

- two thyristor controlled 110V DC/415 V AC inverters;
- two static interrupters and transfer switches;
- one 415/415V three phase isolating by-pass transformer;
- two manual by-pass switches;
- one UPS distribution board with control devices.

The output power shall be designed to meet the uninterruptible consumer demands and shall be in no case less than 6000 VA for a 10hr autonomy period (to be confirmed by calculation).

The UPS shall be suitable for continuous operation, and function satisfactorily with a combination of variations of the incoming supply voltage of $\pm 10\%$ of nominal and frequency of $\pm 5\%$ of nominal.

The UPS system shall be fed from 110 V DC switchboard by two suitable rated MCCB connected to the separate bus sections.

Multiplication relays with three contacts for each alarm of the UPS system to be provided.

The enclosure of UPS shall be of similar construction and height, as the cubicles of LV AC and DC systems. The UPS cubicle shall be located in the LVAC & DC room, as well. The cubicle shall be suitable for installation on false floor or above floor openings.

The system shall be isolated from the earth.

11.3.4.2. Inverters

Two inverters with static switches shall be supplied and installed to provide the 415 V three phase, 4 wire, 50 Hz, power supply. The output of the invertors shall be continuously synchronized to the input of the static switch.

The inverters shall furnish a constant output voltage to a varying AC load with a varying DC input voltage.

The inverters shall have load switches for the input circuits, as well as contactors, locally/manually and automatically operated, for the output circuits, located upstream the static switches.

The inverters shall have overload and short circuit protection. All internal circuits of the inverters shall be protected by HRC fuses or current limiting circuit breakers.

The electronic control modules printed circuit boards shall be equipped only with solid state equipment. Their regulation shall meet output voltage requirements under all load conditions. It shall be specified whether the

transformers used are off the shelf equipment and easily replaceable. The UPS output shall be Y-connected. Control sensors shall be included for detecting and signalling inverter failures (including internal faults). The specifications outlined below are applicable for the conditions of 0-100% load changes, 0.5 lag to 1.0 power factors, and 0-50 °C temperature range.

Inverter voltage input	110V DC $\pm 10\%$
Inverter voltage output	415V, 50 Hz, 4 wire (solidly earthed at the neutral end)
Voltage adjustment	$\pm 5\%$
Frequency adjustment	± 2 Hz
Overload rating	150% of rated output for 1 minute 125% of rated output for 15 minutes

The inverter shall have natural ventilation.

11.3.4.3. Static Transfer Switches

A static transfer switch shall be provided to bypass the critical load from the inverters directly to the main power source (415/415V 3 phase bypass transformer), and vice versa, without interrupting or degrading computer operations. This operation shall occur in the event that the inverted system fails or an overload beyond the capabilities of the inverters develops either by load faults or inrush currents. The static transfer switch shall consist of static interrupters located on the output of each inverter and a static switch on the bypass transformer.

The static switch shall be capable to feed the output loads and shall be rated 30% above the nominal inverter rating.

Internal failures in an inverter unit shall cause the static interrupter to trip with minimum damage to the inverter and isolate only the inverter which failed. Failure of two inverters or overload conditions discussed above shall remove the inverters and bypass to the main supply. Necessary voltage, frequency and automatic synchronizing devices for synchronization of the inverter outputs with the main supply shall be provided.

11.3.4.4. Manual By-pass Switches

This switch shall allow the load to be supplied from the AC distribution board, during periods when the UPS is being installed or repaired. The switch transfer shall be "make-before-break" to assure loads power continuity.

11.3.4.5. Isolating By-pass Transformer

This transformer shall be 415/415V, three phase, 50 Hz and shall be oversized in order to accommodate overloading and to meet the performance required in the transient and short-circuit states, it shall be of the dry type with electrostatic screen.

Its regulation shall meet output voltage requirements under all load conditions (0% to 100% load at 0.8 power factor).

11.3.4.6. UPS Output Protection (Including Outgoing Lines)

The Contractor shall install the protection devices he deems necessary to protect the UPS from overloads and short-circuits at its output. The devices must not activate as a result of transient caused by connecting in a load drawing a heavy current.

11.4. Diesel Generator

11.4.1. General

A fully rated emergency diesel generating set complete with all accessories shall be provided. The emergency diesel generating set shall be of well-proven design configured to enable the safe shutdown of the plant and maintain essential supplies in the event of loss of DNO supplies.

11.4.2. Foundations and supports

The foundations together with any steelwork, foundation bolts, tubes or other equipment necessary shall be supplied in accordance with the relevant requirements specified elsewhere in this document.

The diesel generating sets shall be mounted on fabricated steel channel sub-frames of the skid type through anti-vibration mountings of an approved type.

All supports for intake air filtration equipment and exhaust silencers, daily service oil tanks and any other equipment shall be supplied. Silencer and exhaust pipe supports shall be of the anti-vibration type. Equipment such as the control panels and any other item likely to be affected shall be protected from vibrations transmitted through the floor.

11.4.3. Fuel and fuel systems

The engines shall be suitable for operating on the specified distillate fuel. A complete distillate fuel oil system including valves, piping, daily storage tanks and fuel meters shall be provided to for the emergency generating plant. The daily service tank for the diesel generator shall be free standing. The tank, which shall be large enough to supply the generator with fuel for a continuous running period of 10 hours, shall be complete with all mountings including a contents gauge. High and low level alarm switches shall be provided together with all fuel piping between the daily service tank and engine. Sight glasses, filters and fire shut off valves for the unit shall be included. Direct motor driven self-priming gear type booster pumps shall be provided (if required) to guarantee the maximum required fuel flow under all circumstances. The capacity to be determined by the engine manufacturer. Replenishment of the daily service tank shall normally be from the distillate fuel oil purge pumps with alternative connection facilities provided for road tanker. A fill point cabinet shall be provided. The cabinet

shall be of mild steel construction with a lockable door and shall include a contents gauge, a flanged valve, cap and chain. Fuel shall be provided as part of the contract as soon as the set is installed to enable the diesel generator to provide power during commissioning. Drawings showing the extent of oil fuel pipework included in the Contract shall be submitted with the Bid.

11.4.4. Engine

The engine shall comply with ISO 3046 and shall be medium speed, of the multi-cylinder, in line or vee arrangement, water cooled, cold starting type, fitted with renewable cylinder liners. Forced lubrication oil systems shall be incorporated and shall include filters with replaceable elements. Suitable oil pressure switches shall be provided to give warning of low oil pressure and to trip the associated unit if the pressure falls to a dangerously low level. Lubricating oil coolers complete with all necessary pipework suitable for operating from the engine cooling water system shall be provide as necessary. An integral fuel system shall be provided for the diesel engine consisting of injectors, metering pumps and duplex filtration equipment which shall be of the replaceable element type, complete with changeover device and pressure difference indicator. A flywheel shall be provided between the engine and the generator. A proximity sensor shall be mounted close to the circumference of the flywheel starter ring and used to measure the speed of rotation of the engine. The Contractor shall state in the Schedules whether turbo-charged or naturally aspirated engines are to be supplied. The Contractor shall include for the provision of a steel drip tray on the diesel generator room floor in front of each unit.

11.4.5. Engine governing

Details of the governing equipment shall be stated in the Schedules. The governing equipment supplied shall comply with ISO 3046. It is anticipated that the load will be stepped onto the diesel generator. A delay of a few seconds will be allowed between application of loads. On return of the mains supply it is anticipated that the load will be removed from the diesel generator at a similar rate. All electric motors will be direct on line started

11.4.6. Cooling equipment

The diesel generator unit supplied shall have an air cooled radiator and engine driven fans arranged to discharge cooling air from within the diesel generator room to the outside of the building. The diesel generator unit shall be complete with a suitable canvas or sheet metal duct to connect the radiator outlet to the cooling air discharge louvre which shall be supplied and fixed to the wall of the building. The Contractor shall provide anti draught flap louvres at each discharge connection to prevent the ingress of wind. The diesel generator room air intake louvre shall open automatically on diesel generator start-up and shall close on shut down. Engine driven fans shall provide the necessary air flow. Water shall be circulated through the radiators and engine jackets by engine driven pumps. The water circulating systems shall have a thermostatic control to ensure the water attains operating temperature as quickly as possible. Thermostatically controlled electrical heaters shall be installed in the engine jackets to maintain the water temperature at a minimum of 10°C under standby conditions. High water temperature alarm, and low water level detection equipment complete with relays shall be fitted to the generator unit, and the engine shall be arranged to automatically shut down should the water temperature reach a dangerous level or cooling water level be unsatisfactory. Suitable drain points for the attachment of a hose connection shall be provided on diesel generator unit cooling system.

11.4.7. Starting equipment

The diesel generator shall be provided with an emergency starting air receiver sized to provide ample storage to allow at least 12 consecutive starts without re-pressurizing between starts. The air receivers shall be constructed in accordance with the ASME code for unfired pressure vessels, or equivalent. Three (3) compressors arranged in parallel shall be provided for the diesel generator units. These compressors shall be low capacity, high discharge pressure, reciprocating multi-stage machines. Two compressors shall be motor driven and the third (back up) compressor shall be driven by a battery start diesel engine with provision for manual cranking. The maximum air pressure for the starting air system shall be 30 bars. Each compressor shall be capable of charging one receiver in one hour or less. The two motor driven compressors shall be controlled by an automatic start/ stop controller which starts the compressor on a preset low receiver pressure and stops the compressor when the air pressure reaches the desired maximum level. Alarm indication of low pressure shall be provided in the Central Control Room.

11.4.8. Intake air system

The diesel generator shall be provided with the following air filtration equipment. A 100 per cent capacity self-cleaning inertial type separator a. A 100 per cent capacity self-cleaning automatically rotated, viscous impingement filter. The above equipment shall be mounted as high as possible above the ground with provision to ensure the equipment can be serviced easily. The turbo-charger provided with the unit will ensure scavenging air as well as fresh air for combustion. The turbo-chargers shall be preferably driven by engine accessory gear. Sound attenuators, which properly reduce the turbo-charger noise within the specified limits, shall be provided.

11.4.9. Exhaust system

The exhaust manifold from the engine shall be taken outside the building and connected to the stack. The diesel engines shall be provided with exhaust silencers mounted outside the building capable of meeting the specified noise levels. Exhaust piping as well as the silencer shall be stainless steel. Exhaust manifolds, stack and silencer shall be insulated with mineral wool and provided with aluminium cladding. The Contractor shall be responsible for the design, furnishing the materials and installation of all supporting steel, rigid duct supports, sliding supports, expansion joints and insulation needed in conjunction with the exhaust system.

11.4.10. Oil/water drain pump

A drain pump shall be provided complete with all accessories, piping, valves, controls etc to drain oily water from the sump pit below the diesel generator.

11.4.11. Barring device

A barring device shall be provided to rotate the engine shaft for engine adjustment and repair purposes. The engine manufacturer shall determine whether the device is power or manually operated. An interlock shall be provided to prevent the starting of the diesel while the barring device is engaged.

11.4.12. Operation of the generating plant

The set shall be complete with auxiliary equipment required to operate the set locally as well as from the SCS via its associated control console in the Substation Control Room. The emergency generator set shall be connected to the LVAC switchboard as shown on single line diagram in Part 2-D. During emergency conditions the generator breaker may be manually or automatically closed either locally or remotely. Controls shall be provided to synchronize (manually or automatically) and load each generator. The generators shall be capable of being started, synchronized to the system without dependence upon the substation ac auxiliary supplies and accepting load within 10 seconds after receiving start signal. With initiation of stop signal the unit shall shut down in an orderly manner. Operation of the generator protective devices shall trip a lockout relay which in turn shall open the generator circuit breaker and cause a set shut down. Failure of starting sequence shall automatically shut down and make insensitive any further start signals until the fault has been corrected. Active and reactive load sharing with other machines and load control, speed, voltage and VAR control shall be provided.

11.4.13. Generator

The diesel generating set shall be complete with a direct driven generator together with automatic voltage control equipment (AVR). The AVR shall be of well-established design selected in conjunction with the other features of the diesel generating sets offered, to ensure trouble free operation. The AVR shall use three phase voltage sensing to minimize the effect of the waveform distortion caused by load. The generator shall be air cooled type and meet the requirements of IEC 60034-1 and IEC 60034-22. Insulation shall be to Class 155(F) or Class 180(H) with winding temperature rises to Class 130(B) or Class 155(F) levels respectively. A solid coupling shall connect the generator rotor to the flywheel.

11.4.14. Generating set protection

The generating set shall be provided with equipment which shall protect the generator set from damage due to fault conditions. All relays or similar equipment for over speed, oil pressure, cooling water level and high cooling water temperature, directly associated with the prime mover shall be mounted on the generating set engine and associated with a suitable trip relay. Protection equipment shall be provided and arranged to trip the associated circuit breaker, suppress the excitation and shut down the diesel engine and control system if faults should occur. The minimum requirement for the protection of the diesel generator shall be:

- a. Differential
- b. Overcurrent
- c. Restricted earth fault
- d. Reverse power
- e. Overvoltage
- f. Diode failure.

11.4.15. Generator control panel

The control panel shall be of the automatic standby type a fabricated steel cubicle, set mounted or freestanding, to form a pre-wired package. Generator control shall be PLC operated to SCS. Visual indication of alarm conditions and system status shall be provided on the control panel through the use of LEDs. Each of the conditions shall be linked to the Substation Control Room. The control panel shall incorporate repeat starting protection. Three repeat starting attempts shall be made. The engine shall be automatically cranked for a 10 second period with a 10 second rest period between each attempt. All adjustable timers shall be factory set to a nominal value, along with all adjustable sensing systems. The adjustable sensing systems shall be factory set to a nominal value. The control panel shall include a selector switch, the positions shall be:

- Test off load - Exercise mains failure detection
- Normal/automatic - Alert status monitoring auxiliary system
- Off position - Set will not start/set will stop

When on normal/automatic the system shall sense a transient, a permanent fall, or a complete failure of the supply voltage on one or more phases. Depending on the pre-programmed time delay settings, a start command signal shall initiate the automatic starting sequence. Once the generator frequency and voltage have attained the correct level, the standby contactor shall close. If the auxiliary system supply returns during the start sequence, the system shall abort starting and return to normal. In the event of a further start of the auxiliary system supply during the shut-down sequence, the plant shall automatically resume supply of the load. On complete shut-down the system shall automatically reset itself in readiness for further failures. The diesel generator auxiliary system shall be self-supporting to allow diesel generator start in the absence of external power.

11.5. Inspection and Tests

11.5.1. General

Tests shall be carried out in order to determine whether the material and equipment comply with the required properties.

All tests on material and equipment shall be made in accordance with IEC Standards if not otherwise specified.

The following lists of tests do not restrict KETRACO's right to call for further tests if he considers these necessary.

High temperature operation tests shall be performed at the maximum ambient temperature of 50°C.

11.5.2. Workshop Test

11.5.2.1. Type Test

Type test shall be performed on each type and rating of the specified equipment with the purpose of proving its properties, according to the IEC standard. An internationally recognized laboratory shall certify the type test reports. The Contractor shall submit certified copies of type test reports covering the proposed equipment.

Type tests certificates/ reports shall be considered acceptable if they are in compliance with the relevant Standards and the following:

- Type Tests conducted at an internationally recognized laboratory acceptable to the Employer/ Employer's Representative.
- Type Tests conducted at the manufacturer's laboratory and witnessed by representatives from an internationally recognized laboratory acceptable to the Employer/ Employer's Representative.

If the presented type test reports are not in accordance with the above requirements, the Employer may decide to ask for the type tests to be carried out in the manufacturer's premises or other places subject to the approval of the Employer and at no additional cost. These tests shall be performed in the presence of an internationally recognized laboratory, which shall issue the relevant type test certificates upon successful test.

The following type tests shall be performed in addition to the tests mentioned in the standard:

- Testing of breaking and making capacity of circuit breaker and fuses (breaking capacity);
- Testing of current-time characteristics of protective releases on circuit breakers and of fuses, verification of selectivity of different elements.
- Temperature rise test(s).

LVAC and DC distribution boards shall be arc tested according to IEC 61641, criteria 1 to 7.

11.5.2.2. Routine Tests

Routine tests shall be performed on each piece of equipment to be supplied for the purpose of revealing faults in material or construction. They shall not impair the properties and reliability of any part being tested or reduce its lifetime.

The following routine tests shall be performed:

- Visual checking of all the equipment to verify conformity with the specifications;
- Power frequency withstand voltage test for all LVAC equipment with 2500 V, 1 min. and for all DC equipment with 1500 V, 1 min.
- Electrical test of charging rectifier to check the automatic current limitation, trickle and boost charging, ripple and manual control.

- Operational test.

11.5.3. Site Tests

On arrival at the site and during and after completion of erection all items of equipment shall be inspected and tested in order to check quality, correct operation and correct installation of the equipment.

The following tests shall be performed:

11.5.3.1. Batteries

Verification of proper and complete erection of the batteries;

Checking of intercell connections;

First filling with electrolyte and initial charging;

Checking of electrolyte level and density;

Checking of voltage of each cell after the charging;

Measuring of the insulation resistance to earth;

Charge and discharge tests.

11.5.3.2. Chargers

Verification of proper and complete erection of chargers;

Verification of proper AC supply voltage, all connections;

Measuring of insulation resistance to earth;

Checking of operation of chargers in each mode;

Checking of control, signalling and tripping circuits;

Load voltage - characteristics.

11.5.3.3. LVAC and DC Switchgear

Verification of proper and complete erection;

Checking of all connections;

Checking of labelling of the cubicles, fuses, circuit breakers, etc.;

Measuring of insulation resistance;

Operation checking of different elements such as contactors, relays, circuit breakers, signalling devices, etc.

Commissioning tests shall be done according to a programme agreed with KETRACO.

11.6. Documentation with Tender

The Tender shall contain at least the following information and documents:

- 1) Single line diagrams of the LV Services;
- 2) General arrangement, construction and overall dimension drawings of the LV Service Equipment including front and section views;
- 3) Manufacturing specification of the LV Service Equipment;
- 4) Catalogues, literature and reference lists of proposed equipment;
- 5) Type test certificates from an independent testing authority or independently witnessed;
- 6) Quality Management System Manual and ISO Certificate of the equipment manufacturer.

12. Tariff Metering

12.1. Substation Works

The following specification applies to all new substations.

12.2. General Requirements

The metering system must provide accurate, reliable and secure measurement of electric energy and make available this information to all commercial parties.

Both Main and Check energy meters shall be provided and must be installed and commissioned to agreed procedures and standards. These shall be of class 0.2s.

The meters and the metering system must be designed such that it can be integrated into the substation control system (SCS) or a separate metering system with facilities to provide secure local and remote (National Control Centre or Regional Control Centre) interrogation of the metered data.

The energy meters shall appropriately be programmed to provide the following information:

(a) Stored in the meter (for local and remote reading)

- (i) Maximum Active Power (P)
- (ii) Maximum Active Power, Date
- (iii) Maximum Active Power, Time
- (iv) Maximum Reactive Power (Q)
- (v) Maximum Reactive Power, Date
- (vi) Maximum Reactive Power, Time
- (vii) Maximum Apparent Power (S)
- (viii) Maximum Apparent Power, Date
- (ix) Maximum Apparent Power, Time
- (x) Active Energy (Total in the month, frozen at end of the month)

(b) Transmitted to the National System Control Centre SCADA reports database

(at each bus bar and/or line bay/ transformer incomer bay)

- (i) Active Power, MW (Import and export values)
- (ii) Reactive Power, Mvar (Import and export values)
- (iii) Current, A
- (iv) Voltage, kV
- (v) Active Energy, MWh
- (vi) Voltage Angle, degrees

The Energy metering values described in (b) above shall be available at the substation SCADA system and the National system control.

The energy meter shall be able to communicate on IEC 61850 and have remote access capability for interrogation.

The meters must have the functionality to be accessed by the various monitoring equipment at both the substations and the NCC and RCC.

The programming codes shall match with Kenya's grid practice. The existing meters would be re-programmed appropriately, if needed.

12.3. Measurement Transformers

The measurement transformers shall be located at the commercial interface between power systems.

Measurement transformers may be of the combined CT/VT type or separate CTs and VTs. The transformers shall be dedicated to tariff metering purposes; usage for other purposes is subject to approval.

The CT cores shall have accuracy class 0.2s and the VT core accuracy class 0.2.

For transmission systems separate CT cores and separate VT secondary windings shall be provided for each Main and Check metering systems.

12.4. Required Smart Meters

Accurate smart meters, with the ability for remote reading, should be installed at

- i. Both ends of all transmission lines and
- ii. The low voltage side of all transmission transformers.
- iii. On the LV side of the auxiliary/earthing transformers.

12.5. Marshalling and Cabling

12.5.1. General

A Marshalling box shall provide a common connection point for CT and VT cables from phase measuring transformers and the metering cubicle. The marshalling box shall also provide suitable environmental protection for the internal equipment.

12.5.2. Cabling

Separate multi-core cables shall be provided for VT and CT signals from the measuring transformers to the marshalling box. In order to minimise coupling between signals, separate multi-core cables are required for VT

and CT signals from the marshalling box to the metering panel(s) and shall avoid being ran adjacent to power cables.

The VT and CT cabling shall be dedicated to tariff metering and not be shared for any other purpose.

The cables for both VT and CT signals shall have a minimum 2.5mm^2 and 4mm^2 conductor. For cabling runs in excess of 300m, the conductor size must be increased in order to reduce the connected cable burden and keep within the rated CT burden.

The metering voltage measuring and auxiliary (where relevant) supplies shall use separate cores from the marshalling box to the metering cubicle. These measuring and auxiliary supplies may be combined from the measuring transformer to the marshalling box.

For each CT circuit 6 cores shall be provided i.e. 2 per phase providing a go and return arrangement.

12.5.3. Marshalling Box

The marshalling box shall provide the following:

- Be lockable to prevent unauthorised access.
- Suitable terminations for CT, VT, meter auxiliary supply (if relevant), earthing links and alarm circuits that permit testing and isolation and shorting (where relevant) of circuits without disturbance to the integrity of wiring connection.
- VT winding neutrals shall be earthed via a removable link to create the neutral star-point.
- CT secondary earth applied via removable links.
- Cable armouring should be earthed at one end only, preferably within the marshalling box.
- Any VT gas discharge trips and alarms shall be brought out from the VT to a separate facility in order to avoid disturbance to the security locks and seals on the tariff metering marshalling box.

12.6. Metering cubicle

12.6.1. General

As a minimum the metering cubicle shall provide accommodation for the energy meters, data loggers, test terminal blocks, MCBs and instrument transformer burden padding resistors. The cubicle shall also accommodate any other equipment necessary to interface the meters to external equipment for remote data interrogation.

The metering cubicles for two adjoining bays shall be installed in the belonging Bay Control Room. The maximum allowed number of meters installed in one cubicle (W:800mm, D:800mm) shall be six (6). The

substation control building will house the metering data collection and communication system, with the connection between meters and that system to be done by fibre optic cables.

12.6.2. Construction

Main and Check meters may be housed in the same cubicle. When viewed from the cubicle front Main meters shall be on the left side and check meters on the right side. Wiring terminals shall also be arranged in the same manner with each circuit clearly segregated and labelled.

The metering cubicle shall be constructed to at least IP52 in accordance with IEC60529, be free standing and constructed from folded sheet steel of adequate thickness and be located on a base frame.

Access into the cubicle may be via a front swing frame door or rear door, this to be coordinated with the other cubicles installed in the same room. A transparent external front door shall be provided. The doors shall be lockable, provided with locks and keys and have provisions for sealing.

The cubicle dimensions shall be minimum 800mm wide and maximum height of 2400mm and have provisions for lifting, sizes to be coordinated with the other cubicles installed in the same room.

12.6.3. Test and Isolation

Separate test facilities shall be provided for each Meter to enable testing from the front of the metering panel with the primary circuit(s) in service. The test points shall be clearly identified and labelled.

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

It is preferred that test facilities match those provided in the substation protection and control cubicles.

Terminals shall provide shorting (where applicable) and isolation facilities.

12.6.4. Cubicle Auxiliary Equipment and Wiring

The cubicle shall have adequate internal lighting, a power point for hand tools and test/maintenance equipment, be suitably ventilated and heated with adjustable thermostatic and hydroscopic controls. A suitably rated MCB shall control the auxiliary AC respectively DC supply and give indication to the SCS of its operation.

A suitably rated MCB shall be provided for each 3ph measuring supply VT circuit and, where relevant, each metering auxiliary supply. The MCB shall provide isolation for the VT wiring to the meter and be located on the

VT side of the test facility and any VT burdening resistors. The MCB shall be provided with sufficient auxiliary contacts wired out to a terminal block for raising an alarm within the SCS.

Auxiliary power supply wiring and terminations, except for meter auxiliary supplies from VTs, shall be segregated from meter wiring and terminations.

12.7. Energy Meter

12.7.1. Construction

Energy meters shall be numerical and of the 3-phase 4-wire measuring principle and conform to IEC62053-22 accuracy class 0.2s for active meters and IEC62053-23 accuracy class 2.0 for reactive meters.

All meter functions shall be accessible from the front. The front cover shall provide a clear window for reading the display and all removable covers shall be sealable to prevent unauthorised access.

The meter shall be rear mount construction and have a degree of protection of IP51 (IEC60529).

The meter shall be powered from an auxiliary AC (via UPS) or DC. Upon normal supply failure meters shall be powered from auxiliary VT supplies.

The meter terminals shall be brass or nickel plated brass and accommodate cable cores of at least 6mm².

The meter shall have self-monitoring capability and raise a remote alarm via the substation control system (SCS) when faulty.

12.7.2. Measurements and Display

Separate Main and Check meters shall be provided for each measuring point.

Each meter shall measure active and reactive import and export energy with nominal measuring voltage of 110V ($110V/\sqrt{3}$) and nominal measuring current of 1A at a frequency of 50Hz. Maximum current shall be $\geq 6I_n$.

The display shall be a minimum seven-digit backlit LCD, single rate registers for each direction of energy flow. The registers shall be non-volatile.

Meter shall display readings in primary quantities. The meter parameters shall be configured via the metering software. Software access to the meter shall be password protected.

The energy meter shall be capable of measuring, displaying and record per interval at least the following: -

- Import and Export kWh, kVArh
- Import and Export kW, kVA

- Reactive Energy in four quadrants.
- V, A
- Maximum Demand
- Total Harmonic Distortion (THD)

The principle measuring unit shall be kWh or kVArh however this shall be changeable to MWh and MVarh.

Meters shall be provided with adjustments for external measurement error compensation.

12.7.3. Data Storage

The record (load profile) for the above values shall be over a programme interval that shall provide at least 180 days of profile data across four channels.

All data shall be retrievable by hand held retriever, server, notebook or other communication media via the meters optical port, Ethernet or serial data ports. Other communication facilities shall be provided as necessary to interface the meter into the substation control system or remote meter data system.

Each energy meter shall have a minimum of three pulsed outputs and for connection to a data logger (if separately required). A single control shall set all outputs to the same units per pulse.

The Contractor shall integrate the energy meters into the Substation Automation System (SAS). The contractor shall ensure that the communication protocols used in the energy meters can be accommodated by the supplied SAS.

The difference between test and pulse outputs shall not exceed 0.01%. The pulsed outputs shall comply with the requirements of IEC62053-31.

12.7.4. Timing

The meter shall have an internal clock with back-up battery to last for 1 year and be capable of synchronization with other meters via a GPS clock signal.

The GPS auxiliary power supply shall be either AC (from a UPS) or DC.

12.7.5. Security

For purposes of security the meter shall have multi-level password protection for reading and programming.

12.7.6. Markings

Each meter shall be provided with a nameplate conforming to IEC 62052-11.

12.8. Software

The proprietary metering software shall be supplied in order to locally and remotely configure and retrieve data from the metering system.

12.9. Metering System Auxiliary Power Supply

Normal auxiliary power supplies shall be derived from station battery 110V DC supply.

Failure of the normal auxiliary supply shall cause the meters to draw alternative auxiliary power from the VT.

12.10. Testing

Type test reports must be submitted for all equipment supplied to demonstrate compliance to the appropriate standards.

Meter compensation adjustments shall be performed by the Contractor. Data necessary to perform these adjustments shall be supplied in the form of test certificates, lead resistances and working burdens.

Installation, setting, testing and commissioning of the metering system shall be carried out at site by the Contractor.

Site tests shall be performed by the Contractor in accordance with a test schedule prepared by the Contractor and agreed in advance with KETRACO. These tests shall include full functionality and safety testing of the equipment, cabling and items of plant supplied. On completion of tests the contractor shall provide a signed copy of the test procedure. The testing shall be done to the satisfaction of KETRACO.

12.11. Training and Capacity Building of Staff

KETRACO staff shall be adequately trained to:

- i. Be empowered skill wise on meters/metering and associated wiring;
- ii. Programme/re-programme the meters when necessary; and
- iii. Read the meters when required.
- iv. Establishment of a meter unit

This training aspect should be part of the pre-commissioning process.

13. Fault Monitoring System and Alarm System

13.1. General

This specification covers the design (including all software), manufacture, factory testing, marking, packing, shipping, transportation to site, installation, on-site testing and commissioning of a Fault Monitoring System (FMS).

FMS shall be provided at new build substations and this specification provides the functional and performance requirements.

FMS shall be supplied for acquiring the power system real time data, and providing the historical information of its faults/disturbances with all possible events detected thereafter.

The FMS system shall continuously monitor analogue & event input signals, and upon detection of a fault/disturbance or event, it shall automatically:

- Capture and store fault data in the buffer memory.
- Process and upload the information to a data concentrator resident with all analysis software providing a local evaluation station.
- Capture and store additional fault/disturbance data without affecting any tasks in progress.

FMS shall provide, in analogue form, current and voltage information, and in digital form, event information such as outputs from protection relays, protection signalling equipment, and circuit breaker operation at the time of primary system faults.

In addition, FMS shall be able to perform calculation and fault location in order to help find the fault points in the shortest possible time.

When the FMS is triggered, the analogue and event channel input data, for a certain time prior to, and after the trigger pulse, shall be recorded with all channels relating to the same time reference. The FMS shall record the analogue and event data simultaneously.

The system shall process the recorded data locally and also be accessible remotely via the SCS LAN.

All records of fault data shall be processed in either the local or the NCC Master evaluation stations to determine:

- Type, presence, severity and duration of a fault
- Fault locations and persistency of faults
- Performance adequacy or inadequacy of protection, tele-protection signalling equipment and circuit breakers

- Any failures or operation outside the limits of performance and any malfunctions
- Cause and possible resolution of a problem.

The fault recorder concept shall be a distributed principal with measurement and signal acquisition units per diameter and a central unit to be installed in the substation control building, which collects and archives all the fault records from the different diameter acquisition units. The cubicles with the diameter acquisition units shall be installed in the Bay Control Room belonging to the diameters. The connection between acquisition units and the central system shall be done by fibre optic cables.

13.2. Network Integration

Where compatible systems are provided at NCC/RCC fault record data shall be automatically transferred to the evaluation station for analysis.

13.3. FMS Architecture

The Manufacturer shall be cognizant that the FMS system offered must support, with hardware and software devices, a local analysis facility at the substation, and a seamless integration with NCC/RCC (where supported).

To facilitate fault analysis at each substation, the FMS system shall comprise a local evaluation facility set up with a suit of PC (data concentrator), monitor, printer, etc., which shall be implemented with complete application (analysis) software.

13.4. Accommodation

The FMS data acquisition units, master station, Local HMI and printer (where relevant) and other associated equipment shall be preferably housed in front access, swing-rack design however front and rear is acceptable but should not be a mixture of both at the same substation.

All equipment shall have dust-proof enclosures. All metal bases and frames of relays shall be earthed except where they are installed for special requirements.

13.5. Hardware Requirements

13.5.1. Data Acquisition Units (DAUs)

The DAUs of FMS shall be of the stand-alone type (not integrated with any protection or control systems) and connected via the substation LAN to the SCS Engineering Workstation.

Independent DAUs shall be supplied with a minimum of 8 analogue channels (voltages & currents) and 16 event channels for each incomer and outgoing transformer feeder circuit and OHL circuit. For other non-feeder circuits, such as coupler/section, busbars, etc. common DAUs with a large capacity shall be used. Separate common DAUs shall be provided for each system voltage.

The Contractor should note that the common DAUs are only acceptable provided that the channel allocation for each bay shall comply with the Data Sheet and this specification, and that the fault record for each bay (circuit) shall be independently processed and stored.

For future use, a separate DAU shall be provided with 16 analogue and 32 event channels. This shall be available as a spare-point wherein all the equipment is fully installed, and wired into FMS cubicles with all the modules in place, but not utilized.

The DAUs shall embody several data processing properties at both the field level where data are acquired and the analysis level where waveforms are processed and examined. Data acquisition shall be in the form of collecting current & voltage signals from the secondaries of current and voltage transformers and binary status information (contacts) from circuit breakers, protection relays, tele-protection signalling equipment, etc.

The DAUs and other FMS components (including the data processing and evaluation equipment) shall comply with requirements stated in IEC 60255-6 for thermal and environmental tests. The FMS system shall be designed to ensure correct performance even in the presence of radiated electromagnetic field disturbance (IEC 60255-22-3).

The DAUs shall be capable of retaining its selected parameterization and settings when its DC supply is removed and subsequently reinstated within 2 weeks.

The DAUs shall be designed with a non-volatile flash memory with a 500 Mb capacity. If internal batteries are used for backup purposes, then they shall have a nominal life of 10 years.

The fault records held within the DAU's memory shall be retained for 2 weeks upon loss of DC supply.

The DAU's shall be provided with an internal clock to time tag each fault record. The clock shall identify the date and time on each fault record to the nearest 1ms, which is necessary to compare fault data recorded at different substations. The internal clock shall be synchronized with the GPS standard time reference. The drift of the internal clock shall not be greater than 1 s/day, in the absence of a GPS time reference.

DAU local setup tools (software, cables and laptop computer) shall be included in the scope of supply.

13.5.2. Channel Requirements

The analogue channels for voltage and current inputs shall be rated at 110 V AC (phase-to-phase) and 1A AC respectively. The bandwidth of the analogue signals shall cover a frequency range of 20 Hz-1500 Hz. The analogue information shall have an amplitude resolution of at least 1:65500 using a 16-bit A/D converter.

The analogue channel for the current input shall be provided with the maximum amplitude of recording up to 30 times nominal. The accuracy of the current and voltage inputs shall be better than 0.5% of the full scale.

The event channels shall be capable of accepting either N/O or N/C contacts.

13.5.3. Trigger Facilities

It is necessary to trigger DAU's in order to acquire data during system fault and abnormal conditions. The DAUs shall be offered with various types of sensing algorithms, Boolean logic, and external events to detect the occurrence of a fault.

13.5.4. Trigger Time

The fault recorder shall have a pre-trigger recording time selectable within the range of 100ms - 500ms in steps of not greater than 50ms. The post-fault recording time shall be adjustable within the range of 100ms - 2000ms.

13.5.5. Event Channels

External binary triggering facilities shall be provided to enable FMS to capture the system fault information.

13.5.6. Analogue Channels

Each analogue channel shall be provided with at least one of the following independently selectable triggering facilities:

- Threshold Triggering & Variation Triggering: Current, Voltage and Frequency
- Negative phase sequence triggering: Current.

The threshold trigger shall take place when the voltage falls below or rises over a preset threshold or when the current rises over a preset threshold.

The variation triggering shall take place when the voltage falls or the current rises by a preset percentage of nominal maximum amplitude of recording in 1 cycle.

In the negative phase sequence current triggering, both over threshold and positive variation triggering shall be provided.

Manual triggering facility shall be provided on the hardware front panel.

The response time of an event trigger shall be sufficiently short to capture event durations of 2ms. However, triggering shall not take place for event duration of less than 0.5ms or for electrical noise. The response time of an analogue trigger shall not be greater than 40ms.

13.5.7. Signal Requirements

The FMS shall be configured for the analogue and event signals as follows:

Bay	Configuration	
	Analogue Channels	Event Channels
Feeder (Incomer & Transformer)	4 x current & 3 x voltage, 1 open delta (or residual voltage)	16
Outgoing Transformer Feeder	4 x Current & 3 x Voltage	16
Bus Coupler/Bus Section	4 x Current	16
Busbar	3 x Voltage	8
Frequency channel (per busbar)	1	-

The above number of channels/event signals shall be assumed, as a minimum requirement, however if at the time of implementation, more signals are deemed necessary, the same shall be provided. The list of channels to be wired up shall be subject to approval of KETRACO/KPLC.

13.5.8. Printer

Colour print facilities shall be provided. Printing either locally at the FMS and/or via the LAN connected SCS printers.

13.5.9. Self-Supervision & Alarms

On-line supervision is to be provided to detect hardware and software failures. All types of failures shall be detected and alarmed, which shall typically include the detection of internal equipment failures, loss of auxiliary (DC) supply, printer paper low/out.

The hardware shall be equipped with indicators for system power ON, power supply output present, watch dog time being reset, fault indication, etc.

Fault recorder operated and fault recorder faulty alarms shall be provided in the substation (SCS).

Individual modules, MCBs, operating buttons, and terminals shall be clearly identified by labels affixed in a permanent manner. All indication LEDs, particularly, those used for the event signals, shall be identified on the front of the equipment shelf.

13.5.10. Engineering Interface

The fault recording system shall be provided with interrogation facilities containing software and interface hardware for communication with a PC. Communication shall be achieved by local interrogation via the direct

connection of a PC to the front panel RS232 or Ethernet port. Communications shall also be achieved remotely via the SCS over the substation LAN.

Where provided, the remote interrogation software package resident at NCC Evaluation Station shall be capable of downloading settings and trigger commands into the fault recorder.

13.5.11. Communication with NCC

The communication between the substation and the NCC Evaluation Station (where available) shall be provided via KETRACOs telecommunication networks. Standard communication protocol shall be used. The Contractor shall state in their offer which protocol is to be used.

13.5.12. Functional Requirements

The FMS shall have, as minimum, the following features:

- Be of a modern, fully numeric and modular design.
- Low power consumption and be powered by the station battery.
- Requisite software and hardware built-in both for stand-alone working and for operation over a network up to the master station.
- A memory (RAM) that is sufficient for capturing fault/disturbance and event data of at least 50 seconds at a sampling rate of 4000 Hz.
- An accurate crystal controlled clock with external GPS synchronization facility. The GPS of the SCS shall be utilized for the FMS.
- A battery to back up the system memory and clock, in the event of a power supply failure.
- Each event channel shall be adjustable for disabling its function, or for matching it to a normally closed or a normally open contact. Also, recording or suppression of recording by an event occurrence shall be adjustable.
- Time adjustable filter to suppress contact bounce.
- Scan rate of at least 2000 Hz per event channel.
- Scan rate of at least 4000 Hz per analogue channel.
- Analogue channels with an amplitude resolution of not less than sixteen bits.
- Recording initiation by individual analogue channels shall be adjustable by the setting of under/over limits.

- When the hardware memory is in danger of becoming full, an alarm must be produced in the station.
- A standard interface for connecting a hand terminal (PC), for retrieving data and reconfiguration of trigger values, date/time setting, parameter setting of analogue and event channels, and for system testing or fault diagnosing. This facility shall not be capable of modifying or deleting fault records held within the recorder's memory.
- Have indications on power supply failures, system failure, communication link interruption, or memory buffer full. The failures are to be externally signalled through potential free contacts to either common alarm annunciation or to the substation control system.
- Evaluation station shall be comprised of a latest PC with the available largest hard disk memory and fast scanning capacity at the time of awarding the contract. The evaluation station shall have a standard interface connected to a colour laser type printer of latest technology (suitable for at least A4 & A3 paper size), which is to be located in the control room. The print out shall at least invariably include date/time, station name, all the event and analogue channels with the X, Y axes scaled.
- In-built power supplies for the signalling contacts. The number of circuit breakers to be used shall be such as, by switching an MCB, which is associated with a particular acquisition station, it shall not cause any of the remaining recording unit to be out of service. This supply output shall be monitored.

13.6. Evaluation Facilities

13.6.1. Analysis Objectives

The FMS shall provide sufficient data to perform the following analyses:

- Fault clearing
- Power swing conditions
- Under frequency conditions.

Since the data required for one type of analysis are quite different than that required for another type, the Contractor shall confirm that the FMS offered shall be suitable to perform all types of analysis. The FMS shall acquire data with a clear distinction of differences in the required frequency response and the duration of the event to be captured, depending upon the types of disturbance the power system being subjected to.

For fault clearing analysis, the FMS shall capture data with a high sampling rate of up to at least 4 kHz, and a short record length of up to 2 seconds.

For analysis of power swing and under frequency conditions, the FMS shall acquire data with a lower sampling rate of 15 Hz and a long record length of up to 5 minutes or more.

In fault clearing analysis the FMS shall process and compute the following information:

- The fault duration time and the magnitude fault current/voltage including the type of fault (single phase, multiphase, evolving) and the phases involved.
- Analogue waveform data on all voltages and currents to display harmonics, Ferroresonance conditions, transient voltages, breaker restrikes, or arcing.
- Distance to fault estimation.

For analysis of power swing, dynamic oscillation and under frequency conditions, the outputs computed by FMS shall include, but not be limited to, plots of volts, currents, frequency, apparent impedance's, negative sequence currents, power swings, etc.

The DAUs shall be able to switch over automatically to the required operational parameters and settings depending on the power system faults and disturbance conditions, and shall supply sufficient data to enable different types of analysis to be conducted.

13.6.2. Data for Relay Testing

The FMS system offered shall provide facilities to replay fault recorder files into protection relay test sets in order to reproduce the relaying performance under an actual fault condition. The fault data shall be provided as input to test sets in the COMTRADE format. Transient analysis of the relay performance required signal parameters such as peaks, RMS values, power, system frequency, phasor quantities, etc. The FMS shall provide the required information both in the time domain and in the frequency domain.

13.6.3. Fault Records

The fault records shall contain, in alpha numeric characters, the identity of the substation and circuit, the fault reference number, the trigger data, time and source, identification of individual analogue and event channels, amplitude scale, and time increment markers.

The fault record shall be available in the COMTRADE format.

A print out of settings and other programmed parameters shall be achievable on demand from the recorders.

The time coincidence error between recorded event and analogue channel shall not be greater than 1 ms. The reconstructed waveforms that are developed from the stored data shall be accurate within 1 percent of the input waveforms in amplitude and phase angle.

The fault locating function shall perform with an error accuracy of plus or minus 1 percent.

The overall accuracy of the printed output of the analogue channel shall be such that at a frequency of 50Hz the error between input and output shall not exceed 0.4 mm at any point between 10 percent and 100 percent of the nominal amplitude.

13.6.4. Software

The required FMS system shall have the requisite software for achieving the following:

- Analogue triggering (over voltage, under voltage, over current, over / under frequency, and voltage, current & frequency gradients)
- Triggering because of protection trips or CB status
- Software for maintaining a database for data uploaded from FMS units, keeping a register for parameter setting and running hardware and software diagnostic subroutine.

The operating system software shall be user friendly. The software packages at the substation evaluation station shall be suitable to run multitude of software for data collection from the acquisition units as well as data processing, storage, fault analysis, graphical representation, data communication (between local and master station).

At the NCC evaluation station (where available) similar software as for the substation evaluation station is also required.

13.7. Fault Evaluation Package

13.7.1. Fault Analysis

The software package shall include mathematical analysis features such as calculation and display against time of:

- Sequence components
- Harmonics
- Frequency
- Phase angles
- Real and reactive power
- Fault location
- Power swing
- X/R and time constant.

13.7.2. Analysis Tools & Facilities

The required evaluation software shall be an interactive tool for the evaluation and interpretation of fault recorder files. It shall execute the following tasks as a minimum:

- Viewing on the screen the identity of the substation, fault reference number, trigger date, time and source, identification of analogue and event channels, and amplitude scales, etc.
- Each analogue channel or each group of events shall be capable of being displayed individually or together with other selected channels. Each channel shall be capable of being amplified individually or with other selected channels.
- The display's time base shall be capable of being expanded or contracted.
- The instantaneous primary values of current and voltage shall be capable of being displayed at a movable cursor position. The instantaneous time with respect to a selectable cursor position shall also be displayed.
- Formatting of the menu (time scale, amplitude, axis height, colour, markers, clipping, and interpolation) shall be made possible.
- It shall have the facility either to show or not to show check value by cursor for the measured menu item.
- The software shall have the feature of calculating the signal from the recorded data.
- It shall perform the function of merging different fault event files on opening of the same in order to allow global analysis of data.
- It shall execute batch mode operation by opening the dialog box in which batch mode status can also be indicated.
- In the batch mode, operations such as calculation, automatic fault location, time calculations, print function; etc. shall be possible to be carried out.

13.7.3. Hardware Availability

Contractor shall state in their offer the FMS hardware availability while in service i.e. MTBF and MTTR values. Supporting document from the Contractor shall be enclosed.

13.7.4. Alarms

The alarm system equipment shall contain all alarms necessary for the safe and reliable operation of the station.

The system shall be solid state and completely hardwired to the various modules and contact devices.

All the logic elements shall be mounted on printed circuit boards with gold plated edge connectors and complete card shall be tropicalized.

The equipment shall have the following main features:

- Built-up from a basic units of 8 or 16 channels extendable to a large system
- Microprocessor based with communication facility. Self-monitoring with alarm on failure
- Easy fault detection and rectification
- Suitable for NO and NC contacts
- Re-transmission of alarms via output relays
- Grouping (at least 2) of alarms for remote transmission
- Generation of internal power for field contacts
- Push buttons for horn off, alarm acknowledge, reset, LED test and self-check with remote initiation facility for the same

On an incoming alarm the horn will sound and an LED will flash. The horn shall stop on pressing the horn off button or by a delay timer. Upon pressing the acknowledge button the flashing light will become steady. Simultaneously remote transmission of grouped alarms shall be cancelled. The LED shall reset after the alarm condition resets and on operating the reset button.

The alarm system equipment shall be installed in a separate panel.

14. Phasor Measurement Unit

14.1. General

The specification identifies some minimum requirements for each of the major PMU (Phasor Measurement Unit) component which are essentially required for measurement of complex phasor quantities and transmitting the same to the PDC (Phasor Data Concentrator) at control centre. The delivered system is expected to provide meaningful synchronized measurements (Synchrophasors) of the acquired data so that it is useful to the operators in assessing the current state of grid and can also be used for carrying out the post-facto analysis.

The bidders are encouraged to offer their standard products that meet or exceed the specification requirements.

14.2. Intent of Specification

The intent of this Specification is to describe the technical requirements for supply installation, testing, commissioning & integration of PMUs. The PMUs to be supplied under this Specification shall be installed at the Substations/Power stations and shall communicate to the Phasor Data Concentrator (PDC) at the Control Centre on IEEE C37.118 format.

14.3. Scope of Work

The scope of work shall include supply, installation, testing, training, commissioning, and documentation of:

- a) Phasor Measurement Units (PMUs).
- b) One set of Synchrophasor Vector Processor.
- c) All associated Accessories & Software
- d) All cabling, wiring, terminations and interconnections to the equipment including necessary trench/surface condition to interconnect the PMUs to the installed or being installed communication equipment by the Owner.
- e) Integration of supplied PMUs to PDC (Phasor Data Concentrator) conforming to IEEE C37.118 standard.
- f) Cable connection / interfacing with communication equipment.
- g) Any other work which is not identified in the specification but is required for completion of the work within intent of the specification and full utilization of the PMU shall also be in the scope of the Bidder.
- h) On-site training of the Employer personnel.
- i) 5 years warranty period.

- j) Satisfactory performance and synchrophasor data acquisition shall be demonstrated at site by supplier.
- k) Separate GPS, Ethernet Switch, Industrial PC with all accessories such as wiring, Lighting, heater, socket, terminal, Indication lamp, transducer, control equipment, monitor, keyboard, mouse, printer, I/O card and etc. (all requirements for future extension must be considered)

14.4. PMU Requirements

The offered PMUs shall collect data from all 400kV and 220kV feeders (as per scope of work) and be complete in all respect so that they can be installed at the substation/power plant and can communicate with Control center having Phasor Data concentrator (PDC) and central PMU. The necessary cable and connector and installation hardware shall also be supplied by the bidder. The PMUs shall conform to IEEE C37.118 standard and shall be designed to meet the following requirements to accommodate data from each feeder:

- a) The PMUs shall be designed to measure the electrical parameters in the power system frequency band of 45-55 Hz.
- b) The supplied PMU will be standalone in the substation control rooms/relay panel room.
- c) The auxiliary power supply to PMUs will be provided from the station DC which is used for control and protection of substation devices.
- d) Capable of delivery data to control center PMU collection unit through Ethernet
- e) The PMU shall be capable to stream up to 32 users – selectable single – phase, 3-phase, +/-, zero sequence, and summated phasors.
- f) One (1) frequency channel.
- g) Twelve (12) analog values (at least).
- h) 64 digital status data (at least).
- i) Magnitude and phase angle supervision.
- j) GPS time synchronized to 1 μ s accuracy.
- k) PMU reporting rates shall be up to 60 frames/second.
- l) Capable to stream to two PDC's with independent MAC addresses.
- m) IEC 61850 station bus protocol.
- n) The PMU shall have two Ethernet ports (Copper/Fiber optic) with independent MAC addresses.

- o) IRIG-B time sync, modulated or un – modulated or NTP.
- p) Thermal Withstand 100A for 1 second (at least).

14.5. Phasor Data Contractor (PDC) Requirements

The PMU to be supplied shall communicate to the PDC. However, the PDC to which PMUs to be integrated shall meet at least the following features:

- a) Shall support data streaming in IEEE C37.118 format.
- b) Shall be capable of receiving data in Unicast and Multicast.
- c) PDC shall be able to receive the loss of signal event of the time receiver from PMU and shall result in an alarm at PDC.
- d) PDC shall support Remote configuration of PMU.

14.6. Training

Training shall be conducted by manufacturer's personnel who are experienced instructor. All necessary training material shall be provided by the contractor. Each trainee shall receive individual copies of all technical manuals and all other documents used for training. Minimum period of training shall be three (3) days.

14.7. Maintenance

After taking over the system KETRACO will maintain the system with the support of contractor in the case of any failure occurrences. The hardware and software function warranty period is for 24 months, which begins after Taking Over Certificate (TOC) issued by KETRACO.

14.8. Documentation

Complete documentation is required to support PMU setup, operation and maintenance. The documentation shall include the following:

- a) Procedures for PMU setup and use with regard to all features.
- b) Documentation of procedures regarding routine maintenance including use of system diagnostics.
- c) Detailed connection diagrams showing how the PMUs are installed at site.
- d) A complete copy of PMUs functional design.
- e) Details of hardware/software and as built system.

14.9. Testing of PMUs

The Bidder shall offer the PMUs for inspection & Factory Acceptance Tests (FAT). During FAT the supplier shall demonstrate all the functions of PMU the procedure for all the testing shall be agreed between the supplier and purchaser before proceeding for the testing.

15.Auto Transformers

15.1. Scope of Works

The transformer supply and services to be performed by the Contractor shall comprise the design, manufacture, shop testing, packing, transport, insurance, unloading, storage on Site, construction works and erection, corrosion protection, site testing, submission of documentation, commissioning, training of KETRACO's personnel and warranty of the works.

The Contractor is bound to provide complete works, even if the equipment or services to be provided are not specifically mentioned in the specification.

○ Reference Documents

IEC 60076-1	- Power transformers - General.
IEC 60076-2	- Power transformers - Temperature rise.
IEC 60076-3	- Power transformers - Insulation levels, dielectric tests and external clearances in air.
IEC 60076-5	- Power transformers - Ability to withstand short circuit.
IEC 60076-7	- Loading guide for oil-immersed power transformers
IEC 60076-8	- Power transformers – Application guide (For calculation format)
IEC 60076-10	- Power transformers - Determination of sound levels.
IEC 60137	- Insulated bushings for alternating voltages above 1000 V.
IEC 60214	- On-load tap-changers.
IEC 60529	- Degrees of protection provided by enclosures
NEMA TR1	- Transformers, regulators and reactors [for audible sound levels]

15.2. General

Transformers shall be outdoor, oil-immersed, three-phase type, generally with on-load tap-changer. (Exceptions with off-circuit tap-changer are detailed in Clause 17.2.11 'Voltage Control' of this specification.) They shall comply with the requirements of the schedules and standards listed in Clause 14.1 above and other relevant IEC standards.

The transformers shall be suitable for continuous operation on a three-phase 50 Hz high voltage transmission system as specified in the Technical Schedules.

Transformers and associated equipment shall be designed in such a manner as to meet the requirements in this section, Technical Schedules and Drawings at ambient site conditions. Therefore, the temperature-rise limits given in IEC 60076-2 and IEC 60354 (i.e. hotspot) shall not be exceeded.

Note: the annual average temperature needs to be considered with the necessary correction to the IEC 60076-2 allowable temperature rises to ensure meeting the life criteria of the transformers.

Transformers shall meet the latest stage of development reached in design, construction and materials.

The transformers and all associated facilities (e.g. tap-changer) shall have the ability to withstand the effects of short-circuit currents, defined as symmetrical short circuit current in the Technical Schedules, when operating on any tapping position according to requirements of IEC 60076-5.

All metal parts of the transformer with the exception of the individual core laminations, core bolts and associated individual side plates shall be maintained at the same fixed potential. The earthing structure shall be designed to carry, without damage, the maximum possible earth fault current for a duration of at least equal to the short circuit withstand period of the main windings.

The design and manufacture of the transformers and auxiliary plant shall be such that the noise level is at a minimum and that the level of vibration does not adversely affect any clamping or produce excessive stress in any material. The transformer manufacturer shall supply sufficient information to the civil works contractor to ensure adequate design of the transformer mounting structure.

Where noise measurements are specified, they shall be made at the Manufacturer's works in the presence of KETRACO or their appointed representative.

If required by KETRACO, the transformers shall be subject to vibration tests.

The transformers shall be designed with particular attention to the suppression of harmonic currents, especially the third and fifth, so as to minimise interference with communications circuits.

The transformers shall be designed to ensure that leakage flux does not cause overheating in any part of the transformer.

Note: This specification covers the requirements for all system transformers, including EHV units on the KETRACO system. Simplified requirements may be acceptable for transformers of low to medium capacity where this can be demonstrated to be typical of good industry practice. When simplified requirements are proposed, they shall be clearly stated in the tender documents, showing any deviation from the specification and/or accompanying technical schedules.

The auto transformer shall incorporate and include the following:

- a. access ladder,
- b. Communication from the on line monitoring system and the DGA devices (The system shall be provided with the relevant software, which will be integrated in the overall SCMS using a

protocol according to standards like IEC 60870, IEC 61850 or DNP 3.0 The system will have to allow the methods of following access.

- i. direct access by RS232/485 port
- ii. access by a commuted line to an optional modem by means of a phone line or of a mobile telephone network connection of communication using protocols corresponding to the standards of the industry and via footbridges to pass on the information to systems SCMS access via an internet connection or a router (route planner) / firewall to a waiter (server) of PC on internet.

15.3. Magnetic Circuit

The core shall be built up of high-grade, non-ageing, low-loss, high-permeability grain oriented steel sheets. Both sides of each steel sheet shall be insulated with a durable, hot oil and heat resistant baked enamel varnish or other chemical treatment.

The cores shall be clamped and braced to withstand, without damage or deformation, the forces caused by short-circuit stresses, transportation, or handling, and to prevent the shifting of the core laminations. The bolts, nuts, and end plates of the assembly and clamp structure shall be of a nonmagnetic type, and shall be effectively insulated and locked so that they ensure an even pressure on the whole core assembly and are not loosened by vibrations caused by transport and operation. The supporting framework of the cores shall be designed to avoid the presence of pockets which could prevent complete draining of the tank or cause the trapping of air when filling during service.

Suitable axial cooling ducts shall be provided to ensure free circulation of oil and efficient cooling of the core. The ducts shall be so dimensioned that the maximum temperature at any point remains within the admissible limits.

Particular care shall be given to the design and construction of the corner joints between columns and yokes to avoid concentration of mechanical and magnetic stresses

Adequate metallic bridges shall be provided between the core lamination packets in order to keep all portions of the core assembly at the same potential.

Lifting eyes or lugs shall be provided at suitable points of the core assembly.

The core shall be earthed to the clamping structure at one point only through a removable link with a captive bolt and nut, placed for convenient access adjacent an inspection housing on the tank cover or tank wall. All earthing connections with the exception of those from individual core clamping rings, shall have a cross sectional area of not less than 80 mm². Connections inserted between laminations shall have a cross sectional area of not less than 20 mm².

The core shall be free from overfluxing liable to cause damage or to cause maloperation of the protection equipment when the transformer is operating under the continuous overvoltage condition specified in the Technical Schedules. Under this steady overvoltage condition, the maximum flux density must not exceed 1.9 Tesla and the magnetizing current must not exceed 5 per cent of the rated load current at normal rated voltage.

15.4. Windings

The windings shall be of high conductivity electrolytic copper. High purity cellulosic Kraft Paper shall be used for the principal conductor insulation.

The conductors shall be transposed at sufficient intervals to minimize eddy currents and equalize the current and temperature distribution along the winding. Coils shall be constructed to avoid abrasion of the insulation, (e.g. on transposed conductors), allowing for the expansion and contraction set up by the changes of temperature or the vibration encountered during normal operation.

Windings shall be so designed as to obtain an optimal value for series and shunt capacities in order to ensure a favourable distribution of the voltage for full impulse waves and chopped impulse waves.

Leads from winding to bushings shall be adequately supported to prevent damage from vibration and short-circuit forces.

Permanent current-carrying joints or splices shall be welded or brazed, properly formed, finished and insulated to avoid concentration of dielectric stresses.

The windings shall be subjected to a thorough shrinking and stabilising process. Compensation devices shall be provided for possible further shrinkage of the coils in service.

The coils, windings and leads shall be sufficiently braced and fastened to form rigid assemblies, preventing any relative movement due to transport, vibrations or other circumstances that may occur in service.

The windings shall be designed to reduce to a minimum the out-of-balance forces inherent in the transformers. Tappings shall be arranged at such positions on the windings as will preserve, as far as possible, electro-magnetic balance at all voltage ratios.

Tappings shall not be brought out from the inside of a coil; nor from intermediate turns.

The winding shall be capable of withstanding the forces to which it is subjected under all conditions, particularly the forces due to a short circuit between terminals or between any terminal and earth, with full voltage maintained on all other windings intended for connection to external sources of supply and allowing for any feedback through windings connected to rotating machines.

The assembled core and windings shall be vacuum and/or vapour-phased processed to ensure optimum moisture removal.

15.5. Tertiary Windings

Tertiary windings may be specified either as an auxiliary third winding or as a stabilising winding. When specified as a third winding the general terms for primary and secondary windings applies (as above), appropriate to the assigned tertiary voltage and MVA rating.

The tertiary windings of star/star connected transformers are, unless otherwise specified, stabilising windings for control of zero sequence current and for harmonic suppression. Additional information is given in the 'Neutral and Tertiary Connections' part of this specification.

For single phase transformers rated 100 MVA and above, the stabilising winding shall be brought out by two bushings at one corner of the delta; these are to be connected and grounded in service.

A single bushing may be used at ratings below 100 MVA.

15.6. Neutral Earthing

According to general effective earthing policy of KETRACO, 400 kV, 220kV, 132kV and 66 kV systems, neutral points of transformers shall be directly connected to earth. Additional information is given in Clause 15.15, 'Neutral and Tertiary Connections' part of this specification.

15.7. Tank

The transformer tank shall be of welded construction with bolted cover, fabricated from steel plate of a suitable strength grade to meet the following requirements.

The tank shall be of adequate strength so that, when containing the core plus coil assembly and fully oil filled, any packing, lifting, rolling and handling shall not cause overstressing of any part of the tank or leakage. The main tank body, tap changing compartments, radiators and associated piping facilities shall be capable of withstanding full vacuum when empty of oil.

Each tank shall be provided with minimum of four jacking pads conveniently located to allow the raising or lowering of the completely mounted and oil filled transformer. The load carrying capacity of each jacking pad shall not be less than 50% of the total weight of the transformer. Lifting eyes or lugs for lifting the complete transformer and tank cover and facilities for the pulling and pushing of the transformer in any direction shall be provided for each unit. Tank stiffeners and mounting brackets shall be continuously welded to the tank.

Wherever possible, the transformer tank and its accessories shall be designed without pockets wherein gas may collect. Where pockets cannot be avoided, pipes shall be provided to vent the gas into the main expansion pipe. The vent pipes shall have a minimum inside diameter of 20mm^(note 2) and, if necessary, shall be protected against mechanical damage.

The shape and arrangement of the tank cover and external stiffeners shall permit rainwater and desert sand to flow easily and completely to the ground.

All oil-tight joints shall be made with machined flanges and approved types of gasket.

The gaskets shall be tight under all prevailing service and atmospheric conditions; especially against the hot oil (synthetic rubber or neoprene-bonded cork is not permitted). Means shall be provided to prevent over-compression of the gaskets. The tanks shall be provided with bolted type manholes for easy inspection of bushings and windings.

The tank cover shall be fitted with thermometer pockets, for oil and winding temperature indicators, with a captive screw cap and be located in the position of maximum oil temperature at continuous maximum rating.

A pressure relief device of self-re-setting type and sufficient size capable of functioning without electrical power, shall be provided for the rapid release of any pressure that may be generated within the tank and which might result in damage to the equipment, but it shall be capable of maintaining the oil tightness of the transformer under all conditions of normal service. The device shall operate at a static pressure of less than the hydraulic test pressure for transformer tanks and shall be designed to prevent further oil flow from the transformer during its operation.

The relief device shall be mounted on the main tank and if mounted on the cover it shall be fitted with a skirt projecting inside the tank to prevent an accumulation of gas within the device. Two sets of contacts shall be provided to initiate the alarm and trip relays.

Terminals shall be provided close to each corner at the base of the tank for earthing purposes and each shall be designed to meet system fault levels.

The following plates shall be fixed to the tank at an approximate height of 1.75 m above the ground level: -

- b. A rating plate bearing the data specified in IEC 60076.
- c. A diagram plate on which the transformer tapping voltages in kilovolts shall also be indicated for each tap, together with the transformer impedances at minimum and maximum voltage ratios and for the principal tapping.
- d. A property plate of approved design and wording.
- e. A title plate.
- f. A valve location plate showing the location and function of all valves, drain and air release plugs and oil sampling devices.

15.8. Valves

Valves shall be of the fully sealing full-way type and shall be opened by turning counter-clockwise when facing the hand wheel. They shall be suitable for operation between the minimum ambient and the maximum oil temperatures stated in the Schedules. All valves shall be lockable with appropriate sub-master series padlocks. Padlocks shall be provided for locking all valves in the "open" and "closed" positions. Valves other than filter and drain valves shall be provided with an indicator, readily visible from ground level, to show clearly the position of the valve.

All valve hand wheels shall be fitted with nameplates that shall be chromium plated brass not less than 3 mm thick with the engraving filed with enamel. All valves shall be fitted with spoked hand wheels, the spokes and rims of which shall be smooth and where necessary, for appearance, shall be chromium plated.

Each transformer tank shall be fitted at least with the following:

- One 50 mm valve at the top and one 50 mm valve at the bottom of the tank, mounted diagonally opposite each other, for connection to oil circulating and oil filtering equipment. The lower valve shall also function as a drain valve, for which a suitable combine arrangement shall be made.
- Oil sampling devices at the top and bottom of the main tank.
- All parts containing oil, and liable to trap air during filling, shall be fitted with a flanged type air release plug at their highest point.
- Valves shall be provided on both sides of the gas and oil actuated relays.

All valves opening to atmosphere shall be fitted with blanking plates.

15.9. Conservator

Transformers rated at 10 MVA and above shall be fitted with an oil conservator. Sealed construction or corrugated tanks may be offered for lower ratings.

The conservator shall be made of welded steel. It shall be designed to withstand full vacuum. The conservator shall be of sufficient volume to enable expansion and contraction of oil within the highest and lowest oil levels in the conservator.

The conservator vessel shall be mounted at the highest point of the oil system and shall be connected to the highest point of the tank through a straight sloping pipe. Adequate isolating valves shall permit the removal of the main and tap-changer Buchholz relays while the conservator is still connected to the tank by a pipe bypassing the relays.

For the power transformers, the conservator vessel shall contain two compartments, one for oil in the main tank and the other for the oil associated with the current making and breaking contacts of the tap change equipment. There shall be no communication between the two compartments in respect of the oil and air spaces. Each compartment shall be provided with the fittings detailed in this clause as if it were a separate conservator vessel.

For transformers rated above 20 MVA, each conservator shall include a synthetic diaphragm (or equivalent, e.g. an airbag) ensuring an airtight seal between the transformer oil and the external air. A description of the proposed system shall be submitted with Tender. Additionally, the air outlet from each conservator vessel or its compartment shall be connected to a dehumidifying breather mounted at approximately 1.4 m above the ground level.

Where silica gel type breathers are used, they shall be of adequate capacity and of the maintenance-free type, with integrated heater, capable of automatic recharge. Breathes shall be fitted with oil traps and contain a minimum of 2.5 kg of silica gel. Breather compartments and oil cup shall be made of glass. The breather and associated pipework shall be firmly fixed to the transformer tank.

As an alternative to the air-bag/diaphragm method, an automatic repetitive cycle type breather may be offered. (Note: A diaphragm restricts the operation of this class of breather and consequently, the diaphragm requirement is deleted when an automatic repetitive cycle type breather is specified.)

Each conservator compartment shall be equipped with filling valve, drain valve, lifting lugs, etc. An oil level gauge complete with low-level alarm shall be fitted to each conservator. The indicated minimum oil level shall occur when the feed pipe to the main tank is covered with not less than 12 mm depth of oil. The oil levels at 15°C, 35°C and 90°C shall be marked on the gauge.

The front cover of all gauges shall be made of glass.

15.10. Transformer Oil

The transformer oil shall comply with IEC 60296 and other relevant IEC standards if not otherwise stated in this Tender Documents. The oil shall be a highly refined mineral oil suitable for use as an insulating and cooling medium in transformers. On the existing KETRACO system, Shell Diala S4 ZX-I oil has been used. To avoid possible difficulties and eliminate the risk of incompatibility, mixing of different oils (brand or type) in the same equipment is not permitted.

Transformer Oil should comply as minimum to the applicable requirements of the following IEC Standards :

- IEC 60296 Specification for unused mineral insulating oils for transformers and switchgear
- IEC 60567 Guide for sampling of gases and oil from oil-filled electrical equipment and for the analysis of free and dissolved gases
- IEC 61181 Mineral oil-filled electrical equipment - Application of dissolved gas analysis (DGA) to factory tests on electrical equipment
- IEC 62535 Insulating liquids - Test method for detection of potentially corrosive sulphur in used and unused insulating oil

The oil type shall be of uninhibited and purely naphthenic base crude with no PCB content (Polychlorinated biphenyls). This should reflect on the name plate of the equipment. Bidders shall declare the brand and grade of oil to be supplied and guarantee the minimum and maximum guarantee of aromatic, paraffinic and naphthenic content with no PCB content. To avoid possible difficulties and eliminate the risk of incompatibility, mixing of different oils (brand or type) in the same equipment is not permitted.

The insulating oil shall conform to properties complying with IEC 60296 - class II and DIN 51554 with regard to Baader test values (subject for approval) and all specified below, while tested at the Supplier's premises. No inhibitors shall be used in oil. Prior to dispatch of oil from refinery to site the Supplier shall furnish test certificates from the oil Supplier, in compliance to the requirements mentioned below. Oil shall be delivered in the separate barrels.

Sufficient new oil for complete filling at site to the recommended level shall be furnished with each equipment. Additional five percent (5%) of the total oil in the autotransformer (transformer) shall be delivered, and its value should be included in the price of autotransformer (transformer).

These subjects should take account:

- a) Accuracy class according to ISO4406 up to 750 kV (inclusive) - / 14/12.
- b) Density at 20 °C, kg / m³ to be not more than 900.

- c) The sulfur content shall not exceed 0.3%.
- d) The test certificate shall show the following content, for oil inside main tank during test:
- e) Break Down Voltage (BDV)
- f) moisture content

15.11. Cooling Plant

Transformers rated up to and including 10 MVA shall be ONAN cooled. For ratings above 10 MVA but below 20 MVA, there is an option of ONAN (only) or ONAN/ONAF. The choice of cooling in this range shall be made on an assessment of the economic considerations, unless otherwise specified in the schedules.

Two-stage cooling (ONAN/ONAF1/ONAF2) shall be used for transformers rated 100 MVA and higher and facilities shall be provided at the marshalling kiosk or cubicle for the selection of AUTOMATIC or MANUAL control of the cooling plant motors. The power transformer of this project shall employ ONAN/ONAF1/ONAF2 cooling

Radiators and coolers shall be hot dip galvanized, before painting; their design shall be such as to allow ease of cleaning and painting when in position. Design features offering reduced maintenance requirements such as unpainted radiators (i.e. galvanised only) may be acceptable if there is no visual impact and if the manufacturer can demonstrate long-term and trouble-free experience with this finish in similar environments. If the manufacturer wishes to offer unpainted radiators for consideration, it must be stated clearly in the tender documents.

Detachable radiators and separate cooler assemblies connected to the main tank shall be provided with machined flanged inlet and outlet pipes.

A minimum of two cooler banks shall be provided for all transformers having ratings of 30 MVA and above. Where forced oil cooling is employed, two 100% rated pumps shall be supplied with one as standby, to be automatically operated in the event of failure of the other.

Plugs shall be fitted at the top and bottom of each radiator for filling and draining.

Starting or stopping of the forced-oil circulation pumps shall not cause mal-operation of the gas and oil actuated relays. The oil circuit of all coolers shall be provided with the following as appropriate to tank mounted or separate bank coolers: -

- a. A valve at each point of connection to the transformer tank.
- b. A valve in the main oil connection at the bottom of each cooler.
- c. Loose blanking plates to permit the blanking off of the main oil connection to the top of each cooler.

- d. A 50 mm oil-filtering valve at the top and bottom of each cooler, the bottom valve shall also function as a drain valve.
- e. A thermometer pocket fitted with a captive screwed cap on the inlet and outlet oil branches of each cooler.
- f. Visual oil flow indicators in the pipework adjacent to the coolers. In the event that this will offer impedance to oil flow under ONAN conditions a differential pressure gauge of approved design and manufacture may be connected across the pumps, as an alternative.

The material of the tube plates and tubes shall be such that corrosion shall not take place due to galvanic action.

Where separately mounted cooling equipment is provided a flexible piece shall be included in each oil pipe connection between the transformer and the oil coolers. Drain plugs shall be provided in order that each section of pipework can be drained independently.

Complete set of loose blanking plates to suit the blanking of radiator and cooler connections to the main transformer tank shall be supplied complete with gaskets and delivered to KETRACO stores.

All flange joints that are separated from the main transformer tank by gaskets shall be connected thereto via adequately rated copper earthing connections. Connecting bolts shall not serve the purpose of earth continuity.

Each forced oil cooler shall be provided with a fully weatherproof motor driven oil pump. The motor shall be of the submersible type. It shall be possible to remove the pump and motor from the oil circuit without having to lower the level of the oil in the transformer or coolers.

Where forced air-cooling is provided it shall be possible to remove the fan, complete with its motor and supporting structure without disturbing or dismantling the cooler framework or pipework. The fans shall not be mounted directly on the radiator fins or radiators itself. Fans shall be numbered and have clearly marked direction of rotation.

Stainless steel wire mesh guards shall be provided to prevent accidental contact with the fan blades. Metal guards shall also be provided over all other moving parts. The guards shall be designed so that neither the blades nor other moving parts can be touched by a Standard Test Finger to IEC 60947-1.

Control of cooling shall be provided at the marshalling kiosk or cubicle with facilities for the selection of automatic or manual control of the cooling plant motors and remote indication/alarms.

15.12. Cooler Control

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

Where forced cooling is used on transformers, provision shall be included under this contract for automatic starting and stopping from contacts on the winding temperature indicating devices. The control equipment shall

be provided with a short time delay device to prevent the starting of more than one motor, or group of motors in the case of multiple cooling, at a time.

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

The control arrangements are to be designed to prevent the starting of motors totalling more than 15 kW simultaneously either manually or automatically. Phase failure relays are to be provided in the main cooler supply circuit.

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

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

Two independent sources of power shall be made available to ensure loss of cooling capacity for a single contingency is not greater than 50 per cent.

15.13. Voltage Control (OLTC)

Unless otherwise specified, transformers with an HV U_m equal to 36 kV or higher shall be equipped with an on-load tap-changer (OLTC) on the high voltage winding. The on-load tap-changer shall comply with the requirements of IEC 60214 and other relevant IEC standards if not otherwise specified in these Specifications. It shall be possible for the power to flow in both directions.

Generally, transformers rated at U_m equal to 12 kV will be equipped with an off-load (DETCT) tap-changer with a range of plus/minus 5% in four steps (five positions).

The OLTC shall be based on the Jansen principles and shall feature low-maintenance characteristics, preferably with belt-type (oil-free) transmission gear. Leading European or Japanese manufacturers of international standing shall provide the OLTC; units from recent licensees are not acceptable.

The diverter switch unit shall be placed in a separate gas tight compartment, which shall be, like the whole tap-changer, integrated in the transformer tank (in-tank mounting). The diverter switch shall have an oil system completely separated from other transformer's oil and shall be equipped with a conservator, pressure relief device with alarm/trip contacts and other devices stated for the main tank. A separate gas actuated relay is to be provided in the connection between the on-load tap-changer tank and conservator.

Note: Diverter switches with vacuum type interrupters are also acceptable.

The diverter switch compartment shall be easily accessible for inspection and it shall be possible to remove the diverter switch without difficulties for maintenance purposes. The inspection and maintenance of the diverter switch shall be possible without lowering the oil level in the main tank. One set of each type of lifting tackle shall be supplied to facilitate removal of the tap-changer unit. Necessary attachment facilities shall be incorporated in the main tank design.

Any enclosed compartment not oil-filled shall be adequately ventilated and designed to prevent the ingress of vermin. All contactors, relay coils or other parts shall be suitably protected against corrosion or deterioration due to condensation.

Means shall be provided to ensure that the operating mechanism can be locked only when the switches are making full contact.

The driving motor shall be rated for 415/240 V a.c. and shall be equipped with thermal overload and overcurrent protection to be installed in the motor drive cubicle. Control voltage inside the motor drive cubicle shall be from the station control supply of 110V. D.C. Limit switches shall be provided to prevent the tap-changer mechanism overrunning. These shall be directly connected to the operating motor circuit. In addition, mechanical stops shall be fitted to prevent the mechanism overrunning under any conditions. For on-load tap-changer equipment these stops shall withstand the full torque of the driving mechanism without damage to the tap changing equipment. The terminals of the operating motor shall be clearly and permanently inscribed with numbers corresponding to those on the leads attached thereto.

A device shall be fitted to the tap changing mechanism to indicate the number of operations completed by the equipment.

The tap-changer shall be arranged for local hand and electrical operation, remote electrical operation and for automatic control.

Equipment for local and remote electrical and local hand operation shall comply with the following conditions:

- It shall not be possible to operate the electric drive when the hand operating gear is in use;
- It shall not be possible for any two electrical control points to be in operation at the same time;
- Each step movement shall require separate initiation at the control point;
- All electrical control switches and the local operation gear shall be clearly labelled in an approved manner to indicate the direction of tap changing;
- The remote or supervisory-remote raise/lower control shall be blocked when the AVC selector is in "automatic" position;
- The local control switches shall be housed in the marshalling kiosk. These switches shall be so arranged that it is necessary for the AVC selector to be in a non-automatic position and the "local/remote" selector switch, located in the transformer marshalling kiosk, to be in the "local": position before operation is possible. Under these conditions the local selector switch shall have overriding control. If the "local/remote" switch is not in "local" position, then local operation of tap-changer shall not be possible.

The equipment shall be arranged so as to ensure that when a step movement has been commenced it shall be completed independently of the operation of the control relays or switches or failure of auxiliary supply or any other contingency.

The control and signalling equipment shall be provided:

- To give an indication mechanically at the transformer and electrically at the remote control point of the tapping in use. The indicator at the transformer shall show the number of tapping in use and the indicator at the remote control point shall show clearly the actual voltage ratio in kilovolts and the tap number representing this ratio. The numbers shall range from 1 upwards. Position 1 shall refer to the maximum LV no-load voltage and the highest number position shall refer to the minimum LV no-load voltage, for the nominal HV voltage.
- To give an indication at the remote control point that a tap change is in progress by means of an illuminated lamp and alarm buzzer. If the tap change is not completed within the specified time the buzzer shall continue to sound until switched off by hand but the lamp shall remain illuminated until the tap change is completed.
- To give an indication at the remote control point by means of an approved illuminated indicator and the buzzer alarm as described above when the units of a group of transformers arranged to operate in parallel are operating at different ratios.
- To read with digital circuit voltmeter based on L.C.D. displays.

An automatic voltage control relay and all other associated equipment shall be provided for each transformer with on-load tap-changer. The relay shall be responsive to variation in the measured voltage and cause the necessary tap change to be made to restore the voltage to the desired level within pre-determined limits.

The automatic voltage control relay shall be suitable to work in automatic independent control mode, where the tap-changer is controlled irrespectively of the method of control selected for the other associated transformer, and automatic parallel control mode, where in a group of parallel working transformers it shall be possible to select any transformer for master control.

During a master/follower tap change operation, tap changing shall be sequential of slightly time staggered to ensure that at any time only one transformer is changing tap.

The reference voltage shall be taken from voltage transformers on the low voltage side of the power transformer.

The relay setting voltage, expressed as a percentage of the relay nominal voltage, shall be adjustable over a range of not less than ± 10 per cent of nominal.

The relay sensitivity shall be adjustable and shall suit the chosen tap change step.

On-load tap change transformers provided with fully automatic control and required to operate in parallel as a group shall be provided with the means to ensure proportionate sharing of watts and VARs.

All transformers operating in a group shall be on the same tap. Operation with a tap difference between transformers in a group shall be automatically prevented by an "out-of-step" device and an "out-of-step" alarm

signal shall be transmitted to control point(s) after an agreed time interval. The tap change scheme shall be arranged so that the maximum difference between the transformers during a tap changing sequence is one tap.

For transformers which differ significantly from each other, in electrical characteristics and/or when they have substantial loads of differing types, it may be necessary to operate with more than one tap position difference in order to improve sharing between transformers. In such cases schemes based on voltage/current compounding to achieve the desired objectives shall be provided. Alternatively, a programmable control equipment (microprocessor) shall be provided.

The load compensation shall be provided.

All equipment shall be suitable for operation within the limits 85 per cent/110 per cent of the auxiliary voltage supply. In the event of the reference supply voltage being outside the specified operating limits the voltage control relay shall initiate an alarm and block further operation of the tap-changer until voltage is restored.

AVC relay shall be suitable for supervisory-remote adjustment of a setting voltage (set point control).

Requirements for supplementary adjustment of the voltage setting for operational reasons, (other than load shedding), will not exceed 5 steps nor an effective setting change of 10 per cent.

15.14. Terminations

Alternative termination arrangements are possible for the HV, LV and TV connections. The appropriate terminations for a particular project shall be identified in the Technical Data Sheets which accompany this specification.

Unless otherwise specified the termination will be brown-glazed outdoor bushings with IEC Class IV (31 mm/kV) creepage distance which shall include the diameter correction factor (k_D) appropriate to the insulator diameter.

The following termination options with their appropriate codes are possible:

- AIS = Transformer to Air bushing = Standard arrangement
- GIB = Connection to GIS or cable via Gas Insulated Busduct
- CSC = Separable cable connector with oil filled box on transformer
- CSE = Cable termination in oil-filled cable-sealing end chamber
- CAF = Air-filled cable box

15.15. Neutral and Tertiary Connections

Unless otherwise specified, Neutral terminations shall be via outdoor bushings grounded via an insulated copper connection secured to the transformer tank

Where tertiary stabilising winding connections are brought out, they shall be via outdoor bushings in accordance with the requirements given earlier and grounded to the tank via a removable link (or links). A reduced creepage distance for bushings, which are grounded in service, is acceptable but the specific creepage distance should be at least 25 mm/kV.

When tertiary bushings are required to provide an auxiliary supply or for the provision of reactive compensation, they shall retain the full project specific creepage distance of 31 mm/kV.

15.16. Protection, Measuring and Indicating Devices

The power transformers shall be equipped with a range of protection, measuring and indicating devices supplied by the transformer manufacturer, to include:

- Buchholz relay shall be fitted to transformer main tank, and on each compartment where oil is separated from the other oil in the transformer.
- Diverter switch chamber shall be equipped with an oil surge actuated relay.

They shall have:

- Alarm contacts which close when gas collects or at low oil level;
- Redundant tripping contacts which close following an oil surge, and gas collection in the 2nd stage.
- The normally open, electrically separate, alarm and tripping contacts shall not be exposed to oil.
- Pressure relief device should have indication and signal pin.
- Each relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay from ground level.

Winding temperature indicators shall be associated with one phase only and shall be provided for each winding.

One indicator shall basically serve as a thermometer for winding temperature, mounted in the control cubicle. It shall be of conventional construction with a sensing bulb positioned in a separate pocket, arranged in the top oil capillary connected with a dial. A separate pointer to register the maximum temperature reached shall be incorporated in the dial. Two adjustable trip/alarm contacts shall be provided.

The second winding temperature indicator shall be preferably of electronic simulated design with adjustable contacts for cooling control, trip and alarm and with mA output suitable for remote and supervisory measuring of winding temperature. It shall be connected to a resistance (platinum 100 W at 0°C) inside a stainless steel tube placed in a pocket located in the top oil capillary.

The characteristics of the winding temperature indication devices shall be forwarded to KETRACO for approval prior to the delivery of the transformers and shall also be included in the operating and maintenance instructions.

- A dial type oil thermometer with two (alarm/trip) adjustable contacts shall be mounted in the control cubicle. It shall be of conventional construction with a sensing bulb positioned in a separate pocket arranged in the top oil capillary and connected with a dial.
- An oil thermometer, connected to a resistance (platinum 100 W at 0°C) inside a stainless steel tube placed in a pocket located in the oil, suitable for remote and supervisory measuring.

All indicating instruments shall have hard glass front covers.

15.17. Topping Up with Oil and Drying Out on Site

If oil is to be added to a transformer at site prior to commissioning, the oil in the transformer shall first be tested for dielectric strength and water content and each container of additional oil shall be similarly tested. All tests shall be witnessed by KETRACO.

Should it be found necessary to resort to oil treatment before a transformer is commissioned, the Contractor shall submit to KETRACO, in writing, a full description of the process to be adopted, the equipment to be used and statement of the precautions being taken to prevent fire or explosion. Similarly, if a transformer should arrive on site without positive pressure of gas in the tank, it shall be dried out at Site at the Contractor's expense using a heating and vacuum process, which has been approved by KETRACO. Insulation resistance values shall be taken throughout the drying process to indicate clearly the point of full moisture removal.

Clear instructions, in English shall be included in the Maintenance Instructions regarding any special precautionary measures, which must be taken before vacuum treatment can be carried out. Any special equipment necessary to enable the transformer to withstand vacuum treatment shall be provided for each type of transformer. The maximum vacuum which the complete transformer, filled with oil, can safely withstand without any special precautionary measures being taken shall be stated in the Maintenance Instructions.

15.17.1. Control Cubicles

Each transformer shall be fitted with a control cubicle of welded galvanized sheet steel housing, mounted on the transformer tank, in a position easily accessible from the ground level. The cabinet shall contain all control and protective equipment for the cooling system, as well as the termination of all secondary circuits.

The internal arrangement of the cabinet shall keep the various circuits clearly separate from each other, permitting easy and safe independent maintenance and repair of each of them without disturbing the others.

Additionally, for the power transformers, tap-changer cubicle for local control shall be provided as required in previous clauses.

All control cubicles shall be of IP 65 degree of protection, weather, vermin and insect-proof with sufficient ventilation and equipped with humidity controlled heating and sufficient illumination switched on and off by door contacts as well as one socket outlet 240V a.c, 16 A. Separate sunshades shall be provided for each cubicle. Wherever applicable, window panels shall be fitted with laminated glass only.

15.17.2. Corrosion Protection and Painting

The corrosion protection and painting shall meet requirements as stated elsewhere in the tender documents.

Conservator vessel^(note 1), radiators, fan grills^(note 2), pipework, control boxes or cubicles, marshalling cubicles shall be hot-dip galvanized and painted.

Note 1: Where these are too large to galvanise, the same corrosion protection treatment as the tank shall be used.

Note 2: Not applicable to stainless steel grills.

The proposed method for tank corrosion protection manufacturer shall submit for approval.

External surfaces shall be treated with anticorrosive and water-resistant paint and internal surfaces with oil-resistant anti condensation paint.

In any case the manufacturer shall submit for approval the proposed painting coats with their chemical content and recommended application guide of the manufacturer.

The equipment must be so designed that any features that may encourage the formation of rust, are avoided.

15.18. Fire Protection

The manufacturer shall include in his offer a suitable fire protection for Main Transformers (equal to and above 100 MVA), using Nitrogen Injection and Oil Evacuation System (NIFPS) as per KETRACO, KEBS, IEEE 979, NFPA 850 requirements, Detailed requirements have been mentioned in clause No. 18.25.6.

Nitrogen Injection and Oil Evacuation System shall be designed, installed and tested in accordance with NFPA/IEC, consisting of:

- Fire Extinguishing Cubicle (FEC),
- Control box,
- Fire detectors
- Signal box,
- Transformer Conservator Isolation Valve (TCIV) and oil drain pipe suitable for transformer oil quantity,
- Electrical Resistance Welded pipes with support & fitting as per standard norms for connection between transformer & FEC,
- Electrical resistance welded Gas Injection pipes & fittings as per standard norms for oil connection between FEC and oil pit,
- Fire survival cables and Fire Retardant Low Smoke (FRLS) Armored Cables,
- Erection, testing, commissioning (including all civil (Plinth of FEC & Oil Pit), structural work, electrical, mechanical, instrumentation jobs) of Nitrogen Injection Fire Protection systems cubicle.

Complete systems, complying to the relevant NFPA standards, shall be provided with all components required for smooth automatic operation.

Manual release by means of release valves in break glass boxes must also be possible.

Such break glass boxes shall also be provided next to each individual transformer.

All pipe work shall be made of seamless steel and hot-dip galvanised. The threaded ends of galvanised pipes shall, after installation, be properly protected against corrosion and painted with red paint, RAL 3000.

Drains and vents shall be provided as required.

Adequate drainage for the area to be protected shall be arranged for safe disposal of escaping flammable liquids and to prevent the spread of fire.

Fire department connections shall be provided as required by NFPA.

Hydraulic calculations shall be provided.

The transformers shall be protected by fire barrier walls as described in the civil works section clause 17.22.11.

15.19. Online Condition Monitoring

For all transformers rated 100 MVA and above, the manufacturer shall include in the offer a modern Transformer Monitoring System with the following minimum features:

DGA detection– It shall be suitable for five fault gases . The sensor shall use the principle of gas chromatography. The transformer DG unit must extract transformer oil from the transformer through suitable pump, and return the oil back into the transformer as needed. It shall have the feature of periodic self-calibration for accuracy of measurement.

Moisture in Oil sensor; bidder shall offer composite unit for dissolved gas and moisture in oil

- A remote temperature device for measurement of top-oil temperature & winding temperature.
- Load current measurement via a current transformer on HV side or LV side

OLTC monitoring unit-Tap Changer monitoring system shall be able to communicate with the central OLCM system

The system shall be equipped with a modem and Ethernet outputs for connection to the substation communication system.

Further details are specified in the Technical Data Sheets.

Noise Limits

The equipment shall be designed and constructed in a way that harmful vibrations are eliminated and the minimum noise occurs at any operating conditions

15.20. Transformer Inspection and Testing**15.20.1. General**

All tests shall be performed in accordance with IEC 60076, IEC 60060, IEC 60270 and other relevant IEC Standards.

15.20.2. Factory Tests

Routine and Type tests shall be generally in accordance with the requirements of IEC 60076-1, -2, -3, -4, -5 and -10 appropriate to the voltage class of the transformer under consideration. Additionally, some tests in the class identified as 'Special' in IEC 60076 are included, which may in practice be effectively a Routine or Type Test, as appropriate. These are included in Clause 17.6.5

The following list of tests is generally in accordance with the requirements for Large and Medium classes of transformers; further data will be included in the Technical Schedules.

15.20.3. Routine Tests

Tests which include partial discharge measurements shall be made after the principal dielectric withstand tests and after temperature rise type tests.

The following routine tests shall be performed:

1. Measurement of winding resistances of all phases (phase to neutral, where applicable) and at all tap positions
2. Measurement of voltage ratio and check of voltage vector relationship
3. Measurement of impedance voltage (principal tapping) short-circuit impedance and load loss.
4. Dissolved gas-in-oil analysis by chromatography prior to dielectric tests and after completion of dielectric tests
5. Measurement of no-load losses and no-load current at rated frequency and nominal voltage.
6. Lightning impulse (LI) withstand test: Transformers with HV $U_m > 72.5$ kV.
7. Switching Impulse (SI) withstand test: Transformers with HV $U_m \geq 245$ kV
8. Induced-voltage test with partial discharge measurement.

- a. Long Duration AC (ACLD): $U_m \geq 245\text{kV}$

The test steps U_1 (withstand level) and U_2 (PD measurement level) will be at the enhanced values of $1.8 U_m$ and $1.6 U_m$ respectively. The test sequence and PD limits shall be as given in IEC 60076-3. The phase to ground test values for transformers with HV windings rated at 220 kV and 400 kV are given in the following table.

HV U_r (kV)	HV U_m (kV)	U_1 (kV)	U_2 (kV)	PD test duration (minutes)	Max PD (pC)
220	245	255	226	30	500
400	420	436	388	60	500

- b. Short Duration AC (ACSD): $U_m \leq 170\text{kV}$
9. Separate source voltage test.
10. Tests on on-load tap-changers.
11. Oil test and function tests of auxiliary equipment.
12. Measurement of insulation of core.

15.20.4. Type Tests

The following type tests shall be performed:

- Temperature Rise Test
These tests shall be carried out with the transformer at tap positions giving highest losses and with the standby cooling unit out of service.
- Dissolved gas-in-oil analyses by chromatography prior to and after the temperature rise test
- Lightning Impulse (LI) test ($U_m \leq 72.5\text{kV}$)
These tests shall be carried out in accordance with IEC Recommendations on the HV and LV line terminals and on the neutral terminals. Tap-changers shall be in the position of minimum, principal and maximum tap as each phase is tested in turn (A-B-C).
- Switching impulse (SI) tests are applicable as a Routine Tests on transformers having an HV $U_m \geq 245\text{kV}$. There is currently no requirement to apply this test as a Type Test at $U_m < 245\text{kV}$.

5. Short-circuit: In-lieu evidence from demonstrably similar units and/or mechanical and thermal calculations shall be provided to demonstrate clear margins of short-circuit current withstand at system fault levels for all transformers. All tests and calculations shall be fully in accordance with IEC 60076-5.

15.20.5. Special Tests

The following 'special' category tests shall be performed as indicated:

1. Dielectric tests in accordance with IEC 60076-3; tests appropriate to the HV side transformer voltage class are identified under Routine and Type Tests and in the schedules. In terms of the system voltages, the applicable special dielectric tests are:
 - a. Chopped wave lightning impulse. This test is a requirement at all system voltages on line terminals and shall be at 110% of the full wave impulse level. (Type or routine test as appropriate to transformer HV U_m .)
 - b. $U_m = 145$ kV: The long duration AC (ACLD) is a special optional test at this voltage, in the manner of a routine test, i.e. on all transformers when specified. Unless otherwise specified, this will not be required on KETRACO contracts
 - c. $U_m = 245$ kV: The short duration AC (ACSD) is a special option at this voltage, in the manner of a routine test, i.e. on all transformers. (Note: In accordance with IEC 60076-3, if the ACSD is specified the requirement for a routine switching impulse test is deleted.)
 - d. $U_m > 245$ kV: The ACSD test may be included as special option as an additional routine test. Unless otherwise specified, this will not be required on KETRACO contracts
2. Measurement of zero-sequence impedance: Routine test for all transformers with U_m equal to or greater than 12 kV.
3. Determination of sound levels to IEC 60076-10: Type test for all transformers with U_m equal or greater than 12 kV.
4. Measurement of the harmonics of the no-load current: Routine test for all transformers with U_m equal to or greater than 36 kV.
6. Measurement of the power by the fan motors and oil pumps (Power Transformers): Type test.
7. Determination of capacitance, windings to earth and between windings: Routine test for all transformers with U_m equal to or greater than 36 kV.
8. Measurement of insulation resistance to earth and loss angle of insulation system capacitances: Routine test for all transformers with U_m equal to or greater than 36 kV.

15.20.6. Site Tests

The following tests, after installation on Site shall be performed:

1. Verification of correct and complete erection.
2. Verification of the soundness of porcelain surfaces and sealing.
3. Verification of correct connections to the earthing system.
4. Checking of auxiliary and control wiring and cabling and operation of all electrical LV equipment.
5. Voltage tests of all electrical LV circuits.
6. Verification of the operation of the cooling system.
7. Measurement of the physical, chemical, and electrical characteristics of the oil after filling and shortly prior to transformer energization.
8. Verification of turns ratio with measurement of charging current using an L.V. supply:
9. Resistance measurements of windings with records of oil & ambient temperatures.
10. Insulation resistance tests.
11. Frequency response analysis (FRA-test) with a DOBLE-SFRA device (or equivalent) using swapped frequency in a range of 10 Hz to 2 MHz. The measurements shall be taken with tap changer at tap position "1".
12. Oil tightness test on tank assembled with radiator 0.3 bar over oil level, 24 hrs (on oil-filled cable termination boxes at 0.2 bar, 5hrs.
13. Measurement of Winding Insulation Resistance (R15s, R60s, R180s, R600s). The absorption ratio R60/R15 shall not exceed 3.0 (R10/R1 shall not exceed 1.1 according to American Standards) after oil-treatment. Results shall be compared with the factory test results.

and other necessary checks and verifications.

15.20.7. Tests on Transformer Components

Tests during and after manufacture shall be carried out on the transformer components in order to verify compliance with the Specifications, good workmanship and their capability to perform the required duties when in service.

Unless otherwise specifically mentioned these tests shall be made in accordance with the one of the applicable international standards, subject to the approval of KETRACO, or according to a method proposed by the Contractor and approved by KETRACO.

15.20.8. Transformer Tanks

15.20.8.1. Type Tests

Vacuum:

One transformer tank, tap changing compartment, radiator and cooler of each size shall be subjected when empty of oil to the vacuum test level specified in the Schedules. There shall be no permanent deflection of the stiffeners, nor shall the permanent deflection of the panels exceed the value specified in the following table:

Major dimension of panel between Stiffeners meters vertical or horizontal	Maximum permanent deflection
Up to 1.5 m	3 mm
1.5 m – 3.0 m	8 mm
Above 3.0 m	13 mm

A further test at a vacuum equivalent to 3 m bar absolute pressure for a period of 8 hours shall be made for the purpose of checking the mechanical withstand capability of the tank; during this test no damage or fractures shall occur. This test is only applicable to units of 220kV and above and may be combined with other tests or made during the processing of the unit.

Pressure:

One transformer tank of each size shall be subjected to a pressure corresponding to the normal pressure plus 35 kN/m². After the release of the excess pressure there shall be no permanent deflection of the stiffeners nor shall the permanent deflection of panels between stiffeners exceed the value specified in the above table. This test may be combined with a routine oil leakage test.

The tap changer barrier shall be shown to withstand an over pressure test of normal pressure plus 35 kN/m² for 12 hours.

Pressure Relief Device:

When required by KETRACO one pressure relief device of each size shall be subjected to increasing oil pressure and shall operate before reaching normal pressure plus 35 kN/m².

The operating pressure shall be recorded on the test certificate.

15.20.8.2. Routine Tests

Oil leakage - All tanks and oil filled compartments including all forms of radiator shall be tested for oil tightness by being completely filled with oil of a viscosity not greater than that of IEC 60296 insulating oil at a temperature

of 150°C and subjected to a pressure equal to the normal pressure plus 35 kN/m². This pressure shall be maintained for a period of not less than 24 hours, during which time no leakage shall occur.

The tap changer barrier shall be subjected to normal oil pressure head for 24 hours, during which time there shall be no leakage from the panel or bushings.

Detachable radiators may be tested as separate units.

15.20.9. Fans, Motors, Pipework, Oil Sampling Devices and Valves

15.20.9.1. Type Tests

Motors - Performance tests shall be in accordance with IEC 60034-1 however, certificates of type tests in accordance with IEC will be accepted.

Except for non-return valves, all valves and oil sampling devices which are subject to oil pressure in service or during maintenance shall withstand, when empty of oil, absolute pressure not exceeding 350 m bars. In the case of valves this test is to be applied to the body only. This type test shall subsequently be followed by a repeat oil leakage test.

15.20.9.2. Routine Tests

Oil filled equipment - The bodies of all oil pumps complete with submerged motors, if any, and the oil pipework, oil sampling devices and valves shall withstand an hydraulic pressure of 140 kN/m² for 15 minutes.

Fans - Static and dynamic balance shall be checked on all fan impellers.

Control gear - All control gear shall be subjected to the tests specified in the appropriate IEC.

Motors - Each machine shall be subjected to the following tests where applicable:

1. Measurement of winding resistance (cold).
2. No load test at rated voltage for determination of fixed losses.
3. An overvoltage test at 1.5 times rated voltage applied with the machine running at no load, for a period of 3 minutes, to test interturn insulation.
4. High voltage in accordance with IEC 60034-1.

15.20.10. Oil

15.20.10.1. Sample Tests

Samples of oil from each consignment shall be tested in accordance with IEC 60296 before despatch.

Subject to the agreement of KETRACO a test certificate, confirming that the oil from which the consignment was drawn has been tested in accordance with IEC 60296, may be accepted. Before commissioning any transformer, the electric strength of its oil shall be check-tested and the results approved by KETRACO.

15.20.11. Gas and Oil Actuated Relays

15.20.11.1. Routine Tests

The following tests shall be made on relays when completely assembled. Where oil is referred to, it shall have a viscosity not greater than that of IEC 60296 insulating oil at 150°C.

Oil leakage - The relay, when filled with oil shall be subjected to an internal pressure of 140 kN/m² for 15 minutes. No leakage shall occur either from the casing or into normally oil free spaces, such as floats, within the casing.

Gas Collection:

1. With the relay mounted as in service and at a rising angle of 5 degrees (tank to conservator) and full of oil, gas shall be introduced into the relay until the gas collection contacts close. The oil level contacts shall not close when gas is escaping freely from the relay on the conservator side. These contacts shall, however, close when the pipework is empty of oil.
2. The empty relay shall be tilted, as if mounted in pipework rising from tank to conservator, at an increasing angle until the gas collection contacts open. The angle of tilt shall then be reduced and the gas collection contacts shall close before the angle is reduced to less than 13 degrees to the horizontal.
3. With the relay mounted at a falling angle of 16 degrees to the horizontal and full of oil, the gas collection contacts shall be open.

Oil surge - with the relay mounted as in service and full of oil at approximately 150°C, the surge contacts shall close within the steady oil flow limits specified in the Schedules. This operation shall not be adversely affected when the gas collection contacts have already closed and gas is escaping freely.

Voltage - with the relay empty of oil, a voltage of 2kV shall be applied in turn between each of the electrical circuits and the casing for one minute, the remaining circuits being connected to the casing.

15.20.11.2. Sample Test

At the discretion of KETRACO, the following tests shall be made:

Variation of performance with mounting angle with the mounting conditions as in service, the mounting angle shall be varied within the rising angle limit 10 and 90 and tests repeated in the manner prescribed for the routine tests.

15.20.12. Voltage Control Equipment

Type and routine tests shall be carried out in accordance with IEC 60214.

15.20.12.1. Tests on Bushings

It is not intended to test the bushings separately during the transformer factory tests.

All bushings supplied including spares, shall be supplied with full documentation in accordance with IEC 60137 and/or IEC 61639, plus additional items as follows:

1. Routine test certificates. All condenser-graded bushings shall have a routine lightning impulse withstand test of five full wave negative impulses at a level not less than the transformer rating.
2. Type test reports, which shall include confirmation of creepage distance and pollution tests. The lightning impulse type test shall include chopped impulses and is applicable to all condenser-graded bushings.
3. Bushing temperature rises shall be based on local ambient temperatures.
4. Installation and maintenance instructions

15.20.12.2. Structures

A representative sample of each type of support structure being provided shall be assembled prior to despatch to site, and loads applied which simulate the specified design parameters.

15.20.12.3. Galvanizing

Samples selected by KETRACO of all galvanized material shall be subjected to the galvanizing tests set out in BS EN 10244-2 (Testing of Zinc Coating on Galvanized Wires) or BS EN ISO 1461 (Testing of Zinc Coating on Galvanized Articles other than Wire) whichever is applicable.

15.20.13. Handling Devices and Lifting Tackle

15.20.13.1. Routine Tests

Mechanical Tests:

All handling devices and lifting tackle supplied for maintenance purposes under this Contract shall, unless they are built into and form part of the equipment, be tested and marked and certificates of the test provided in the manner required by the appropriate regulations.

Operational Tests:

Lifting tackle built into and forming part of the equipment shall be operated with the maximum working load to the IEC or BS Specifications.

15.20.14. Dielectric Tests on Auxiliary and Control Circuits

All secondary wiring, including panel wiring and control circuits and all apparatus connected directly thereto shall withstand a high voltage test of 2000V to earth unless otherwise specified.

15.21. Installation/Dismantling Requirements

The transformer shall be designed for outdoor installation;

Arrangements are to be provided for the hauling of transformers.

15.22. Packing, Shipping and Transport

If the transformer is to be transported with oil it shall be filled to such a level as to cover the windings completely.

If the transformers are to be shipped without oil, the tank shall be filled with dry nitrogen gas, and automatic pressure regulating equipment shall be provided to maintain the pressure of the gas. Transformers to be transported with gas shall be filled and maintained by the Contractor at a pressure in excess of atmospheric pressure until the gas is replaced by oil. The gas pressure before despatch and upon receipt on site shall be recorded. Means shall be provided for measuring the pressure in the tank.

Where oil for the first filling is to be provided it shall be supplied by the manufacturer in non-returnable drums.

All openings for transformer components, e.g. bushings which have been removed from the transformers during transport, shall be covered by blanking-off plates. Condenser type bushings shall be shipped with self-contained oil filled tanks. Transformers shall be equipped with instruments to register "Shock" loading suffered during transit.

Transformers shall be equipped with Impact recorders (to record acceleration values of vibration and shock) of KETRACO approved type.

Manufacturer shall advice for the acceptable "shock" limit criteria prior to transformers shipment.

Impact recorders (impact recorders with electronic data storage), capable of indicating all horizontal and vertical impacts, shall be rigidly attached to each transformer.

Provisions must be made to ensure that these indicators are sealed, that they will be completely functional without interruption of indicated records during the entire period of shipment, including loading and unloading, and to ensure that KETRACO will receive clearly indicated data by breaking the seal. Instructions for interpretation of the recorded data and a user manual for the equipment shall be provided prior to shipment.

All parts shall be carefully packed for transport in such a manner that they are protected against mechanical injury and the injurious effects of water and climatic conditions encountered during transit to their destination, as well as during long storage before erection.

Manufacturers should give special consideration to five-limb transformers, which may require temporary support of the unwound limbs during transport.

The Contractor shall prepare and submit for the approval of KETRACO drawings and complete instructions about the means and methods to be used for the installing and removing of heavy equipment such as transformers.

15.23. Documentation with Bid

The Bid shall contain at least the following information and documents, failure of provision of the mentioned documents will lead to disqualification:

General arrangement drawings, showing particulars of all associated equipment and accessories, their overall dimensions, shipping and lifting dimensions, mass of the complete transformers, their components, and oil, etc. as well as details about the required foundations.

Schematic diagram of cooling system.

Manufacturing specification of the proposed types of transformers and associated equipment.

Reference lists of transformers of the same types as quoted, installed in similar climatic and service conditions.

Minimum five (5) written recommendations from clients/ utilities for previously, the last five years, supplied power transformers of similar or higher size.

Transportation methodology from port to site

Detailed description of core assembly comprising:

- Properties of materials used for the core and coil assembly,
- Core construction,
- Core clamps,
- Yoke/limb joints,
- Oil ducts.

Detailed technical information on the coil assembly including the following:

- Winding construction,
- Wire preparation and insulation,
- Interturn insulation,

- Taps,
- Coil clamping processing,
- Detailed description of facilities and methods proposed for carrying out the test,
- Descriptive catalogues and literature on the proposed types of transformers, protective relays and cooling systems.

Type test certificates from an independent testing authority or independently witnessed;

Quality Management System Manual and ISO Certificate of the equipment manufacturer.

16. Earthing / Auxiliary Transformers

16.1. General

Earthing/auxiliary transformers shall be in accordance with IEC 60076 and generally to the requirements of the Power Transformer section of this technical specification, as applied to transformers with a U_m of 12kV and with a rating up to 10MVA. This document gives supplementary specification for the class of Earthing/Auxiliary Transformer.

Earthing/auxiliary transformers shall be capable of withstanding for a period of 30 seconds the application of normal 3-phase line voltage to the line terminals of the interconnected star winding with one-line terminal and the neutral terminal connected solidly to earth.

The interconnected star winding of each earthing/auxiliary transformer, when at its maximum temperature due to continuous full load on the auxiliary winding, shall be designed to carry for thirty seconds without injurious heating an earth fault current not less than the full load lower voltage winding current of the main transformer to which it is connected or the following current, whichever is the greater:

- Lower voltage of main transformer kV 11
- Earth fault current required Amp. 1000

The earthing/auxiliary transformers shall have zero sequence impedance equal to the positive sequence impedance.

Where required, the transformers shall be protected by fire barrier walls as described in the civil works section of the Employers Requirements.

The Contractor shall verify the need for a earthing resistor to be installed in the primary star point connection to earth. The supply and installation of these resistors, if needed, including cubicles and all accessories, shall be included in the contract price.

16.2. Construction

The construction and general requirements of the earthing/auxiliary transformers shall be in accordance with that specified for 2-winding transformers with ratings up to 10MVA in of the Power Transformer section of this technical specification. This includes but is not limited to the following features:

- Off-circuit tap-changer with $\pm 5\%$ voltage variation in 4 equal steps
- ONAN cooling
- Oil preservation system: May be conservator with Buchholz and dehydrating breather or sealed type (gas cushion or corrugated tank). Where corrugated type is offered, the manufacturer shall provide adequate reinforcement to prevent damage during transport, installation and service.

- HV connections shall be housed in an air-filled cable box suitable for separable connectors for XLPE cable; these shall be of the Euromold type or equivalent.
- The LV (auxiliary) terminals of the earthing/auxiliary transformer shall be brought out into a weatherproof cable box fitted with a lockable, hinged lockable door. The cable box shall incorporate an adequately rated fuse-switch unit suitable for cable connections.
- The installation of protective current transformers (CTs) in primary and secondary neutrals is required. CT details including class and rating are included in the Technical Data Sheets. Primary located CTs shall be located in-tank.

16.3. Testing

Routine and Type tests shall be generally in accordance with the requirements of IEC 60076-1 and IEC 60076-3, appropriate to the voltage class of the transformer under consideration. Additionally, some tests in the class identified as 'Special' in IEC 60076 are included, which may in practice be effectively a Routine or Type Test, as appropriate.

16.3.1. Routine Tests

The following routine tests shall be performed:

- Measurement of winding resistances at all tap positions
- Measurement of voltage ratio and check of voltage vector relationship
- Measurement of impedance voltage (principal tapping) short-circuits impedance and load loss.
- Measurement of no-load losses and no-load current at rated frequency and nominal voltage.
- Induced-voltage test with partial discharge measurement.
- Short Duration AC (ACSD)
- Separate source voltage test.
- Oil test and function tests.
- Measurement of insulation of core.
- Measurement of insulation resistance (R15, R60, R600) at 2500 V DC. The polarisation index R10min: R1min shall not be less than 1.0.
- Measurement of ratio and polarity check of current transformers

16.3.2. Type Tests

The following type tests shall be performed:

Temperature Rise Test: This test shall be carried out with the transformer at tap positions giving highest losses. The temperature rise qualification of the earthing/auxiliary transformers shall be based on the sum of two factors; the first is a test in accordance with IEC 60076-2, at the auxiliary rating when the temperature rises of the main and auxiliary windings will be measured. The second factor will be the calculated rise according to IEC 60076-5 at the 30-second duty rating. The total temperature rise will be the sum of both figures and the overall winding temperature shall be less than 250°C.

Lightning Impulse (LI) test: This test shall be carried out in accordance with IEC 60076-3 on the HV and neutral terminals. Tap-changers shall be in the position of minimum, principal and maximum tap as each phase is tested in turn (A-B-C).

In-lieu evidence from demonstrably similar units and/or mechanical and thermal calculations shall be provided to demonstrate clear margins of short-circuit current withstand at system fault levels for all transformers. All tests and calculations shall be in accordance with IEC 60076-5.

16.3.3. Special Tests

The following 'special' category tests shall be performed when specified the Schedules of Technical Information and may be on each unit (equivalent to a routine test) or on one unit (equivalent to a type test) as indicated:

- Measurement of zero-sequence impedance: (Routine test)
- Determination of sound levels to IEC 60076-10: (Type test).
- Measurement of the harmonics of the no-load current: (Routine test).

16.4. Documentation

16.4.1. Documentation with Bid

The Bid shall contain at least the following information and documents, failure of provision of the mentioned documents will lead to disqualification:

6. General arrangement drawings;
7. Manufacturing specification of the proposed types of transformer;
8. Catalogues, literature and reference lists of proposed equipment;
9. Type test certificates from an independent testing authority or independently witnessed;
10. Quality Management System Manual and ISO Certificate of the equipment manufacturer.

16.4.2. Documentation after Award of Contract

All documents required for KETRACO's approval shall be submitted by the Contractor.

17.Optical Fibre Cable for Pilot & Telephone/ Data Application

17.1. Scope

This specification details the requirements for the design, manufacture and testing of optical fibre cable and accessories for application as Pilot & Telephone/data cable with EHV power cable circuits.

IP-Phones & integration telephone system shall be provided.

Fiber Optic and Multiplex equipment for Tele-protection, voice and data communication between substations to be provided according to KETRACO requirements.

17.2. FO Cable and Accessories

This section contains equipment requirements for pilot fibre optic cable and accessories. Design criteria shall be in accordance with IEC 60793-1, 2 60794-1, 2 and ITU-T (G.655) recommendations as well as Telecommunication system requirements Type test certificate for the fibre optic cable is required.

17.2.1. Fibre Optic Pilot Cable

The Contractor shall include design, manufacture, supply, installation including hardware and splicing, supply of spares, testing, commissioning, remedying of defects, and maintaining the works during the defect liability period and any incidental work necessary for the proper completion of the work in accordance with the Specification.

The fibre optic pilot cable shall have the following main characteristics:

- Fibres contained in loose tube.
- The fibre shall be of single mode type according to ITU-T Recommendation G.655 suitable for transmission of information at the ITU-T recommended rates of either 2, 8, 34, 140, 155 or 622 Mb/s.
- The fibre shall have dual operative windows, at 1550 nm and 1625 nm.
- Minimum of 48 fibre cores.
- Maximum optical attenuation shall be 0.22 dB/km for 1550 nm, and 0.24 dB/km for 1625 nm.

Each individual fibre shall be colour coded for identification purposes, with details of the colour coding scheme adopted being provided in the Tender.

The Bidder shall provide a drawing showing a cross-section of the cable indicating the dimensions of each element it contains. The drawing shall provide a clear illustration of the design and make-up of the cable. Technical descriptions detailing the fibre optic cable performance shall be provided.

All necessary civil works and installation materials required to complete the fibre optic cable system shall be included in the Contract.

All fibre optic cables shall have a design life of at least 25 years.

17.2.2. Fibre Optic Joint Closures

Fibre optic joint closures for fibre optic communication / pilot cables (if any) shall have the following characteristics

Splice capacity	min. 48 fibres with a loose buffered
Installation alternatives	direct buried, in manholes, on portal supports
Attenuation	max 0.05 dB/splice

17.2.3. Optical Terminal Boxes

Optical terminal boxes for fibre communication and approach cables shall have the following characteristics

Capacity	min. 3 fibre optic cables, each with 48 fibres
Installations	wall - mounted type
Attenuation	0.5 – 1 dB/per connector 0.05 dB/per splice
Optical connectors	F.C. - P.C. type

17.2.4. Installation

17.2.4.1. Fibre Optic Cable

The following requirements shall be fulfilled:

- The cables shall be laid in plastic ducts (diameter approx. 40 mm), buried in the ground, using "blow-in" technique.
- Fibre optic pilot cables shall be laid in the same trench together with a power cable.
- Trenches shall be excavated to form straight lines running parallel to the building grid lines, wherever possible. Cables shall be routed in accordance with tender drawings and KETRACO's instructions.
- The plastic duct with the cable shall be laid over a bed of sand, approx. 200 mm thick.

- Joint closure (if any) shall be installed at every 1.5 km (delivery length, approximate average value) in the same joint pit with power cables.
- Backfilling of the trenches shall not commence until the cables have been inspected by KETRACO. Backfilling shall be carried out in layers not thicker than 150 mm and shall be well consolidated by punning of each layer.
- Each cable shall be protected from mechanical damage over the entire buried length by means of reinforced concrete covers. The covers shall have a minimum width of 150 mm and shall interlock to resist lateral displacement following installation. The covers shall be laid centrally approximately 200 mm above the cable during backfilling of the trench.
- The design of the hydraulically pressed concrete covers shall be subject to approval by KETRACO.
- Cable warning tape shall be installed 250 mm above the cable covers during backfilling of the trench. The tape shall be manufactured from high grade PVC and shall be 150 mm wide with a minimum thickness of 0.1 mm. The tape shall be bright coloured with warning messages printed in black continuously along its length. The printing shall be minimum 200 mm high; the wording shall be subject to approval of KETRACO. The printing shall be fully resistant to deterioration effects of direct burial.
- Where the cable passes under a roadway, reinforced concrete trench or similar structure, as indicated on the site layout drawings, the Contractor shall supply and install PVC ducts of approximately 110 mm diameter, rather than 40 mm diameter.

17.2.4.2. Optical Fibre Joints

The Contractor shall design, supply and install optical fibre cable joints. Each cable joint shall include termination box, mounting hardware, optical fibre splice kits, cable entry seals and all accessories required to produce a permanent optical joint. Details of the proposed optical fibre joints shall be submitted by the Contractor for the approval of KETRACO.

Each termination box shall be capable of being hermetically sealed after jointing, and hermetically sealed after re-opening. The quality and type of termination boxes shall be determined by the Contractor and subject to approval by KETRACO.

Optical fibre splices shall be of the fusion type and the optical attenuation of each splice shall be less than 0.05 dB/splice.

17.2.4.3. Terminations

The interface between the fibre optical transmission system and the fibres of the optical cable shall be at the optical terminal boxes using low loss de-mountable optical connectors of the plug-in type. The maximum insertion loss for a pair of mated connectors shall be 0.25 dB.

In order to cater for system failures, system expansions and re-routing etc., manual patching facilities shall be provided.

Mating connectors shall be provided as part of the Contract. Caps shall be provided for each coupler to prevent dust ingress to the couplers of unused fibres. The Bidder shall state the manufacture and type of connectors proposed. All connectors shall be so positioned to facilitate easy cleaning and inspection.

All spare fibres shall be terminated with appropriate optical connectors.

17.2.4.4. Cable Joint Enclosures

It is preferred that a universal joint enclosure is proposed for all types of cable. The enclosure shall provide adequate protection for splices, and shall provide storage for sufficient length of fibre for at least ten future splices. The size of the enclosure shall be of sufficient size to meet the minimum bending radius requirement of the fibre optic cable.

The enclosure shall either be made from a high stability polypropylene material, or constructed from metal. Where metal is used, all surfaces shall be protected by galvanising. The enclosure shall be made weatherproof by the use of a corrosion-resistant sealing compound. Where metal is used, an integral earth terminal shall be provided.

17.2.4.5. Optical Terminal Boxes

Optical terminal boxes (OTBs) shall be provided by the Contractor to facilitate the termination of incoming fibres into the substation.

The OTBs shall be wall mounted in the substation telecommunication room. Optical fibres shall be terminated by detachable connectors, complying with the requirements of IEC 60874, at the optical terminal box and shall be properly labelled with fibre identity, destination or source, go or return.

All fibre terminal boxes shall have an earth connection provided, and shall be protected from corrosion by painting or galvanising.

At the overhead line (OHL) to EHV power cable interconnection point, the fibre optic cable and the OPGW shall be joined in splice boxes located on the tower legs at the locations where the fibre optic cable and OPGW are dead ended. The supply and installation of the splice box is part of the Lot 2 Contractor scope of works.

17.3. Testing

17.3.1. Type Tests

The type tests as specified here shall be carried out in the presence of the Engineer's Representative on the complete item of each kind of equipment at the Manufacturers works in accordance with the latest revision of relevant ITU -T and IEC Publications, except where otherwise specified. The test results shall be furnished to the Engineer for consideration after conclusion of tests.

The following type tests shall be performed:

For the Optical Fibre Pilot Cable (before assembly)

1. Mode Field Diameter Test (variable aperture ITU-T G655)
2. Cladding Diameter and Non-circularity Test (near field ITU-T G655)
3. Mode Field Concentricity Error Test (near field ITU-T G655)
4. Tensile Strength Test (Weibull IEC 60793-1 UTS measurement)
5. Microbending Sensitivity Test
6. Torsion Test
7. Flexing Test
8. Abrasion Test
9. Spectral - Attenuation Cutback test (cutback ITU - T G 655)
10. Chromatic Dispersion Test (phase shift variation ITU-T G655)
11. Cut-off Wave-length Test (multi-mode reference ITU-T G655)
12. Point Defects Test (backscattering ITU-T G655)
13. Temperature Cycling Test (transmitted power IEC 60793-1)
14. Min. /Max. Temperature Test (to be done under the temperature cycling test)
15. Temperature - Shock Test (to be done under the temperature cycling test)
16. Temperature dependence of attenuation test (to be done under the temperature cycling test)
17. Accelerated Oxygen Ageing Test

For the completed Fibre Optic Pilot Cable:

1. Overall Diameter measurement
2. Optical Cable Length measurement
3. Bend, low and high temperature test (IEC 60794 1 E11)
4. Cyclic Flexing test (IEC 60794 1 E6)
5. Impact Test (IEC 60794 1 E4)
6. Compressive Loading and bending Test
7. Tensile, loading and bending test (IEC 60794 1 E1)
8. Spectral-Attenuation Cutback Test and Backscatter Light Test (IEC 60793 - 4)

9. Temperature Humidity Cycling Test (IEC 60794 1 F1)
10. Cut-off Wavelength Test (ITU - T G650)
11. Accelerated Oxygen Ageing Test

Type test for:

1. Optical Joint Box, and
2. Optical Terminal Box

shall be carried according to IEC Publications, where applicable.

17.3.2. Routine Tests

The routine tests shall be carried out on all drums of cables to be supplied in accordance with the requirements set out in the relevant ITU-T and IEC Publications. The test results shall be furnished to the inspector for consideration immediately after conclusion of tests.

The following test shall be performed:

1. Overall Diameter Measurement
2. Length of Fibre Measurement
3. Cable Length Measurement
4. Fibre Point Defects Test
5. Fibre Attenuation Test

Routine test for:

1. Optical Joint Box, and
2. Optical Terminal Box

shall be carried out according to IEC Publications, where applicable.

17.3.3. Special Tests

The full set of the routine tests shall be repeated on the selected drums among the drums ready for shipment in the presence of the Engineer.

17.3.4. Commissioning

On arrival on site and during and after completion of erection, all cable drums shall be inspected and tested to insure that there shall be no delay in commissioning due to supply of incorrect or damaged equipment. The site tests are subdivided into two stages:

- Test During and After Installation, and
- Commissioning Test.

In order to ensure correct installation of the equipment as well as to prove that the cables from all drums have been correctly installed, the following Tests During and After Installation shall be performed:

1. Fibre Optic Pilot Cable Length Measurement,
2. Verification of Fibre Optic Pilot Cable Continuity, and
3. Optical Attenuation Measurement.

The main objective of the commissioning tests is to check the proper and safe operation of the cable and in particular to verify and confirm performance guarantees as defined in the Technical Specifications and the Schedules of Technical Information.

The following commissioning test shall be done:

1. Optical Attenuation Test.

18.Civil Works

18.1. Description

This document describes in detail the standard building requirements for Substations. It outlines the issues and requirements that must be considered as part of the overall Substation design and planning process. By nature it is a generic specification and site specific details may be provided to supplement the advice within this document to suit the local environment and/or plant specific requirements.

The designer must have due regard at all times to designing a Substation that complies with all current Kenyan legislation and legal requirements.

Third party considerations, designers risk assessments, developer's requirements, government agencies, etc may influence the adopted design but it is essential that the requirements of this document are embedded within the final design of the Works.

18.2. General Scope

The principal function of the Civil design is to provide buildings, structures and civil infrastructure to house and support the electrical equipment and ensure a safe environment for operational and maintenance staff as well as the general public.

The general scope of civil works shall include but not be limited to the following:

- The work includes site clearance, site surfacing and back filling wherever needed and leveling.
- Contractor is obliged to send a model file with drawings and report calculation to be checked by engineer. Documents specially the ones, which are related to buildings, will be rejected if model files have not been sent.
- All buildings to be constructed and equipped as bid drawings, with reinforced concrete frames, masonry walling, bolted connections preferably (welding may be adopted for steel roof trusses)
- Concrete cable trenches to be provided as bid drawings.
- Substation Control Building Civil works (including Excavation, concrete works, masonry works, backfilling, and etc.) together with building services such as Lighting, Small Power System, Water Supply and Sewage System, HVAC, Water Solar Heating, Fire Detection and hand held capsule fire extinguishers, Eyewash facility and access control
- Substation Guard House and Telecom Collocation Room Civil works (including Excavation, concrete works, masonry works, backfilling, and etc.) together with building services such as Lighting, Small Power System, Water Supply and Sewage System, HVAC, Water Solar Heating, Fire Detection and hand held capsule fire extinguishers, Eyewash facility and access control
- Substation Diesel generator house Civil works (including Excavation, concrete works, masonry works, backfilling, and etc.) together with building services (e.g. Lighting, Small Power System, Fire Detection and hand-held fire extinguishers)
- Substation Storage Warehouse Civil works (including Excavation, concrete works, masonry works, backfilling, and etc.) together with building services e.g. Lighting, Small Power System, Water Supply and Sewage System, HVAC, Water Solar Heating, Fire Detection and hand held capsule fire extinguishers, Eyewash facility and access control, etc.
- Technical staff Housing Civil works (including Excavation, concrete works, masonry works, backfilling, and etc.) together with building services e.g. Lighting, Small Power System, Water Supply and Sewage System, HVAC, Water Solar Heating, Fire Detection and hand held capsule fire extinguishers, furniture and furnishing

- Security staff Housing Civil works (including Excavation, concrete works, masonry works, backfilling, and etc.) together with building services e.g. Lighting, Small Power System, Water Supply and Sewage System, HVAC, Water Solar Heating, Fire Detection and hand held capsule fire extinguishers, furniture and furnishing
- Complete water supply system shall be provided For water availability throughout the substation, borehole is called for. The water supply for the control building and guard house and staff housings is via an overhead tank. Main water reservoir of 30,000 liters (as minimum) capacity, adequate to serve requirements of control building, guard house, staff housings and etc. with automatic level controls shall be provided. Also 3 X 5,000 liters elevated water tanks shall be considered near the control building, guard house and staff housings with required pumps to be fed from the main water reservoir.
- Fire Detection and Alarm System for Buildings
- Firefighting Pump House Civil works (including Excavation, concrete works, masonry works, backfilling, and etc.) together with building services e.g. Lighting, Small Power System, Water Supply and Sewage System, HVAC, Water Solar Heating, Fire Detection and hand held capsule fire extinguishers, Eyewash facility and access control, etc.
- Standard drainage system including flood protection and storm water canals shall be implemented around the whole substation perimeter for complete dewatering of the compound and external storm water. Canals shall be surfaced by stone pitching. All waste drainage shall be taken to septic tank and soak away pit. The design for the plumbing and drainage system should ensure smooth operations in the substation.
- Complete sewage system (including pipes, Vent Pipes, Floor Drain, Toilet, Septic Tank with sufficient size) and other Mechanical Installations (including Shower with Faucet, Basin Faucet, Basin, Kitchen Sink, Pedestal Eye Wash), etc.
- Flood protection and storm water canals around the whole substation perimeter for complete dewatering of the compound and external storm water. Canals shall be surfaced by stone pitching.
- For water heating, solar heaters and backup electric heating element shall be considered, which its design shall be subjected to approval of Client/Engineer.
- HVAC system shall include DX Split Units and shall be considered in the control building, guard house and telecom collocation room, staff housings, BCRs and etc. according to KETRACO requirements. These should be adequately sized to ensure the room temperature is ideal for the optimal performance of equipment. The refrigerant should comply to KEBS standards. The individual HVAC units will be sized according to the dimensions of the particular room for approval

by the client/consultant. In addition, the HVAC system is to be designed to fit the particular local conditions of the substation.

- The control room shall use either Dry Powder or Foam Fire Extinguishers, in addition to Carbon Dioxide Extinguishers. No Water Extinguishers shall be used in the control room or yard. For the housing units, water extinguishers can be used in addition to Carbon Dioxide Extinguishers and fire blankets. The Diesel Generator shall be served by Carbon Dioxide Extinguishers and Dry Powder/Foam Extinguishers.
- Compound boundary wall/chain-link fence with barbed wire equipped with electric shock facilities for the substation plot, fencing, gates, concrete trenches/ tunnels/ duct banks, and etc. shall be constructed, which their design shall be subjected to approval of Client/Engineer.
- Retaining wall should be implemented when there is a considerable level difference in the site. In the extension substations, the existing retaining walls shall be extended for extension area to ensure the required stability of the equipment's foundation.
- Outdoor galvanized steel apparatus support structures and foundations, grading and leveling of the site and spreading of crushed aggregates over all unpaved areas.
- Foundations, concrete firewalls and oil pits for transformers and Earthing & Auxiliary transformers. Grading, Fencing, Oil pit sizing shall be based on approved calculations. In addition, burnt oil pit (common for a couple) transformers shall be provided and its sizing shall be subject to approved calculations. The transformer's and reactor's firefighting system shall be based on Nitrogen injection.
- Walkways of pedestrian, such as from gate to the control building, from parking to control building and etc.
- Internal access roads to switchyard and to buildings shall be implemented to bituminous standard. Necessary warnings / signage shall also be fixed. Suitable slopes / drains / manholes shall be provided for water to flow to the substation drainage system. The road shall have adequate lighting which is automatically controlled based on the ambient light intensity.
- External access road from main road to substation by a standard junction shall be implemented to all-weather murrum standard and according to Kenya roads regulations. Necessary warnings / signage shall also be fixed. Suitable slopes / drains / manholes shall be provided for water to flow to the drainage system. The road shall have adequate lighting which is automatically controlled based on the ambient light intensity.
- In Design of Reinforced concrete buildings, minimum concrete compressive strength (f'_c) shall be 300 Kg/cm² on Standard Cylinder Sample, or 350 Kg/cm² on Standard Cubic Sample. Also minimum rebar yield point (F_y) shall be 4000 Kg/cm².

18.3. Control Building

At the new substations, the effective area and rooms in the control building shall be according to the bid drawings; The sizing of the Control building shall consider space for installation of control and protection panels for the future diameters.

Electric and mechanical system installation works including cabling system installation works, Test and Commissioning shall be delivered.

The Control building layout shall be as per the drawings in Part 2-D, considering the followings but not limited to:

- One-floor building comprising relay room (control, protection, metering and fault recording panels, etc.), operator and SCADA room, telecommunication room, office, store, kitchen, separate toilets and bathrooms for ladies and gents, meeting room, battery room, AC/DC room, which shall be fully equipped and/or furnished according to this specification and bid drawings;
- With individual access to all the rooms from inside the building
- The rooms contained panels, shall have False Floor as indicated in bid drawings
- All rooms/areas shall have acoustic false ceiling
- With sandwich panel gable roof and galvanized steel gutter and gutter strap. The rooms contained panels, shall have available usable height of 3.5 meters as minimum (to have 1.2 m clearance over the top of the tallest cabinets/panels to the bottom of ceiling, as minimum)
- Suitable ramps shall be considered for entry of material handling equipment (e.g. forklifts) into store room and battery room and relay room, with a maximum slop of 1:12, for loading and unloading of the equipment during maintenance period.
- The areas/rooms should be adequate for current and future scope of work
- The substation Control Room Building and all other buildings to be painted with high-quality durable material according to KETRACO approved colors (refer to Part 2-F).
- All external and main walls are made of 200mm thick machine-cut stones which are then plastered to received approved paint. Thickness of partitions (internal walls) e.g. in the wash room areas shall be considered 150mm as minimum.
- The windows and also the external doors shall be dust proof. All windows shall be double glazed with heavy duty anodized aluminum frame.
- The store room shall be located in manner to allow for movement of equipment with large enough bending radius.

- The control building shall be located in the substation plot to ensure full view of the switchyard by the operator while seated in the operator room.
- A suitable eye wash and foot pedal shall be provided for the battery room as per international safety standards. The eyewash design shall be subject to KETRACO's approval. It shall be installed at a height of 1.5 m above finished floor. Floor area shall have adequate tiling and bund to collect splashed water. Necessary plumbing for supply of water and drainage shall be included. The battery room floor shall have anti-acid tiles and the cables shall pass through the walls (boring and punching of the battery room floor shall be avoided). Big windows shall be avoided in the battery room to prevent batteries to be exposed to sunshine.
- The fire rating of the doors within the control building shall be as per the Kenya Building Standards. The main access doors shall be of fire proof type with a panic bar mechanism. The doors shall have adequately sized glass windows at suitable height subject to approval by the KETRACO.
- The control building entrances shall be equipped with an adequate electronic access control system, powered by the substations DC or UPS system. In the emergency case of total loss of power supply means shall be provided so that the doors can be opened manually.
- A covered car parking of 3m x 6m size per vehicle for 10 vehicles shall be provided. The structure of the cover shall be of suitable structural steel / pipes with proper galvanizing and painting and fixed on necessary foundations with bolts. Steel sheets shall be used for the cover and shall be of a shade confirming to KETRACO color codes. The dimensions of each parking bay shall be adequate for easy movement of vehicles like pick up / project vehicles. The floor of the car parking shall be of concrete blocks or same as internal roads. Suitable slopes / drains / manholes shall be provided for water to flow to the substation drainage system. The parking shall have adequate lighting which is automatically controlled based on the ambient light intensity. Necessary warnings / signage shall also be fixed.
- HVAC system shall be considered with DX split units including indoor evaporator unit and outdoor condenser unit for all rooms except battery room, store, toilets and kitchen. Floor-standing cooling system shall be also considered for the relay panel room. The battery room shall be served by two properly sized extractor fans. The toilets shall also be served by properly sized extractor fans.
- Firefighting system shall be considered including hydrant at the entry and fire extinguisher capsules inside the control building as per KETRACO requirements. The control room shall use either Dry Powder or Foam Fire Extinguishers, in addition to Carbon Dioxide Extinguishers. No Water Extinguishers shall be used in the control room or yard.
- Complete electric and mechanical system (water, wastewater, etc.) including piping and cabling system installation works, test and commissioning shall be delivered for all buildings according to Kenya building code and KETRACO requirements.

Note: In the existing substations, the battery room windows shall be modified to minimize the batteries exposure to sunshine, as per Client/Consultant approval.

18.4. Guard House with Telecom collocation room

Effective area of this building shall be according to bid drawings in one floor with gable roof. Spaces are including: guard room, kitchen, ladies and gents' toilets and washrooms, customer equipment room, main equipment room and battery room, according to bid drawings. It shall be constructed using a reinforced concrete frame with in-fill, insulated block work walls and a reinforced concrete roof slabs. An outdoor lean-to sunshade with profiled steel sheet roof shall be provided for the water dowsers.

The telecom rooms are constructed next to the guard room to be known as the "Telecom Collocation Room" for the purpose of hosting other service providers who will be using KETRACO infrastructure such as OPGW fibres. The general scope of works for Telecom room shall entail:

- i. Construction of main and customer telecom collocation rooms;
- ii. Construction of cable tranches and covers from the main control building's telecom room to the Customer Equipment room;
- iii. Access road in concrete paving blocks finish;
- iv. General drainage works and rehabilitation; and
- v. Making good all disturbed areas.

The Telecom Collocation room shall contain the following rooms (with the respective minimum dimensions in meter Length*Width*Height and details as per bid drawing):

- Customer Equipment Room (with minimum dimensions 6.9m*5.2m*3.5m) – One double leaf entrance door (large enough to wheel in and out control cabinets), one single leaf door into the main Equipment Room, external windows (facing the substation) (1.2m*1.5m), one row of minimum 4 equipment cabinets each with overhead and underground cable trenches linking to the main control building telecom room and control and protection rooms.
- Main Equipment Room (with minimum dimensions 5.2m*2.5m*3.5m) – KETRACO equipment room with ODF cabinets.
- Battery/Storage Room (with minimum dimensions 3.5m*2m*3.5m) – One large door (minimum 0.9m wide large enough to wheel in and out equipment). The placing of this room shall also be away from public access and preferably facing the direction of the substation.
- Ladies and Gents Washrooms (with minimum dimensions 3.2m*2.8m*3m) –fitted with a fully functioning sink installed external between the washrooms. The access of these facilities shall be away from public and secured (preferably facing the direction of the substation and away from the road).

18.5. Emergency Diesel Generator House

The emergency diesel generator (EDG) shall be housed in a separate building/room according to bid drawings and away from the control building in a suitable location within the substation land.

The design for the EDG set housing shall be according to bid drawing and subject to Employer/Employer's Representative's approval.

18.6. Telecommunication collocation Room

Area of this building shall be according to bid drawings in one floor with sloping roof. Spaces are including: customer equipment room, main equipment room, battery room, office and toilets according to bid drawings.

18.7. Bay Control Rooms (BCRs)

For the housing of the diameter's protection, control, metering and fault recorder cubicles, Bay Control Rooms shall be foreseen in-between the diameters. Each house shall accommodate the cubicles for each diameter.

The No. of cubicles shall be approved by the Client/Engineer and for each cubicle, a dimension of 2200mm height, 800mm width and 800mm depth is supposed.

18.7.1. Other Requirements

The Bay Control Rooms shall be equipped with raised floor to house the power, control and signal cabling.

The Bay Control Rooms shall be designed to ensure that internal noise, vibration, temperature and dust levels are kept within lowest acceptable limits to provide proper operating conditions for the equipment which is to be installed and a comfortable working environment for the operation and maintenance staff throughout the year.

The houses shall be protected against the ingress of moisture according to DIN 18195, "Water-proofing of buildings" and the common rules of IEC 61936-1 "Power installations exceeding 1 kV a.c." are to be considered.

The air conditioning, heating and ventilation system shall be adequate to maintain the permissible operation conditions of the equipment under extreme weather conditions and to allow working of maintenance personnel. The design parameters of the houses and the complete equipment in the houses shall allow the operation without running cooling or heating under normally expected weather conditions.

The houses shall be designed and supplied complete with following services:

- Lighting and Small Power (with inside 300 lux / entry outside 150 lux level). Also an emergency lighting will have to be installed.
- Fire detection/alarm systems (acoustic alarm and signalization in the substation control room) and portable ABC 5 kg fire extinguishers.

- Air conditioning, heating and ventilation system
- Insulation of Walls/Doors/Roof-Ceiling
- Installation at least 0.20 m above the nominal ground level
- Raised floor with a minimum height of 0.80m
- Internal/external painting with color (according to KETRACO's standard design).
- Labelling (name identification, no smoking, unauthorized entrance prohibited, etc.)
- CCTV (Closed-circuit television)
- Telephony system

Preferably the Bay Control Rooms shall be constructed as pre-fabricated container solution, providing that there are no manufacturing or transport limitations preventing such solution. The contractor shall check for any limitations before the design is finally decided. In case the container solution is not feasible, the Bay Control Rooms shall be an on-site construction by concrete/brickwall.

The container shall be designed as complete modules to accommodate the electrical equipment and accessories equipment. The specification for the container is as below:

Structural Components

- Support seating underside points at the four corners of concrete or steel piers installations.
- Double acoustic door sets for equipment access ~1800/2400mm (width/height) with inside panic bolts.
- Access stairways 1m above ground level
- Steel structures of stainless Steel
- Roofs consisting of two weather roofs, to reduce heat loading and door roofings against rainfall
- Walls shall be made of aluminium featuring as double wall (clearance between wall ~60mm, filled with insulations material and min. thickness 1mm/3mm inner/outer).
- Floors steel construction shall be designed to withstand all anticipated loads on the structure including that of transportation of completed already installed equipment.
- Fixed points for panels/boards/etc. on walls/floors.
- Cable double floor by means of individual double floor plates and water proof cable entries

- Earthing connection points (Container- S/S earthing min. two)

The complete container with all inside installed equipment shall be factory tested before shipped to site. The factors of safety used in the design of the container must at least take the lifting (lifting lugs), permanent position operation requirements transport to site and permanent position operation requirements for a long-term operation (>25 years) aspects into account.

The following fire ratings shall be applicable for the outdoor containers (not cubicles):

- External walls 120 minutes
- Fire rated steel doors 90 minutes.

Should the design of the Bay Control Rooms be an on-site construction by concrete/brickwall, the specification is as below:

Structural Components:

- Concrete foundations as required according to the soil investigation. The foundations to be protected by a bituminous coating.
- Walls and roof of concrete/brickwall construction or steel structure with insulated cladding and adequate corrosion protection.
- Double acoustic door sets for equipment access ~2000/2400 mm (width/height) with panic bolts inside.
- Access stairways ca. 1 m above ground level.
- Raised floor steel construction to be designed to withstand all anticipated loads on the structure including that of transportation of completed already installed equipment.
- Water proof cable entries or equivalent solution for easy cabling and cabling modifications.
- Earthing connections points.

18.8. Fire Water Pump House

Fire Water Pump House area shall be according to bid drawings with suitably sized electric motor- pumps and diesel-pumps and piping to fulfill the required water flow and head via calculations.

Hydrants shall be considered within the switchyard, CO2 or powder hand held capsule fire extinguishers shall be placed in the Control Buildings and in other buildings.

Fire water tank(s) shall be considered for firefighting use (the capacity shall be approved by Employer's Representative). The whole firefighting systems shall be in line with relevant NFPA standards, KEBS and KETRACO requirements.

18.9. Storage Warehouse

A warehouse with a usable space area of 1600 square meters shall be built.

The store shall be appropriately partitioned by the Contractor to the approval of the Employer.

This partitioning shall take into consideration that a forklift shall be used for moving the Material/equipment.

The warehouse store should be well ventilated and with sufficient air circulation.

18.10. Design Life and Maintenance

The civil works shall be designed for a minimum life of 40 years with a minimum of maintenance during this period. The designer shall consider all future maintenance requirements together with possible addition and alterations to the installed plant.

In addition to general maintenance, provision is to be made for the future removal and replacement of all items of plant. This provision shall include consideration for maintaining wayleaves and access agreements throughout the life of the Substation.

18.11. Standard Specifications

The British Standards and Codes of Practice specifically referred to in this Specification are listed below for convenient reference. The absence of any relevant BS or CP from the list shall not relieve the Contractor of his obligation to comply with such BS or CP as required by this Specification.

Number	Title
BS 4	Structural steel sections. Specification for hot-rolled sections.
BS EN 197-1:2011	Specification for Portland Cement
BS EN 13043	Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas
BS EN 295	Vitrified clay pipes and fittings and pipe joints for drains and sewers. Performance requirements.
BS EN 124	Gully tops and manhole tops for vehicular and pedestrian areas. Design requirements, type testing, marking, quality control.
BS EN 771	Specification for masonry units. Clay masonry units.
BS EN 197-1:2011	Cement. Composition, specifications and conformity criteria for common cements
BS EN 295	Vitrified clay pipes and fittings and pipe joints for drains and sewers
BS 405	Specification for uncoated expanded metal carbon steel sheets for general purposes.
BS EN 13808:2005	Bitumen road emulsions (anionic and cationic). Specification for bitumen road emulsions
BS 434-2	Bitumen road emulsions. Code of practice for the use of cationic bitumen emulsions on roads and other paved areas

Number	Title
BS EN 1993-1-1:2005, BS EN 1993-1-10:2005	Specification for the use of Structural Steel in building. Metric units
BS EN 598: 2007+A1:2009	Ductile Iron Pipes, Fittings, Accessories and Their Joints for Sewerage Applications - Requirements and Test Methods
BS EN 752	Drain and Sewer Systems Outside Buildings (Parts 2-14)
BS EN 932 Parts 1 to 6	Testing for General properties for aggregates.
BS EN 12620: 2002 + A1 :2008	Aggregates for concrete
BS EN 934-2:2009 parts 1 to 6	Concreting Admixtures
BS EN 13279 Parts 1 and 2	Gypsum binders and gypsum plasters.
BS 1196	Specification for clayware field drain pipes and junctions.
BS EN 13139	Aggregates for mortars
BS EN 845 Parts 1, 2 & 3	Specification for ancillary components for masonry
BS EN 13101:2002	Steps for underground man entry chambers. Requirements, marking, testing and evaluation of conformity.
BS 1377	Methods of test for soils for civil engineering purposes.
BS EN 1401 – 2 & 3	Plastics piping systems for non-pressure underground drainage and sewerage. Unplasticized polyvinylchloride (PVC-U). Specifications for pipes, fittings and the system
BS 1521	Specification for waterproof building papers.
BS EN 1610	Construction and testing of drains and sewers
BS 1722	Fences.
BS EN 771-1 to 6	Specification for masonry units.
BS 4190	Specification for ISO metric black hexagon bolts, screws and nuts.
BS ISO 8992	Fasteners. General requirements for bolts, screws, studs and nuts
BS EN 10080:2005	Steel for the reinforcement of concrete. Weldable reinforcing steel. General
BS 4449:2005 + A2:2009	Steel for the reinforcement of concrete. Weldable reinforcing steel. Bar, coil and decoiled product. Specification
BS 4460	Specification for unplasticised polyvinyl chloride (PVC) pipes and plastic fittings of nominal sizes 110 and 160 for below ground gravity drainage and sewerage.
BS 4483	Specification for steel fabric for the reinforcement of concrete.
BS 4514	Specification for unplasticised PVC soil and ventilation pipes, fittings and accessories.
BS EN998-1 & 2	Specification for ready-mixed building mortars.
BS EN 10067	Hot-rolled structural steel sections. Bulb Flat
BS EN 10056-1	Hot-rolled structural steel sections. Equal and unequal angles
BS EN 10210-2	Hot-rolled structural steel sections. Specification for hot rolled sections
BS 4987 Parts 1 and 2	Specification for Coated macadam for roads and other paved areas.
BS EN 1995	Structural use of timber.
BS 8500	Concrete. Specification for the procedures to be used in producing and transporting concrete
BS 8500, BS EN 206-1	Methods for specifying concrete, including ready-mixed concrete
BS 9999:2008	Fire Precautions in the Design and Construction of Buildings
BS EN 1996	Code of practice for use of masonry

Number	Title
BS 5911	Precast concrete pipes, fittings and ancillary products.
BS 5930: 1999	Code of practice for site investigations
BS 5950	Structural use of steelwork in building.
BS 6031	Code of practice for earthworks.
BS EN 12056-3:2000	Code of practice for drainage of roofs and paved areas.
BS EN 1991-1-1:2002, BS EN 1991-1-7:2006	Loading for buildings. Code of practice for dead and imposed loads
BS EN 1991-1-4:2005	Loading for buildings. Code of practice for wind loads.
BS EN 1991-1-3:2003	Loading for buildings. Code of practice for imposed roof loads
BS EN 1339	Precast concrete flags, kerbs, channels, edgings and quadrants.
BS EN 1997-1:2004	Code of practice for foundations
BS EN 1992-3:2006	Code of practice for design of concrete structures for retaining aqueous liquids
BS EN 14161:2011	Code of practice for pipelines. Pipelines on land: general
BS EN 1992-1-1:2004	Structural use of concrete. Code of practice for design and construction
BS EN 752-1:1996, BS EN 752-2:1997, BS EN 752-3:1997	Code of practice for building drainage.
BS EN 10210-1	Hot finished structural hollow sections of non-alloy and fine grain structural steels.
BS EN 12056	Gravity drainage systems inside buildings
BS ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods

18.12. Surveying Instruments

The Contractor shall keep on site such surveying instruments as are necessary for the complete and accurate setting out and construction of the works. These instruments shall be modern, shall be maintained in excellent condition, and shall be accurate in all respects. They shall be kept available for use by the Employer/ Employer's Representative if so required, and their accuracy and adjustment shall be regularly checked in an approved manner.

18.13. Site Surveys

18.13.1. Topographical and Condition Surveys

At award of contract the Contractor shall conduct a complete topographical and condition survey of the Site and the surrounding area. These surveys shall be agreed with the Employer/Employer's Representative before any work starts on the site.

The purpose of the topographical survey of the Site and the surrounding area is to determine and agree with the Employer/Employer's Representative the existing levels. It is also envisaged that this data will allow the Contractor to allocate a relatively local low area in which any surface water run-off from the site can be directed for subsequent natural evaporation; ideally this zone will be well away from the working area of the site.

The condition survey will comprise a visual survey to record any aspect of the site and its surroundings which may have an impact on the construction or subsequent operation of the Works. The survey will include but not be limited to the following:

- a. observing the vegetation (changes in colour of vegetation may indicate changes in soil conditions)
- b. the presence of any buildings or habitation
- c. the presence of overhead obstructions, (transmission or distribution lines)
- d. tree or tree roots and any changes the removal of the trees may have upon the site
- e. geological outcrops or erosion
- f. signs of previous occupation
- g. wild life
- h. access routes etc.

The condition survey should be accompanied by a comprehensive photographic record.

18.13.2. Soil Investigation (Geo-technical and Geo-electrical)

The purpose of the Soil Investigation is to determine the nature of the sub-surface soil conditions which exist within the Site and to determine the most suitable type of foundation types. The soil investigation shall be carried out in accordance with the latest edition of the "Specification for soil investigation" published by the Institute of Civil Project Managers.

18.13.3. Data Provided by Client

The accuracy of any subsoil and survey information supplied to the Contractor is given in good faith but is not guaranteed, and any variation between this information and actual site conditions will not be accepted as the basis of a claim or reason for variation of unit rates in the Contract.

18.13.4. Scope of Soil Investigation

The Contractor shall satisfy himself regarding the geotechnical condition of site and any matters relating to the extent and magnitude of the proposed development. He shall carry out all soil investigations (geo-technical and geo-electrical) necessary to establish the basis for the proposed plant and building arrangements and foundation designs. A part of this work will include a contamination survey to the site to identify the presence or otherwise of contaminated materials.

According to the scope of work in the contract the boreholes (6 No. for substation) shall be augured to a maximum depth of 6m below existing grade by a rotary drilling rig equipped with conventional soil sampling and testing

tool. Trial pits (3 No. for substation) shall be hand-dug to 1m depth after ensuring stability of the immediate subsurface. The excavated faces shall be examined and logged capturing the depths of the various layers and their physical characteristics. The proposed locations of boreholes and trial pits by contractor, shall be subject to Client's approval.

Samples obtained during the investigations are to be available for inspection by the Employer/Employer's Representative at the site.

The Contractor is to provide an interpretative geotechnical report for review by the Employer/Employer's Representative to confirm the criteria to be used in the foundation designs. This report shall include at least the following information:

- a. A detailed record of all factual information obtained in the field and via laboratory testing, including detailed borelogs, description of the different layers, stability of side slopes etc,
- b. Identification of all elements of contaminated material providing advice on their extent and the potential impact on personal health and durability of construction materials,
- c. Accurate logging of groundwater levels including global and perched,
- d. The results of the investigations into the soil resistivity and thermal resistance necessary for the design of the earthing rods,
- e. Foundation design parameters,
- f. Detailed recommendations regarding any specialist foundation solutions, including piling, soil improvement techniques etc.,
- g. Location of the site and Coordination of the substation,
- h. Boreholes (Trail pits) coordination and logs information,
- i. Depth of the Boreholes and trial pits,
- j. The Ground Water Conditions and specially the Ground Water Level,
- k. General geological Information of the region,
- l. Permeability and Consistency tests,
- m. Seismicity of the construction site,
- n. Earthquake acceleration coefficient,
- o. Results of the SPT (sand penetration test),
- p. Results of the Hydrometer test, Particle size analysis, Determination of Atterberg limits,
- q. Results of the Direct Shear Test,
- r. Chemical analysis of soil samples for determining soil properties and recommendations for the concrete criteria considering the Sulphate and chloride content of the samples and prevailing exposure conditions,
- s. Important characteristics of the soil layers like Cohesion coefficient (C) , Angle of internal friction (ϕ),
- t. Immediate settlement and Consolidation settlement,
- u. Modulus of subgrade reactions (Ks),
- v. Coefficient of lateral earth pressure,
- w. Allowable slope of excavation,
- x. Depth of the poor soil,

- y. Recommendations for the foundation type,
- z. Cement type and water-cement ratio,
- aa. Allowable bearing capacity (q_{all}),
- bb. Soil Collapse potential,
- cc. Soil Liquefaction,
- dd. Earth resistivity test report,
- ee. Thermal resistivity test report,
- ff. Corrosion study report and
- gg. Conclusions and Guidelines.

Within this geographical region it is possible that highly expansive soils may exist naturally and as such the above testing regime should identify their presence or otherwise. However, to ensure that the requisite testing is carried out it is recommended that at least the following properties are determined from soil samples taken from within the foundation zones, i.e. this will probably be within the top 3m of natural ground.

- a. The percentage of elements in the make-up of the soil with particular reference to montmorillonite, chilkinite and kaolinite and any other element which could cause volumetric change to occur. These percentages shall be determined for every 0.5m of depth.
- b. The volumetric change which the sample will undergo when exposed to water
- c. The pressures which the sample will exert when undergoing volumetric change
- d. The long term effect of a cycle of wetting and drying (i.e. does the swelling and shrinking repeat itself with the same intensity or do the effects diminish with repetition)

18.14. Datum

A datum to which all levels are to be related will be defined or established at a convenient point by the Employer/Employer's Representative. The Contractor shall then establish a minimum of four temporary bench marks, approximately equally spaced round the site, which shall be related to the datum. Each temporary bench mark shall be securely set in concrete, and shall be protected from damage or disturbance.

18.15. Setting Out

The Employer/Employer's Representative will establish two lines mutually at right angles from which the Contractor shall set out the works. Each of these main lines shall be defined by not less than four steel pins set in concrete at points indicated by the Employer/Employer's Representative. The Contractor shall supply all necessary labour and materials for this purpose.

18.16. Dimensions and Levels

All dimensions and levels shown on the drawings shall be verified on site by the Contractor.

18.17. Water, Electricity and Other Services

The Contractor shall be responsible for supplying all water, electricity and other services required for the construction of the Works and for any other purpose in connection with the Works.

Water pump and borehole with reservoir tank of capacity adequate to serve requirement of control building, residential houses, guard houses etc. with automatic level controls shall be provided.

For supplying water to the control building, guard house, staff housing and other facilities, the contractor shall supply, construct and mount 6 X 1,500-liter water tanks made of 3mm thick galvanized flat metal sheet complete with metal stiffeners (Bracings), inlet pipe, outlet pipe, vent pipe, overflow pipe, drain pipe, iron posts or equivalent support and necessary accessories and a water system to circulate water from overhead reservoir to the 30,000-liter capacity water tanks at each residential houses, control building and guard houses with automatic controls.

Galvanised steel pipes shall be supplied and installed for cold water distribution from the main inlet to the water tank and from the water tank to all sanitary fixtures according to the design accessories such as bends, unions etc.

The contractor shall determine the most practical way to provide water and submit the design of the water supply system for approval.

18.18. Inclement Weather

No payment will be made to the Contractor in respect of loss of output of plant or labour due to inclement weather.

18.19. Labour, plant and materials

The Contractor shall provide on the site, and elsewhere as required, sufficient labour, plant, materials and all other things necessary to construct the works in accordance with the agreed programme.

18.20. Programme

The Contractor shall construct the works in compliance with the outline programme appended to the Form of Tender, and shall submit for approval a detailed programme in accordance with the Conditions of Contract.

18.21. Provision of Testing Equipment

The Contractor shall provide a laboratory testing facility on site, alternatively tests can be done at an accredited laboratory. This shall comprise a purpose built facility capable of testing concrete, aggregates and soil samples as prescribed in the various codes of practice applicable to this project. As a minimum the following equipment shall be provided which shall be accurate and maintained in good condition:

Curing bath(s) for concrete samples plus compressive testing machines

Full set of testing equipment for the testing of soils, as prescribed in the various codes of practice applicable to this Project. This will include weighing scales, ovens, sieves, oedometers, shear box testing equipment, etc.

Employer/Employer's Representative shall be invited to all laboratory tests well in advance.

Wherever on site testing is impractical then alternative specialist subcontractors are to be employed by the Contractor to carry out this work, all associated costs being borne by the Contractor.

18.22. Design Process

18.22.1. Management of the Design

The Contractor shall prepare a 'Basis of Design' (BOD) for each element of the civil and structural works. A list of BOD's shall be prepared and this shall be submitted to the Employer/Employer's Representative within twenty-eight days after the Award of Contract for review and comment. The 'Basis of Design' shall include:

- a. A concise description of the form of each element,
- b. A statement of assumptions made,
- c. Loading and performance criteria,
- d. The particular editions of all Standards, Codes of Practice and References used,
- e. A description of the design approach including statements on the use of any computer programs and checking procedures adopted.
- f. Working methods,
- g. Plant utilization,
- h. Construction sequence,
- i. Safety arrangements.
- j. Output file from a value engineering exercise on the proposed works

These documents will establish the basis for formal reviews and appraisal of the design analysis. The Contractor shall submit these to the Employer/Employer's Representative for review at least 2 months prior to the commencement of the relevant construction activity in order that the Contractor can consider any comments made by the Employer/Employer's Representative at the most opportune time.

The development of the BOD's and the detailed civil design shall be reflected in the design and construction sections of the Contract programme.

Acceptance or rejection of the Contractor's BOD, calculations or drawings by the Employer/Employer's Representative shall not relieve the Contractor of any of his obligations to meet all the requirements of the Contract. The Contractor shall make any changes in the design, which are necessary to comply with the Contract.

18.22.2. Detailed Design Submissions

Following the review of the Basis of Design, the Contractor shall provide such detailed design submissions supported by comprehensive design calculations and drawings of the works as considered necessary by the Employer/Employer's Representative for his appraisal. The design calculations and drawings shall be submitted to the Employer/Employer's Representative in a phased manner.

These submissions will be reviewed at regular meetings held between the Employer/Employer's Representative, the Contractor and the Contractor's Civil Designer.

18.22.3. Loading

18.22.3.1. General

The loading applied to all buildings and structures shall comprise a combination of dead, imposed, wind, thermal, accidental and seismic. All loading shall be ascertained from the applicable codes of practice and standards applicable to this project.

18.22.3.2. Design Loads

It is anticipated that Equipment suppliers will give the weights and sizes of all 'heavy equipment', i.e. transformers, coolers, switchgear etc. specific to each project. These are to include dismantled transportation weights. Allowances shall be made for equipment and cables which are to be hung from the roof and ceilings of the various buildings/structures with regards to the overall load to these elements.

18.22.3.3. Internal Overpressure

A notional internal blast incident generated by an electrical fault requires the building fabric in the switchroom to be designed to retain integrity under a 5kN/m^2 ultimate overpressure load internally. Around the transformers the building fabric is to be designed to retain integrity under a 10kN/m^2 ultimate overpressure load.

Materials are to be considered at ultimate strength.

The building is to be designed such that the catastrophic loss of a wall will not result in building collapse or collapse of structures above the substation.

18.22.3.4. Floor Loads

The Contractor is to advise on the minimum characteristic loads that the floors within the substation building are to be designed to. Characteristic design loads are based on accommodating all equipment. All other floor loads are to be in accordance with BS 6399-1 1996.

18.23. Materials and Workmanship

18.23.1. General

Materials and workmanship are to be of best quality. All materials used in the works shall be new and of the best quality of their respective kinds. They shall comply with the requirements of the latest edition of any relevant Kenyan or British Standard and/or Code of Practice where such exist, and current at the date of bidding.

All workmanship shall be of the highest standard, and shall be executed by competent men skilled in their respective trades.

18.23.2. Samples

In addition to the special provisions made in this Specification for sampling and testing of materials by particular methods, samples of any materials and workmanship proposed to be used in the Works may be called for at any time during the Contract by the Employer/Employer's Representative and shall be furnished by the Contractor without delay and at the expense of the Contractor. Samples when approved shall be regarded as the acceptable standard, and any material or workmanship subsequently not complying with that standard shall be rejected and replaced by those of acceptable standard at the expense of the Contractor. Sample storage boxes shall be provided by the Contractor free of cost if requested by the Employer/Employer's Representative.

18.23.3. Tests

Whenever considered desirable by the Employer/Employer's Representative, Inspectors may be sent to manufacturer's or subcontractors' premises to test materials or inspect their manufacture. In addition the following will apply:

- a. Where specified or requested the Contractor shall obtain from the manufacturer and send to the Employer/Employer's Representative certificates of test, proof sheets, mill sheets, etc., showing that materials have been tested in accordance with this Specification or the relevant Kenyan or British Standard.
- b. Notwithstanding any tests which may be directed to be carried out at a manufacturer's and/or subcontractor's works, the Employer/Employer's Representative may carry out any tests or further tests he considers necessary or desirable after delivery of materials to the site.
- c. The Contractor shall provide all labour, equipment and facilities necessary for the carrying out of tests both in works and on site.
- d. The cost of routine tests required by Kenyan Standards or British Standards and this Specification shall be borne by the Contractor. The cost of other tests shall be borne in accordance with the Conditions of Contract.

18.23.4. Names of Suppliers and Copies of Orders**18.23.4.1. All Materials**

If so required, and before ordering material of any description, the Contractor shall submit for approval the names of makers or suppliers proposed. Copies of orders shall also be submitted if so required. The Employer/Employer's Representative may at any time withdraw his previously given approval to obtaining materials from any maker or supplier should such maker or supplier fail to supply materials of the specified quality or quantity in the requisite time.

18.23.4.2. Rejection of Materials and Workmanship

The Employer/Employer's Representative shall at any time have power to reject materials and workmanship not complying with this Specification or with the Drawings. Materials so rejected shall be immediately removed from site and replaced by materials of an approved standard at the expense of the Contractor. Rejected workmanship shall be broken out and replaced by work of an acceptable standard including the supply of new materials by the Contractor, at the expense of the Contractor, and without delay.

18.23.5. Site Clearance and Demolition**18.23.5.1. Clearance of Vegetation**

Unless otherwise directed or shown on the Drawings all bushes, trees and vegetation generally on the site shall be cleared and burned or removed to a tip provided by the Contractor. Where the Drawings or the Employer/Employer's Representative direct that any of these items are to remain undisturbed, the Contractor shall take all necessary action to prevent damage to them.

18.23.5.2. Demolition of Structures

Buildings or other structures or foundations to be removed shall be demolished by approved methods, which shall ensure that no damage is caused to any structures which are to remain.

18.23.5.3. Wells and Existing Excavations

Any wells or other existing excavations on the site shall be completely filled with approved material in layers not exceeding two hundred (200) mm, well rammed and compacted or by puddling with water. When these wells or excavations occur under, or within, three metres of new load bearing construction, they shall be filled with cement stabilised soil consisting of one (1) part cement and fifteen (15) parts sieved soil, thoroughly mixed and with a minimum quantity of water added to make a workable mix.

18.23.5.4. Explosives

Explosives shall not be used in the Works.

18.23.6. Earthworks and Excavation

18.23.6.1. Character of Ground

The Contractor must satisfy himself as to the ground conditions on the site, including the character of the strata to be excavated, obstructions, possibility of flooding and suchlike, and shall employ excavation techniques and equipment best suited to the site conditions.

18.23.6.2. Earthworks and Excavation Generally

Unless otherwise stated in the Contract the rates for earthworks and excavation shall be held to include for excavation in any material except rock.

18.23.6.3. Rock Excavation

The term "rock" shall mean a material which in the opinion of the Employer/Employer's Representative cannot be excavated except by means of explosives or compressed air drilling equipment. Boulders over one quarter (0.25) cubic metres in volume will be classed as rock and those of lesser volume as normal excavation.

18.23.6.4. Excavations for Foundations

Excavations shall be taken take out the minimum sizes necessary for the proper construction of the works, and excavations shall not be kept open for periods longer than that reasonably required to construct the works. The Contractor shall take all precautions necessary to ensure that the bottoms of excavations are protected from deterioration and that the excavations are carried out in such a manner that adjacent foundations, pipes or such like are not undermined, damaged or weakened in anyway. Any excavation taken out below the proper level without approval shall be made good at the expense of the Contractor using concrete or other material as directed.

18.23.6.5. Support of Excavations

The Contractor shall be responsible for the stability of the sides of the excavations, and shall provide and install all timbering and shoring necessary to ensure stability. If any slips occur, they shall, as soon as practicable, be made good in an approved manner at the expense of the Contractor. Shoring shall not be removed until the possibility of damaging the works by earth pressure has passed. No payment for shoring or timber left in shall be made, unless agreed in writing by the Employer/Employer's Representative.

18.23.6.6. Works to be put in Dry Excavations

All excavations shall be kept free from water and the Contractor shall take whatever action is necessary to achieve this. Pumping, well pointing and other means necessary to maintain the excavations free from water shall be at the expense of the Contractor, and carried out in an approved manner.

18.23.6.7. Inspection and Trimming of Excavations

Unless otherwise agreed, the bottoms of all excavations shall be inspected and approved before concrete is placed. Soft areas shall be excavated and filled in with concrete or other suitable material as directed. The excavations shall be properly trimmed and levelled before the placing of blinding or foundation concrete.

18.23.6.8. Backfill

As soon as possible after the permanent works are sufficiently hard and have been inspected and approved, backfill shall be placed where necessary and thoroughly consolidated in layers not exceeding two hundred (200) millimetres in depth.

18.23.6.9. Disposal of Surplus

Surplus excavated material not required or not approved for fill or backfill shall be loaded and deposited either on or off site as directed. The Contractor shall not delay disposal of surplus material after receipt of instructions from the Employer/Employer's Representative.

18.23.6.10. Hardcore

Hardcore shall consist of clean, hard, natural broken stone, rubble or gravel all to pass an eighty (80) millimetre ring, but retained on a thirty (30) millimetre ring.

18.23.6.11. Weed-killer

Weed-killer shall be spread over areas to be covered with site surfacing before such surfacing is laid. The weed-killer shall be of approved make which does not cause corrosion of metals. It shall be used strictly in accordance with the manufacturer's instructions.

18.23.6.12. Site Surfacing

Site surfacing shall consist of clean, hard natural gravel or crushed stone all to pass a thirty (30) millimetre ring but all retained on a ten (10) millimetre ring. Site surfacing shall be spread after installation of services and cables, each strip and suchlike by other Contractors. It shall be spread where indicated on the Drawings on a properly levelled or graded surface, free from weeds, to a compacted thickness of one hundred and fifty (150) millimetres and lightly rolled.

18.23.7. Concrete, Reinforced Concrete and Mortar**18.23.7.1. General**

To achieve the service life specified, a high quality, durable concrete shall be provided to protect reinforcement, embedded metals and concrete against attack from aggressive chemicals such as chlorides, sulphates and other agents.

The Contractor shall take the following key exposure categories into account whilst preparing the design mix(es) requirements. Design mix(es) shall be subject to the Employer/Employer's Representative's approval.

- Dry internal environments;
- Wet internal environments;
- External environments not exposed to seawater or seawater spray;
- External environments exposed to seawater spray/splash zone;

- External environments exposed to seawater immersion.

As mentioned previously the Contractor shall establish by soil investigation the aggressive chemical environmental conditions for concrete exposure. Concentration levels of airborne and below ground chloride and sulphate salts and any other aggressive chemical agents shall be determined. The below ground conditions for concrete shall be assessed in accordance with the requirements of BRE Special Digest 1 “Concrete in aggressive ground”.

The Contractor shall, as a minimum requirement, comply with the specified concrete mix design, and the specified additional protective measures noted herein.

All structural concrete shall develop a minimum compressive cube strength (f'_c) of 30N/mm² at 28 days.

Blinding concrete shall have a minimum 28 day cube strength of 15.0N/mm².

In the event that slip formed construction is offered for any part of the works then a special concrete design shall be developed by the Contractor and offered to the Employer/Employer's Representative for approval.

For all reinforced concrete, the following minimum mix design requirements shall be provided.

• Cement Type	Type I, ASTM C 150
• Cement replacement	Ground granulated blast furnace slag to BS6699, BS EN 15167-1:2006
• The cement and GGBS shall be blended at the point of batching in the following proportions by weight:	120kg minimum OPC but not less than 30% of the total cementitious quantity + 280kg minimum GGBS
• Minimum total cementitious quantity	370 - 380kg/m ³
• Maximum water/cement ratio	0.42 – 0.45

Admixtures shall be selected by the Contractor to accommodate his requirements for placing of fresh concrete. However, their inclusion must be approved by the Employer/Employer's Representative prior to their use.

Compliance with any concrete mix design in this Specification shall not relieve the Contractor of his responsibility for the final concrete mix design. The Contractor shall demonstrate to the satisfaction of the Employer/Employer's Representative that the intended durability of the concrete mix for the required design life can be satisfied for the particular exposure environment.

The Contractor shall be responsible for ensuring that all constituent materials used for the concrete works (e.g. cementitious, aggregate, reinforcement, water, admixtures etc.) comply with recognised international material standards and methods of testing and meet the requirements of this Specification. The use of proposed constituent materials shall be agreed with the Employer/Employer's Representative prior to their use on the Project.

The following values of minimum reinforcement cover shall be provided:

Concrete exposed to seawater; upper tidal range and splash zone	75mm
Concrete exposed to seawater; permanently submerged	75mm
Concrete buried below ground in contact with the ground	75mm
External superstructure, away from splash zone	75mm
Internal superstructure, beams, columns	40mm
Internal superstructure, slabs	30mm

In addition the Contractor shall provide sufficient concrete cover and overall cross-sectional dimensions to ensure the correct fire protection to the various elements of structure (where fire protection is required) are achieved. This shall be in accordance with BS 8110.

For below ground concrete protective measures shall, as a minimum be provided to meet the requirements of BRE Digest No 1 and as specified below. The contractor shall assess sulphate, chloride and pH levels existing in representative soil and groundwater samples as part of his programme of supplementary geotechnical investigation of the site. The concrete protective measures set out below shall be upgraded where necessary based on the recommendations of the Kenyan and British Codes of Practice.

Location	Sulphate levels below 6.0g/l (groundwater) 6.7g/l (soil).	Sulphate levels in excess of 6.0g/l (groundwater) 6.7g/l (soil).
Parts of structure in contact with the soil above the capillary rise zone	Bitumen emulsion paint	Bitumen emulsion paint and minimum cover to reinforcement shall be 100mm.
Parts of the structure within the capillary rise zone or below ground water level.	Bitumen emulsion paint and minimum cover to reinforcement shall be 100mm.	Bitumen emulsion paint and minimum cover to reinforcement shall be 100mm.
Precast concrete piles	Steel moulds.	Steel moulds

Note that the depth of the capillary rise zone shall be taken as 1.5m above the highest ground water level. Sulphate levels shall be determined by the Contractor's soil investigation.

Bitumastic paint shall be applied on top of all blinding concrete except where horizontal shear resistance is required.

Embedded materials shall be accurately fabricated and assembled to suit the construction interface required.

All steel embedments in concrete shall be accurately positioned and securely anchored either directly to the formwork or by templates prior to pouring the concrete. Pockets for later insertion of assemblies generally will not be allowed.

Embedments shall be clean both before they are installed and after placement of the concrete.

Where embedments are required for major equipment items then anchor bolts, attachments and embedments shall be located and secured prior to concrete placement with accurately made steel templates. Tolerances shall be as specified by the equipment manufacturer, but shall be not greater than ± 3 mm on plan and verticality. Templates shall be interconnected and braced with steel members that maintain the anchor bolt alignment and position.

Welding of embedments, to the reinforcement cage to secure their location, will not be accepted.

Corrosion protection shall be provided to all embedments, suitable to the environment in which they are cast. Generally, the following exposure conditions shall be considered as a minimum:

- Dry internal environments;
- Wet internal environments;
- External environments not exposed to seawater or seawater spray;
- External environments exposed to seawater spray/splash zone;
- External environments exposed to seawater immersion.

The materials that will be used for embedded items shall comprise either carbon steel or stainless steel. The selection of material will be based on strength and durability requirements. Additionally, the choice of material may be dictated by interfacing issues with plant requirements.

The necessity of welding plant fixings etc. to embedments exposed at the concrete surface in exposed environments shall be considered at design stage and wherever possible alternative fixing details shall be provided in order to preserve the original corrosion protective coatings.

18.23.7.2. Cement

The cement used throughout the works shall be best quality Portland cement and shall conform in every respect with BS 12 or the equivalent Kenyan Standard. Other cements may be used only with written approval, or on written instructions, and shall conform in every respect with the relevant KS and BS.

18.23.7.3. Special Additives

Air entraining, water reducing, set accelerating, set retarding, or other additives can be used with the prior written approval of the Employer/Employer's Representative, following comparative concrete durability and compression strength tests carried out on concrete made with and without additives. Tests with additives shall give durability and compressive strength at least equal to those without additives except that water reducing agents shall increase the compressive strength by ten (10) percent. The use of all additives shall be strictly supervised. Any admixtures used shall comply with the relevant part of BS EN 480. Calcium chloride or admixtures based on calcium chloride shall not be used.

18.23.7.4. Delivery and Storage of Cement

The cement shall be delivered to the Site in bulk or in sound and properly sealed bags and while being loaded or unloaded whether conveyed in vehicles or by mechanical means, and during transit to the concrete mixers, must be protected from the weather by effective coverings. Efficient screens are to be supplied and erected to prevent wastage of cement during strong winds.

If the cement is delivered in bulk, the Contractor shall provide at his own cost approved silos of adequate size and number to store sufficient cement to ensure continuity of work. The cement shall be placed in these silos immediately when it has been delivered on the Site. Suitable precautions shall be taken during unloading to ensure that the resulting dust does not constitute a nuisance.

If the cement is delivered in bags, the Contractor shall provide at his own cost perfectly waterproof and well-ventilated sheds having a floor of wood or concrete raised at least 150mm, above the ground. The sheds shall be large enough to store sufficient cement to ensure continuity of work. Each consignment of each type of cement shall be stacked separately therein. On delivery at the Work the cement shall at once be placed in these sheds and shall be used in the order in which it has been delivered.

18.23.7.5. Coarse Aggregate

Coarse aggregate for concrete shall be clean, hard, strong, fine grained, non-friable, non-porous and durable stone of approved quality and shall be obtained from an approved source. It shall be roughly cubical or rounded in shape and be free from dust.

18.23.7.6. Fine Aggregate

The fine aggregate for concrete shall be clean, sharp sand, or other suitable and approved material, and shall be free from all impurities.

The fine aggregate for mortar shall, unless otherwise specified, be rounded sand or other suitable and approved material and shall be free from all impurities. The clay, silt or fine dust shall not exceed five (5) percent by volume. The sand shall consist of particles between two point three six (2.36) millimetres and six hundred (600) millimetres in size.

18.23.7.7. Storage of Aggregates

The coarse and fine aggregates shall be stored on site in bins or on clean, dry, hard surfaces, and be kept free from all sources of contamination. Aggregates of different gradings shall be stored separately, and no new aggregate shall be mixed with existing stocks until tested and approved.

18.23.7.8. Water

Water used for mixing concrete and mortar shall be clean, fresh water obtained from an approved source and free from harmful chemicals, oils, organic matter and other impurities.

18.23.7.9. Steel Bar Reinforcement

Steel reinforcement shall comply with one of the following:

- Carbon steel bars for the reinforcement of concrete – BS 4449
- Cold reduced steel bars for the reinforcement of concrete – BS 4482
- Steel fabric for the reinforcement of concrete – BS 4483.

All bar reinforcement shall be hot rolled steel except where the use of cold worked steel is specified on the Drawings or otherwise approved.

The bars shall be round and free from corrosion, cracks, surface flaws, laminations, rough, jagged and imperfect edges and other defects, and the tolerance by weight shall not exceed two and one half (2.5) per cent.

The bar reinforcement shall be new, clean and of the lengths and diameters described on the Drawings and Schedules. Bars shall be transported and stored so that they remain clean, straight, undamaged and free from corrosion, rust or scale. Bars of different diameters shall be separately bundled.

Where environmental conditions dictate the use of epoxy coated or stainless steel reinforcement bars shall be used; the use of these being at the discretion of the designer.

18.23.7.10. Steel Fabric Reinforcement

Unless otherwise specified or described on the Drawings or in the Bills of Quantities, all fabric reinforcement shall comprise hard drawn steel wire fabric and shall comply in all respects with BS 4483. Each consignment of steel fabric reinforcement shall be accompanied by a test certificate giving the results of tests on the material carried out in accordance with BS 4483.

Steel fabric reinforcement shall be new, clean, free from corrosion, rust or millscale, and shall be transported to and stored on site so that it remains clean, undistorted and otherwise undamaged. Fabrics of different type or weights shall be separately bundled or rolled.

18.23.7.11. Tying Wire

The tying wire for reinforcement shall be one and one half (1.5) millimetres in diameter annealed soft iron tying wire.

18.23.7.12. Threaded Inserts

The threaded inserts for casting into concrete shall be electro-galvanized and of malleable iron or mild steel.

18.23.7.13. Waterproofing Admixture

Waterproof concrete and mortar shall be used where shown on the Drawings. Waterproofing shall be by the use of a reliable and approved brand of admixture. The admixture shall be used strictly in accordance with the manufacturer's instructions.

18.23.7.14. Availability of Materials

The Contractor shall be deemed to have satisfied himself that suitable materials for concrete and mortar can be obtained in sufficient quantities to carry out the works.

18.23.7.15. Approval of Supplies

As soon as possible after the Contract has been placed the Contractor shall submit a list giving details of the sources from which he proposes to obtain concrete and mortar materials. Only materials from approved sources shall be brought to site, but the Employer/Employer's Representative will be prepared to extend his approval to other satisfactory sources of supply which may be proposed by the Contractor. Approval of a source of supply shall not imply acceptance of material found not to conform to this Specification.

18.23.7.16. Preliminary Tests of Concrete Ingredients

After submission of the list of approved sources of supply of concrete materials, the Contractor shall, when required obtain representative samples of water and of fine and coarse aggregate in sufficient quantities for testing as directed by the Employer/Employer's Representative. The tests to be carried out shall be decided by the Employer/Employer's Representative, and shall be carried out by the Employer/Employer's Representative and/or at an independent laboratory. The test will normally consist of mechanical, and if necessary chemical, analysis of the aggregate plus chemical analysis of the water.

As soon as possible after the Contract has been placed, the Contractor shall prepare trial mixes of the proposed concrete mixes and subject them to various tests, including:

- Compressive strength tests at 7 and 28 days
- Slump tests
- Expansivity tests to aggregates and concrete

Testing of the concrete samples shall be carried out by an independent authority to be agreed with the Employer/Employer's Representative. When concrete grades have been approved, the Contractor shall not vary the proportions without approval.

18.23.7.17. Testing on Site

Samples of concrete shall be taken from the works at a rate of one sample per 20m³ or one sample per 20 batches, whichever is the lesser. Test cubes shall be made from these samples in sets of six. All concrete testing is included in the Contract.

Test cubes shall be made, cured, stored and transported and test in compression in accordance with BS EN 12350.

Concrete may be assumed satisfactory if the cube strengths at 7 days are 50% of the 28 day strength. Should the 7 day values be below 50% of the final strength the concrete may still be assumed satisfactory if the 28-day test results conform with the target strengths. If the results of both the 7 day and 28-day works cube tests show crushing strengths less than those specified, the Employer/Employer's Representative may suspend all concreting work and order further tests to ascertain if the concrete placed in the works is acceptable. Any concrete found

not to comply with the Specification shall be broken out and replaced, or otherwise rectified, to the satisfaction of the Employer/Employer's Representative.

All remedial measures including cutting-out, reinstating, mix adjustment, further testing and the like, which, in the opinion of the Employer/Employer's Representative, are required shall be at the expense of the Contractor.

18.23.7.18. Measurement of Materials

In proportioning concrete, the quantity of cement shall be determined by weight and when the cement is supplied in bags the concrete shall be mixed in batches using one or more complete bags of cement. The quantities of fine and coarse aggregate should be determined by weight but where written approval has been obtained from the Employer/Employer's Representative may be determined by volume.

18.23.7.19. Mixing of Concrete

The concrete materials shall be weight batched and mixed with mechanical mixers. The machines are to ensure that all the concreting materials including the water are thoroughly mixed together between the time of their deposition in the mixer and before any portion of the mixture is discharged. The machines must be capable of discharging their content while running.

All equipment shall be thoroughly cleaned before use or re-use for other grades of concrete.

18.23.7.20. Workability of Concrete

The concrete shall be of a dense, homogeneous nature produced with the minimum quantity of water necessary to ensure a compact mass sufficiently workable to enable proper placing and consolidation in corners and around reinforcement, and to give the specified finish, strength, density or other required qualities. The water/cement ratio for each grade of concrete shall be agreed with the Employer/Employer's Representative.

The control of the workability of concrete shall be maintained by application of Slump Tests carried out in accordance with the procedure laid down in BS 1881. Slump tests shall be made at least twice daily or as directed and a record of results kept on site for periodic review.

18.23.7.21. Transporting

Concrete shall be distributed from the mixers to final position in the works as rapidly as possible and by approved methods which will prevent segregation or loss of ingredients. All equipment shall be thoroughly cleaned before use or re-use for other grades of concrete.

18.23.7.22. Placing

Not more than thirty (30) minutes after water is first added to the mix and before initial set has occurred, the final placing of the concrete shall be completed. On no account shall water be added after the initial mixing.

All concrete surfaces in contact with the earth shall be suitably protected with a bituminous membrane.

Concrete shall be introduced into the forms, between pre-determined construction joints, as near as practicable to its final position in a manner which will not cause segregation of the mix or displacement of the reinforcement or forms.

Concrete shall not be dropped from a height greater than one (1) metre unless 'tremmie' techniques are adopted. The placing and consolidation of concrete shall be done in a manner which will not disturb previously placed concrete.

Before the placing of the concrete the formwork and reinforcement shall be inspected and approved by the Employer/Employer's Representative. The Contractor shall invite the Employer/Employer's Representative well in advance to these inspections.

18.23.7.23. Compacting of Concrete

Concrete shall be consolidated by an approved method of ramming, tamping or vibration. It shall be carefully worked round reinforcement and embedded fixtures, into corners and against the forms to produce a dense uniform mass free from defects. Care shall be exercised to ensure the whole depth is thoroughly compacted without disturbance to parts of the work already placed. Excessive ramming and tamping shall be avoided.

18.23.7.24. Mechanical Vibration

All concrete shall be vibrated unless otherwise directed. Vibration shall be additional to hand compacting and numbers and types of vibrators shall be approved before use. Vibrators shall be the immersion type operated at an approved frequency and external formwork vibrators may only be used on agreed sections of the works.

Operators of vibrating tools shall have received adequate instruction and training in their use. Every care shall be taken to avoid contact of vibrators with the reinforcement or previously placed concrete. Excessive vibration shall be avoided.

18.23.7.25. Construction Joints

Concreting shall be carried out continuously up to approved construction joints with moulded bonding chases. Unless otherwise approved or instructed concrete shall be placed to the full depth of slabs, beams and the like and shall be placed in horizontal layers not exceeding one and one half (1.5) metres deep in walls, columns and similar members.

Construction joints shall be formed in the horizontal and vertical planes by means of stop boards which allow the reinforcement to run through. Where practicable, laitance shall be removed whilst the concrete is still soft so as to expose the coarse aggregate. Where concrete already deposited has set but not set hard the laitance shall be removed and the coarse aggregate exposed by wire-brushing and washing.

At joints where the placed concrete has set hard any skin or laitance shall be removed by hacking, care being taken to avoid damage to the aggregate.

Immediately before concreting proceeds the roughened joint surface shall be thoroughly cleaned and loose matter removed, then treated with a layer, 12mm thick, of cement mortar 1:1 mix. The concrete shall be immediately deposited and punned into the cement mortar.

Where construction joints will be permanently visible, the cement mortar shall be kept back from the exposed face of the concrete.

18.23.7.26. Contraction Joints

Contraction joints in concrete slabs and walls shall be formed in positions and to details shown on the Drawings or as directed by the Employer/Employer's Representative. The joints shall be straight and vertical except where otherwise approved and concrete surface levels on both sides of the joint shall be flush. The joints shall be sealed with 'Compriband' bituminised polyurethane foam strip, pre-compressed before insertion and installed in accordance with the recommendation of the manufacturers, Compriband (Great Britain) Ltd, or 'Pliastic' tropical grade rubber bitumen compound, produce of Expandite Ltd, poured hot into horizontal joints or other approved product of equal properties and quality.

18.23.7.27. Expansion and Deflection Joints

Expansion and deflection joints shall be formed in positions and to the details shown on the Drawings or as directed.

Joints shall be straight and vertical except where otherwise approved and concrete surface faces shall be flush on both sides of the joint.

The joints shall be filled with 'Flexcell' non-extruding wood fibre bitumen impregnated boarding, and sealed with 'Pliastic' tropical grade rubber bitumen compound, both products of Expandite Ltd, or other approved products of equal properties and quality.

18.23.7.28. Protection of Concrete

Proper protection shall be provided to prevent cement from being taken or washed away and the concrete from being diluted during the process of storing, handling, transporting, apportioning and mixing the materials, and transporting, placing, compacting and curing the concrete.

All foundations constructed below the water table and within the capillary rise zone are to be suitably protected from chemically aggressive ground conditions by tanking with a bitumen type membrane if required by the Ground Investigation Results.

Care should be taken to ensure that concrete during hardening is not disturbed by direct or indirect loading, movement or projecting reinforcement, vibration or other similar effects. All concrete shall be protected from the harmful effects of sunshine, wind and rain and foundation concrete shall also be protected from damage by storm or subsoil water.

18.23.7.29. Curing

It is vitally important that prolonged moist curing is carried out in order to achieve long-term durability.

Exposed surfaces shall be protected from wind and low humidity until the concrete has reached sufficient maturity.

Start the curing immediately after finishing, to prevent rapid surface drying.

Keep the surface continuously moist or by the application of impermeable sheeting for at least 10 days to avoid plastic shrinkage cracking caused by faster surface moisture evaporation than the rate of moisture migrating to the surface.

For floor construction where a surface treatment such as power floating or the like is to be used curing agent should be applied immediately after the completion of the surface treatment.

18.23.7.30. Bending of Reinforcement

All steel bars are to be accurately bent cold to the shapes and sizes indicated on the Drawings and Schedules unless otherwise approved. Bending dimensions shall be in accordance with BS 8666 unless otherwise stated. Re-bending of bars and bending in position in the works shall not be allowed.

18.23.7.31. Welding of Reinforcement

Spot or track welding for positioning bars in heavily reinforced areas will only be allowed with the express permission of the Employer/Employer's Representative. Extension of lengths of reinforcement by welding will not be permitted.

Welding will be approved only in low stress members, and lap welding will not be approved in any circumstances.

18.23.7.32. Fixing of Reinforcement

Before fixing in the works bars shall be seen to be free from pitting, mud, oil, paint, loose rust or scale or other adherents harmful to the bond or strength of the reinforcement. Bars shall be fixed rigidly and accurately in position in accordance with the working drawings, unless otherwise approved by the Employer/Employer's Representative.

Reinforcement at all intersections shall be securely tied together with soft annealed tying wire the ends of which shall be cut and bent inwards. Cover to the reinforcement shall be as stated previously and sufficient spacers and chairs or precast concrete or plastic of approved design shall be provided to maintain the specified cover and position. No insertion of bars in previously placed concrete shall be permitted. Projecting bars shall be adequately protected from displacement. The fixing of reinforcement in the works shall be approved before concrete is placed.

18.23.7.33. Formwork

Formwork shall be constructed from timber, metal, plastic or concrete, lined as necessary for special finishes and designed with the quality and strength required to ensure rigidity throughout placing, ramming, vibration and setting of the concrete, without detrimental effect.

Formwork shall be erected true to line, level and shapes required using a minimum of approved internal ties. Faces in contact with the concrete shall be true and free from defect, jointed to prevent loss of water or fines, in panels or units which permit easy handling, and designed to permit sideforms to be struck independently of soffit shuttering. Ties or spaces remaining embedded shall have the minimum cover specified for reinforcement. Forms for exposed concrete beams, girder casings and columns shall provide for a twenty-five (25) millimetre chamfer on external corners. Formwork described as wrot shall be planed timber, plywood, smooth steel or other material of a similar smooth surface. Samples showing the standard of finish may be required.

Forms for concrete surfaces not exposed shall be described as 'rough' and may be timber as left from the saw or approved similar material.

Construction joints in the works shall be so arranged to provide a 'starter' to which the forms for the next lift may be clamped. Wedges and clamps shall be kept tight during vibration operations. Before commencement or resumption of concreting, the interior of forms shall be cleaned and free of sawdust, shavings, dust, mud or other debris and openings shall be formed to facilitate this cleaning and inspection. The inside of the forms shall be treated with a coating of an approved substance to prevent adhesion. Care shall be taken to prevent this substance being in contact with the reinforcement.

18.23.7.34. Inspection and Approval of Formwork

All formwork moulds and reinforcement shall be subject to inspection and approval by the Employer/Employer's Representative immediately prior to the placing of concrete.

18.23.7.35. Removal of Formwork

Formwork shall be kept in position, fully supported, until the concrete has hardened and gained sufficient strength to carry itself and any loads likely to be imposed upon it. Stripping must be effected in such a manner and at such a time that no shock or other injury is caused to the concrete. The responsibility for safe removal rests with the Contractor but the Employer/Employer's Representative may delay the time of striking if he deems it necessary.

Minimum periods, in the absence of agreement to the contrary, between completion of concreting and removal of forms are given below but due regard must be paid to the method of curing and prevailing conditions during this period.

Removal of formwork	
Positions in works	Minimum before striking formwork period
Removal of shuttering to sides of rafts, walls, beams and columns	2 days
Removal of shuttering to slabs, beams and arches (props left under)	6 days
Removal of props to slabs, beams and arches	16 days
Lifting to precast members	16 days

18.23.7.36. Precast Concrete Members

Precast concrete members shall be used in the works and only where specified on the Drawings or approved by the Employer/Employer's Representative.

All the requirements for concrete, formwork and reinforcement shall apply equally to the moulds for precast members and concreting shall be carried out in one continuous operation.

Precast members shall not be disturbed or lifted until the minimum periods specified for formwork removal have elapsed.

18.23.7.37. Replacement of Damaged Concrete

In the event of any portion of the concrete work being damaged so that in the opinion of the Employer/Employer's Representative it does not fulfil the requirements of the Contract, the replacement or reinstatement shall be carried out at the expense of the Contractor to the directions of the Employer/Employer's Representative.

18.23.7.38. Finish of Concrete Surfaces

i. Concrete cast against formwork

The following finishes to concrete surfaces, unless otherwise specified or shown on the drawings, shall be as follows: -

Class A1: All permanently exposed surfaces, including exposed sides of foundations.

Class A1 surfaces shall be dense, fair, smooth, even, free from honeycombing, water and air holes and other blemishes, true to line and surface and free from board or panel marking. They shall be of uniform colour. Rendering of defective surfaces shall not be permitted, and, if ordered by the Employer/Employer's Representative, the Contractor shall at his own

expense cut out to expose reinforcement and make good any unsatisfactory work. All areas so treated shall be rubbed down and kept moist for several days.

Class A2: Surfaces to be covered by backfill, plasters or the like.

Class A2 surfaces shall be dense, even, free from honeycombing and true to line and surface.

Any special finishes will be to details or instructions given by the Employer/Employer's Representative.

ii. Concrete not cast against formwork

The following finishes shall be provided unless otherwise specified or shown on the drawings: -

Class B1: All permanently exposed surfaces, including tops of equipment foundations, wall copings, window sills, precast items (except paving flags).

Class B2: Paving flags and paths. Floors and slabs to be surfaced with blocks, tiles or waterproofing materials.

Class B3: Roads, buried concrete and floors or slabs to be covered by screed.

Class B1 surfaces shall first be levelled and screeded to produce a true surface. After the moisture film has disappeared, and the concrete has hardened sufficiently, the surface shall be finished with a steel trowel under firm pressure to give a smooth, dense, even and hard surface free from all marks and defects.

Class B2 surfaces shall be levelled and screeded to produce a true surface, and be finished with wooden or steel float to give a level surface free from screed marks. Excessive floating shall be avoided.

Class B3 surfaces shall be levelled and screeded to produce a true and uniform surface.

18.23.7.39. Holes, Pockets, Threaded Inserts, etc.

Holes, cavities and fixings shall be provided in the works only at the positions indicated on the drawings or as directed and they shall be incorporated as necessary during the work of concreting. Unless otherwise agreed a tolerance in position of plus or minus (5) millimetres shall be allowed. Inserts and bolts shall be fixed square in the works by means of temporary bolts or nuts, and then concrete cast around them. The projecting portions of such fixings, and concrete within fifty (50) millimetres of them, shall be bitumastic painted and all threads well-greased on completion of the work. Holes and pockets shall be stripped down clean on completion.

18.23.7.40. Ties to Blockwork

Galvanized steel dowel ties ten (10) millimetres diameter, one hundred and fifty (150) millimetres long shall be bedded for half their length in the structural concrete where it abuts concrete blockwork infill panels. Ties shall be fixed at their correct positions to meet blockwork joints at a maximum of one (1) metre centres. Positions of ties will not normally be indicated on the Drawings.

18.23.7.41. Blinding

Under all foundations and elsewhere as indicated on the Drawings a layer of concrete grade f_{ck} 15/20 shall be laid immediately the excavation is carried down to foundation level. The blinding surface shall be thoroughly clean before foundation concrete is deposited thereon. Sumps shall be provided where necessary to facilitate the control of drained water.

18.23.7.42. Structural Steel

Steel sections shall be new and shapes shall conform to the Kenyan and/or British Standards. All structural steel sections shall be hot rolled with a minimum grade 460 in accordance with BS EN 1994. As a minimum the following shall apply:

Hot rolled sections	BS 4	Part 1 and addenda
Hot rolled hollow section	BS EN 10210	
Weldable structural steels	BS EN 10025	
Black bolts, screws and nuts	BS 916	

The structural steelwork shall be designed, fabricated and erected in accordance with BS 5950: "The structural use of steelwork in building" - unless otherwise described, directed or permitted.

Auto/manually fabricated welded sections shall only be permitted when a suitable rolled section does not exist i.e. when section required is greater than the largest rolled section size available from the manufacturer/mill.

All bolts in elevated steelwork connections shall be minimum grade 8.8 high strength bolts to suit the required design. All holding down bolts shall be minimum grade 5.6. Finishes etc. shall be selected such, to eliminate galvanic corrosion. Bolt finishes shall conform with the finishes applied to the steelwork elements to which they connect. Welded connections will comply with the relevant Kenyan or British standard.

The Contractor shall select coating systems on consideration of climatic conditions prevailing at the site. Such systems shall have a design life to first maintenance of at least 20 years. As a minimum an atmospheric environment category of C5-M, C4 or Im2 should be considered for all structures, as defined in BS EN ISO 12944. The C5-M classification shall apply to all areas within 100m of a sea shore line, the C4 classification shall apply to areas more than 100m from the shoreline and the I_m^2 shall apply to all submerged structures.

In the case of paint applied systems these shall consist of shop applied coatings and site applied finishing coat(s) all in accordance with BS EN ISO 12944. The final site coat(s) shall be applied after steelwork erection/alignment and bolt tightening activities have been completed, unless otherwise agreed with the Employer/Employer's Representative.

Where zinc coatings are proposed as protection against corrosion the guidelines of BS EN ISO 14713 (Protection against corrosion of iron and steel in structures – Zinc and Aluminium coatings – Guidelines) shall be used. Galvanized steel elements exposed to seawater spray, those located in the seawater structures and those in drainage sumps etc. shall be suitable for a Class C5 exposure as defined in BS EN ISO 14713.

Some items of secondary steelwork shall be hot dip galvanized to BS EN ISO 1461 i.e. steel flooring, ladders, sheeting rails, purlins, access stair stringers, treads and handrails.

18.23.7.43. Grouting

Non-shrink grouts are to be used for grouting machine base plates and column bases.

Where specifically noted on final construction drawings or directed by the Employer/Employer's Representative, grouting shall be with premixed, expansive cement, non-metallic, inorganic, non-shrink grout. Grout shall be manufactured by a firm normally engaged in the manufacture of such items, having a proven record of successful installations, and acceptable to the Employer/Employer's Representative. Grout shall be mixed and placed in strict accordance with the manufacturer's recommendations. Compressive strength of grout shall be not less than 350 kg/cm² after 7 days and not less than 600 kg/cm² after 28 days.

18.23.8. Concrete Blockwork

18.23.8.1. Concrete Blocks for Building

Concrete blocks shall be made in approved machines incorporating mechanical vibration. All blocks, unless otherwise described on the Drawings or in the Bills of Quantities shall conform to BS 5628 Structural use of unreinforced blockwork as regards constituent materials, grading of aggregates, mix properties, dimensions of blocks, methods of manufacture, curing, testing, specified strengths and drying shrinkage characteristics. If any blocks tested do not meet the requirements of the tests, all blocks from the same batch shall be rejected.

18.23.8.2. Surface of Concrete Blocks

Where walls are to be painted or have similar finishes, the blocks shall be fair face. Where walls are to be rendered, tiled or similarly covered the surface shall be of a suitable rough texture to provide a good key.

18.23.8.3. Mortar

Concrete block walls shall be constructed using mortar which complies with the requirements of BS EN 998-2:2010 Specification for Mortar for masonry.

18.23.8.4. Building Block work Walls

Walls shall be built to the dimensions and levels shown on the Drawings, and shall be carried up in level courses with true perpendiculars. No section of blockwork shall lead any other section by more than four courses at any one time. All blocks shall be thoroughly wetted before laying, and the tops of blocks shall also be wetted before the next course is laid.

18.23.8.5. Joints

The total thickness of any four horizontal joints shall not exceed forty (40) millimetres. All joints shall be fully flushed up as work proceeds.

18.23.8.6. Bond

Each block shall be centred over the vertical joint in the course below.

Blocks of special sizes necessary to form proper bonding at angles, openings, intersections, etc. which cannot be made in a standard machine may be made in specially constructed moulds. In all other respects they shall be of a quality equal to the standard blocks.

18.23.8.7. Finish to Walls

Where walls are not to be rendered or tiled, the blocks shall be fair face and shall have flush joints, struck as work proceeds.

Where walls are to be rendered or tiled, the surface shall be of rough texture, and all joints shall be raked out to form a key.

18.23.8.8. Filling of Cavities

The cavities in blocks shall be filled with Grade 15/20 concrete from foundation level up to damp proof course as work proceeds. Cavities adjacent to door, window and such openings shall be similarly filled. Fixings for doors and windows shall be built in as the walls are built.

18.23.8.9. Completion

Upon completion of blockwork, it shall be thoroughly washed down and left clean.

18.23.8.10. Protection of work

Partially completed work shall be adequately protected from damage by rain, heat or any other cause.

18.23.9. Drainage

18.23.9.1. Surface Water Drainage Systems

The surface water and foul drainage systems shall be separate and shall be designed in accordance with BS EN 752 Parts 1 to 4 "Drain and sewer systems outside buildings". Manhole and chamber covers shall be heavy duty throughout. The Contractor shall be responsible for determining the adequacy of the drainage systems. He shall prepare calculations for submittal to the local authorities and to the Employer/Employer's Representative that take into consideration the estimated sewer flows.

All drainage ditches shall be lined, either with concrete or stone pitched walling. The entire open drainage system shall also be fitted with open steel gratings that shall be recessed into the top edge of the concrete walling. The gratings shall be of flat bar on edge, galvanized after manufacture, with openings sufficient to allow the passage of surface water but not stones or rubbish, and shall be capable of taking superimposed loads from foot traffic (but not vehicular traffic). The gratings shall be arranged to present a neat appearance with all sections to a standard size, and edges properly finished. The gratings shall be arranged in short sections for ease of removal and refitting.

Where the drainage system passes under roads it shall be in reinforced pipework or pipes laid within concrete ductwork.

The gradients to which all sizes of drains and sewers shall be laid, shall be completely sufficient to ensure self-cleaning velocities in the pipes.

Minimum self-cleaning velocity shall be taken to be:

In pipes up to 225mm diameter 0.75m/sec to 0.9m/sec

In pipes between 225mm and 600mm diameter 0.75m/sec

Maximum self-cleaning velocity shall be taken to be:

1.8m/sec under reasonable circumstances and

3.0m/sec absolute maximum

18.23.9.2. Manholes and Inspection Chambers

Manholes and Inspection Chambers shall be constructed in accordance with BS EN 1917:2002. They shall be built in masonry or concrete with galvanized step irons and cast iron covers and frames. Heavy duty cover and frames shall be used for trafficked areas.

18.23.9.3. Drainage during Construction

The Contractor shall maintain all existing drains and drainage channels in good order during the period of the works, and also cut any additional temporary channels which may be necessary to prevent flooding of the Site

until the permanent drains have been laid. Particular attention shall be directed to dealing with ground and surface water before, during and after construction as these may present problems during the rainy season.

18.23.9.4. Waste Water Drainage

All waste drainage shall be taken to a septic tank. A septic tank is a type of settlement tank intended to provide quiescent conditions for settlement of sludge and the development of anaerobic conditions for the decomposition of organic matter. Raw sewage is fed to the tank, and settled sewage is discharged to the soakaway by means of an overflow pipe. The capacity of the septic tank shall be sufficient to cater for the load arising from the sub-station.

The septic holding tank shall be constructed in a manner and using appropriate materials so as to remain water tight at all times and be strong enough to withstand heavy vehicular traffic. It shall be GRP or made of concrete. Openings and covers shall be provided to permit easy access and all covers shall be of the heavy duty type suitable for vehicular traffic. Ventilation shall be provided by a ventilation pipe terminating in a copper wire balloon to prevent the access of adventitious matter. The construction and internal configuration of the tank shall be in accordance with the current environmental regulations.

A soakaway pit of adequate capacity shall be constructed as part of the sub-station development. It is essential that the soakaway walls shall be built with solid concrete blocks in mortar which contains lime putty to which an approved waterproofing agent has been added. All joints in blockwork shall be well filled with mortar. The liquid effluent from the septic tank shall be drained to the soakaway pit. The soakaway pit shall be covered by a reinforced concrete slab with access through a manhole cover. The dimensions of the soakaway pit shall be determined by the percolation characteristics of the local soil as determined by a standards test and the result expressed as minutes/mm reduction in surface level.

The Sanitary system within the buildings will be developed by the Contractor as per standards referred to in the specification and continued into the general outdoor sanitary sewer system and finally to the septic tank and connected to the existing system.

18.23.9.5. Stormwater Drainage

The capacity of the surface water drainage system shall be designed in accordance with an international standard using a storm return period of 1 in 5 years. The surface water drainage shall include all necessary gutters, down pipes, gullies, traps, catch pits manholes etc. All water likely to contain oil shall be passed through approved oil separators before passing into the drainage system. The quality of the discharge shall be acceptable in all respects to the local water and environmental authorities.

The stormwater system for drainage from buildings shall comprise down pipes into gullies and buried pipes discharging into existing water courses and channels. Where it is not possible to obtain sufficient cover to bury the pipes the water shall be conveyed in reinforced concrete channels, laid to falls which shall ensure that the channels are self-cleansing. The drainage channels shall be covered with an open grid galvanized grating as specified above.

The stormwater system for the Site general shall consist of lined channels (concrete or stone pitched walling) or pipework, manholes and stand traps that shall discharge to open ground outside the site boundary. Discharged water shall not be permitted to pond within 50m of the site boundary.

18.23.9.6. Pipes for Stormwater Drainage

- a. Concrete pipes and fittings:** These shall conform to BS 5911, and shall be obtained from an approved manufacturer. They shall be suitable for flexible jointing unless otherwise approved.
- b. Porous concrete pipes:** Porous concrete pipes shall be used where indicated on the Drawings and shall conform to BS 5911-114:1992. They shall be wholly porous with ogee joints.

The structural design of pipework shall be in accordance with the pipe manufacturer's recommendations in respect of pipe grade, trench dimensions and pipe bedding.

18.23.9.7. Bends, Gullies and Fittings

All bends, gullies and fittings used in the drainage systems shall be of the same materials and of equally high quality as the adjacent pipework.

18.23.9.8. Catchpit Covers

Where concrete slabs covers are required they shall be pre-cast and have a strength of 35N/mm³ after 28 days. Where cast iron covers are required they shall conform with BS EN 124. Covers to be watertight and prevent ingress of surface water.

18.23.9.9. Step Irons

Manhole step irons shall comply with BS EN 13101:2002 or be of equal strength and dimensions. They shall be galvanized or coated with best quality bitumastic composition.

18.23.9.10. Inspection of Pipes

All pipes and fittings shall be examined before laying and any found to be damaged, defective or otherwise unsound shall not be used in the works.

18.23.9.11. Excavation and Backfill

Trench excavations for drains shall be carried out with the minimum disturbance to adjacent ground and in such a way that existing or new work shall not be undermined. Where trenches are to be backfilled with hardcore, gravel or the like, or where open channels are to be constructed, excavated material shall be removed immediately after excavation. No backfill shall be placed until pipes, etc. have been inspected, tested and approved. Backfill shall be carefully placed by hand tools round pipes etc. and rammed in layers not exceeding one hundred (100)

millimetres thick in a manner which will not cause damage. When a minimum thickness of three hundred (300) millimetres above the pipes has been so placed, normal methods of backfilling and ramming may be adopted.

18.23.9.12. Laying of Pipes

Pipes and fittings shall be of the types, qualities and sizes specified by the designer. They shall be laid to the lines and levels shown, and the barrel of each pipe shall bear firmly and uniformly on the trench bottom or prepared foundation bed, any projections in the trench bottom which could cause damage to pipes being first removed. Pipes shall be kept clean during and after laying, and open ends shall be provided with temporary plugs to prevent entry of foreign matter. Each pipes shall be accurately boned to gradient between sight rails and drain laying shall commence at the lowest end and proceed uphill. Pipes shall be laid with the sockets leading uphill.

18.23.9.13. Jointing of Pipes Generally

The jointing of pipes shall be carried out as specified below. The pipes to be jointed shall be accurately centred and butted together, and joints shall be made only by experienced drain layers using the special tools recommended for the particular type of joint. Joints shall generally be of a flexible type.

18.23.9.14. Flexible and Proprietary Joints

The joints in concrete, asbestos cement, unplasticized PVC and pitch fibre pipes designed for flexible jointing shall be made in accordance with the manufacturer's instructions and relevant British Standards. Unless otherwise directed or agreed, the joints in concrete and asbestos cement pipes shall be of the compressed rubber ring type, and when loose collars are used these shall be accurately located over the centre of the joints.

18.23.9.15. Rigid Jointing of Spigot and Socket Pipes

Concrete, asbestos cement or salt glazed ware spigot and socket pipes for rigid jointing shall be used only where specified or directed. They shall be jointing by inserting and caulking one complete ring of tarred gasket which shall centre the pipes and prevent mortar from entering the pipes. The joint shall then be completed by filling with mortar which contains lime putty. The mortar shall be well rammed into the joint and finished with a 45° bevel. Joints shall be undisturbed and kept covered with wet sacking for 7 days.

18.23.9.16. Porous Pipe Joints

Joints in porous pipes shall be made by butting the pipes tightly together so that no soil or the like can enter the pipes. If, due to minor changes of line or gradient, a joint cannot be completely closed, it shall be wrapped with bituminous felt and surrounded with weak concrete.

18.23.9.17. Concrete Surroundings

Where required the pipes shall be bedded on or surrounded by Grade 12/15 concrete with an aggregate size of 20mm.

18.23.9.18. Catchpits

Details and sizes of bases, benching, covers and manholes generally shall be obtained from typical manhole details shown on the Drawings. Unless otherwise directed catchpit walls shall be built with solid concrete blocks, as specified, in Grade B mortar to which an approved waterproofing agent has been added. All joints in blockwork shall be well filled with mortar.

Catchpits deeper than (1) metre shall be provided with step irons. Precast concrete relieving blocks manufactured with Grade 25/20 concrete shall be provided and set in the blockwork walls over each pipe.

18.23.9.19. Testing of Drains

All drains, other than open channel, stone filled drains and porous drains, shall be of watertight construction, and all waste water and surface water drains shall be subjected to a water test before backfilling of trenches is commenced. Drains may be tested in sections, and catchpits may be tested separately. The Contractor shall submit to the Employer/Employer's Representative for approval his proposals for testing. The drains shall withstand, without leakage, a water pressure of not less than one and one half (1.5) metres at any point for a period of 20 minutes or such other time as the Employer/Employer's Representative may direct. All necessary plugs, temporary connections and other equipment and all labour required for the tests shall be provided by the Contractor and at the expense of the Contractor. For testing of pipes in areas where an adequate supply of water is not readily available, the Employer/Employer's Representative will accept an air (smoke) pressure test, always provided that the method of testing is approved. Further testing may be called for after backfilling of trenches to ensure that pipes have not been damaged during that operation.

Open drainage channels shall be tested to ensure that they are completely self-draining, with a continuous fall and no ponding of water in the base.

18.23.9.20. Regulations

The regulations and recommendations of any relevant drainage or sanitary authority shall be fully observed, and the Contractor shall be responsible for acquainting himself with any such regulations.

18.23.10. Oil Containment

Power transformers shall be sited in oil containment areas and drain via a flame trap to an underground facility to remove oil away from a fire in the event of an incident. The capacity of the underground containment shall be equal to the volume of oil contained within the transformer plus 50% to allow for rainwater and firefighting materials externally applied by the firefighting service.

Where there is more than one power transformer on a site, it may be economic to link the oil containment drainage areas of these to a single underground tank with capacity for the largest transformer alone. Connecting pipe work shall be designed to ensure rapid discharge of oil to the underground facility that, together with the pipe work, shall be resistant to transformer oil at a temperature of up to 80°C. Underground oil containment facilities shall be provided with a means of inspection and allow for pumping out of accumulated rainwater or oil.

Concrete surfaces inside the pit shall be protected by an approved oil resistant paint. A layer of stone (38 mm single size stone chipping) shall be placed 150 mm below the top of the transformer pit wall. The layer shall be 300 mm thick and set on galvanized grille (grating). A sump shall be provided and shall be readily accessible through a manhole, which will be fitted with galvanized grating cover. Petrol motor driven mobile pump of adequate capacity for drainage of transformer pit shall be supplied under the Scope of Works.

The area within the transformer enclosure shall be designed as a water retaining structure to BS 8007 and coated with 2 coats of bituminous paint and be surfaced with a 100 mm thick layer of gravel on steel grating. It shall be tested in accordance with Part 19 of Section 5 of QCS.

The road immediately adjacent to transformers used by oil handling equipment for maintenance will also drain to the containment facility to prevent ground pollution in the event of accidental spillage.

18.23.11. Fire and Blast Design Requirements

Plant within close proximity of power transformers/reactors shall be protected by fire barrier walls. Protection shall be provided for other circuits and transformers/reactors, control equipment, and external property according to the recommendations of NFPA 850.

Fire barrier walls and building fireproof walls will be designed for 4-hour fire resistance and a blast pressure of 0.5 kN/ m². The fire barrier wall height shall be a minimum of 500mm above the highest part of the transformers.

18.23.12. Permanent Access Roads

18.23.12.1. General

The permanent road system within the site shall be designed to allow for adequate access and emergency situations during operation and maintenance. The road system shall form an integral part of the existing road system.

The substation access road shall be to bituminous standard, complete with drainage facilities and culverts as necessary shall be constructed by the contractor, the length of this road as stipulated in the price sheets.

The permanent roads within the site are to be designed in accordance with accepted international standards that shall be proposed by the Contractor and agreed by the Employer/Employer's Representative on the basis of a 25 year life with 50 commercial vehicles per day. Due account is required to be taken in the road design of abnormal loads during both the construction phase and also during the operational life of the plant resulting from heavy maintenance.

All permanent roads are required to be of such geometrical alignments (longitudinal gradient, cross-fall, radius and width) to accommodate the movement of heavy goods vehicles at the design road speed of 15mph.

Road markings and signs shall be in accordance with the Department of Transport publication 'Traffic Signs Manual Volumes 1 to 14'.

Footpaths shall be of 1500mm nominal width and designed for an accidental wheel load of 20kN. Footpaths shall be either precast concrete flags or bitumen macadam.

Within the plant area height limit gauges shall be provided where height clearances are limited and in particular where there is danger from overhead lines.

Safety barriers shall be provided where there are exceptional local hazards or where specific plant protection is required. These barriers will be of the Armco or substantial bollard type.

External access road from the nearest main road up to substation gate to be implemented. The proposed route of access road shall be in line with the Substation layout and existing pathway. The substation access roads shall be made to bituminous standards. The road shall be connected to existing major roads via a standard road junction to the approval of the highway authorities. The width of the main carriageway shall be 7 m (two 3.5 m lanes) with 1 m shoulder on each side. The road shall be lined with channels and kerbs for drainage, with storm water draining into Inverted Block Drains (IBDs) on either sides of the road, road markings and signs. The slope from the shoulders to the invert level of IBD shall be lined to Employer's Representative approval.

18.23.12.2. Codes and Standards

Materials and workmanship shall comply with the latest revisions of the following Codes and Standards: -

- BS 13108 Bituminous mixtures. Material specifications.
- Department for Transport "Specification for Highway Works".
- Department of Environment "Traffic Signs Manual".
- BS EN 12591 Bitumens and bituminous binders. Specifications for paving grade bitumens.
- BS 3690-3 Bitumens for Building and Civil Engineering

18.23.12.3. Car Parks

All materials, workmanship and testing shall be in accordance with the Department for Transport 'Specification for Highway Works, Part 3'. All areas of roads or hardstanding that could be subjected to a fuel, oil or chemical spillage shall be constructed in concrete.

A minimum capacity of 10 No vehicles shall be provided.

18.23.12.4. Road Drainage

Access roads shall be constructed with an elevated grade above the level of water that ponds on the surface during the rainy season. The roads shall be graded to drainage gullies which shall discharge into the main drainage system.

Culverts should be installed through the elevated roadway to allow the free movement of the water and to avoid ponding adjacent to the roadway.

Where pipes pass under the road they shall be surrounded by concrete or laid in concrete ducts and the road shall be bridged over them if necessary.

18.23.12.5. Kerbs

The roads shall be constrained between kerbs.

Kerbs shall conform to BS EN 1340:2003 Concrete Kerb Units – Requirements and test methods.

They shall be cast to the required radii for all curves less than 12 metres. Paving slabs will be to BS EN 1339.

Concrete bedding and backing to kerbs shall be cast in-situ to the dimensions shown on the drawings. Bedding mortar shall consist of freshly mixed moist 1:3 cement sand mortar using sand complying with BS 882 grading M. Kerbs shall be backed with concrete with a grade of not less than C15.

Flush kerbs shall be similarly laid or may be cast in-situ. The outside corner of the kerbs shall be chamfered.

Marginal strips and kerbs shall be protected against covering or splashing with bitumen or cement. Kerbs and manhole frames shall be primed before bituminous macadam is laid.

18.23.13. Fencing and Gates

This section specifies fixed chain link fencing. This type of fencing shall be used for the entire substation site boundary of 3 meters high.

This shall also apply to the fencing of the Switchyard land and staff housings of 2 meters high.

The provisions and installation of the chain link fence shall be in accordance with the requirements of BS 1722 Part 10 "Specification for anti-intruder fences in chain link and welded mesh" except where varied by this Specification.

18.23.13.1. Chain link fabric

Chain link fabric shall be galvanized wire (Grade A) and PVC (plastics) coated and have a diamond mesh pattern size of 50mm in accordance with Clause 3.2 of BS 1722 Part 10. The width of the mesh roll shall be 2.4m. The external diameter of the mesh coated wire shall be 6.4mm conforming to Table 1 of BS 1722-10.

All wire shall conform to the relevant parts of BS EN 10223 or BS 4102.

The fabric shall be furnished on the top and bottom edges with a twisted and barbed selvage. Chain link mesh shall be joined by interweaving a spiral and restoring the knuckle or barb.

A continuous concrete sill 300mm wide x 300mm deep shall be cast in the ground over the full length between posts, with the top approximately 25mm below the bottom of the chain link mesh. Concrete shall conform with requirements specified herein for unreinforced structural concrete. Hair pin staples 4mm diameter shall be threaded over the bottom row of mesh and line wire, at 500 mm centres and set in the sill to a depth of 150mm.

18.23.13.2. Line wire

Line wire shall be galvanized wire (Grade A) and plastics coated conforming to BS 4102 and Clause 3.3 of BS 1722: Part 10. The external diameter of the wire shall be 6.4mm, conforming to Table 1 of BS 1722-10.

Chain link fence shall have a minimum of five rows of line wires. The top row of wires shall be double and secured not more than 50mm below the top of the chain link mesh, excluding the barb. The bottom row of line wire shall be close to the ground.

18.23.13.3. Stirrup wire

Stirrup wire for securing line wires to intermediate posts shall be galvanized and plastics coated conforming to BS 4102 and Clause 3.4 of BS 1722: Part 10. The external diameter of the wire shall be 3.55mm, conforming to Table 1 of BS 1722-10.

18.23.13.4. Tying wire

Tying wire for securing mesh to line wires shall be galvanized and plastics coated conforming to BS 4102 and Clause 3.5 of BS 1722-10. The external diameter of the wire shall be 2.0mm, conforming to Table 1 of BS 1722-10.

18.23.13.5. Posts

Intermediate posts for chain link fencing shall be circular hollow sections in accordance with Table 2 of BS 1722 Part 10. The post size shall be 60.3 mm o.d x 4 mm for supporting 'heavy duty' mesh. Material properties, protective treatments tolerances on size etc. shall conform with the recommendations of BS 1722-10 Section 5.

Straining posts for chain link fencing shall be circular hollow sections in accordance with Table 2 of BS 1722-Part 10. The post size shall be 89.2mm o.d x 4mm x 3.2m length for supporting 'heavy duty' mesh panels. Material properties, protective treatments, tolerances on size etc. shall conform with the recommendations of BS 1722-Part 10, Section 5.

Struts for chain link fencing shall comprise circular hollow sections in accordance with Table 2 of BS 1722-Part 10. The strut size shall be 48.3mm o.d x 3.2mm x 3.2m lengths for supporting 'heavy duty' mesh panels. Material properties, protective treatments, tolerances on size etc. shall conform with the recommendations of BS 1722-Part 10, Section 5.

18.23.13.6. Barbed wire

Barbed wire with electric shock security for use on substation site chain link fence (as well as on all boundary walls) shall only be provided as follows:

- a. Barbed wire for chain link fence shall comprise 3 Nos straight strings, equally spaced, shall be fixed on each supporting arm.
- b. Barbed wire for gates shall consist of 5 rows of "straight" strings, equally spaced.
- c. Each string of barbed wire shall consist of two strands of 2.5mm dia (12 gauge) wire with 2.0 mm dia (14 gauge) four pointed barbs spaced approximately 125 mm apart along the wire. The wire shall be galvanized in accordance with ASTM A121 to produce a minimum zinc coating of 0.244kg/m² of surface area on 2.5mm dia (12 gauge) wire and 0.198kg/m² of surface area on 2.0mm dia (14 gauge) wire.

Barbed wire shall conform to BS EN 10223-1.

18.23.13.7. Fittings for chain link fences

Fittings required for chain link fences, typically comprising: fixing and straining devices, eye bolt strainers and cleats, winding brackets, stretcher bars, staples, droppers for barbed wire, bolts, nuts and washers, extension arms, etc. shall conform with the requirements detailed in Section 5 of BS 1722-10.

18.23.13.8. Concrete sills

Where chain link fences are used in unpaved areas a concrete sill shall be constructed as specified in the "Chain link fabric" section above. The top surface of the sill shall be 50mm above grade, or as otherwise shown on the approved drawings.

18.23.13.9. Foundations

Foundations shall be designed and constructed of cast-in-place concrete in accordance with this specification, comprising a pad base, adequately sized, to support the fence, and loading criteria (including wind) imposed by the works and satisfying the geotechnical parameters of the subsoil at the location of the fence.

Any damage to the fencing caused by the construction operations shall be rectified promptly by the Contractor at his own expense.

18.23.14. Miscellaneous

18.23.14.1. Attendance on Other Trades

Each trade shall attend upon, cut away for, and make good after, the electrical engineers and all other trades as described and directed.

18.23.14.2. Cleaning up at Completion

On completion of the works all floors shall be scrubbed, all work touched up after all trades, and the whole left clean and ready for use. All rubbish and debris shall be removed from site.

18.23.14.3. Raised Floor

Raised access floors shall be carried out in accordance with DIN EN 12825.

The raised access floor system shall be capable of withstanding the following loads:

- concentrated load: not less than 4.5 KN over 25 mm²
- uniformly distributed load: not less than 12 KN/m²

The factor of safety for the uniformly distributed load shall be „3“. The system when subjected to the test loads shall not deflect or deviate more than 1:250 of the shortest span or 2.5 mm whichever is less. The system shall be capable to carry the specified concentrated loads at any position, such as around the perimeter, centre of panel, cut panel, perforated panel or at any point which is considered a point of weakness.

The steel base plate shall be fixed to the floor by epoxy adhesive as well as by bolts.

Application of raised floor according to the attached drawing of the Control Building.

18.23.14.4. Temporary fencing and barricading

The Contractor shall be responsible for all necessary temporary fencing and barricading during the construction works including access control to prevent unauthorized access to the construction site. Stringent measures are to be taken to prevent access to substation parts that are alive.

18.24. Building Services

18.24.1. Electrical Building Services

18.24.1.1. Scope of Works

The scope of works for the Electrical Building Services shall include, but not be limited to, the following:

- Lighting systems;
- Small power installation including cables/wiring and distribution systems;
- Lightning protection system.
- Control wiring, etc.

The Contractor shall be responsible for the complete design, detailed design calculations, equipment selection, installation, testing and commissioning and testing of the complete electrical building services systems.

Design calculations, system diagrams and construction drawings shall be submitted for approval. The Contractor shall ensure that the equipment is provided suitable for the location it is to be installed in taking into account temperature and environmental conditions expected on site.

The Contractor shall include for providing all as constructed drawings, which shall be prepared as the works proceed. Completed sets of Operational and Maintenance Instructions including all test, commissioning and any other documentation required to maintain the works.

18.24.1.2. Lighting Systems – Normal, Emergency and External

Lighting systems shall be provided throughout the station for all areas, outbuildings and external areas to the levels required, with considering energy saving through LED type luminaries as per KETRACO requirements.

The lighting system provided shall be in compliance with the Regulations, Codes and Standards and comprise normal, emergency (including security lighting) and external lighting systems that will include a fence security lighting system.

The design and installation of lighting and small power systems shall be based on the following Regulations/Standards or equivalent international (e.g. IEC) standards:

- Requirements for Electrical Installations, IEE wiring regulations BS 7671 as issued by the Institution of Electrical Project Managers, London and British Standards, UK.
- The Code for Lighting, Lighting Guides, as issued by the Chartered Institution of Building Services Project Managers (CIBSE) London, UK.

All interior and exterior lighting designs shall be undertaken using computerized calculation.

The lighting systems will consist of the following systems:

- The normal lighting installation shall cover approximately 75 per cent of the total lighting in a given area;
- The emergency lighting system serving 25 per cent of the total load in a given area and its power shall be from the 110V batteries. The emergency lighting system shall also be capable of illuminating all exit signs, doors, stairways, corridors, other routes of exit and outside each fire exit together with other areas of specific risk.
- Operational (high risk task area) lighting system connected via distribution boards for control rooms and walkways. Basic source of power shall be from the 110V batteries.

Circuit design shall ensure that operation of a circuit protective device or failure of a circuit component shall result only in limited loss of illumination in a room or area.

The lighting installation, under normal operating conditions and throughout the Plant's operational life, shall be capable of providing the minimum service levels of illumination as listed below: These levels shall be based on measurements being taken after the lamps have operated for not less than 100 hours. The method of measurement is to be carried out in accordance with the International Commission of Illumination (CIE) Publication No 29. Measurements shall generally be taken at floor level.

Areas typically	Description of activity	Standard maintained illuminance (lux)
Substations	Control areas/room	250-500
Emergency Diesel generator building	Data printers	300
Control and administration building	Employer/Employer's Representatives/offices	300
Workshop and stores	Monitoring room	300
Firefighting pump house	Telecoms room	300
	Mess room	200
	Metering room	200
	Switch room	200
	Toilets	150
	Access corridors	150
	HV equipment floors	150
	Marshalling room/stairwells	150
	Cable floor/cable risers	50
	Battery room	150
	Entrance	150
	Fuel oil plant room	150
	Stairwells/corridors	150
	Station unit switch room	200
	Workshop/store	300
	C&I equipment	300
	Electronics room	300
	Switchgear room	200
	Prayer room	250
	Stores	200-300
	Kitchens	500
	Conference rooms	300-500
	Locker rooms	200
	Cable tunnels	50
	Transformer compounds	30

If there are areas that are not included in the above, BS ISO 8995 (or equivalent international (e.g. IEC) standards) shall be used for guidance.

The Contractor shall take into account the expected wall, floor and ceiling reflectance values when undertaking the design calculations. The lighting designs shall also take into account the proposed equipment locations.

The Contractor shall base his design calculations on fluorescent lamps of a white colour and a colour-rendering index of typically 95. Lamps shall be triphosphour or multi-phosphour type. High frequency ballasts shall be provided in all fluorescent luminaries and shall be cool daylight with a minimum life of 7500 hours.

High-pressure sodium discharge lamps shall be colour corrected deluxe white with a minimum lamp life of 24 000 hours operation with the required ballasts. All normal lighting shall have uniformity levels (ratio of average to minimum) no less than 0.8. The selection of luminaries and requirements of illumination for various areas shall be in accordance with the recommendations published by the Society of Light and Lighting with consideration of the safety and working conditions on the Project.

All emergency lighting schemes shall be arranged to provide the required illumination on interruption or failure of normal lighting supply, operation of a circuit breaker or fuse or manual acts such as accidental opening of a switch controlling normal lighting facilities. The Contractor shall design, supply, install, wire and connect up a complete emergency lighting installation for a minimum of 3-hour operation, in accordance with the following or equivalent international (e.g. IEC) standards:

- BS 5266, Part 1, 2011 (Code of Practice for the Emergency Escape Lighting of Premises);
- BS EN 1838, Lighting Application – Emergency Lighting.

Emergency lighting including operational (high risk task area) lighting system shall be supplied to all normally occupied spaces and escape routes including coverage to all fire doors.

Emergency lighting on paths of egress at floor level shall have a maximum-to-minimum illumination uniformity ratio of 40 to 1 the emergency lighting for stairs and escalators shall emphasize illumination on the top and bottom landings and at all intermediate landings

The Contractor shall design supply, install wire and connect up a complete external lighting system for all areas of the development.

All external lighting shall be designed to meet the requirements of lighting guide LG06: 1992 for the outdoor environment issued by the Chartered Institution of Building Services Project Managers. Illumination levels shall also be in accordance with the lux levels indicated below. Where a range of average illuminances are recommended in the guide for a particular application, the Contractor shall design his lighting scheme to provide an illuminance not less than midway between the recommended upper and lower values.

- Transformer area 30 lux
- Operating plant areas:
 - Machinery areas 200 lux

- Platforms/ladders (active) 50 lux
- Walkways 50 lux
- Road, platform/ladders (inactive), 30 lux

The security fence shall be continuously illuminated during hours of darkness to provide an even vertical illuminance of 25 lux on the face of the fence.

In terms of luminaries and switches, all areas shall be individually switched with two way and intermediate switching provided where necessary if there is more than one method of access and for walkways and stairways. Luminaires installed on different floor levels or at different task locations to be controlled by their own switches.

Luminaires used indoors shall be minimum IP21 protection and for external use IP65

Excluding cable tunnels and other underground spaces, the mounting height of luminaires shall not be lower than 2.4m unless restricted by the available mounting height or if otherwise approved.

In the central control room the fluorescent lighting (excluding emergency lighting) shall be provided with "dimming" control to give a graded reduction in lighting levels

In large areas luminaries for access and inspection lighting shall be switched by contactors controlled by a switch adjacent to the plant covered by a specific load centre.

Emergency lighting shall be automatically energized on failure of the electrical supply to normal lighting in the relevant area.

All switches shall be mounted at 1.5 metres above finished floor or platform levels. The switches shall be positioned such that they can be easily located and accessed for use.

The external lighting installation shall be contractor controlled using photoelectric cells.

18.24.1.3. Small Power Installations

The Plant and any ancillary areas shall be provided equipped with socket outlets, connection units and isolators to suit the purpose of each building or area. These outlets will be suitable for providing power supplies to all portable equipment, hand tools, portable lamps and fixed equipment required for operating and maintaining the systems

For office areas, equipment and control rooms, maintenance and testing areas or similar, the socket outlet layout shall be designed so as to effectively cover work areas with a 3 metre flexible cable.

Socket layout design for all other areas shall give effective cover with a 15 metre portable extension. 240V socket outlets shall be provided in plant areas to supply power for hand tools etc. used for maintenance.

Power socket outlets shall be rated at either 16A, 32A, 63A or 200A and shall have 4 pole connections and two earth connections. They shall be provided as required by the design to all areas where equipment is to be maintained.

The Contractor shall also supply and install 63A welding socket outlets complete with plugs at strategic points located on a nominal 50-metre grid so that all parts of the Plant can be reached using a maximum cable length of 35 metres.

The mounting height of general-purpose socket outlets and power socket outlets for general-purpose socket outlets mounted in walls of rooms such as offices and control room areas shall be 300mm above finished floor. In all other maintenance type areas, equipment or station areas the mounting height shall be 600mm above finished floor.

Power socket outlets shall be mounted 1.2 metres above finished floor.

18.24.1.4. Distribution System

Sub distribution boards shall be provided for the lighting and small power supplies throughout the Substation.

The 415/240V ac power socket boards shall be fed from transformers, the capacity of which will be varied by design, for each group of 240V ac socket outlets.

Enclosures shall have a degree of protection to IP21 for office type rooms (indoor locations) IP44 for indoor locations in plant areas and IP65 for outdoors and damp situations.

18.24.1.5. Lightning Protection System

The Contractor shall provide and install a lightning protection system to provide the necessary protection to each building. Each building shall have its own air terminal network, down coming tapes and earth points.

The Contractor shall connect together with a perimeter conductor all earth rods of each individual lightning system. From the nearest point of the perimeter conductor the Contractor shall provide a link to the Plant earthing system.

18.24.2. Mechanical Building Services

18.24.2.1. Scope of Works

For piped services, the Service Water and Compressed Air Installations shall be extended into each building as required to provide wash down/maintenance facilities. The site Potable Water distribution system shall be extended into each building as required for domestic hot and cold water supplies. The domestic hot and cold

water services shall comply with the latest ASHRAE and EN standards. Plant areas and emergency washing/shower facilities are also to be supplied with Potable Water.

The heating, ventilation and air-conditioning (HVAC) systems shall be installed to provide the required inside conditions as indicated in the Specification below, based on the external design conditions applicable to the site location as published by ASHRAE. Design, installation, testing and commissioning of systems shall comply with the latest applicable Codes and Standards, e.g. ASHRAE, NFPA, SMACNA, ARI.

The contractor shall also make reference to local regulations, standards and approval processes, to ensure the designs are fully compliant with local and international standards.

The Contractor shall be responsible for the complete design, detailed calculations, detailed design and construction drawings, equipment selection, construction, metering, controls, testing and commissioning of the whole of the Mechanical Building Services, subject to approval. The above systems shall comply with the relevant sections of both Part A and B of the Contractors MFS. These shall include, but not be limited to, the following:

- Potable water;
- HVAC;
- Service water;
- Service (compressed) air;
- General mechanical plant;
- Public Health (including sanitary ware);
- Thermal insulation;
- Fire detection;
- Fire suppression;
- Earthing and lightning protection
- Testing and commissioning;
- Handover, O&M manuals, record drawings.

18.24.2.2. Design Information

Design calculations, system diagrams, detailed design and construction drawings for all services and systems shall be submitted for approval, before procurement/construction is commenced. Design information shall be submitted with descriptions and calculations under the following headings. Sufficient time shall be allowed within the construction programme for the review/approval period, including any required rework.

- Objective;
- Concept of system, including control and metering strategies;

- Method of calculation;
- Design criteria;
- Calculations;
- Detailed Design and Construction Drawings;
- Appendices.

18.24.2.3. Quality Control

All equipment for the Mechanical Building Services shall be obtained from member firms of the relevant Trade Association(s). All equipment shall be new and suitable for the specific application. Equipment shall be suitably protected against damage during transit, site storage and installation. Equipment stored on site shall be done so in line with manufacturer's recommendations. An item which is damaged or incorrectly stored will be rejected and replaced at the contractor's expense.

The Contractor shall submit full details for approval, including samples where necessary, of the following components that they propose to use:

- Refrigeration plant and accessories;
- Outdoor and indoor parts of split units and their pipes and fittings
- Fans (all types);
- Energy meters;
- Fire/Smoke dampers;
- Control systems and BMS;
- Water storage tanks;
- Pipes and fittings for all systems.

18.24.2.4. Domestic Hot and Cold Water Services

The domestic hot and cold water services within the buildings shall comply with the latest ASHRAE and EN standards.

The Administration and Control Building, Guard House, Technical Staff Housings, and Security Staff Housings and Storage Warehouse shall be provided with a cold-water storage tank of sufficient capacity to meet one day's consumption for the building or area served. The pipes shall be of Polyethylene and the tanks shall be of GRP insulated construction, shall be located so as to prevent water damage or consequential losses in the event of a tank leakage for any reason and shall feature condensation drip trays to prevent nuisance damage. All tanks which are located above water sensitive areas should be surrounded by a bund wall with adequate evacuation ducts.

Consideration shall be given to the location of the tanks in relation to localised heat gain and storage temperatures shall be maintained within recommended limits, to prevent the potential for legionella growth.

The elevated cold water storage tank shall be of sectional GRP modules to the size as shown on drawing and shall be mounted on purpose made concrete upstands to suit the manufacturers details. The tank shall consist of access hole and hinged lockable cover, drain connection, overflow main water supply connection via ball valve and bowser feed connection. All internal tie rods, and fixtures shall be of stainless steel. All panel joints shall be made externally and be made with galvanized structural steel nuts and bolts.

All pipework, fittings and valves and the installation of services shall conform to the relevant clauses of the pipework specification. Pipework shall be fixed or supported at appropriate intervals.

The hot water systems shall be served from local electrical water heaters, with central storage systems being provided only for large buildings with heavy demand for hot water. Suitable measures shall be taken to limit pipe losses and to maintain circulating temperatures within recommended limits, to prevent the potential for legionella growth. Systems shall be adequately sized to reflect the anticipated demand within each building or individual area.

Pipe sleeves shall be fitted where pipes pass through walls, floors and ceilings. Sleeves shall be of PVC, shall be of sufficient diameter to permit free movement of the pipe and shall be fixed in a manner that will ensure that they do not become detached from the building fabric.

At the end of each sleeve the approved set screw pattern CP cover plates shall be fitted. Pipework insulation/vapour seal shall be installed through the annular spaces between sleeves and pipes.

HWS-s and CWS-s shall be run directly to taps on sanitary fittings etc. The hot tap shall be on the left when facing the fitting.

The Contractor shall connect up the appropriate service to all bib taps, sinks, showers, basins and closets where required and shown on the drawings, and fit valves for isolating purposes on each individual draw-off.

The Contractor shall also include for Potable Water supplies to emergency wash-down and shower facilities in battery rooms and chemical areas, and to HVAC humidifiers.

The Contractor shall include for all necessary inspection, testing and commissioning, including disinfection, of the complete hot and cold water services installations.

The test pressure to be applied to the various services shall be as follows, and the pressure gauge readings for these tests shall be taken at the lowest points in the respective systems:

1. Domestic hot water flow and return lines - 7 bars
2. CWS and cold feed lines - 7 bars
3. Drinking water lines - 7 bars
4. Cold water rising mains - 13.5 bars

All plugs, caps, tees, drain fittings etc. required to enable the tests to be carried out shall be supplied by the Contractor.

The Contractor shall arrange for the domestic hot water service, cold water down service and mains water systems to be chemically cleaned immediately after the completion of the required flushing out, following the pressure tests. The systems shall be first treated to remove corrosion products, followed by a further treatment to inhibit corrosion.

The Contractor shall allow for the provision of suitable tapping points for introduction of chemicals and all the necessary drain/flushing connections. To provide a base treatment (after flushing procedures) the Contractor shall introduce an approved chemical treatment for scale and corrosion prevention obtained from specialist suppliers into the cold water storage tanks at the rate of approximately 1 l per 4,000 l of water and agitate the tanks to distribute the chemical evenly.

The Contractor shall carry out the chlorination of all main water and drinking water services.

All necessary charging and raining down points shall be provided on the pipework as required to allow the chlorination and flushing out to be completed throughout. The chlorination of the services shall be carried out in accordance with the method described in BS EN 806 and the requirements of the Water Supply Authority.

18.24.2.5. HVAC Systems and Design Conditions

The HVAC system will be provided for the following purposes:

- To provide a comfortable working environment within the building for personnel and equipment.
- To warm up the incoming outside air during winter to prevent freeze-up problems.
- To maintain sufficient air circulation within the building to ensure that heat losses from the equipment do not result in an excessively uneven temperature distribution.
- To remove fumes and gases from the areas where undesirable build-up of these could otherwise occur.

The design parameters and necessary requirements to meet the design intent must be read in conjunction with other appropriate sections.

HVAC systems shall be designed, installed and commissioned in accordance with the latest applicable codes of the following:

- ASHRAE American Society of Heating, Refrigerating and Air Conditioning Project Managers.
- SMACNA Sheet Metal and Air Conditioning Contractors National Association.
- NFPA National Fire Protection Association.
- ARI American Refrigeration Institute.

- ANSI American National Standards Institute.
- AABC Associated Air Balance Council.

Calculation of heat loads and losses, cooling loads, ventilation and air flow requirements shall be made in accordance with the ASHRAE Standard for Cooling Load Calculation.

Commercially available latest version cooling load and duct system design programs (hourly analysis program (HAP)) shall be used for load calculation and the results of the calculation process shall be submitted along with a hard and a soft copy of the calculations for review and approval.

The Contractor is obliged to co-ordinate the design, installation and integration of the air-conditioning and ventilation system at the building with the related design and construction requirements of the architectural, civil, electrical and mechanical works.

All systems shall be designed and installed to provide acceptable environmental conditions for each area. The conditions of temperature, humidity, air movement and air filtration shall be controlled as required in the respective areas in summer and winter.

Main plant, equipment and distribution systems shall be provided with a 20% spare capacity allowance for future expansion.

HVAC systems serving critical areas such as Control Rooms shall be provided with duty/standby air handling and mechanical cooling plant to ensure continuity of operation.

HVAC systems shall be arranged to shut down in the event of a fire alarm, seal supply and extract ducts as required for the application of clean agent fire suppression systems, and start up smoke control pressurization systems. Provision shall be made in all plant areas for the venting and clearance of smoke and fumes in the event of fire, by means of roof vents or extract fans.

All systems and components shall be suitable for the design life of the Plant, and be designed for minimum life cycle cost and complexity, consistent with functionality, ease of maintenance and reliability.

For all general cases the HVAC system's ambient design conditions shall be as ASHRAE recommendations to suite the site conditions.

The HVAC systems shall be designed to obtain the internal conditions and system redundancy as indicated in the table below.

Area (s)	Internal Condition	Comment
Control rooms Offices Electronic rooms Laboratories	Summer: 25°C db \pm 1.5°C 50% r.h \pm 5% Winter:	Central air conditioning systems with 2 x 100% air handling units and standby mechanical cooling.

Area (s)	Internal Condition	Comment
Relay rooms	22°C db \pm 1.5°C 40% r.h minimum.	
Workshop/stores Lecture rooms Prayer rooms.	Summer:- 25°C db \pm 1.5°C 50% r.h \pm 5% Winter: 22°C db \pm 1.5°C No humidity control.	Central air conditioning systems 2 x 50% air handling units. No standby mechanical cooling.
Corridors. Stairs.	28°C db max. 20°C db min.	Pressurization systems for smoke control may be required in these areas.
Toilets	28°C db max. 18°C db min.	Extract ventilation (10 AC/h min.) Rooms under negative pressure.
Mess rooms.	25°C db max. 18°C db min.	Extract ventilation (6 AC/h min.) Rooms under negative pressure.
Excitation Switchgear Rectifier/inverter	42°C db max. 25°C db min 40°C db max No humidity control	AC systems with 100% fresh air facility for free cooling. 2 x 50% air handling units. Contractor to ensure Maximum and minimum temperatures (as specified by the equipment manufacturers) are not exceeded under maximum site conditions
Battery rooms	27°C db max. 22°C db min.	100% exhaust with duty/standby fans. Max 1% hydrogen concentration. Rooms under negative pressure. Contractor to ensure Maximum and minimum temperatures (as specified by the equipment manufacturers) are not exceeded under maximum site conditions
Standby diesel generator room	5°C above ambient db max. No winter heating.	Supply/extract ventilation for “normal” operation (DG off) plus boost ventilation (DG running) to DG. Contractor to ensure Maximum and minimum temperatures (as specified by the equipment manufacturers) are not exceeded under maximum site conditions

All HVAC units and systems shall be provided with local control panels for local manual/automatic control. The operation status such as alarms, humidity, temperature, fault indication, status indication of each air conditioning system shall be indicated and available at the local control panel and any individual fault signal results in a group signal, which shall be transmitted to the central control room.

In addition, the following criteria shall be considered in the design of the HVAC system:

- i. A general lighting level dissipation of 20 watts/m²
- ii. Sensible and latent heat gains for occupancy should be allowed on the basis of one person per 10m².
- iii. A minimum quantity of fresh air should be provided at the rate of 0.00125m³/s per m² of floor area or 12 l/s/person, whichever is the greater and this should be shown in the calculations. Actual equipment gains within each room should be allowed for in determining Plant capacities. Determination of these values should be identified within the calculations.
- iv. Re-circulated air should be filtered. Air from areas where pungent fumes are likely to be present should not be re-circulated.

Battery rooms should be air conditioned by self-contained air conditioning units, where appropriate, or alternatively a centralized air conditioning system. The design of the air conditioning system shall avoid recirculation of air back into the battery room. These units should be of the non-recirculation type and sized to provide the internal conditions previously specified with a minimum of five air changes per hour. Duplicate extract fans should be provided, mounted at high level and positioned such that accumulations of hydrogen cannot occur. The fan units should be suitable for long life in the acidic environment

18.24.2.6. Fresh Air Requirements

Fresh air shall be supplied for the following purposes:

- Fresh air for occupied areas, minimum 12 litres/second/per person;
- Free cooling during periods of low ambient temperatures;
- Make-up air for exhaust ventilation systems;
- Building pressurization to exclude dust. Minimum fresh air supply shall not be less than 5 per cent of supply air volume.

Fresh air supplies shall be obtained from areas not subject to contamination from fumes. Air intakes shall be located at maximum available height, to reduce dust load.

Fresh air intakes on large systems shall have inertial sand filters with bleed fans and access sections. Small systems with fixed amounts of fresh air shall be provided with sand louvres.

All supply systems shall have two-stage air filtration, comprising washable primary panel filters and secondary bag filters, efficiency as required for the areas served.

18.24.2.7. Mechanical Cooling

Complete cooling systems shall be provided. The units and complete installation shall comply with (but not be limited to) the latest ASHRAE 15 & 34 – Safety Code for Mechanical Refrigeration – and ASHRAE Guideline 3 for Refrigerant Leaks, Recovery, Handling and Storage Requirements.

Air-cooled air conditioning systems shall be provided for each Plant building.

Critical air-conditioning systems shall be provided with 100 per cent standby plant. Critical air conditioning systems are those which are essential for the continued operation of the buildings and allow continued occupancy of essential working areas.

HCFC refrigerants shall not be used.

18.24.2.8. Power Supplies

The Contractor shall include for all power and control cabling and containment, MCC and controls for the complete HVAC systems.

Dual redundant power supplies (normal ac and safe ac) shall be provided for systems requiring 100 per cent standby plant, including mechanical cooling. The control system for HVAC will be powered by safe AC however the HVAC's motors, heaters etc., with the exception of the control system will be powered by emergency DG power.

18.24.2.9. Ventilation

All rooms, except toilets and battery rooms shall be kept under positive pressure to reduce dust penetration, by providing proper fresh air to air conditioned areas

Toilets shall be kept under negative pressure by exhaust ventilation, with spill air from the cooled supply air system to corridors or adjacent areas.

Battery rooms shall be provided with dedicated exhaust ventilation, and kept under slight negative pressure. Exhaust ventilation rate shall be sufficient to maintain hydrogen level at below 1% under maximum charge conditions, but be not less than minimum AC/h which defined at data sheet Duplicate (duty/standby) bifurcated exhaust fans shall be provided. Re-circulation of the air from the Battery Room will not be permitted.

18.24.2.9.1. Axial Fans

General exhaust fans shall be of the axial-flow type, single stage long casing with adjustable pitch air foil blades.

Each fan and motor shall be completely housed in a heavy galvanized mild steel casing with flanged ends for duct connections. Fan casings shall be complete with access door, extended lubricators and terminal block. Casings shall be truly circular to maintain throughout a maximum blade to casing mean tip clearance. Adjustable pitch impellers shall be galvanized, and fixed to the extended shaft of the drive motor.

18.24.2.9.2. Battery Room Exhaust Fans

Battery rooms shall be ventilated to give a maximum residual hydrogen concentration in the room air of one percent by volume under battery boost charge conditions.

Proper explosion proof bifurcated fans shall be installed complete with exhaust insulated ductwork, grilles and louvers. The fans shall be with the additional fitting of a spark minimizing impeller track and suitable for Group II gases (Battery room applications). The entire system shall be proofed against corrosive gases. The fans shall be interlocked with the battery charger systems so that during normal trickle charge a single fan will operate at slow speed and at high speed during boost charge. During boost charge the additional air supply requirements will be met by wall mounted electrically powered ON-OFF damper with external/sand louver all mounted at semi-low level in an external wall. Damper actuator shall be interlocked with the battery charger system.

Air flow/pressure switches shall be provided across the battery room exhaust fans to monitor their performance and provide automatic changeover in the event of supply fan failure.

18.24.2.9.3. Toilet Exhaust Fan

Toilets shall be provided with exhaust ventilation to provide minimum air change based on standards. Fans for toilets within the main building shall be packaged duty/standby units within a common casing, with back draught shutters and automatic changeover in the event of failure of the duty fan. Units shall be provided with a wall mounting control box, with facility for fault indication to the central control panel.

18.24.2.9.4. Wind driven roof top ventilation

A wind driven, roof mounted ventilator designed to exhaust heat & moisture from the roof space without the use of electrical energy. It Operates when the wind hits the turbine fins and causes the vent to rotate. It can also be driven by the expanding air in the roof space due to rising temperatures. This rotation creates a vacuum that sucks out air from the roof space. Most them are made of galvanized steel or aluminium. This type of ventilation system is used for storage warehouse.

18.24.2.10. Solar Water Heating System**18.24.2.10.1. General**

This specification addresses the installation solar heated hot water systems for use within KETRACO's facilities. It includes specifications for hot water to be used both in buildings and swimming pools.

The contractor shall ensure that all material used in the construction, assembly and installation of the hot water system shall be of high quality, ensuring a life of 20 years for hot water systems installed in buildings, and 12 years for hot water systems installed in swimming pools. Furthermore, solar water heating system shall be equipped with an electric heating element as back up.

Design and installation work to be done according to the professional standards. This specification indicates guiding standards. The contractor shall comply with at least, but is not limited to these standards.

The contractor shall adhere to the specifications and guidelines provided by the equipment manufacturer.

18.24.2.10.2. Design Specifications

The products, design and installation shall comply with at least, but not limited to, the following industry standards wherever applicable:

- IEEE – The Institute of Electrical and Electronics Engineering
- NCA – National Construction Authority
- KEBS – Kenya Bureau of Standards
- IAPMO – International Association of Plumbing and Mechanical Officials
- IBC – International Building Code

SRCC – Solar Rating and Certification Cooperation

18.24.2.10.3. Solar Collectors

The contractor shall ensure that his design incorporates, but is not limited to the following:

- SRCC OG-100 for Solar Thermal Collectors
- SRCC OG-300 for Solar Water Heating System
- Mounting Instructions to be provided by the manufacturer
- In the event the collectors contain hazardous material, this shall be disclosed to the client, and any special maintenance and proper disposal/recycling practices provided.
- The collectors transmission shall be at least 95%

18.24.2.10.4. Collector Array

All collectors shall be arranged in such a manner that they face the same direction

The collectors shall be arranged such no shadow from a collector falls on another at any given time

In case of several collectors, the piping should be done such that they are interconnected in a reverse return configuration.

Each collector bank to be provided with isolation valves. The banks should also have a pressure release and it should be possible to drain them

The existing support structure is to be used for the collector array. In case a separate support system is to be used, the contractor is to provide this in the design.

18.24.2.10.5. Transport System

The system should be able to handle 150 psi for systems including heat exchangers.

The heat exchanger should be made out of a non-corrosive material

The heat exchanger should be able to handle 115 °C

For active systems involving pumps, the contractor shall ensure the pumps shaft is made of non-corrosive material. The pump should be solidly mounted on a concrete surface. The pump shall be controlled by the solar

thermal temperature regulation system. Isolation valves shall be provided to enable the pump get serviced without draining the system

Any heat transfer fluid used in the system shall be compatible with all materials in the system. It shall be non-toxic and purposed for use in portable systems.

18.24.2.10.6. Plumbing Works

The contractor shall provide appropriate pipes, pipe fittings, valves, strainers, expansion loops, pipe hangers, inserts, supports, anchors, guides, sleeves and any other accessories deemed necessary for the proper installation of the hot water heating system.

All material used in the installation shall adhere to the appropriate codes and standards in its category.

All exposed sections carrying hot water must be insulated.

Supply thermometers with wells and appropriate bronze sockets

Provide pressure gauges with throttle type needle valve, or a pulsating dampener and shut off valve.

Piping shall be supported and firmly hung to ensure no sagging. The supporting shall be done in such a manner as to ensure the piping does not provide weight to other building or equipment members.

18.24.2.10.7. Electrical Works

All wiring and electrical installations to be done in accordance with IEEE and other relevant standards.

Motor starters to be provided with overload protection.

18.24.2.10.8. Mounting System

The mounting system shall be designed to ensure the panels are properly fixed. The mounting should be able to handle dead load, live load, winds, UV degradation, corrosion, seismic loads for a period of 25 years.

The mounting shall not compromise the structural dignity of the building/structure it is assembled on.

The contractor shall ensure that the thermal load fluctuations of the system shall not bring out fatigue on the mounting.

The final paint coat of the mounting shall be approved by the client. The paint shall not interfere with the grounding and bonding of the array.

The mounting shall be designed in such a manner as to allow for ease of operation and maintenance.

18.24.2.10.9. Corrosion

The whole system must be designed to handle the environmental conditions of the particular site.

Unprotected steel shall not be used in any part of the system

Fasteners shall be made of corrosive resistant material, or be anodized sufficiently to protect them from the elements.

18.24.2.10.10. Roof Installation

The installation shall be done in such a manner as to provide enough spacing to allow for access and maintenance. If other equipment is installed on the roof, a minimum of 900mm shall be maintained between the solar system equipment and the other installation.

The solar water heating system shall not be installed in such a manner as to obstruct the air flow into the building.

The installed equipment shall not exceed the ability of the existing structure to support. The contractor's design shall ensure the existing structure can handle the weight and installation process of the solar water heating system.

The installation process of the solar water heating system shall not interfere with the integrity of the roof. The works shall not negatively impact existing roof warranties.

All penetrations shall be waterproofed. Any chemicals/material used shall be chemically compatible with the existing structure.

Any damages arising during installation shall be borne by the contractor

The assembly design to be approved by the client.

18.24.2.10.11. Warranties

All solar collectors must have a minimum of a 10 year manufacturer's performance warranty to protect against defects and a 15% performance degradation. Additionally, the contractor shall provide a 20-year warranty option if commercially available.

All systems must have a minimum 10 year performance warranty to protect the host against more than a 15% degradation of system performance over the 10 year period that may occur as a result of faulty installation.

All systems must have a minimum 1 year warranty on installation labour and workmanship not otherwise covered by the manufacturer's performance warranty.

The mounting system shall have a 20-year warranty covering at least structural integrity and corrosion.

The contractor shall provide a comprehensive ten (10) year warranty on all system components against defects in materials and workmanship under normal application, installation, and use and service conditions.

All warranties must be documented in advance and be fully transferable to the client.

All work performed by the contractor must not render void, violate, or otherwise jeopardize any pre-existing Purchaser-Owner facility or building warranties or the warranties of system components.

18.24.2.10.12. Acceptance Testing

The contractor shall conduct comprehensive tests on each system. The acceptance test procedures shall be shared with the client for approval. All testing shall be conducted according to the manufacturers' specifications.

After the test have been conducted, the contractor shall provide the client with documented results for approval.

18.24.2.10.13. System Start Up

Once the client approves the acceptance tests, the contractor shall conduct a 24 hour test on the system. The following parameters shall be observed every 30 minutes:

- Thermal output (Btu)
- In-plane irradiance
- Ambient temperature
- Collector inlet temperature
- Thermal energy storage temperatures

The results of this shall be properly documented and given to the client for approval.

18.24.2.10.14. Monitoring period

Once acceptance testing and start-up has been undertaken, the contractor shall monitor the system for a period of thirty (30) days.

- During this period, data on the following parameters shall be collected on an hourly basis:
- Date and Time of data points
- Thermal output (Btu)
- Total Btu's delivered (per tank if system has multiple tanks)
- In-plane irradiance
- Ambient temperature
- Collector inlet temperature
- Thermal energy storage temperatures
- Quantity of back-up fuel consumption
- System availability

The system shall be deemed fit once the data collected throughout the monitoring this 30 day period is considered acceptable, and approved by the client.

18.24.2.10.15. Training

The contractor shall provide on-site training on operational and maintenance practices of the solar water heating system. The client shall provide members of a team to attend the training.

18.24.2.11. Automatic Controls

The automatic controls, controllers, cubicles and panels shall be designed, equipment selected, installed, tested and commissioned in line with ASHRAE and EN standards.

The Automatic Controls installation shall comprise the following:

- Outstation controllers within each building
- Central monitoring station located within the central control room

- All detectors, sensors etc.
- All valves, meters and actuators
- Control panel within each building c/w local user interface
- Local Area Network
- Testing and commissioning
- Graphics and user instructions

The contractor shall install all motorised valves, dampers, actuators, linkage kits to be supplied by the BEMS specialist and allow for all necessary pipework, ductwork, pockets for pressure switches / temperature detectors etc.

Control and monitoring of the plant will be via a central monitoring station, located within the central control room and provided as part of the works.

The controls shall be set to effect maximum fuel economy and interconnections to and between the various items of equipment will be carried out by the BEMS specialist under the supervision of the mechanical contractor.

All electrical equipment and apparatus shall be in accordance with the Institute of Electrical Project Managers Wiring Regulations (latest edition).

The control manufacturers (via the mechanical contractor) shall supply all wiring connection diagrams and all other similar relevant information necessary to carry out all wiring and interconnections. Wiring connection diagrams shall be submitted for review.

It is essential that wiring connection diagrams are made available at the beginning of the contract so that no delays are incurred.

All elements of the control system shall be designed to be high reliability and be replaceable for up to 15 years after the installation.

18.24.2.12. Metering

Energy metering shall be provided within each building to ensure all energy utilised is identified and assessed. The following measures shall be incorporated to ensure adequate metering is included:

- Metering and sub-metering to be provide in line with ASHRAE, EN, local and international standards
- At least 90% of the estimated annual energy consumption of each fuel shall be accounted for within each building

In addition to metering required by the above standards, energy meters and sub-metering shall be provided to the following:

- All incoming services to each building
- Metering of any heating or cooling services within each building when provided from a central system
- Sub-metering for large usage areas
- Sub-metering of all electrical final distribution boards to meter lighting usage
- Sub-metering of all central domestic hot water plant

A metering data collection system in parallel with the BEMS shall be provided ensuring quality real time data is available to the proposed monitoring and targeting system to identify avoidable wastage.

18.25. Fire fighting

The complete fire protection system shall be designed, installed, tested and taken into operation in accordance with the latest state of the art in the field of fire protection engineering and shall comply basically with the codes and standards of NFPA (National Fire Protection Association, USA) and associated international recognised standards.

Fire detection and alarm system, fire protection and firefighting system for Substation including water storage tanks, firefighting room with fire pumps and associated piping and valves, all pertaining equipment, external pipelines, hydrants and fire hose cabinets to cover entire site.

All buildings and structures shall be made of non-combustible or fire resistant materials.

In order to avoid an uncontrolled fire spread inside a building, which would result in a considerable or total loss of the building and equipment, and to provide safe escape routes for the personnel, the buildings shall be subdivided into various fire areas, also called fire zones, separated by approved fire resistant barriers and elements, such as fire walls, fire resistant ceilings, doors, dampers and fire partitions.

Fire walls, ceilings and partitions shall have in general a fire resistance rate of not less than 2 hours, except for oil-insulated transformers installed indoors, for which the fire barriers shall have a fire resistance rate of not less than 3 hours.

Fire doors, dampers and shutters installed in 2-hour rated fire barriers shall have a fire resistance rate of not less than 1½ hours.

In principle, the following plants and rooms shall be designed as independent fire areas:

- Staircases
- Transformer rooms
- Switchgear rooms
- Control, electronic and computer rooms
- Battery rooms
- Cable floors, shafts and tunnels

- Air conditioning rooms
- Storage rooms

All ventilation and air conditioning ducts penetrating fire resistant walls or ceilings shall be provided with approved fire and/or smoke dampers, which shall be released via the fire detection and alarms. All control and power cables penetrating openings in walls or ceilings of fire rated walls or boundaries shall be sealed with an approved sealing system, consisting of fire resistant constructions and materials, providing a fire resistance rate consistent with the rating of the fire barrier system, providing a fire resistance rate consistent with the rating of the fire barrier.

A digital and intelligent, centralized or modular fire detection and alarm system shall be designed, installed, tested and commissioned in accordance with NFPA 72.

A reliable central fire alarm control panel shall be supplied including all necessary electronic cards and equipment to receive, operate, supervise and display all detection and alarm installations and to release and initiate all other functions as applicable.

The central fire alarm control panel shall be located inside the control room.

Portable and mobile (trolley-mounted) fire extinguishers shall be provided for the various areas, rooms, components and equipment. Numbers and locations of extinguishers shall be satisfactory to local authorities and are subject to approval. The fire extinguishers shall be in accordance with the requirements of NFPA 10, latest edition, and shall be installed at locations approved by the Employer/ Engineer.

Firefighting water shall be taken from a firefighting water tank, automatically filled with potable / non-saline public network water line for firefighting purposes and where public network water line is not available Contractor shall fill using water tankers until contract final acceptance . Independent fault signal shall be initiated to LDC (Load dispatch center) for low water level at $\frac{3}{4}$ tank level.

The fire water tanks reservoir shall be capable of providing 2 hour supply to fire protection system.

External hydrant shall be designed with a flow rate not less than 1890 l/m.

The capacity and pump head of each Electric Main Pump and diesel Main Pump shall be the equal to simultaneous operation of one largest single hazard system and one external hydrant for 2 hrs

The firefighting water tanks shall be designed, constructed and tested in accordance with NFPA 22, latest edition

Next to each outdoor hydrant, a weather resistant hose cabinet properly ventilated and painted red shall be provided.

Design, installation and tests shall be accomplished in accordance with the latest edition of NFPA.

The following design principles shall be observed as minimum fire prevention requirements:

- The stuffing of cable and wall penetrations shall be of incombustible material.
- Cable and pipeline ducts shall be arranged so as to avoid the risk that they will be flooded with flammable liquid.
- Covered floor ducts shall be easily accessible for inspection and cleaning.

- All parts of plant and equipment shall be arranged so that no corners or pits difficult to inspect and clean are formed, where flammable matter could collect.
- For the paneling of walls and ceilings, for floor covering as well as for cubicles and cabinets, incombustible materials are to be used.
- Fire escape paths shall not be longer than 30 m and not less than 1.0 m wide.

18.25.1. Fire Zones and Required Considerations

The fire protection system shall mainly consist of the following installations and equipment as per KETRACO, KEBS, IEEE 979 and NFPA 850 requirements:

- Linear heat detection system for cable spreading rooms and cable shafts
- Nitrogen injection and oil evacuation system (NIFPS)
- Sprinkler systems
- Clean agent gas extinguishing systems (as per NFPA 2001)
- Standpipes and hose systems
- Fixed water spray systems (as per NFPA 15)
- Fire detection and fire alarm system
- Passive fire protection system (Fire resistant/retardant coatings for cables)
- Firefighting water tank
- Fire water service main ring surrounding substation complex
- Firefighting water pump station (containing NFPA-listed and jockey pumps)
- Hydrants and hose cabinets
- Wheeled and portable fire extinguishers
- Spare parts and special tools

The fire detection and protection systems for each fire zone are recommended as following table:

Fire Zones	Protection system	Detection system
Switchyard area	Outdoor hydrants and hose cabinets as per scope of work, Dry Powder/ Carbon Dioxide Extinguishers.	Outdoor point type heat detectors, Manual fire alarm stations
General areas, offices, lobbies, kitchens, small stores, guard room, etc.	Dry Powder / Foam Fire Extinguishers, in addition to Carbon Dioxide Extinguishers.	Smoke and/or heat detectors, Manual fire alarm stations
Staff housings	Water Extinguishers, Dry Powder /Foam Fire Extinguishers/ Carbon	Smoke and/or heat detectors, Manual fire alarm stations

Fire Zones	Protection system	Detection system
	Dioxide Extinguishers and fire blankets.	
Oil filled transformers, reactors	Nitrogen injection and oil evacuation system (NIFPS), for equal and above 100MVA or 100MVar	NIFPS detection, Heat detectors for Fire Alarm, Manual fire alarm stations
	Note: Protection & detection requirements of Transformers shall be based on Fire Protection Design Basis.	
Dry-type transformers	Portable dry Powder/Carbon Dioxide extinguisher	Outdoor heat detectors, Manual fire alarm stations
Cable basements, cable spreading rooms and cable tunnels within substation premises	fire resistant/ retardant coating of cable penetrations, portable dry chemical and CO2 fire extinguishers	Linear heat detection system, Smoke detectors, Manual fire alarm stations
Cables in reinforced concrete trenches within substation premises	Fire barriers with fire stopping at the cable penetrations	Detection not required
Cable Shafts	Fire barriers at every floor level. Fire barriers and fire stopping at cable penetrations.	Linear Heat detection system
Relay, computer and telecommunication rooms, Control rooms, SAS, LVAC, DC charger room, BCRs, indoor capacitor/reactor, HVAC control panel room	Portable dry chemical and CO2 fire extinguishers	Smoke detectors, Manual fire alarm stations
Service shafts for HVAC ducts etc.	Fire barriers at each floor level	Smoke detectors at each floor level
Battery rooms	Portable dry chemical and CO2 fire extinguishers	Smoke and H2 detectors in every beam pocket, Manual fire alarm stations
Fire pump house as per scope of work	Portable dry chemical and CO2 fire extinguishers	Manual fire alarm stations, smoke detectors
All other buildings and areas including A/c condensing unit yards, outdoor capacitor banks/reactors	Outdoor hydrants and hose cabinets, Portable dry chemical fire extinguishers	Outdoor point type heat detectors, Manual fire alarm stations
Guard house and Telecom room	Portable dry chemical and CO2 fire extinguishers and fire blankets.	Smoke detectors, Manual fire alarm stations
Diesel Generator house	Portable Dry Powder/Foam and CO2 fire extinguishers	Heat detectors, Manual fire alarm stations

Note: No Automatic Water Extinguisher shall be used in the control room or yard.

18.25.2. Separation Distance & Fire Walls between Transformers

- For transformers using mineral based dielectric fluid, the method of separation shall be in accordance with NFPA-850.
- Transformers containing more than 500gal (1.9m³) of oil shall be provided with 2 hour rated fire wall or spatial separation between transformers and/or between transformers & structures. Where a fire wall is provided to protect from a transformer fire, it shall be extended in accordance with NFPA 850.
- For transformers using less-flammable dielectric fluid, the method of separation shall be in accordance with NFPA-850, Section 5.1.4 and 5.1.5.

18.25.3. Fire Hydrants

- The Hydrant system requirements shall be determined in accordance with Local Code.
- Hydrant system shall be installed, tested & commissioned in accordance with NFPA-24.
- Pressure at the remotest hydrant shall be accordance with Local code.
- Pipe size of hydrant network shall not be less than 150mm. (NFPA14)
- Hydrants shall be located not less than 40 ft (12 m) from the spaces to be protected. (NFPA24)

18.25.4. Portable and Trolley-Mounted Fire Extinguishers**18.25.4.1. Portable fire extinguishers**

The following types of portable extinguishers shall be provided:

- Powder BC fire extinguishers
- Carbon dioxide fire extinguisher

Where extinguishers are provided externally, or in other areas where they may be subjected to the weather, they are contained inside a protective cabinet.

The extinguishers are of the type operated by means of a lever provided with a safety pin, which allows for the partial discharge.

18.25.4.2. Trolley-mounted fire extinguishers

The following types of wheeled extinguishers shall be provided:

- Powder ABC fire extinguisher
- Carbon dioxide fire extinguisher

Each powder unit consists of a powder container to which a carbon dioxide cylinder operating as propellant gas is attached; it is provided with a 15 m hose with controlled nozzle. The powder unit is mounted on a metal frame with two wheels and a driving handle.

Each carbon dioxide unit consists of a carbon dioxide cylinder, a hose, a control valve and a discharge nozzle. The cylinder and discharging devices are mounted on a metal frame with two wheels and a driving handle.

18.25.5. Fire Alarm

- Automatic fire detectors shall be designed, installed, tested & commissioned in accordance with NFPA 72.
- The type of protective signaling system for each installation and area should be determined by the Fire Protection Design Basis in consideration of hazards, arrangement, and fire suppression systems.
- Fire detection and automatic fixed fire suppression systems shall be equipped with local audible and visual signals with annunciation in a constantly attended location, such as the main control room.
- Audible fire alarms shall be distinctive from other plant system alarms and shall comply with NFPA-72.
- The fire-signaling system or plant communication system shall consist of the following:
 - 1) Manual fire alarm devices (e.g., manual pull station) shall be provided in all occupied buildings and for yard hazards.
 - 2) Plant-wide audible fire alarm or voice communication systems, or both, for purposes of personnel evacuation and alerting of plant emergency organization shall be provided. The plant public address system, if provided, should be available on a priority basis.
 - 3) Two-way communications for the plant emergency organization during emergency operations.
 - 4) Means to notify the public fire department shall be provided.

18.25.6. Nitrogen Injection system

Nitrogen Injection system should be a dedicated system for each oil immersed transformers (equal to and above 100 MVA) / reactors (equal to and above 100 MVAR). It should have a Fire Extinguishing Cubicle (FEC) placed on a plinth at a distance of 5-10 m away from transformer / reactor or placed next to the firewall (if firefighting wall exists). The FEC shall be connected to the top of transformer / reactor oil tank for depressurization of tank and to the oil pit (steel tank) (capacity is approximately equal to 10% of total volume of oil in transformer / reactor tank / or existing oil pit) from its bottom through oil pipes. The FEC should house a pressurized nitrogen cylinder (s) which is connected to the oil tank of transformer / reactor oil tank at bottom. The Transformer Conservator Isolation Valve (TCIV) is fitted between the conservator tank and Buchholz relay. Cable connections are to be provided from signal box to the control box in the control room, from control box to FEC and from TCIV to signal box. Detectors placed on the top of transformer / reactor tank are to be connected in parallel to the signal box by Fire survival cables. Control box is also to be connected to relay panel in control room for receiving system activation signals.

On receipt of all activating signals, the system shall drain - pre-determined volume of hot oil from the top of tank (i.e. top oil layer), through outlet valve, to reduce tank pressure by removing top oil and simultaneously injecting nitrogen gas at high pressure for stirring the oil at pre-fixed rate and thus bringing the temperature of top oil layer down. Transformer conservator isolation valve blocks the flow of oil from conservator tank in case of tank rupture

/ explosion or bushing bursting. Nitrogen occupies the space created by oil drained out and acts as an insulating layer over oil in the tank and thus preventing aggravation of fire.

18.25.6.1. System components

Nitrogen Injection system shall broadly consist of the following components. However, all other components which are necessary for fast reliable and effective working of the system shall deemed to be included in the scope of supply.

- Fire Extinguishing Cubicle (FEC)
- Control box
- Detectors
- Signal box
- Fire survival cables and Fire Retardant Low Smoke (FRLS) Armoured Cables,
- Electrical Resistance Welded pipes with support & fitting as per standard norms for connection between transformer & FEC,
- Transformer Conservator Isolation Valve (TCIV) and oil drain pipe suitable for transformer oil quantity,
- Power supply
 - For Control Box
 - For FEC Auxiliary

18.25.6.2. Tests

Contractor has to submit valid type test reports as per relevant NFPA/IEC. including IP 55 on FEC, control box etc., from a reputed authority nationally or internationally and must be valid till expiry of validity of offer. Reports of all routine test conducted as per relevant NFPA/IEC standards in respect of various bought out items including test reports for degree of protection for FEC / control box / signal box shall be submitted by the supplier. The supplier shall demonstrate the entire functional test associated with the following as Factory Acceptance Tests:

- FEC, Control Box
- Fire Detector
- Transformer Conservator Isolation Valve

The performance test of the complete system shall be carried out after erection of the system with transformer at site.

18.26. Earthing and Lightning Protection

All buildings shall be connected to the earthing grid of the substation.

Wherever required a lightning protection system shall be provided under strict observation of the local regulations and relevant Standards (e.g. IEC62305). The system shall consist but not be limited to the following:

- Each super-structure shall be provided with the necessary lightning catching rods of stainless steel, with a minimum diameter of 10 mm, roof and down conductors of tinned copper or galvanised steel.

Steel constructions or down conductors of a civil construction shall be connected at ground elevation to a ring main equipped with an adequate number of earthing electrodes of sufficient length to obtain an earthing resistance of approx. $0.1\ \Omega$. Such ring main shall not be directly connected to the sub-grade earthing system or the protective earthing system.

19. XLPE Insulated 11kV Cable & Accessories

19.1. Scope of Works

This specification details the requirements for the design, manufacture and testing of XLPE insulated 11kV cable and accessories.

19.2. Design and Manufacturing Requirements

19.2.1. General

The 11kV XLPE insulated cable shall comprise a circular stranded Copper conductor insulated by a continuous vulcanization, triple extrusion process, simultaneously applying a semiconducting conductor screen, a thermosetting insulating dielectric and a semiconducting core screen. The extruded core shall be cured using a dry curing process and the byproducts of crosslinking removed by a prolonged degassing process. The core shall be sheathed overall with an extruded lead sheath and protected with a continuously extruded polymeric oversheath. A thin layer of graphite or semi-conducting polymer shall be applied overall and firmly bonded to permit testing of the cable oversheath.

11kV XLPE insulated cables shall comply with the requirements of IEC 60502 plus any additional requirements specified hereafter.

The cable shall be designed for a reliable service life of at least 40 years.

19.2.2. Conductors

Conductors shall be stranded, annealed, high conductivity copper, or aluminum of at least 99.5 per cent purity. The copper wire before shaping shall be smooth, uniform in quality, free from scale, inequalities, spills, splits and other defects and should comply with the requirements of international specification IEC 60228.

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 150mm and not more than 300mm long.

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 300mm of any other joint in the same layer. The jointing of wires shall be by brazing, silver soldering cold welding or electrical welding. No joint shall be made in the wire after it has been formed up into the required length.

The 11kV conductor will be waterblocked to meet the requirements of IEC 60502 using waterblocking tapes and/or yarns. The use of waterblocking powder on its own is not permitted.

19.2.3. Conductor Screens

A conductor screen shall be used to provide a smooth interface between the conductor and the cable insulation. A suitable semi-conducting binder tape will be applied over the conductor to prevent the extruded screen falling between the interstices of the conductor strands.

The semi-conducting screen will have a spot minimum thickness of 1.0mm.

The conductor screen will be made from semiconducting cross-linked polyethylene (XLPE) using carbon black material and will be applied as part of a triple extrusion process.

The conductor screen shall be extruded and consist of a black, semi-conducting thermoset material fully compatible with the conductor and extruded insulation. The outer surface of the semi-conducting screen shall be super smoothing, cylindrical and firmly bonded to the overlying insulation.

A smoothness assessment should be conducted on extruded tape samples of the semi-conducting screen material. The contact surface between the screen and the insulation shall be cylindrical, smooth and free from protrusions and irregularities which extend more than 0.125mm into the insulation.

19.2.4. Insulation

The insulation shall be an extruded crosslinked polyethylene (XLPE) material forming a concentric dielectric surrounding the conductor.

The use of insulation based on pure LDPE is preferred to the use of insulation based on Co-polymer.

The materials for the manufacture of HV cables shall be delivered in clean bulk containers.

The preferred manufacturing process is the vertical continuous vulcanisation (VCV) line however cable manufactured with either MDCV or CCV lines will also be considered.

Every effort is to be made by the manufacturer to ensure the purity of the insulation extruded on the cable core. Frequent sampling during compound manufacture should take place.

A contamination check of extruded tape samples of the insulation should be laser checked for contamination prior to manufacture. The contamination level shall be:

Not more than 5 contaminants	>100um/100g
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Not more than 2 contaminants	90um<X<110um/100g
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2kg per tonne of material should be checked

Suitable sieves are to be employed to remove particulate contamination from the extruded material which may affect the electrical performance of the cable insulation.

The thickness of the insulation shall be specified as the minimum average value measured according to IEC 60502 for the 11kV cable.

The insulation thickness shall be based on the maximum conductor screen stress. The maximum conductor screen stress used will be clearly stated and justification for its selection will be provided in the form of Type Test reports and Experience lists.

Evidence is required of Weibull Life Prediction from endurance and voltage ramp testing and of your calculations to predict cable service life.

Any information supplied pertaining to XLPE insulation should be related to a unique compound identification number that can be cross-referenced to Type Test reports etc.

The Cable Manufacturer shall demonstrate their system of incoming material control, manufacturing process control, and cable quality control.

Manufacturing processes that utilize advanced monitoring systems including i) Ultrasense on-line ultrasonic core inspection equipment and ii) Pellet Checking equipment are considered desirable.

19.2.5. Insulation Screen

The insulation screen shall be extruded and consist of a black, semiconducting thermoset material fully compatible with the extruded insulation. The interface between the insulation and the semiconducting screen shall be super smoothing, cylindrical and firmly bonded.

Testing of the material should be as for the conductor screen.

19.2.6. Cushioning/Waterblocking Layer

The core shall be taped overall with semiconducting cushioning tapes to prevent possible mechanical damage of the cable core caused by thermal expansion during normal operation of the cable.

Provision should be made to prevent the longitudinal penetration of water along the interface between the cable core and the metallic sheath by the application of suitable water swellable tapes applied over the cable core.

19.2.7. Metallic Sheath

The sheath is required to fulfill the following requirements:

- a. provide a radial watertight barrier to the ingress of moisture into the extruded cable core,
- b. provide a low resistance path for cable charging current,
- c. provide protection against minor accidental damage caused by third party interference with cable during installation and service and

- d. be capable of sustaining the specified earth fault currents for the time stipulated by the user.

The water impervious sheath shall consist of a seamless and continuously extruded tube of lead alloy. The lead alloy used for the sheath shall be alloy 1/2C. A thin layer of bitumen shall be applied over the sheath.

Lead alloy sheath of best quality metal, free from pinhole flaws and other imperfections shall be tightly extruded over the water blocking layer.

The minimum thickness at any point shall not fall below the specified nominal thickness by more than 0.1mm or 5% of the nominal thickness.

For the purpose of increasing the total short circuit current rating of the cable, a copper wire screen of suitable cross sectional area may be applied between the core bedding layer and the lead sheath. A copper tape shall be applied directly over the copper wires in an opposite lay to the lay of the copper wires, to ensure equal current sharing in the copper wire screen. A suitable binder tape shall be applied over the copper wire screen.

19.2.8. Oversheath

The cable serving shall be robust enough to prevent unnecessary damage during installation and shall insulate the cable from earth.

The outer covering shall be of a Low Smoke Zero Halogen material.

The minimum average thickness and minimum thickness at a point shall comply with IEC 60502 for the 11kV cable and not be less than the value stated in the schedule.

An outer conductive coating (graphite coating or extruded layer) shall be applied to the covering to serve as an electrode for the voltage test on the outer covering.

19.2.9. Anti-Termite Protection

All cables installed in concrete troughs within a substation shall have suitable anti-termite protection, to be approved by KETRACO.

19.2.10. Fire Resistance

All cable sections installed within substations will have an oversheath with a fire performance that conforms to the requirements of,

- IEC 60332-1 (Fire)
- IEC 60332-3A (Fire)
- IEC 61034 (Smoke)
- IEC 60754 (Minimal Halogen)

Ideally, oversheath materials will also have an oxygen index of less than 30% and a temperature index of greater than 260°C.

19.2.11. Markings

The following information will be clearly printed with indelible ink on the semiconducting XLPE screen of every cable;

‘11kV XLPE Cable – KETRACO – Cable No. XXXXXX - Date’

The oversheath should be legibly embossed along its length with the following information:

‘66000V Electric Cable, (Manufacturer), (Year of Manufacture) PROPERTY OF KETRACO’

‘11000V Electric Cable, (Manufacturer), (Year of Manufacture) PROPERTY OF KETRACO’

The embossed letters and figures shall be raised and consist of upright block characters along two or more lines, approximately equally spaced around the circumference of the cable.

For both the semiconducting XLPE screen and the oversheath, the maximum size of the characters shall be 13mm and the minimum size not less than 15 per cent of the nominal or specified external diameter of the cable or 3mm, whichever is the greater.

For both the semiconducting XLPE screen and the oversheath, the spacing between the end of one set of embossed characters and the beginning of the next on the legend shall not exceed 150mm. Any additional information embossed on the sheath (e.g. the Manufacturer's name) shall not affect the spacing between repetitions of the legend.

19.2.12. Dispatch

Both ends of the cable shall be rendered fully watertight by fitting a metallic end cap and a pulling eye which are plumbed to the cable metallic sheath. The pulling eye shall be directly connected to the conductor and be capable of withstanding a tensile load of 100N/mm² of conductor area up to a maximum of 6 tonnes. When requested by the user, pulling eyes shall be fitted to both ends of the cable.

The cable shall be dispatched on a drum of suitable construction of minimum hub diameter 20D (where D is the overall diameter of the cable). The drum shall be fully enclosed by either adjacent fitting wooden battens or continuous metallic cladding.

19.3. Design & Manufacturing Requirements for Accessories

19.3.1. Outdoor terminations

Termination insulators must be manufactured from Porcelain materials; all materials shall be fully factory tested during production. In accordance with IEC 60815 the pollution level specified is ‘very heavy’.

The stress control method must allow for the thermal expansion of the cable and the bidder must state how this is achieved. The sealing ends shall be filled with high viscosity polyisobutylene, silicone oil, or equivalent and expansion devices shall be provided where necessary.

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.

19.3.2. Transformer Terminations

The terminations may be of "dry type" or "wet type" construction, containing an epoxy resin insulator and an elastomeric stress cone. The insulator shall have a blind-ended construction to eliminate the possibility of transformer oil leaking into the cable termination via the conductor connection.

The cable glands of the sealing ends shall be insulated from the transformers.

The cable manufacturer will liaise fully with the transformer manufacturer to ensure that the cable sealing ends will interface correctly with the transformer.

19.3.3. Straight Joints

The conductor connection will be made using a compression ferrule.

The following types of joint only will be considered for offer;

- i. Premoulded One-Piece rubber

The design of joint will accommodate insulation retraction and expansion.

The joint shall be provided with a copper joint shell suitable for a metallic seal to the extruded metallic sheath of the cable.

Cable joints buried in the ground shall be enclosed in a fibreglass casing and the space between the joint and casing shall be completely filled with bituminous compound of approved grade. Alternative methods of insulating and protecting the joint e.g. heat shrink sleeve, rubber tape, may be offered subject to demonstration of development tests and type tests.

19.4. Cable System Tests

19.4.1. General

11kV cable and cable accessories should be tested together as a complete system for type test purposes. All tests shall be carried out under the conditions stipulated in sections 15 to 19 of IEC 60502-2.

Commissioning tests will inherently test these components as a complete system.

19.4.2. Type Tests

The appropriate type tests specified in this clause shall be made before the manufacturer supplies on a general commercial basis the type of cable described in this specification in order to demonstrate satisfactory performance requirements.

These tests excepting those which are also required as additional regular tests need not be repeated once they have been performed successfully, unless alterations are made to cable design or materials which might affect the performance.

The accessory manufacturer must demonstrate by type test approval tests on the specific cable that any joint or termination that it is intended for use with the cable supplied for a specific contract is compatible with that cable.

Tests are required to demonstrate satisfactory performance characteristics of the basic accessory design.

Designs suitably tested may be used for applications where the electrical design stresses are the same or lower than those tested.

Type Testing will be in full accordance with IEC 60502 for 11kV cable.

19.4.3. Schedule of Type Tests

The type tests shall comprise electrical tests on complete cable and the appropriate tests on cable components.

The electrical tests shall be carried out in sequence on one sample of cable. The bending test shall be included in this sequence of tests to check that the electrical properties of the cable after bending are satisfactory.

19.4.4. Electrical Tests

The normal sequence of tests shall be:

- c. Bending test followed by partial discharge test according to clause 16.4 of IEC 60502-2 for 11kV cable.
- b. Heating cycle voltage test, followed by partial discharge measurement according to clause 18.1.6.4 of IEC 60502-2 for 11kV cable.
- c. Impulse withstand test followed by power frequency voltage test and according to clause 18.1.7 of IEC 60502-2 for 11kV cable.

19.4.5. Tests on Cable Components

The following tests should be completed on the cable components:

- d. Measurement of thickness of insulation
- b. Measurement of insulation concentricity

- c. Measurement of insulation purity
- d. Measurement of moisture content in extruded insulation and screens
- e. Hot set test for XLPE insulation
- f. Shrinkage test
- g. Measurement of resistivity of semiconducting screens
- h. Measurement of screen protrusions
- i. Tests for determining the mechanical properties of the insulation before and after ageing (IEC 60502 for 11kV cable)
- j. Ageing tests on pieces of complete cable to check compatibility of materials IEC 60502 for 11kV cable)
- k. Impact test on metallic sheath
- l. Water penetration test (IEC 60502 for 11kV cable)

19.4.6. Additional Tests for Accessories

Upon completion of the Type Test the joint will be fully dismantled and examined for any signs of distress or disruption not detected by the Type Test.

The sheath insulation used to enclose the joint will be subjected to the following tests;

- a. Impulse tests in accordance with Engineering Recommendation C55/4 'Insulated Sheath Power Cable Systems' from the Electricity Council, UK.
- b. Water penetration tests in accordance with CENELEC HD 632 S1:1998 PART 2, Section 6.2.9 (page 2-61).

19.4.7. Routine Test Requirements for XLPE Insulated Cable

General

The following tests shall be carried out on dispatch drum of cable, to check that the whole of each length complies with the requirements.

- e. Voltage test
- b. Partial discharge test
- c. Dielectric loss angle
- d. Conductor examination
- e. Measurement of electrical resistance of conductor

- f. Oversheath voltage withstand test

Voltage Test

The voltage test shall be conducted in accordance with IEC 60840.

Partial Discharge Test

The partial discharge test shall be conducted in accordance with IEC 60502 for the 11kV cable. Measurements shall be made at least after initial voltage energization and at the end of the specified test period.

Dielectric Loss Angle

This shall be measured at $1.5U_0$. The value shall be less than or equal to 0.0008.

Conductor Examination

Compliance with the requirements of IEC 60228 for conductor construction shall be checked by inspection and measurement.

Measurement of the Electrical Resistance of the Conductor

The measurement of the electrical resistance of the conductor shall be made in accordance with IEC clause 16.2 of IEC 60502-2 for the 11kV cable. The measured resistance of the conductor should comply with the value specified in IEC 60228.

Oversheath Voltage Withstand Test

For the 11kV cable each drum length of completed cable shall be subjected to a maximum voltage of 10kV DC for one minute between the metal sheath and the external conducting surface.

Additional Tests

The Contractor shall carry out the following tests on a representative sample, according to clauses 17.4 and 17.5 of IEC 60502 for the 11kV cable. All supplements as appropriate to the type of cable under test.

The samples shall be randomly selected from the completed and routine tested drums during the factory acceptance test, or on other agreed way. The testing piece (about 1.5m length) shall be taken from each drum and shall be available for selection to perform the hot set test and verification of cable dimensions. Each piece shall be marked with the drum number.

If the samples from any length selected for the test should fail any of the tests, the procedure given in clauses 17.4 and 17.5 of IEC 60502 for the 11kV cable shall apply.

The sequence of special tests shall include the following:

1. Visual checking of packing and drums appearance.
2. Repetition of the complete routine test.
3. Measurement of thickness of insulation and non-metallic sheaths, as per section 6 of IEC 60502 for the 11kV cable and clause 8 of IEC 60811-1-1 for 11kV cables.
4. Measurement of thickness of metallic sheaths, as per clause 17.7 of IEC 60502 for the 11kV cable (ring method for both cables).
5. Dimensional checking of copper screen, (no. and diameter of wires).
6. Hot set test of XLPE insulation, as per IEC 60502 for the 11kV cable and clause 9 of IEC 60811-2-1 11kV cables.
7. Checking of all cable dimensions against the values guaranteed in the Technical Schedules.
8. Bending test and partial discharge test, as per clause 18.1.4 and 18.1.3 of IEC 60502 for the 11kV cable.
9. Abrasion test of PVC sheath, as per clause 4.1 of IEC 60229.

19.4.8. Routine Test Requirements for XLPE Insulated Cable Accessories

One-Piece Premoulded Joints

The insulation and screening material used for all one-piece Premoulded joints shall be identical to those used to manufacture the Type Test accessories. The characterisation of the insulation and screening material shall include;

- i. Fourier Transform Infrared Spectroscopy (FTIR) to characterise the insulating polymer.
- ii. Cleanliness measurement on the incoming insulation material.
- iii. DLA measurement of insulation at 90°C.
- iv. Thermogravimetric Analysis (TGA) on the incoming semiconducting material to characterise the carbon black content.

The above tests will be carried out on one joint in every ten manufactured for the contract.

The following, additional tests, will be conducted on every one-piece joint or rubber stress cone;

- a. HV Withstand Test at $2U_o$ for 30 minutes.
- b. Partial Discharge Measurement at $2U_o$. Discharge to be $< 10\text{pC}$ with background noise level of 2pC .
- c. Mechanical stretch of each rubber component over a mandrel equal in diameter to the Contractors site assembly mandrel.

- d. Resistance of outer semi-conducting screen < 20kohms.
- e. Integrity of insulated gap 25kV DC for 15 minutes.

Commissioning Tests

For each completed circuit, the following site tests shall be carried out:

Measurement of Conductor Resistance and Circuit Impedance

The Contractor shall measure and record the following as-installed circuit data:

- (i) As-installed circuit length in km
- (ii) DC conductor resistance
- (iii) AC conductor resistance
(Measured and/or derived)

Test on Sheath Protective Covering

For the 11kV cable a voltage of 10kV DC for one minute shall be applied between the sheath and ground on each length of cable sheath, with all sheath voltage limiters disconnected.

High Voltage AC Field Acceptance Test

An AC overvoltage, of $2.0U_o$, will be applied to each phase of the cable system for a period of not less than 1 hour.

Additional Tests

The following additional tests need to be carried out on all power cables during commissioning:

- a. Circuit phasing check.
- b. Capacitance of circuit.
- c. Sheath continuity checks.
- d. Cross-bonding configuration checks (if applicable).

19.5. Packing, Shipping and Transport

Each length of the finished cable shall be wound into a steel drum, and each end of a cable shall be sealed hermetically before shipment. The drum shall be lagged with strong closely fitting battens, which shall be securely fixed to prevent damage to the cable. The reels and lagging shall be sufficiently strong to withstand the conditions of shipment. All wooden parts shall be appropriately treated for protection against vermin.

The cable drums shall be arranged to take a round spindle and shall have smooth internal flanges to accommodate an equal number of turns per layer.

Any cable end, which is left projecting from the drum, shall be protected against damage.

Each drum shall bear a distinguishing number for identification purposes painted on the outside of the steel flange.

Each reel shall be marked with the following particulars:

- 1) Type of cable;
- 2) Direction of rolling;
- 3) Rated voltage and conductor size;
- 4) Reel length;
- 5) Cable net weight and gross weight;
- 6) Name of manufacturer/trade work;
- 7) Year of manufacture;
- 8) Contract No.

Shipping reels shall be free of any information not pertaining to the order.

The ends of lead sheathed cables shall be sealed by plumbing a cap or disc on the lead sheath. The ends of PVC sheathed cables shall be suitably sealed to prevent the ingress of moisture.

The drums shall be of good quality and care must be taken to ensure that cables are not damaged during shipping, storage etc. The gross weight of the loaded drum should be suitable for handling by KETRACO's cable drum trailer during maintenance.

19.6. Performance Guarantees

The performance of the cross bonding system shall be confirmed by the appropriate site tests after installation. If the Contractor fails to meet the performance requirements, KETRACO shall decide either to reject the installation completely or to accept compensation appropriate to the extent of deficiency.

19.7. Training

Works to be done under this section include training of KETRACO's personnel to operate and maintain equipment efficiently and safely. There shall be no constraints on the number and category of KETRACO's personnel to be trained.

The training shall cover design, operation, maintenance and testing aspects of the offered equipment. A training programme shall be submitted and mutually agreed and be implemented at least 30 days prior to shipment of the equipment.

The training programme shall include on -site training of KETRACO personnel to provide them with experience in 11kV cable jointing and all associated activities. The Contractor shall submit training details to KETRACO for approval and shall also supply a video CD describing the various steps of cable jointing relevant to this project. All costs associated with the on-site training shall be deemed to be included in the Contract Price.

19.8. Documentation

The Contractor shall provide all necessary drawings, design specifications, design details, operation and maintenance manuals.

19.8.1. Documentation with Bid

The Bid shall contain at least the following information and documents, failure of provision of the mentioned documents will lead to disqualification:

- 1) Detailed cross sections giving dimensions and construction of 11kV XLPE cables;
- 2) Cable joints;
- 3) Cable sealing end;
- 4) Schematic diagram of the proposed installation;
- 5) Proposed joint bay arrangement;
- 6) Detailed calculation confirming selected conductor cross section;
- 7) Detailed calculation confirming selected metallic sheath cross section;
- 8) Proposed work schedule, giving tentative timing and phasing of manufacture, testing, shipment, cable laying, jointing and other erection works;
- 9) Proposed cable laying procedure, cable protection covers;
- 10) Manufacturing specification of the proposed cables;
- 11) Catalogues, literature and reference lists of proposed equipment;
- 12) Type test certificates from an independent testing authority or independently witnessed;
- 13) Quality Management System Manual and ISO Certificate of the equipment manufacturer.

19.8.2. Documentation after Award of Contract

All documents required for KETRACO's approval shall be submitted by the Contractor.

20. 11kV Cables Sheath Bonding & Earthing Equipment

20.1. Scope of Works

This specification details all the design, performance and testing requirements for all items of sheath bonding and earthing equipment (link boxes, sheath voltage limiters, bonding leads) required for 11kV cable systems.

The Contractor is bound to provide complete works, even if the equipment or services to be provided are not specifically mentioned in the specification.

20.2. General

Cable circuits may be installed as either solidly bonded systems or insulated sheath systems with special bonding to reduce sheath losses.

The design of all specially bonded systems shall be such as to ensure that there is a continuous metallic return path of adequate cross-section for the specified fault current.

All required direct inter-sheath and sheath-to-earth connections shall be made via disconnecting links enclosed in link boxes. Inter-sheath and sheath-to-earth connections through sheath voltage limiters shall be disconnectable within link boxes. Bonding leads and link boxes shall be of approved design.

20.3. Bonding Arrangements

Special terminal bonding arrangements may be necessary where cables terminate into gas insulated switchgear. The Contractor shall recommend the appropriate measures where appropriate.

20.4. Induced Sheath Voltages

For system design purposes, the magnitude of sheath voltages induced under balanced maximum full load conditions and also under prospective short-circuit fault conditions shall be calculated by the methods and formulae recommended by CIGRE. Details of such calculations shall be submitted to KETRACO and recommendations for cable section lengths.

At terminations, the base metal work of the cable sealing end shall be shrouded against accidental contact if the sheath voltage exceeds 10V.

20.5. Sheath Voltage Limiters

In order to minimize transient over-voltages on sheath insulation, sheath voltage limiters (SVLs) of approved design shall be installed at unearthed ends of single point bonded sections. Under certain circumstances, SVLs may be necessary at earthed terminations into SF₆ switchgear.

SVLs shall be of zinc oxide type and shall consist of three non-linear resistors housed in the link box, the star point being earthed normally to local earth points.

SVLs installed at metalclad terminations shall be encapsulated and mounted directly across the insulating flange of the termination.

The SVLs shall be capable of withstanding the voltages and currents impressed upon them and of limiting transient voltages to acceptable levels.

The units shall be able to withstand the voltages induced by fault currents for a period of 2 seconds without damage. However, it is accepted that the units may be unable to withstand the duty imposed upon them by an internal cable system fault.

20.6. Link Boxes

All links and SVLs, other than those directly connected across sectionalizing insulation at metalclad equipment terminations, shall be enclosed in stainless steel boxes which shall be earthed. SVLs and associated links shall be accommodated in a common housing unless otherwise approved by the Engineer.

The boxes shall be provided with a means of preventing incorrect link positioning and shall also be provided with a label showing the normal link arrangement.

The terminal posts and links shall be suitable for the specified short circuit requirements.

The link housing shall be designed to confine the effects of the failure of SVLs and link insulation to withstand the duty imposed upon them by an internal cable fault due to the high system fault levels. The Contractor shall recommend ways of containing these effects.

All link boxes shall be of horizontal type with bolted-on lids suitable for installation in shallow pits below ground surface unless otherwise agreed by the Engineer. Pits shall be provided with removable cast iron covers.

The link box shall have a label fitted externally bearing the legend:

DANGER - ELECTRICITY

The label shall also give circuit identification details. Appropriate warning labels shall also be affixed inside the box. A phase identification label shall be provided adjacent to each terminal.

20.7. Bonding Leads

Bonding leads shall have PVC or polyethylene insulated stranded plain copper conductors and shall be of concentric construction. The type of PVC or polythene used shall be suitable for a short-circuit temperature of 160°C.

Bonding leads shall comply with BS 6346 in accordance with the cable installation requirements stated within this specification.

The outer insulation of the bonding lead shall be embossed with the legend:

ELECTRIC CABLE-BONDING LEAD

Joints in bonding leads are not acceptable in new installations, but may be used in subsequent alterations e.g. diversions, subject to the approval of KETRACO.

20.8. Sheath Connections

For ease of maintenance and to facilitate testing of cable oversheaths, all bonding and earthing connections shall be made via disconnecting links accommodated in underground box or gantry-mounted boxes. Where sheath voltage limiters are necessary, they shall be enclosed in the same housing as the associated links.

All connecting leads shall be as short as possible and of the concentric type. Except for connections to the SVLs at unearthed sheath positions, bonding and earthing leads shall be of sufficient cross section to meet the prospective system fault and transient duties.

20.9. Test Regime for Sheath Voltage Limiters and Link Boxes used on HV Cable Systems

20.9.1. Sheath Voltage Limiters

Sheath Voltage Limiters (SVLs) shall be of zinc oxide type and shall consist of three non-linear resistors housed in the link box, the star point being earthed normally to local earth points. Connections to SVLs shall be of substantial cross section to withstand electro-mechanical forces and to exhibit low inductance.

The SVLs shall limit transient voltages to acceptable levels both at the insulated flanges of joints and terminations and within link-boxes. The SVLs shall be capable of withstanding the voltages and currents impressed upon them in normal service and system through faults. SVLs installed at metalclad terminations shall be encapsulated.

The SVL units shall be able to withstand the 50Hz voltages induced in the cable sheath by fault currents for a period of 2 seconds without damage. However, it is accepted that the units may be unable to withstand the duty imposed upon them by an internal cable system fault.

The Peak Residual Voltage (PRV) is defined as the peak value of voltage which appears across the SVL device when it is conducting the SVL's normal discharge current rating.

The cable contractor is required to measure the PRV of the Sheath Voltage Limiter device at 10kAp, 15kAp and 40kAp fully assembled within its housing and with the connecting leads attached. Details of these measurements are required to be submitted to KETRACO as part of the Type Approval Test Report for the Link Box. These tests shall be undertaken for each type of SVL employed.

It shall not be acceptable for the cable contractor to merely quote the PRV as given to them by their SVL supplier.

All SVLs provided shall be able to withstand repeated in-situ 5kV DC testing during maintenance checks on the cable sheath. This shall be demonstrated by a 5kV DC test for one minute and the leakage current recorded and demonstrated to be less than 0.1mA.

20.9.2. Voltage Withstand Tests on Link Boxes

The Impulse Voltage Withstand Test

The Impulse Voltage Withstand of the Link Box, between each combination of links and between the links and earth, shall be measured and declared. The Impulse Voltage Withstand value shall be greater than or equal to twice the value of the PRV of the SVL device (including connections) multiplied by the Insulation Co-ordination Design Margin. The Insulation Co-ordination Design Margin shall be greater than or equal to 120% of the twice the value of the PRV. The cable contractor shall state the value for the Insulation Co-ordination Design Margin.

The pass criteria for the Impulse Voltage Withstand Test is that it shall successfully withstand ten positive and ten negative shots of a 1/50 microS wave-form on a completed link-box with the bonding leads fully terminated and the lid fully assembled. The Impulse Voltage Withstand Test shall be conducted with the SVL assemblies in position but utilizing insulating discs instead of Zinc Oxide discs. For information purposes only the test shall be repeated with the Zinc Oxide SVL assembly in place (Note: It is understood that the Withstand Voltage may be influenced by the energy characteristics of the particular Impulse Generator employed and the Zinc Oxide discs).

The impulse voltage shall be applied between the inner and outer of each bonding lead in turn with all floating bonding lead terminations and the link box body connected to earth.

The DC Voltage Withstand Test

The DC Voltage Withstand of the Link Box, between each combination of links and between the links and earth, shall be measured and declared. The DC Voltage Withstand value shall be 25kV DC for 5 minutes.

The pass criteria of the DC Voltage Withstand Test is that it shall successfully withstand the applied voltage on a completed link-box with the bonding leads fully terminated and the lid fully assembled but without the Zinc Oxide SVLs. The voltage shall be applied between the inner and outer of each bonding lead in turn with all floating bonding lead terminations and the link box body connected to earth.

20.9.3. Short Circuit Test on Link Boxes

The Short Circuit Test shall successfully withstand the applied current without damage, distortion or impairment on a completed link-box with the bonding leads fully terminated, the Zinc Oxide SVLs connected and the lid fully assembled. The current shall be applied through each link in turn with all floating bonding lead terminations and the link box body connected to earth.

The terminal posts and links shall be suitable for the system short circuit requirements.

20.9.4. Internal Power Arc Test on Link Boxes

The Internal Power Arc Test shall successfully contain the violent effects of the internal power arc on a completed link-box with the bonding leads fully terminated, the Zinc Oxide SVLs connected and the lid fully assembled.

The link housing shall be designed to confine the effects of the failure of SVLs and link insulation to withstand the duty imposed upon them by an internal power arc. It is permissible for the link box to be distorted during this test but the box should not rupture.

The arc shall be initiated by connecting a suitably sized link of copper wire between the terminals of any two adjacent inner posts. Only one test is required for the link box. The voltage shall be sufficient to sustain the internal power arc magnitude during the test without appreciable attenuation (e.g. 1,500 volts). During the Internal Power Arc test all floating bonding lead terminations and the link box body [shall be] connected to earth.

20.9.5. Site Tests on Substation Earth Resistance

Sheath voltages during external single phase to earth short circuit conditions are greatly affected by the substation earth resistance at the cable terminations. The cable contractor shall measure and record the substation earth resistance at the points where the bonding cable lead is connected to the substation earth.

After the cable contractor has completed the substation earth resistance test he shall demonstrate that the measured earth resistance will not result in SVL rated voltages being exceeded during the specified external single phase to earth short circuit conditions.

Where a substation earth resistance is measured at more than 0.2 ohms then this result must be brought to the immediate attention of KETRACO.

20.9.6. Commissioning Tests on Link Boxes and Sheath Voltage Limiters

Link contact resistance at all link positions shall be measured and recorded.

The leads of the SVL's shall be disconnected from the bonding links and a DC voltage applied between each of the three terminals of the SVL and earth. The voltage applied shall depend on the type of SVL used and shall be subject to approval. The current taken by the SVL shall be recorded.

The insulation resistance, with the surge arrestors connected, between the bonding leads when isolated from earth and the casing shall be measured at 1,000 volts DC. The value shall not be less than 10 megohms.

For cross-bonded systems, the configuration of the bonding connections shall be checked: With the links in the link box in their correct positions, a three phase current of approximately 100 A shall be applied to the main conductors. The currents and voltages shall be measured and agreed with theoretical values supplied by the Contractor.

20.10. Packaging, Shipping and Transport

Packing, shipping and transport shall be arranged according to the requirements in General Technical Requirements.

20.11. Performance Guarantees

The performance of the cross bonding system shall be confirmed by the appropriate site tests after installation. If the Contractor fails to meet the performance requirements, KETRACO shall decide either to reject the installation completely or to accept compensation appropriate to the extent of deficiency.

20.12. Training

Works to be done under this section include training of KETRACO's personnel to operate and maintain equipment efficiently and safely. There shall be no constraints on the number and category of KETRACO's personnel to be trained.

20.13. Documentation

The Contractor shall provide all necessary drawings, design specifications, design details, operation and maintenance manuals.

20.13.1. Documentation with Bid

The Bid shall contain at least the following information and documents, failure of provision of the mentioned documents will lead to disqualification:

1. Disconnecting link boxes, SVL characteristics and bonding cable details and earthing arrangement;
2. Schematic diagram of the proposed installation;
3. Detailed calculation of sheath standing voltage for normal and earth fault conditions;
4. Manufacturing specification of the proposed equipment;
5. Catalogues, literature and reference lists of proposed equipment;
6. Type test certificates from an independent testing authority or independently witnessed;
7. Quality Management System Manual and ISO Certificate of the equipment manufacturer.

20.13.2. Documentation after Award of Contract

All documents required for KETRACO's approval shall be submitted by the Contractor in accordance with the General Technical Requirements.

21. Installation of 11kV Cable Systems

21.1. Scope of Works

This specification details approved methods and practices for the installation of 11kV power cable systems where the complete cable route is contained within the substation.

The supply and services to be performed by the Contractor shall comprise the design, manufacture, shop testing, packing, transport, insurance, unloading, storage on Site, construction works and erection, corrosion protection, site testing, submission of documentation, commissioning, training of KETRACO's personnel and warranty of the works.

The Contractor is bound to provide complete works, even if the equipment or services to be provided are not specifically mentioned in the specification.

All equipment/accessories or works to be provided including Ladders, Trays & Cover, Supports, Pipe, Duct, Conduits, etc.

21.2. Site Coordination and Integration

The Contractor shall be responsible for the selection of the route, method of installation and testing of the cables installed within the substation. The route(s) shall be co-ordinated with the other aspects of substation design to optimise the performance of the installation and minimise access limitations to facilitate maintenance and repair. The length of cables required within the substation is such that jointing of cables will not be required.

Where necessary, the Contractor shall carry out, at his own expense, moisture content, water table level, and soil thermal resistivity tests within the proposed substation site and such other tests as he may consider necessary, sufficiently in advance of the manufacture of any cable, to satisfy himself that the conditions on site and his proposed arrangement of cables and method of installation are such that the required current carrying capacity can be maintained.

If the Contractor considers that the conditions and the proximity to other power cables, spacing and method of installation are likely to reduce the maximum current carrying capacity below the required value he shall develop alternative arrangements coordinated with the overall substation design.

All routes shall be defined precisely, and shown in drawings at an approved scale. The fixed structures within the substation shall be indicated clearly with distances to the cable installation shown. The crossings with roads and other underground installations within the substation shall be shown and each crossing point shall be clearly marked with the route markers, after backfilling. The dates of installation of cable joints, cable drum serial numbers, name of jointers, shall be included in the "AS-BUILT" drawings. Cable section lengths shall also be given.

All drawings shall be subject to KETRACO's approval.

During installation, when crossing other heat sources, or laying at depths deeper than 1.1 m at the crossings or such similar conditions, the Contractor shall maintain the specified rating, either by application of the special stabilised backfill or by increasing the phase spacing. For every situation the arrangement with relevant calculations shall be submitted to KETRACO for approval, prior to installation.

Specific thermal resistance of 2.0Km/W shall be maintained even for completely dry backfilling material. This has to be confirmed before placing the backfill materials in the trench. The ground temperature at depth of laying as well as the thermal resistance of the backfilling material shall be controlled during the cable installation and shall form part of the installation procedure. The works or supply necessary to meet this requirement is deemed included in the Contract Price.

Where conditions require it, the use of a special backfill or other approved means to achieve cable rating shall be allowed. The costs of these measures are deemed to be included in the contract price.

21.3. Civil Works Criteria

21.3.1. General

The Contractor shall coordinate the cable civil works requirements with civil works required for the installation of other substation equipment, buildings and services to ensure technical and programme compatibility. The requirements of each of the installation methods listed above shall be considered and the installation design optimised from technical, availability and cost considerations.

In general the following principles shall be followed

- The power and pilot cable of each circuit shall be laid in separate trenches, troughs or ducts. Two circuits in one trench shall be avoided as far as possible unless the circuit functions are inter-dependent in which case, subject to the approval of KETRACO, two segregated circuits may be installed in one (concrete) cable trench. The minimum separation between independent circuits shall be 1.5m.
- Where cables leave / enter a different installation system (e.g. cable trough into cable basement or direct buried into a cable basement) the transition shall be made via sealed ducts and the impact of the ducts on cable rating shall be taken into account.

In switchgear building basements (where applicable), the cables shall be installed in air with the appropriate supporting structures. The supply and installation of the supporting structures is part of this Contract

Concrete pits and tunnels/trenches at road crossing and area subject to traffic shall be designed for the maximum wheel load of 6T. (Maximum axle load of 12.5T).

All foundations and concrete surfaces at and below ground level are to be isolated from contact with soil.

21.3.2. Cable Laying Condition

21.3.2.1. For direct buried cables

The 11kV cables shall be normally be laid with the group or phase spacing of 150mm and in a flat formation but this may be increased where necessary to improve the thermal performance unless other aspects of the substation design are adversely affected.

The material surrounding the cable in its trench must not damage the cable surface and must be suitable for restraining the cable against any thermal expansion or traffic induced movements and, also must be suitable for thermal dissipation from the cable to its surrounding. Bedding material must be sufficiently dense to ensure that the value of thermal resistivity of cable environment should not exceed 2.0K.m/W even if dried out due to cable loading. The compaction of backfill to obtain a low thermal resistivity is usually carried out with vibrating plates and punners. The cables shall be laid on approximately 100mm sand for the 11kV cable, which will be placed to form a bed for a cable. Upon completed laying of a cable it shall be covered with additional sand layer 200mm thick above the top of the uppermost cable.

The reinforced concrete slabs are to be used as mechanical protection over the cables. They shall be carefully centred over the cables, and each cover being closely interlocked with the adjacent covers along the entire length of cable.

The width of protective covers shall be enough to overlap cable circuits on both sides with 100mm at least. Cable slabs shall be covered with a 50mm layer of dune sand followed by 250mm of back fill over which LSOH warning tapes shall be laid. Semi-permeable membrane shall be provided water table is found above the cable laying depth.

21.3.2.2. For cables installed in surface troughs

The 11kV cables shall be laid with the phase spacing 150mm, in a flat formation.

In the cable troughs, the material surrounding the cable must not damage the cable surface and must be suitable for restraining the cable against any thermal expansion or traffic induced movements and, also must be suitable for thermal dissipation from the cable to its surrounding. Bedding material must be sufficiently dense to ensure that the value of thermal resistivity of cable environment should not exceed 2.0Km/W even if dried out due to cable loading.

The reinforced concrete trough covers are to be used as mechanical protection over the cables. They shall be fully supported and located by the walls of the trough such that covers may not apply pressure to the filling material or cable due to the movement of traffic across them.

21.3.2.3. For cables installed in air

The cables shall be laid with the phase spacing 250mm. in a flat or vertical formation.

When cables are required to be installed in concrete troughs or cable tunnels all cables shall be supported on cable trays, racks, or in hangers supplied and installed under this contract as required by the cable system design. Cables

laid on horizontal and vertical support arms shall be clamped and snaked in accordance with the cable manufacturer's recommendations. The supports shall be at regular intervals and adequate to withstand normal and short circuit forces confirmed by necessary calculations. Sufficient clearance between cable circuits shall be provided to facilitate easy maintenance works, later. If a walkway is required to run along the cable installation a space of at least 750mm shall be allocated for this.

Cable troughs shall not be filled with sand. And sufficient natural ventilation shall be provided to meet the cooling requirements of the installation. Current carrying calculations for proposed cables in concrete troughs/trenches shall be provided for review and approval by KETRACO. Some trench covers may be of the heavy-duty type as required by local loading conditions.

All cables shall be run in a neat and orderly manner and the crossing of cables within the trench shall be avoided as far as possible.

21.3.3. Installation Conditions

21.3.3.1. Direct buried cables

Maximum thermal resistivity of ground 2.0Km/W

In the calculation of current rating, the soil has been assumed to have constant thermal resistivity of 2.0Km/W regardless of the heat input from the cables. The Contractor shall maintain this figure even in case of the moisture migration and completely dry soil.

The main factors determining thermal resistivity are: composition density, moisture content and degree of saturation, burial depth of cables and soil and cable surface temperature.

The Contractor shall check these factors prior to finalising the design of the cable installation, taking into account the overall design of the substation and other heat sources (such as inter-site cables entering the substation) which may affect thermal performance or route selection.

21.3.3.2. For cables installed in surface troughs

Maximum thermal resistivity of ground 2.0Km/W

In the calculation of current rating, the soil has been assumed to have constant thermal resistivity of 2.0Km/W regardless of the heat input from the cables. The Contractor shall maintain this figure even in case of the moisture migration and completely dry soil.

The contractor shall demonstrate by calculation that the thermal performance of the installation meets the requirements of the circuit, taking into account all credible operating conditions.

21.3.3.3. For cables installed in air

The thermal conditions are assumed as follows:

Maximum temperature of ambient air: 40°C

The contractor shall demonstrate by calculation that the thermal performance of the installation meets the requirements of the circuit, taking into account all credible operating conditions. Forced ventilation shall not be used to achieve the thermal performance required but means to enhance natural ventilation process may be incorporated.

21.3.3.4. Termination Supporting Structure

Supporting structures for all cable terminations shall be provided as part of this Contract. They shall be of an approved design and construction. Structure design shall match with the items in existing substations or as appropriate.

All steelwork shall be galvanised.

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 loading shall be provided to enable the foundation design to be checked. Responsibility for final grounding and levelling of the structures and co-operation with the other Contractors shall form part of this Contract.

21.3.3.5. Supporting Steelwork and Cleats

All cable supporting steelwork for the cables in the concrete trenches or substation basement shall be provided under this Contract. Supports and other materials supplied and installed by the Contractor shall carry and hold the cables in a neat and orderly manner so as to prevent undue sagging of any of the cables.

They shall withstand mechanical stresses during short circuits, switching and maintenance personnel climbing such structures. The design shall ensure that there are no circulating currents.

The Contractor shall pay special attention to the supporting and fixing any cable crossing other cables, pipes, ducts or building expansion joints, when preparing these proposals.

Cable supports, cleats and clamps shall be made of material compatible with the cable outer sheath and shall be of the stand-off type shaped to suit the size of cable and not to cause undue distortion of the outer cable sheath. Cleats used for single core a.c. cables shall be of non-magnetic materials and be arranged in such a manner as to avoid setting up of magnetic circuits through steelworks, which may affect the intended capacity of the cable. Trefoil cleats shall be used as required by the cable system design.

The design of claw type cleats shall be such 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 the Contract.

When the cable routes inside the basement have been agreed the Contractor should prepare and submit for approval drawings showing his proposals for the supporting and fixing of the cables. The erection of the supports and cleats shall not proceed until the proposals have been approved.

Cables shall be cleated over the whole of the appropriate section of their length before jointing at either end commences.

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 confirmed by calculation of the mechanical stresses.

Where cables rise from the ground level to sealing ends adequate protection shall be provided against possible mechanical damage to the cables and against solar radiation if applicable.

All cables supports, trays or racks shall be galvanized and shall be constructed or installed to exclude any possibility of electrolytic action between the supports and cable sheath, and shall be adequately earthed.

21.4. Installation Requirements

21.4.1. General

The arrangement of cables and all methods of laying and installation, including any special methods, which may be necessary, shall be subject to approval of KETRACO.

The cables may be laid directly in the ground, installed in cable trenches, shafts, pipes, ducts, in concrete troughs or on racks in air in accordance with the route requirements and approved installation practices.

Adjacent to terminations and joints the cables shall be laid in a loop or snaked in the ground in order to provide approximately 3 metres spare length on each side to facilitate re-termination and re-jointing at a later date, if necessary.

The Contractor shall ascertain from the cable manufacturer, the limitations of the Low Smoke Zero Halogen (LSOH) over-sheath with respect to exposure to sunlight and the maximum temperature for cable laying governed by the tensile strength of the over-sheath at high ambient temperatures. Any damage to cable sheathing during installation must be reported to KETRACO in writing and approval of the method of repair must be obtained. The position of the damage must be accurately recorded prior to commencement of repair. Only repairs to damage to outer LSOH sheath of the cable shall be considered.

The depth of laying for direct buried cables from the surface of the ground to the top of the cable shall not be less than 1.1 m.

It shall be measured from the ground level to the upper surface of the top most cable. This depth may be increased in selected parts of the route or locally to avoid other service installations.

Unless it has been agreed that the construction of cables is such as to permit laying at sub-zero temperatures, cable laying shall take place only when the ambient temperature is above 0°C and has been at this temperature for at least 24 hours, and approved special precautions have been taken to keep the cable above this temperature to avoid risk of damage during handling.

All cables shall be installed with a bending radius not less than that recommended by the cable manufacturer.

All combustible outer coverings of cables installed within buildings shall be protected against the spread of fire in an approved manner. Cables passing through floors shall be installed in the manner specified and where required shall be sealed using fire resisting material to minimise the risk of spreading fire.

All cable specified in the Schedules under this Contract shall be installed in an approved manner. Pilot cables shall be installed in the same trench as power cables.

21.4.2. Provision of Labour and Skilled Supervision

The Contractor shall be responsible for providing all labour and skilled supervisors for handling equipment, and laying cable in accordance with this Specification.

The Contractor shall also provide the necessary trained staff and tools for terminating and jointing all cables supplied and laid under this Contract.

21.4.3. Responsibility

The Contractor shall be responsible for all Site Works associated with the Contract Works, installation and termination of all cables in accordance with this Specification.

21.5. Method of Cable Laying

The procedure of cable laying shall be subject to KETRACO's approval.

Unless instructed to the contrary by KETRACO, the Contractor shall lay cables direct in the ground in the following manner:

The material surrounding the cables, between trench floor, walls and cable tiles, shall be at least, 150 mm of approved material, free of stones or any other material likely to damage or penetrate the cable outer sheath. It may be necessary to use an approved semi-permeable membrane to avoid migration of the fill under wet conditions.

The backfill in the remainder of the trench shall be adequate to meet the required thermal resistivity value as specified. A high degree of compaction is required, sufficient to restore and maintain thermal resistivity levels equal or better than undisturbed ground. At the direction of KETRACO, the Contractor shall remove any material, which is considered harmful, and replace it with an approved backfilling material. If the thermal resistivity of this material can rise above 2.0Km/W, the Contractor shall provide calculations to ensure that effective external thermal resistivity shall remain below the specified value under all operating conditions.

The results of all tests shall be logged and shown on as-laid records of the route.

After any cable has been laid and until the whole length of the cables to be laid in the trenches have been covered with protective covers, no sharp metal tools such as spades or fencing stakes shall be used in the trench or placed in such a position that they may fall into the trench. The protective covers shall consist of interlocked slabs of the

hydraulically pressed concrete or other approved material of approved dimension and of ample width to protect the cables.

If more than one cover is required to cover a group of cables, the width for the covers shall be such that the longitudinal joint between adjacent covers shall be placed above the space between the groups of cables and not immediately above a cable. The position of cables or groups of cables in a trench shall be staked out once the cable has been laid so that covers may be placed in the correct position when the top layer of riddled soil or dune sand has been applied. The width of the cover or covers shall be such that there is a minimum 100mm overlap on each outside edge of the cable or group of cables.

A provisional sheath test shall be carried out for every section before backfilling over the cable tile.

Where, in the opinion of KETRACO, the soil on Site is unsuitable for riddling or back-filling, the Contractor shall arrange for the importation of suitable material (at Contractor's own expense), which shall be subject to approval of KETRACO.

The Contractor shall take all reasonable steps to ascertain where the cables and associated corrodible materials may be subjected to chemical or electrolytic action and shall submit his recommendations for special precautions to the Company for his approval.

Where auxiliary cables are laid under the same covers as power cables, there shall be at least 75mm of riddled earth between the two types of cables.

The position of the cables and joints shall be recorded on the route plans. The route shall be identified by means of a grid with at least two reference points for each length of straight cable run.

The distance between the centres of power cables and power cable circuits shall be in accordance with the cable manufacturer's specification and recommendation and the installation Contractor, if different from the cable manufacturer, shall be responsible for obtaining the correct spacing parameters from the cable manufacturer and details of installation limitations from KETRACO to ensure the cables operate at the pre-determined operation temperatures when installed.

The installation Contractor shall be responsible for obtaining values of the minimum bending radii for all cables covered by the Contract Works from the cable manufacturer prior to the commencement of installation.

Rollers used during the installation of the cables shall have no sharp projecting metal parts liable to damage the cable.

All cables on vertical runs or horizontal runs in the vertical plane shall be cleated.

The Contractor shall provide all necessary pulling tools and equipment such as jacks, shafts, rollers, self-driven rollers, pulling cords, etc. including any required power for this equipment. The procedure for unwinding and pulling the cables shall be approved by KETRACO. Pulling by use of stockings is not allowed.

The Contractor shall strictly conform to the prescriptions given by KETRACO for all handling of cables and their accessories.

The Contractor shall have as many men as necessary for all pulling and supervising operations to be carried out according to the best procedure. The number of men shall be stated in the cable laying procedure and approved by KETRACO.

The Contractor shall be solely responsible for any damage due to the carelessness of his staff or workmen. Any cable length so damaged shall be rejected as destroyed.

Mechanical pull with a winch solely from one end will be allowed only in special cases due to increased fragility of the cables. The self-driven cable rollers shall be used for installation of power cables.

Extra snaking 3m length at termination and joints location shall be provided.

The Contractor shall allow for installation of permanent thermocouples for sheath temperature test in his contract price. At least one set of permanent thermocouples shall be installed at every 3000m. The locations, number and arrangement of testing (the number of thermocouples at each location shall be at least seven) shall be submitted to KETRACO for review and approval, prior to installation

21.5.1. Excavation of Trenches

The exact location of each trench shall be approved on Site. Trenches shall be kept as tight as possible and each trench shall be excavated to the approved formation and dimensions and shall have vertical sides which shall be timbered or otherwise secured where necessary so as to avoid subsidence and damage to all walls, roads, sewers, drains, pipes, cables and other structures. Timber and other material for this purpose shall be supplied by the Contractor.

The depth of all excavations for trenches shall be measured from the surface of the ground and the width of the trench shall be measured between the vertical sides of the trench or between the inside faces of the sheeting (if any).

The bottom of each trench shall be firm and of smooth contour. The Contractor shall take reasonable precautions to prevent damage or ground surface from a slip or breaking away of the sides of the trench.

Where trenches pass from a footway to a roadway or at other positions where a change of level is necessary, the bottom of the trench shall rise or fall gradually. The rate of rise or fall shall be approved by KETRACO.

It is the Contractor's responsibility to ensure that he is acquainted with the nature of the ground conditions prevailing along the cable route and the installation rates of the cables to be quoted in the Schedules shall include for any and all types of excavation and backfill on the "as found" basis.

The Contractor shall deal with and dispose of water to prevent any risk of cables and other materials to be laid in the trenches being adversely affected. He shall provide all pumps and appliances require and shall carry out necessary pumping and baling.

Unless otherwise agreed, provision shall be made during excavation and until interim restoration has been completed for reasonable access of persons and vehicles to the remainder of the substation site so that other work is not unreasonably delayed.

When the excavation for trenches has been accurately executed, the relevant notice shall be given by the Contractor to KETRACO. Laying of cables, or building of structures shall not be started until the Contractor has obtained KETRACO's approval to proceed with the work.

The Contractor shall satisfy himself that there are no other utilities' underground services within the substation site. In case of uncertainty the Contractor shall perform all hand excavations as required to locate existing of services within the limits of the substation site. The existing utilities and services referred to herein shall include, but shall not be limited to all sewers, water mains and lines, gas mains, electric (both power and lighting), telephone and such others as may be encountered under this Contract.

There shall not be any soil classification for excavating either in soft or in hard material. The Contractor is responsible for obtaining information he considers necessary regarding the possibility of encountering soil with varying degree of hardness, and allow for it in his tender.

The excavation of hard material, if any, shall be carried out by pneumatic tools. Blasting shall not be allowed under any circumstances.

All trenches shall be excavated with vertical sides to the width, lines, grades and depths as shown on the drawings or as specified in writing by KETRACO.

All excavations shall be adequately supported and kept free from water from any source at the Contractor's expense and to the satisfaction of KETRACO.

Any over-excavation shall be backfilled with suitable fill material and completed in accordance with the specifications. Where directed by the Company such over excavations shall be backfilled with mass concrete at the Contractor's expense.

The unsuitable or surplus excavated material shall be removed to an approval tip to be provided by the Contractor and at his expense.

The Contractor shall take all necessary security measures, such as signs, lights, supports etc. and generally comply with the recommendations and requirements of the Authorities in order to avoid accidents, landslides and other damages.

21.5.2. Excavated Material

The material excavated from each trench shall be placed so as to prevent nuisance or damage to adjacent hedges, trees, ditches, drains, gateways and other property, objects or things. Excavated material shall be stacked so as to avoid undue interference with traffic. Where, owing to traffic or other considerations, this is not permissible; the excavated material shall be removed from the Site and returned for refilling the trench on completion of laying.

Surplus materials shall be disposed of by and at the cost of the Contractor in accordance with the Conditions of Contract. Surplus material shall never be left on site for more than one week.

Excavated material shall be stacked at a minimum distance of 300mm from the edge of the trench to provide a walkway and eliminate risk of stones falling in the trench.

21.5.3. Cables Drawn into Ducts and Pipes

Cable ducts are required at all road crossing, regardless are they minor or major.

The Contractor shall provide the ducts and pipes. Pipes and ducts in building foundations shall be provided under a separate Contract. The Contractor shall remove any loose material from the ducts, and prove them by drawing through a mandrel of slightly less diameter than the duct, immediately before pulling in the cables. A suitable draw line shall be used to facilitate cable pulling. If the pipe or ducts form a tortuous path with friction a suitable lubrication may be used to ease the stress on the cables when pulled. Any lubricant used shall have no detrimental effect on the cables.

The Contractor shall reapply graphite coating if it is scraped off while pulling or after the application of a lubricant.

Where specified by KETRACO, two split pipes shall be fitted around the cable. The splits shall be positioned on opposite sides of the cable after its installation.

All ducts or pipes, whether in use for cables or not, shall be sealed against entry of water, oil and vermin with a suitable semi-plastic compound supplied and installed by the Contractor after the approval of KETRACO. Cable ducts on the existing road shall be extended 500 mm beyond verge.

All ducts, floor bushings etc. shall be completely filled and sealed at either end. The filling material shall be bentonite mixture with addition of a small quantity of cement to stabilise the gel and sand to improve load bearing. The material shall be pumped into suitably prepared ducts with a cement pump and must be able of being removed by the application of high-pressure water jets. The content of bentonite mix shall be subject to KETRACO's approval.

It is preferable that cable ducts are not longer than 12m, but the maximum allowed length is 30m.

When the cable route is such that changes in direction of pipes do not facilitate a continuous pipe or where a pipe is too long to allow a continuous cable run, facilities shall be made for cable draw pits in which the cables shall be supported and routed in accordance with these Specifications.

21.5.4. Cables Installed in Concrete Troughs and Tunnels

When cables are required to be installed in concrete troughs or cable tunnels all cables shall be supported on cable trays, racks, or in hangers supplied and installed under this contract as required by the cable system design. Cables laid on horizontal and vertical support arms shall be clamped and snaked in accordance with the cable manufacturer's recommendations. The supports shall be at regular intervals and adequate to withstand normal

and short circuit forces confirmed by necessary calculations. Sufficient clearance between cable circuits shall be provided to facilitate easy maintenance works, later. If a walkway is required to run along the cable installation a space of at least 750 mm shall be allocated for this.

Cable troughs shall not be filled with sand. Current carrying calculations for proposed cables in concrete troughs/trenches shall be provided for review and approval by KETRACO. Some trench covers may be of the heavy-duty type as required by local loading conditions.

All cables shall be run in a neat and orderly manner and the crossing of cables within the trench shall be avoided as far as possible.

21.5.5. Concrete Structures

Concrete structures for joint-pits etc. shall be provided under this Contract and the Grade of concrete shall be SRC 25. All foundations and concrete surfaces at and below ground level are to be isolated from contact with soil.

Cover slabs for joint-bays and draws-pits and the joint-bays and draw-pits themselves shall be designed for a 36 tonne truck to pass over it and axle load of 12.5 tonnes. The point load under such a condition shall be indicated accordingly.

21.5.6. Guards

Where cables are exposed to mechanical damage, sheet steel guards shall be provided to protect them. Detailed drawings of all cable guards shall be approved by KETRACO before fabrication has commenced.

21.5.7. Sealing of Holes in Floors and Walls

Where holes and slots have been made through floors and walls for the installation of cables and cable trays, the Contractor shall arrange to seal these holes and slots when the total number of cables to pass through any slot or hole has been installed.

The seal shall prevent access of vermin and shall not permit the passage of air or gas through the hole when sealed. The material used for sealing shall not be magnetic or detrimental to either cable sheaths or conductors, and shall be fire resistant.

21.5.8. Cable Markers and Records

Cable markers and other approved means shall be provided to mark the position of each joint and shall also be used in approved positions to show the positions of all cables, pipes and ducts, particularly where they cross a road, or are laid along a road or where there is an abrupt deviation on the route, and such cable markers shall be erected as reinstatement is being carried out. At road crossings permanent markers shall be provided on both sides of the crossings in the event of damage to or removal of one of the markers.

The Contractor shall supply as soon as possible after installation two copies of the route plan showing the certified depth and position of all buried cables including these laid to the specified instructions of KETRACO. An up-to date copy must be available at Site at all times.

21.5.9. Tests During Cable Laying

Provisional sheath test shall be carried out for every section before backfilling over cable tile.

21.5.10. Cable Routes

The cable routes are completely within the substation and shall be selected to co-ordinate with the overall substation design and the routes used within the substation for inter-site cables supplied and installed under another contract. The proposed routes shall be shown on site layout drawings and submitted for approval before work is commenced. KETRACO may instruct the substation cabling contractor to select an alternative route within the substation to eliminate interference with other cables or systems.

21.5.11. Route Plan

The Contractor shall also record on approved cross-section plans particulars of the depth of the trench, the arrangement of the cables, the positions of all obstructions beneath or above which the cables are laid and such other particulars as may be required. These plans shall be made as reproducible drawings of approved dimensions and shall be the property of KETRACO. They shall be submitted to KETRACO within one month of completion of each section of the Contract Works together with such prints as may be required.

21.5.12. Cable Termination

The Contractor is to terminate and connect up the cables in accordance with details provided by him and approved by KETRACO.

Necessary sunshields shall be provided and installed for cables exposed to direct solar radiation.

The Contractor is to be responsible for the correct phase rotation and connections in accordance with information supplied by KETRACO. Particular care is to be taken in the case of those cables, where subsequent correction may be difficult. Phase tests will be carried out by the Contractor to the satisfaction of KETRACO. All equipment required to carry out these tests shall be provided under this Contract.

Where insulated glands are provided, the Contractor is to ensure that the insulation is maintained after jointing the cable, and shall demonstrate this to the satisfaction of KETRACO.

Cables shall be terminated under controlled environmental conditions preventing ingress of moisture and dust. The point of termination shall be covered with a weatherproof and dust proof cover with a slanting roof mounted on a fixed frame to give adequate working space both above and below sealing end base plate.

Adequate floor space shall be provided, at more than one level, to enable the cable to be clamped and plumbed, if applicable, below the sealing end base plate. The construction of the frame and cover shall be approved by KETRACO before all termination work commences. The humidity of the atmosphere shall be kept below the acceptable value stated in approved installation procedure.

The installation procedure must be continuous. Complete preparation of cleaning, plumbing of metallic sheaths and earth bonding may be carried out before termination work commences and the Contractor shall provide instruction manuals and drawings on Site so that KETRACO may follow the termination procedure in detail.

The Contractor shall ensure that only one team of jointers is assigned to one "Three phase termination" until it is completed to ensure that the termination is continuous without changing personnel.

Terminations shall be carried out in situ, and in no case shall be completed at ground level and lifted into final position.

Cable identification: Each end of a cable run shall be provided with labels for identification. The labels shall be lifted in a suitable position under the cable termination.

The material of the labels and fastenings shall be such as to avoid corrosion due to incompatibility of materials, and to ensure permanent legibility.

21.5.13. As Built Drawings

During the progress of the Work, the Contractor shall record, in approved schedule form and on a set of site plans at a sufficiently large scale (1:500) such particulars, which will allow an accurate reference to be made in case of any fault, or subsequent modification to the cable system. Cross sections are required whenever elevation changes. The schedule and the plans shall be prepared during the course of installation and shall be available for the Company's inspection. On completion of the job, the schedule and plans shall be issued as "as-built" drawings.

It shall be noted that details regarding submission of Operation & Maintenance Manuals are covered in General Technical Requirements. Though the above document submissions for H.V. Cables and accessories will be in accordance with the General Technical Requirements, these will be subject to review and approval by KETRACO.

21.5.14. Method Statement

Before commencement of any site works the Contractor shall develop and submit for approval the Method Statement document comprising at least the following procedures and documents:

- a. Project and Site Organisation
- b. Programme of Works
- c. HSE Policy Document
- d. Local Transportation

- e. Installation Procedures for Each Piece of the Equipment
- f. Site Quality Plan, which, in brief, shall cover the following aspects:
 - All phases of the site works shall be clearly distinguished in their sequential order (e.g. route approval and detailed survey, soil investigation and excavation of the trial pits, trench excavation, cable pulling, jointing, sealing end erection, back-filling and compaction, test on completion, etc.)
 - Quality requirement and responsibilities for each phase shall be described in detail.
 - Conditions to commence the works on each phase shall be set out in the Commencement of Work Form (COW). Each COW Form shall be accompanied by the Applicable Document List (ADL) to confirm that all necessary documents are in order. COW shall be submitted for approval and works should not start before COW is signed by supervising body.
 - The Hold Points (HP) shall be identified, and the Contractor shall invite for inspection for each HP by Control Notification Form (CNF). CNF shall indicate date and time, location and item to be inspected and shall be sent by fax at least 24 hours in advance. The respective inspection form signed by the Contractor and supervising body shall document each HP inspection.
- g. Final inspection of each phase shall be recorded in the separate form, which shall be then included in the Monthly Work Progress Statement as supporting document for the progress reported.
- h. List of proposed subcontractors for approval.
- i. List of the proposed materials for approval (e.g. concrete mixture, PVC ducts, and other small materials not defined in the tendering stage)

At every step during the progress of site works necessary approvals shall be obtained from KETRACO.

22. Overhead Line Works (LILO)

22.1.

The overhead transmission line work is as defined under the scope in Section 1 of this Employer's Requirements document.

22.1.1. Conductors and Accessories

22.1.2. Applicable standards

The equipment or components supplied shall be in accordance with the standards specified below or latest editions and/or amendments thereof. Offers of Item manufactured to any other internationally recognized standards or specifications not less rigid shall accompany an English version of such standards.

- a) IEC 60121 Recommendation for commercial annealed aluminum electrical conductor wire
- b) IEC 60889 Hard-drawn aluminum wire for overhead line conductors
- c) IEC 61089 Round wire concentric lay overhead electrical stranded conductors
- d) IEC 61232 Aluminum-clad steel wires for electrical purpose
- e) ASTM B415 Standard specification for hard-drawn aluminum-clad steel wire
- f) ASTM B416 Concentric-lay-standard aluminum-clad steel conductor
- g) ASTM B502 Standard specification for aluminum-clad steel core wire for aluminum conductors, aluminum-clad steel reinforced
- h) ASTM B193 Standard test method for resistivity of electrical conductor materials
- i) ASTM B232 Standard specification for Concentric-Lay-Stranded Aluminum Conductors, Coated-Steel Reinforced (ACSR)
- j) BS 3288 Insulator and conductor fittings for overhead power lines.
- k) IEC 61854 Requirements and tests for spacers
- l) IEC 61897 Requirements and tests for Stockbridge type aeolian vibration dampers
- m) BS EN ISO 1481 Slotted pan head tapping screws

22.1.3. General

The phase conductors to be applied are triple bundle of aluminum conductor aluminum-clad steel reinforced (ACSR) Conductor as shown in table below. Overhead grounding wires are of type aluminum-clad steel wire (ACS) 58.6 mm² and OPGW.

Table: Conductor and Overhead Grounding Wire Configuration

Items	Description
Phase Conductor	Triple bundle "Condor"
Overhead grounding wire	OPGW (48 fibers) + ACS 58.6 mm ²

All wires making up the conductor shall be uniform and smooth and shall have no defects such as point, sharp edges, abrasions, or other imperfections that would tend to increase radio interference and corona loss. The makeup and lay of the conductor strands shall be such that conductors are free from the tendency to untwist or apart when cut. There shall be no joints in individual wire. The outermost layer of the conductors shall be stranded with a right hand lay (z-lay).

22.1.4. Conductor

The conductor ACSR "Condor" shall comply with the relevant standards listed. The conductor shall have the characteristics stated in Table below. The conductor materials shall be suitable for continuous operation at 80°C without deterioration. The aluminum shall be of the highest purity commercially obtainable which shall not be less than 99.5%. The Contractor shall submit certificates of analysis giving the percentage and nature of any impurities in the metal from which the wires are made. There shall be no joints in individual wire.

Table: Characteristics of ACSR "Condor"

Description	Unit	Characteristics
Construction (Al/st)	No./mm	54/3.08, 7/3.08
Lay direction of outermost layer	-	Right
Cross sectional area _Al	mm ²	402.8
Cross sectional area _St	mm ²	52.0
Cross sectional area _Total	mm ²	454.8
Diameter	mm	27.73
Weight (w/o grease)	kg/km	1,522
Ultimate tensile strength	kN	125.44
DC resistance at 20°C	Ω/km	0.07173
Modulus of elasticity	kN/mm ²	68.65
Coefficient of linear expansion	x10 ⁻⁶ /°C	19.3

The conductor shall be greased to Case 2 of IEC 61089.

22.1.5. Overhead shield wires

The specifications of OPGW are in section 22.2 Overhead grounding wire ACS 58.6 mm² shall comply with the relevant standards listed.

The ACS 58.6 mm² shall have the characteristics stated in the following table.

Table: Characteristics of ACS 58.6 mm²

Description	Unit	Characteristics
Construction	No./mm	7/3.26
Lay direction of outermost layer	-	Left
Cross sectional area	mm ²	58.6
Diameter	mm	9.78
Weight	kg/km	390
Ultimate tensile strength	kN	71.0
Modulus of elasticity	kN/mm ²	160.0
Coefficient of linear expansion	×10 ⁻⁶ / °C	12.6
DC resistance at 20°C	Ω/km	1.463

22.1.6. Joints, Clamps and Connectors

Fittings for conductors and overhead grounding wires shall be designed in accordance with BS 3288: Part 1. The electrical conductivity and current carrying capacity of each joint or clamp shall be not less than those of the equivalent length of conductor or overhead grounding wire.

Dead end clamps and tension joints shall be of the compression type and shall be made so as not to permit slipping of or cause damage to or failure of the complete conductor at a load less than 95% of the ultimate strength of the conductor.

The design of all compression fittings, for each type of conductor, shall be such that only one pair of dies for steel and one pair of dies for aluminum are necessary for the compression of all the steel or aluminum sleeves provided.

All aluminum compression type clamps, connectors and joints shall be of a purity of not less than 99.5%. Non-ferrous alloys shall be such as to withstand atmospheric conditions without painting or other protection. The Contractor shall submit certificates of analysis for the various parts of fittings.

Dead end clamps and tension joints for ACS grounding wires shall be suitable with grounding wire. The construction and grade of stainless steel should be such as to limit the degree of work hardening caused by compression of the fitting. Fitting will not be accepted if they show a hardness after compression of more than 350 (Vickers Pyramid No.) or equivalent.

Jumper terminals shall be of the compression type and suitable for connecting to tension clamps by bolting. The mating faces of the jumper terminals and tension clamps are to be protected at the manufacturers' works by a strippable plastic coating or any other approved means.

The design of joints and clamps and any special tools to be used in their assembly shall be such as to reduce to a minimum the possibility of faulty assembly. All external nuts shall be locked in an approved manner. There shall be no relative movement within the clamp between individual layers of the conductor itself. Bolts and nuts shall be in accordance with an approved specification.

The price for supply and erection of all midspan joints shall be deemed to be included in the corresponding items of conductor and overhead grounding wires (ACS). Quantities of conductors and overhead grounding wires shall be based on the sum of span length and multiplied by the number of conductors per span. All allowances for sag, jumper and any others necessary for construction shall be deemed to be included in the prices in the Price Schedule.

22.1.7. Vibration dampers

Dampers of Stockbridge pattern shall be supplied. It shall be suitable to attach to the conductor without damaging the conductor strands at all line conductor suspension and tension points. The number of vibration dampers to be installed per span on each conductor shall be proposed by the Contractor for approval. Such numbers and locations to be fixed shall be in accordance with the instructions given by the manufacturer of the concerned vibration dampers.

They shall be designed to limit the amplitude of conductor vibrations at point of restraint to an applicable level. Clamping bolt shall be provided with domed self-locking nut designed to prevent corrosion to the threads. Dampers shall be suitable for maintenance under hot line working conditions.

The method of damper manufacture shall be such as to ensure freedom from subsequent drop of the "bells" in service. If considered necessary, the Employer may call for acceptance fatigue test to indicate proof of behaviour in service.

Evidence of the adequacy of the dampers shall be provided by copies of typical vibration recorder test carried out by the damper manufacture. The Contractor shall prove that the life expectancy of the conductors and overhead grounding wires to be more than 100 years.

22.1.8. Spacers

Spacers shall be fitted in order to maintain the specified distance between the sub-conductors under all working conditions. The distance between center to center of sub-conductors shall be 400mm for line conductors. Smaller distance for jumper loops may be proposed for approval. Spacers shall be provided in each span and installed in

accordance with the manufacturer's recommendation. Notwithstanding these recommendations the distance between spacers shall not exceed 60 m and the spacers shall not normally be uniformly distributed within a span. Spacers in the span shall maintain the spacing of the subconductors in the bundle as specified in the Technical Schedules.

Jumpers shall be fitted with not less than two spacers having a spacing required and spaced evenly along the jumpers at intervals to permit not more than 4.5m of free conductor. Assuming that the sub conductors remain parallel to each other no spacer shall allow the conductor centers to become less than 200mm.

Spacers shall be designed to have the following features: -

- a) They are preferably to be of one-piece construction and shall not have separate small components. They shall be suitable for hot line maintenance. All bolts shall be captive; nuts shall only need slackening - not removal - in order to fit the spacer to the conductors. No bolt or nut shall require a tightening torque greater than 35 N-m.
- b) No rubbing shall take place between any parts of the spacer other than the conductor clamps hinges or clamp swing bolts. A joint incorporating a flexible medium is acceptable provided that such a medium cannot slip against any other component.
- c) As far as possible, spacers shall be made of aluminum alloy of an approved type; any ferrous metal parts shall be galvanized and shall withstand tests laid down in BS EN ISO 1481. Other materials may be used subject to satisfactory evidence being given to the Employer/ Employer's Representative that all components shall be suitably corrosion resistant and shall not cause any other components or the conductor to corrode and shall not otherwise unduly deteriorate in service.
- d) Spacer conductor clamps shall incorporate an approved arrangement to ensure that the correct clamping pressure is maintained when conductor strands move due to bedding down, creep and tension or temperature variation. Clamps shall not damage the conductor at any time.
- e) Any nuts or bolts used on spacers shall be locked in an approved manner against vibration loosening.
- f) At an early stage in the design of a spacer, where applicable, the limit of electrical resistance between the conductors and the individual parts of the spacer shall be agreed with the Employer. All the spacers except for jumper loop shall be capable of the following movements without damaging the conductors, assuming one conductor to be fixed and the other moving.

a	Longitudinal Movement ("L") parallel to the conductor	± 90 mm minimum
b	Vertical movement ("V") in a vertical direction at right angles to the conductor	0 to ± 50 maximum (preferably zero)
c	Torsional movement ("T") angular movement in a vertical plane parallel to the conductor	± 50 minimum

Contractor shall submit a full and complete specification of the spacers offered with drawings.

22.1.9. Spacer dampers

The Contractor may propose in addition to Stockbridge pattern dampers and rigid spacers, as specified above, an alternative system of spacer-dampers. Detail drawings of the proposed spacer damper together with laboratory

test reports shall be provided and evidence must be given to show that the spacer-damper has been in successful and trouble-free use for a proof period of several years on similar transmission lines, which shall be named in the Bid. They shall be suitable for maintenance under hot line working conditions. If spacer dampers are accepted in principle by the Employer, they shall be subject to such tests as the Employer shall decide at no extra cost to the Employer, and the Contractor should indicate in his Bid the test specification he would propose. The Employer reserves the right to reject any proposed system of spacer damper without stating reasons.

22.1.10. Armour rods

Armour rods shall be fitted on suspension point of line conductors and ACS grounding wires. However, no armour rod is required on jumper suspension point.

Suspension point of and the fixing point of vibration dampers on OPGW shall also be equipped with armour rods.

Armour rods shall be suitable for maintenance using hot line tools. The price of armour rods shall be included in the corresponding suspension insulator strings.

Armour rods for OPGW shall also be deemed to be included in suspension set. Armour rods for vibration damper of OPGW shall be included in OPGW itself as well as vibration damper.

22.1.11. Corona and radio interference

The design of all line conductor fittings, vibration dampers, spacers etc., shall avoid sharp corners or projections which would produce high electrical stress under normal working conditions. The design of adjacent metal parts and mating surfaces shall be such as to prevent corrosion of the contact surfaces and to maintain good electrical contact under service conditions.

Particular care shall be taken during manufacture of conductors and fittings and during subsequent handling to ensure smooth surfaces to be free from abrasion.

22.1.12. Overhead grounding wire fittings

At suspension towers, overhead grounding wires shall be supported by suspension sets. The suspension set shall consist of a suspension clamp, armour rods, fittings and a bonding wire. Bonding wire shall be copper or aluminum stranded wire and shall be designed to ground the suspension clamp to the steel work. Terminal clamp of copper bonding wire, where ferrous part contact to copper, shall be tinned in order to avoid electrolytic corrosion.

At tension towers, grounding wires shall terminate in dead end clamps but shall be made electrically continuous by means of jumpers. In addition, at tension towers grounding wires shall be bonded to the tower steelwork

At substation, earth wires may be terminated either at gantry structure or on substation earth wire mast as decided by the Employer.

The price for overhead grounding wire tension set shall include two tension clamps, jumper, and bonding system to tower

22.2. Optic ground wire (OPGW)

22.2.1. Applicable standards

Unless otherwise specified elsewhere in this specification, the rating, preference and testing of the OPGW and accessories shall conform to the latest revisions, available at the time of placement of order, of all relevant standards listed below.

- a) IEC 60889 Hard-drawn aluminium wire for overhead line conductors
- b) IEC 61089 Round wire concentric lay overhead electrical stranded conductor
- c) IEC 61232 Aluminum Clad Steel Wire for electrical purpose
- d) ASTM B415 Standard specification for hard-drawn aluminum-clad steel wire
- e) ASTM B416 Standard specification for concentric-lay-stranded aluminum-clad steel conductor
- f) ASTM B399/B399M Standard Specification for Concentric-Lay-Stranded Aluminum-Alloy 6201-T81 Conductors
- g) IEC-60793-1 Optical Fibres, Part 1: Generic Specification
- h) IEC-60794-1 Optical Fibres, Part 1: Generic Specification
 - E1 - Tensile performance of optical fibre cable
 - E3 - Crush strength test on optical fibre cable
 - E6 - Bending test on optical fibre cable
 - F1 - Temp cycling test on optical fibre cable
 - F5 - Longitudinal water tightness test on optical
- i) IEC 60874 Connectors for optical fibers and cables
- j) ITU-T G65-2 Characteristics of single-mode optical fiber and cable
- k) IEEE 812, 1984 Standard for Fibre Optics, Definition of Terms
- l) IEEE 1138, 1994 Standard for construction of composite fibre optic overhead ground wire (OPGW) for use on Electric utility power line

Other equivalent standards, which ensure equal or better quality than the standards listed above, may also be acceptable on the premises of the approval of Employer. The OPGW shall be manufactured, installed, tested and commissioned in accordance with a quality assurance and quality control system in conformity with ISO 9001:2000.

22.2.2. General

The OPGW shall serve as overhead grounding wire for the protection of transmission line and the fiber embedded in it shall serve as carrier for the communication system (i.e., used for Voice and for SCADA).

22.2.3. Scope of work

Design, manufacture, testing before shipment, packing, supply and delivery, erection, site test and commissioning of the OPGW

- a) Fiber Optic Composite Earthwire (OPGW) with associated accessories and hardware (i.e., tension clamp set, suspension clamp set, vibration damper, grounding clamp, armor grip suspension, etc.).
- b) Shield-wire jointing boxes suitable for splicing of OPGW-OPGW.
- c) Terminal jointing boxes suitable splicing of OPGW and fiber optic approach cable.

Configuration of OPGW for each transmission line is as shown below.

Table: OPGW Configuration

Item	Description
OPGW	OPGW (48 cores)
Short-cct current rating	496 kA ² s

The Contractor shall ensure supervision by staff from the OPGW manufacturer, during installation of OPGW and guidance at site to the Contractor's and Employer, and for the testing, commissioning and successfully putting into operation of the OPGW system in totality, to avoid damaging fiber cores inside.

Joint box of OPGW shall be located on the terminal gantries. Locations of joint box of OPGW shall be subject to the approval of the Employer.

22.2.4. Technical requirements of OPGW and hardware

22.2.4.1. OPGW

(1) OPGW

The Bidder shall offer loose buffer or tight buffer type OPGW containing designated numbers of single mode (S.M) optical fibers in conformity with ITU-T Recommendation G.655. The fibers shall be embedded in a watertight OP-unit tube. OP tube shall be of aluminum/aluminum alloy or aluminum-covered stainless steel and surrounded with SA wires. The tube and SA wires shall be continuous and shall not have mechanical joint. The tube shall have sufficient strength in order to protect the optical fibers against radial compression by the metallic wires of the external layers and shall be smooth in internal and external surfaces in order to avoid damage to optical fibers.

The Bidder shall furnish complete description of the metallic and fiber optic components together with cross-sectional drawings of OPGW offered. The drawing shall provide a clear illustration of the design and make-up of the cable. The characteristics of OPGW shall be similar to as stated in the following table.

Table: Characteristics of OPGW

Description	Unit	Characteristics
Numbers of fibres	Nos.	48

Weight	kg/km	850 or less
Tensile strength	kN	93 or more
Modulus of elasticity	kN/mm ²	70 or more
Coefficient of linear expansion	$\times 10^{-6}/^{\circ}\text{C}$	20
Short circuit capacity	kA ² s	496

Concentrically stranded metallic wires shall surround the protective optic unit. The properties of the metallic wires shall be in conformity with ASTM B415 and B416 or IEC 61232. The surface of the OPGW shall be free from all imperfections that are visible to the naked eye such as nicks, indentations, excess of lubricants etc. Adjacent wire layers shall be stranded with reverse lay directions. The direction of lay of the external layer shall be right hand. The wires in each layer shall be evenly and closely stranded around the underlying wires or around the central core. For aluminum-clad steel wires, the aluminum covering on each individual steel wire shall be continuous and uniform and shall provide sufficiently strong bonding strength at the boundary between aluminum layer and steel core.

(2) Optical Fiber

All optical fibers contained within the optical unit shall comply with the requirements of IEC 60793 and IEC 60794 series.

Each individual fiber shall be color coded for identification purpose, with details of the color coding scheme adopted.

Cables with 48 fibres:

- Without rings:
blue, orange, green, brown, slate, white, red, natural, yellow, violet, pink, aqua.
- With 1, 2 and 3 rings:
blue, orange, green, brown, slate, white, red, natural, yellow, violet, pink, aqua.

The fiber cables shall be suitable for operation at 1550 nm and 1625 nm wavelengths.

The fiber shall be manufactured from high-grade silica and doped, as necessary to provide required transmission performance. The chemical composition of the fibers shall be specifically designed to minimize the effect of hydrogen on the transmission properties. The fiber shall be heat resistant. The Contractor shall submit a certificate or test data to guarantee the maximum rated temperature of the fibers.

The Contractor shall indicate index of refraction of the fiber core and cladding at 1550 nm and 1625 nm and the effective group refractive index for use with the Optical Time Domain Reflectometer (OTDR).

Required facility for interconnection between the OPGW and substation fibre optic cable (including joint box, splicing, termination at the gantry, etc.) and final end to end (ODF-ODF) OTDR and core-matching testing and preparing as-built documents shall be considered.

Design requirements of optical fibers shall be as specified in the following table.

Table: Characteristics of Optical Fiber

Description	Specification
Mode field Diameter	$8.6 - 9.5 \mu\text{m} \pm 0.6 \mu\text{m}$
Cladding diameter	$125.0 \mu\text{m} \pm 1 \mu\text{m}$
Cladding non-circularity	Less than 1.0%
Chromatic dispersion	$\leq 2 \text{ ps/nm*km}$ at 1550 nm $\leq 12.4 \text{ ps/nm*km}$ at 1625 nm
Polarisation Mode Dispersion (PMD)	$< 20 \sqrt{\text{km}}$
Splice loss	Less than 0.05 dB/splice
Bending loss at radius 30 mm with 100 turns	Less than 0.1 dB

The attenuation coefficient at zero dispersion shall be in the following range:

- at 1550 nm $< 0.22 \text{ dB/km}$
- at 1625 nm $< 0.24 \text{ dB/km}$

The Bidder shall offer the typical attenuation spectral curves in the 1550 nm to 1625 nm wavelength range. The additional attenuation introduced for 100 turns of uncabled optical fibers (loosely wound) with 37.5 mm radius mandrel and measured at 1,550 nm at +20°C shall be less than 0.5 dB compared to the initial value measured before winding.

The additional temporary attenuation compared to the initial value measured at +20°C due to;

- Temperature cycle (-20°C to +80°C) shall be less than 0.05 dB/km
- Temperature rises on account of lightning stroke shall be less than 0.1 dB/km
- Temperature rises on account of short circuit current shall be less than 0.25 dB/km

The above increase in attenuation shall be only temporary. There shall be no measurable increase in the fiber attenuation after normalcy is restored. The attenuation of the fibers embedded in the OPGW shall be distributed uniformly throughout its length so that there are no point discontinuities in excess of 0.05 dB. The fiber length in reel shall be continuous. No splice of fiber within a reel of OPGW shall be accepted. The optical wave-guide fibers shall completely protected from water penetration and environmental conditions. The Bidder shall indicate index of refraction of the fiber core and cladding at 1,550 nm and the effective group refractive index for use with optical time domain reflectometer (OTDR).

The splicing loss of any two fibers in any case shall not exceed 0.05 dB/splice. Ageing shall not cause increase of the nominal optical attenuation at ambient temperature at 1550 nm by more than 0.05 db/km of fiber over a period of 25 years.

The fiber shall be manufactured from high-grade silica and doped, as necessary to provide required transmission performance. The chemical composition of the fibers shall be specifically designed to minimize the effect of hydrogen on the transmission properties. The fibers shall be heat resistant. The Bidder shall submit a certificate or test data to guarantee the maximum rated temperature of the fibers.

The fiber core and cladding shall consist of silica (SiO₂) glass. In order to prevent damage to optical fiber the optical fiber shall be suitably coated. The coating provided shall guarantee a sufficient mechanical protection while splicing optical fibers. The fiber coating shall be easily strippable during splicing and termination with a mechanical stripping tool. The stripping shall not induce any mechanical stress or notches that weaken the optical fiber.

Each optical fiber for identification shall be color-coded corresponding to sequential numbering. The color shall be integrated in the fiber coating and shall be homogeneous. The color shall not be erased when handled during splicing. The original color shall be discernible through the design life of the OPGW. The color should not bleed from one fiber to the other and not fade when wiping the fiber with acetone or alcohol. If the fibers are regrouped in bundles or in tubes the later shall be colored according to a determined code.

The OP-unit tube shall be made of aluminum, aluminum alloy or aluminum-covered stainless steel with no mechanical joints and shall protect the Optic Fibers from mechanical and thermal loading. The tube shall have sufficient resistance in order to protect the optical fibers against radial compression transmitted by the metallic wires of the external layers. Under the normal operating conditions, including aeolian vibrations, sheave pulling at minimum, maximum temperature and maximum operating tension the tube shall not open, fissure and shall not be deformed. The internal surfaces of the tube shall be smooth, without smudges, notches, residues or roughness that may affect the optical fiber or their sheathing. The internal and external surfaces of the tube shall be circular and the tube thickness shall be constant.

22.2.4.2. Associated Hardware for OPGW

Preformed armor grip suspension clamp shall be supplied. The total drop of the suspension clamp from the center of the attachment to the center point of the OPGW shall not exceed 160mm. The aluminum alloy retaining rods shall be used. The suspension clamp shall have a breaking strength of not less than 25kN and shall have slip strength of 14kN.

The dead-end clamps shall be aluminum alloy and of bolted type/armour grip type using amour rods. The dead-end clamps shall include all necessary hardware for attaching the same to the tower strain plates. Dead-end clamps shall allow the OPGW to be continuous through the clamp without cutting and jointing. The dead-end clamp shall have slip strength not less than 0.95 times the OPGW rated tensile strength. The clamp shall have a breaking strength of not less than the OPGW. The clamp shall be capable of carrying the maximum current for which the OPGW is designed without overheating or loss of mechanical strength.

The grounding wire shall be bolted directly to OPGW and tower structure by means of grounding clamp. The grounding wire shall consist of a 1,500mm long length of lead wire made up of aluminum/aluminum alloy with an equivalent size of OPGW. Suitable extension links shall be provided, where required to maintain the bending radius of the OPGW within specified limits.

The bolted clamps shall attach the OPGW to the towers. The tower attachment plates shall locate the OPGW on the side of the tower. It shall be attached directly to tower legs/cross-arm without drilling or any other modification to the tower.

Vibration dampers shall have aluminum/aluminum alloy clamp capable of supporting the damper during installation and maintain the damper in position without damaging or crushing the OPGW or causing fatigue under the clamp. Armor or patch rod shall be provided. The armor rod shall be made of aluminum alloy. The vibration damper shall restrict the OPGW dynamic strain to 150 micro-strains under normal/aeolian vibration conditions. The dampers shall not be dynamically overloaded during operation to prevent damper fatigue. The Contractor shall be responsible for necessary studies of arriving at the exact placement of the vibration dampers.

22.2.4.3. Joint Boxes

The joint boxes conforming to IP55 shall include all the necessary hardware to retain, terminate, protect and splice all the fibers in OPGW, as well as suitable clamps for fixing to the towers or substation gantries without any need of drilling holes in the tower structure. The Contractor shall supply special Joint Boxes with appropriate cable entry for use at the gantry to splice the approach cable and OPGW (4-way Junction boxes)

The joint box for outdoor installation shall be free standing, vermin proof, watertight with protection degree of IP55 and shall be made of hot dipped galvanized steel. The joint box shall include all necessary hardware to retain, terminate, protect and splice the fibres, patch cord, pigtails, etc., shall give the facility for different cable clamping locations and be suitable for all types of cables.

The OPGW shall be terminated/spliced at the splice locations using joint boxes, which shall be located approximately 10m above ground. Spare length of 15 m of optical fiber shall be coiled on aluminum or galvanized iron drum or 1m diameter approved by the Employer and attached to the tower and gantries near the joint boxes.

The cleanliness and accurate cleaving of fiber ends shall be ensured prior to splicing. The accurate alignment of fiber cores, prior to splicing, shall be verified using a technique that monitors the optical power transmitted across the splice interface. Fusion splicing shall be commenced only after manipulations of fiber alignment have maximized the transmitted power. Single splice loss shall not exceed 0.05 dB. Splices shall be mechanically strengthened and protected from the environment by means purpose designed splice sleeves or enclosures. The finished splice shall be supported within the joint box by means of suitable clips or restrains. It shall be possible to remove and replace the splice in the support device without risk of damage to the splice or fiber. Each fusion splice shall have a spare length of fiber of approximately 1 m associated with it. The excess fiber shall be coiled neatly and clipped in the joint box.

22.3. Insulators and fittings

22.3.1. Applicable standards

The equipment and components supplied shall be in accordance with the standards specified below or latter editions and/or amendments thereof. Offers of items manufactured to any other internationally recognized standards or specifications not included in the list below shall accompany an English version of such standards for approval.

- a) IEC 60060 - High voltage test techniques.
- b) IEC 60120 - Dimensions of ball and socket couplings in string insulators.
- c) IEC 61109 - Composite insulators for a.c. overhead lines with a normal voltage greater than 1000V - Definitions, test method and acceptance criteria.
- d) IEC 62217 - Polymeric insulators for indoor and outdoor use with a normal voltage > 1000V - general definitions, test methods and acceptance criteria
- e) IEC 60437 - Radio interference test on high-voltage insulators.
- f) ANSI C29.12 - For insulators composite - Suspension Type
- g) ASTM A 153 - - Zinc Coating (Hot Dip) on Iron and Steel Hardware

22.3.2. Basic features for design

The insulators will be in service in a severe climate where intense lightning storms at certain periods of the year are expected. The design shall take that into account as well as to minimize the effect of local corona formation and discharge likely to cause radio interference. The detailed design shall be such as to facilitate inspections, cleaning, repairs, simplicity of operation and hot line maintenance. Further, it shall provide reasonable precautions and provisions for the safety of all those concerned in the maintenance of transmission lines. All corresponding parts shall be gauged and interchangeable whenever possible.

22.3.3. Construction

22.3.3.1. General

The insulator shall be of polymer insulators. The polymer suspension insulators shall be designed, manufactured and tested in accordance with the standards listed. Application of the polymer insulators shall be as per following table.

Table: Application of Polymer Suspension Insulator Set

Description	Unit	400kV	
		Suspension	Tension
Insulator string	-		
Electromechanical failing load	kN	210	210
Double or Single string	kN	Double	Double

Polymer suspension insulator set of 70 kN electromechanical failing load with single string shall be used for supporting all jumper conductor all transmission lines.

Polymer inverted tension insulator set of 210 kN electromechanical failing load with single string shall be used for supporting gantry conductor all transmission lines.

22.3.3.2. Material of Insulator Housing

Housing consists of sheath and weathersheds. The fiberglass core of the polymer insulator shall be protected with a rubber housing which shall be made of a silicon elastomeric compound having a minimum 30% silicone (or having a Si-O chemical backbone with fumed silica and tracking control filler, ATH). The housing shall be directly molded on the core through high temperature vulcanization (HTV) process and shall be seamless, smooth and free from imperfections. Molding in multiple steps may cause flaws and residual stress in the joining seams, therefore it shall not be applied.

Only compression molding in a single, one shot process (one-piece molding) shall be accepted. Any other molding methods such as sheath and shed molding or injection molding shall not be accepted. The weather sheds shall provide an open aerodynamic profile without any under ribs.

The housing shall be manufactured of 100% silicone rubber before fillers are added. The housing shall be in one-piece without any rubber-to-rubber joints in any part of the housing. The end fittings (electrodes) shall not be covered with the housing to prevent electrical puncture through the housing.

The housing shall be directly bonded to the FRP core. The interface between the housing and FRP rod shall be chemically bonded to prevent contaminants and moisture ingress. The strength of core-to-housing interface shall be greater than the tearing strength of the housing material itself. The thickness of the housing shall be not less than 3.0 mm.

The color of the housing material shall be blue-grey, and uniform and consistent.

Polymer insulators shall be designed to withstand high-pressure water washing of 3800 kPa (570 psi), with a nozzle diameter of 6 mm at a distance of 3 meters from the nozzle to the polymer insulator.

22.3.3.3. Material of Core

The core shall be a high quality fiber reinforced plastic (FRP) rod. To reduce the risk of brittle fracture, the insulator FRP core shall be made of corrosion-resistant ECR glass. The insulator core shall be mechanically and electrically sound, free from visible voids, foreign substances, and other manufacturing flaws.

22.3.3.4. End Fittings

The mechanical load will be transferred to the FRP rod by end fittings attached to the end of the rod. The end fittings shall be made of forged steel or ductile iron. Ball fittings shall be made of forged steel or ductile iron. Ball

fittings shall be made of forged steel. The inner steel area must be galvanized in order to prevent any rusting if water were to intrude the interface between hardware and the RTV sealant.

The end fitting configuration and dimension shall conform to the applicable requirements and gauging according to IEC 60120 (Ball-Socket). For tension string, Clevis-Tongue type under IEC 60471 may be proposed.

All ferrous materials (except stainless steel) shall be hot-dip galvanized in accordance with ASTM A 153.

The end fittings shall be attached to the FRP rod using a controlled compression process. The compression force used shall not be high enough to cause internal rod cracks.

All end fittings shall be attached to FRP rod by an automatic crimping process. The process must be controlled to detect, record and reject damaged pieces during crimping by acoustic emission or an equivalent method.

The interface of the metal end fitting and the housing shall be permanently sealed to prohibit the access of moisture. This sealing system shall be multi-layered and offer true redundancy.

22.3.3.5. Corona Ring(s)

Polymer suspension insulators shall have grading rings attached. The maximum radio influence voltage (RIV) allowed is 100 microvolts when an insulator is energized at 115% of nominal line-to-ground voltage.

The Contractor must obtain from the manufacturer and submit evidence that the electric field limit on both the live and dead end is less than 0.42 kV/mm.

22.3.3.6. Insulator string sets

Insulator strings complete with all fittings shall be designed to have the following electrical and mechanical characteristics.

The withstand voltages below indicated are effective for <1000m altitude. Accordingly, correction for altitude at site need to be applied.

- | | |
|---|----------|
| a) Power frequency withstand voltage: | 850 kV |
| b) Lightning impulse withstand voltage: | 1425 kV |
| c) Switching impulse withstand voltage phase-earth: | 1050 kV |
| d) Minimum mechanical and electro-mechanical failing load | |
| Suspension string: | 2x210 kN |
| Suspension clamp: | 3*120 kN |
| Tension string: | 2x210 kN |
| Inverted tension string: | 1x210 kN |
| Jumper support string: | 70 kN |
| e) Min. arcing distance with corona rings: | 4070 mm |

- f) Min. creepage distance: 16,000 mm

Retaining pin or locking devices for the insulator units shall be of phosphor bronze or stainless steel and the composition of them shall comply with BS 3288 and/or IEC 60372. They shall be so made and shaped that when set and under any condition of handling and service nothing but extreme deformation of the retaining pin or locking devices shall allow separation of the insulator units or fittings or shall cause any risk of the retaining pins at locking devices being displaced accidentally. The design shall be such as to allow easy removal for line working without the necessity to remove the insulator string from the cross-arms. Retaining pins or locking devices shall be incapable of rotation when in position.

22.3.3.7. Tension Insulator Sets

The Tension Insulator sets shall be completed with polymer insulator and necessary hardware. Compression type conductor tension clamps shall be made of aluminium alloy, steel or other suitable material.

22.3.3.8. Suspension Insulator Set

The suspension insulator sets shall consist of polymer insulator complete with necessary hardware as per the Employer's Requirements. Conductor suspension clamps shall be made of aluminium alloy or other suitable material for attaching conductors as referred to in the Employer's Requirements.

22.3.3.9. Fittings

Fittings shall comply with BS 3288: Part 1 as far as applicable and shall be suitable for maintenance using hot line tools already owned by the Employer.

Suspension clamps shall be made of aluminium alloy, and shall be free to pivot in the vertical plane containing the conductor and shall permit the conductor to slip at a load lower than the breaking load of the conductor. The conductor supporting grooves shall be curved at its ends in the vertical plane to a radius of 150 mm and for a sufficient distance to allow for the conductor leaving the clamp at the maximum angle of inclination obtained in service. The mouth of the supporting groove shall be slightly flared in plan. The grooves in the clamping piece or pieces shall be bell - mouthed at each end and all conductor grooves bell - mouths shall be smooth and free from waves, ridges or other irregularities. Particular attention shall be paid to the elimination or corona emission from all parts of suspension clamps.

Suspension clamp except jumper suspension set shall have a suitable dimension for clamping the conductor with preformed armour rods.

Tension clamps in which the conductor is necessarily cut shall comply in all respects with the provisions of Clause 22.1.5 where these are applicable. The mechanical efficiency of tension clamps shall not be affected by methods of erection involving the use of "come-along" or similar clamps before, during or after assembly and erection of the tension clamps itself.

Adequate bearing area between fittings shall be provided and "point" and "line" contacts shall be avoided. Split pins for securing attachment of fittings of insulator set shall be of stainless steel and shall be backed by washers of approved size and gauge. All insulator strings shall be attached to cross-arms by means of shackles. Hooks shall not be used.

All insulator fittings shall be such that they can be maintained under hot line working condition.

All the tension sets at the lower ends of slack spans (gantry side end) shall be provided with turnbuckle adjusters.

Tension insulator sets shall be equipped with sag-adjusting plates, links or other devices, in each component of insulator strings at line end, provide a total range of adjustment from plus to minus 150 mm in steps not greater than 25 mm.

Each pair of insulator strings of normal tension sets shall be connected together at the earth end by means of yoke plates and be connected independently to the tower cross arm.

Each pair of yoke plate at earth end shall also have sag adjusting link of total range adjustment from plus to minus 150 mm in steps not greater than 25 mm.

22.3.3.10. Arcing Horns

All insulator sets shall be fitted with line and earth end arc horns. Arc horns shall be made of galvanized steel. Where tube is used, the wall thickness shall be approved by the Employer/ Employer's Representative and both inner and outer surfaces shall be galvanized. The parts of horns where arcs are expected to make contact shall be solid.

The design of arc horns shall be such as to obviate damage to clamps and conductors, and shall prevent cascading over the line end insulator units when flashover occurs. They shall be suitable for use with hot line tools. The amount of lift and general shape shall at the same time given maximum values of power frequency and impulse flashover voltage consistent with the above provisions.

Any special tests considered necessary to prove the correct setting of arcing fittings shall be carried out at the manufacture's works without extra cost.

Details of the arcing horns shall be in accordance with the following:

- a) Suspension sets - Double point horns shall be arranged in the vertical plane containing the conductors. The lower arcing horns shall be strong enough to support a man weighing 90 kg standing on the horizontal portion with adequate security.
- b) Tension Insulator sets - Single point arc horns shall be fitted so as to provide a horizontal arc path above the insulator rod.
- c) Tension Insulator sets for slack spans - Tension insulator sets for use at the upper end and lower end of the slack spans shall be fitted with arc horns at both line end and earth end, providing arc gap adjustable from -20% to +20% of the specified gap. Line end horn shall be fixed and the earth end horns adjustable.

22.3.4. Additional requirements

22.3.4.1. Identification

Identification details as indicated below shall be provided on the insulator and shall be weatherproof and corrosion proof.

- a) Manufacturer's identification
- b) Minimum mechanical failing load
- c) Year of manufacture

Each insulator shall have mark on it the manufacture's name or trademark. Insulators shall also be marked with the guaranteed electro-mechanical strength. Marks shall be visible after assembly of fittings and shall be imprinted and not impressed.

When a batch of insulators bearing a certain identification mark has been rejected no further insulators bearing this mark shall be submitted. The Contractor shall satisfy the Employer that adequate steps will be taken to mark or segregate the insulators constituting the rejected batch in such a way that there is no possibility of the insulators being subsequently resubmitted for tests or supplied for the purchaser's use.

22.3.4.2. Information to be supplied with the Bid

Details with descriptive matter, catalogues indicating the drawing, reference number and literature of the items offered in accordance with relevant clause of the standard specified including the following particulars shall be furnished with the offer.

- a) Constructional features, materials used for components
- b) Complete dimensional drawings with cross section of insulator
- c) Details of suspension and tension insulator sets
- d) Certificate of type tests carried out in accordance with the specified standard by internationally acknowledged independent laboratory outside manufacturer's country. Test certificates should be given for polymer insulator as well as for suspension and Tension Insulator sets.
- e) Manufacturer's evidential documents of five (5) certificates from the five (5) different end users for minimum 5 years operation of the polymer insulators. Three (3) of them shall be from outside the manufacturer's home country. The end users shall be utility companies.
- f) Certificate issued by an independent International Organization to ensure compliance with the ISO 9001 standards or equivalent by manufacturer.

22.4. Steel Tower Design, New Conductor and Existing Steel Towers

22.4.1. General

The new towers shall be of the self-supporting type in Danube configuration to match the existing towers. Since the transmission line of the project is LILO of the existing lines, the contractor is advised to use the same towers

data in order to create harmony with the existing line, however this is contractor's responsibility to check the existing towers data (based on the as built drawings attached to the tender documents) and re-design (if necessary). It should be noted that in case of re-design / new design, new towers should have more strength than existing ones.

The new towers shall be designed to carry the line conductors with the necessary insulator sets, earth conductors and all fittings under the conditions specified.

For double circuit towers the line conductors of each circuit shall be disposed in 'Danube' configuration and symmetrically arranged with two overrunning earth conductors to provide the shielding angle.

The methods of attachment of the earth conductor(s) to the towers shall be by means of suspension clamps at the suspension towers and by means of tension anchor clamps at tension towers. Suspension towers shall be capable of accommodating OPGW suspension and tension clamps.

e. Computations shall be presented in a clearly arranged format and worked out in detail to demonstrate clear evidence of each stage of the work. The use of PLS-Tower Software is desirable, using other softwares is subjected to the employer's representative approval. Computer input data shall be provided. Stability calculations shall be computed in accordance with the 1st order theory. Graphical calculation of forces will not be admissible. The applied formulae for computation of tower member stability shall be clearly stated to enable subsequent checking.

22.4.2. Applicable standards

The equipment or components supplied shall be in accordance with the standards specified below or later editions and/or amendments thereof.

Offers of Items manufactured to any other internationally recognized standards or specifications, provided they are not less rigid shall accompany an English version of such standards.

ISO 630 - Structural Steels - plates, wide flats, bars, sections and profiles

ISO 657 - Hot rolled Structural Steel Sections,

Part 5: Equal-leg angles and unequal-leg angles

ISO 7452 - Hot rolled structural steel plates tolerances on dimensions and shape

ISO 898 - Mechanical properties of fasteners. Part 1-Bolts, Screws and studs

ISO 7411 - Hexagon Bolts for high strength structural bolting with large width across flats

ISO 1459 - Metallic coatings - Protection against corrosion by Hot Dip Galvanizing.

ISO 1461	-	Hot dip galvanized coatings on fabricated iron and steel articles
ASCE 10-97	-	Design of latticed steel transmission structures.
IEC 60826	-	Design criteria of overhead transmission lines
IEC 60652	-	Loading tests on overhead line structures

22.4.3. Wind pressure and temperature

For design purposes, a maximum wind velocity of 40m/s (3s wind) shall be assumed.

Temperatures of conductors shall be as stated in the following table.

Table: Conductor Temperature

Item	Unit	Value
Minimum Temperature	°C	1
Everyday Temperature	°C	25
Maximum Temperature	°C	80

22.4.4. Conductor tension

Limiting conditions for sag tension calculation to be applied for tower design are as follows:

- Minimum Factor of safety for Line & Earth conductors
 - Based on Ultimate strength = 2.5
 - At everyday temperature, still air, based on Ultimate strength = 5.0
- At everyday temperature, still air, the earth conductor sag shall be approximately 10% less than the line conductor sag

22.4.5. Tower types

Tower types to be applied for the Project are as mentioned in the following table

Tower type 400S is suspension and tower types of 400T10, 400T30, 400T60, and 400T90 are tension towers. 400T90 is also used for dead-end point (TRM).

Table: Deviation Angles and Design Spans

Tower Type	Dev. Angle	Normal Condition			Broken Wire Condition		
		Wind span	Weight Span		Wind span	Weight Span	
			Max.	Min.		Max.	Min.
	deg	(m)	(m)	(m)	(m)	(m)	(m)
400S	0-2	440	800	-	0.75* Normal condition	0.75* Normal condition	0.75* Normal condition
400T10	0-10	450	900	-450			
400T30	10-30	450	900	-450			
400T60	30-60	450	900	-450			
400T90 (TRM 0-45)	60-90	450	900	-450			
	0-45	450*0.75	900*0.75	-450*0.75			

Normal tension insulator strings shall be installed to the crossarms by two points.

Towers shall be provided with body extensions of +3m, +6m, +9m and +12m and each type designation will carry the construction type (ie.400S+3m etc.).

Leg extensions of +1m, +2m, +3m, +4m shall be provided where necessary.

22.4.6. Deviation angle and design spans

The basic span for 400 kV Line is 400 m.

The basic span shall mean the horizontal distance between the centers of adjacent towers on level ground from which height of normal towers is derived with the specified conductor clearances to ground in still air at maximum temperature.

Deviation angles and design spans for each type of towers to be applied for tower design shall be as stated before.

Spans for broken wire condition apply only for the conductors or earth wire considered broken. Loading for the intact conductors shall be based on Normal Spans.

The wind span shall mean half the sum of adjacent horizontal span lengths supported on any one tower.

The weight span shall mean the equivalent length of the weight of conductor supported at any one tower at minimum temperature in still air. At suspension positions the minimum weight of conductor, inclusive of counter-weights where used, is not to be less than 25%, of the total weight of conductor in the two adjacent spans.

However, the design span may be modified according to the final results of the check survey to be conducted by the Contractor.

22.4.7. Conductor and overhead grounding wire spacing and clearance

Conductors and overhead grounding wire/OPGW for each circuit of double circuit towers shall be arranged as done for the existing towers. The clearances from conductor, arcing-horns, jumper loops and all live metal to the tower steelwork shall be not less than those specified later on under still air conditions and at assumed swing conditions. Where uplift occurs at tension tower positions the minimum clearance between any arcing horn and jumper loop or phase immediately above it shall not be less than the minimum still air clearance from live to earth metal stated later on.

No tension tower shall be designed to give a smaller dimension between conductors in a plane perpendicular to the conductor axis than that existing at suspension towers.

Allowance shall be made for increasing or decreasing the length and varying the arrangement of all terminal crossarms to enable down lead span connections to be made in any desired phase sequence.

22.4.8. Clearance

The clearance from live metal to tower members shall be at least as stated in the following table.

Table: Minimum Clearance from Tower Members

Item	Unit	Clearance
Suspension insulator string		
0°- 10° swing	mm	3,600
65° swing	mm	1,200
Overhead grounding wire shielding angle	deg.	17

Note: The specified values are for bidding purpose. Final clearance may be modified based on the final design.

The clearance between the line conductors and the ground in still air under the maximum specified temperature shall be in accordance with the following table.

The clearance under all specified conditions between any part of any fences, walls, buildings or other structures on which a man may stand, or against which a ladder may be placed, and the nearest line conductor shall also be as specified in the table above.

Table: Minimum Clearance from Ground and Obstacles

Situation	Minimum clearance (metres)
	400 kV
Normal ground,	8.8
Main road (road level of any road that is normally maintained by the Government and/or other recognized public authority.	10.8
Power transmission & Telecommunications lines:	
- Lowest line conductor of upper line to highest conductor or earthwire of lower line	5.6
- Lowest line conductor of upper line to support of the lower line on which a person may stand	7.0
Railway crossing	
- Rail level	9.3
- Electrified Railway crossings, building, gantries, or other structures on which a man can stay	8.8
Ground level at roads or yards where road mobile cranes are likely to be employed	10.8
Any wall, building or other structure on which a man may stand, or on which a ladder may be placed	5.6
Street lighting	5.6

An additional clearance of 0.3 m required to allow survey and sagging errors shall be considered in profile design.

22.4.9. Assumed working load

22.4.9.1. Normal Condition

Normal condition shall be designed for 3 wind directions of 90°, 45° and 0° to the line. The assumed maximum simultaneous working loading on towers shall be as follows;

(A) Suspension Tower (400S)

(i) Vertical loading

The weights of the insulators and all other fittings and the actual dead weight of specified span lengths of line and earth conductors

(ii) Transverse loading

Transverse horizontal components of the maximum conductor and earth wire tensions resolved for the maximum angle of deviation concerned

Wind pressure caused by the wind of stated directions to the line on the whole projected areas of the conductors, overhead grounding wire, and insulators and on the projected area of the members of one face of the towers.

(iii) Longitudinal loading

Wind pressure caused by the wind of stated directions to the line on the whole projected areas of the conductors, overhead grounding wires, and insulators and on the projected area of the members of one face of the towers.

(B) Tension Towers (400T10, 400T30, 400T60, 400T90)

(i) Vertical loading

The weights of the insulators and all other fittings and the actual dead weight of specified span lengths of line and earth conductors

(ii) Transverse loading

Transverse horizontal components of the maximum conductor and earth wire tensions resolved for the maximum angle of deviation concerned

Wind pressure caused by the wind of stated directions to the lines on the whole projected areas of the conductors, overhead grounding wires, and insulators and on the projected area of the members of one face of the towers.

(iii) Longitudinal loading

Wind pressure caused by the wind of stated directions to the line on the whole projected areas of the conductors, overhead grounding wires, and insulators and on the projected area of the members of one face of the towers.

All tension towers shall be designed for the out-of-balance longitudinal components of loading. The magnitude of these loads shall be 15 per cent of the maximum actual line conductor and earth conductor tensions stated in the Technical Schedules.

Where crossarms are not pointed in the plan at the outer ends, the design shall be made as follows;

- a) The entire horizontal and vertical loading for span length of broken wire condition shall be applied to one outer corner of each crossarm.
- b) The horizontal and vertical loads derived from the valance span length of normal and broken wire conditions shall be applied at the other outer corner of crossarms.
- c) Tower body shall have equal strength in front and back faces and in left and right faces.

(C) Terminal Tower (400T90)

In addition to deviation angle of 60-90 degree, 400T90 type tower shall also be used as Terminal towers. 400T90 shall also be designed to accommodate slack span conductors to the substation gantry at any angle of exit from 0°-45° to the tower and from the horizontal to the vertical plane. All terminal towers shall also be designed for up to 4 slack span grounding wires (2 per crossarm) to connect to the substation gantry structure or earth masts. Where necessary additional tension plate for 4 slack span shall be provided for terminal towers. Where necessary auxiliary conductor and grounding wire crossarms shall also be applied.

(1) Slack span 0° angle

(i) Vertical loading

The weights of the insulators and all other fittings and the actual dead weight of specified span lengths of line and earth conductors

(ii) Transverse loading

Wind pressure caused by the wind of stated directions to the line on the whole projected areas of the conductors, overhead grounding wires, and insulators

Wind pressure on 1.0 times the projected area of the members of one face of the tower

(iii) Longitudinal loading

Wind pressure caused by the wind of stated directions to the line on the whole projected areas of the conductors, overhead grounding wires, and insulators

Wind pressure on 1.0 times the projected area of the members of one face of the tower

Maximum tensions of all conductors and overhead grounding wires in the span of line side

Tension of slack span shall also be considered for 90°, but applying tension of slack span for reducing longitudinal load by balancing with the other side is not allowed.

(2) Slack span 45° angle

(i) Vertical loading

The weights of the insulators and all other fittings and the actual dead weight of specified span lengths of line and earth conductors

(ii) Transverse loading

Wind pressure caused by the wind of stated directions to the line on the whole projected areas of the conductors, overhead grounding wires, and insulators

Wind pressure on 1.0 times the projected area of the members of one face of the tower.

The maximum tensions of conductors and overhead grounding wires in slack span

(iii) Longitudinal loading

Wind pressure caused by the wind of stated directions to the line on the whole projected areas of the conductors, overhead grounding wires, and insulators

Wind pressure on 1.0 times the projected area of the members of one face of the tower.

Maximum tensions of all conductors and overhead grounding wires in line side span.

22.4.9.2. Broken Wire Condition

This loading case will be considered under Minimum temperature +full wind condition.

Suspension structures shall be designed for the reduced vertical and transverse loading derived from the span lengths of broken wire condition as stated before, plus the unbalanced longitudinal force at maximum working tension due to the breakage of one phase conductors or one grounding wire.

In case of a conductor breakage the pull on a suspension tower may be assumed to be reduced to 70% of the specified maximum working tension. This reduction shall not be assumed in the case of earth wire breakage.

Tension towers and terminal tower shall be designed for vertical & transverse loading plus the full unbalanced longitudinal forces at maximum working tension due to the simultaneous breakage of two points of any combination among phase conductors and overhead grounding wires on the same side of the tower. Breakage of phase conductor shall mean breakage of all conductors in one phase.

Calculation of stresses in tension tower members under broken wire loading shall be made for the worst conditions of loading of that particular member for the range of loading for which the tower may be employed.

22.4.9.3. Stringing Condition

This loading case will be considered under EDS condition and no wind pressure will be considered.

(1) Eccentric Loading

Vertical load caused by one circuit conductors and overhead grounding wires strung on tower shall be considered in the design.

Transverse horizontal components of the EDS tensions of conductors and earth wires resolved from the maximum angle of deviation concerned shall be applied.

For terminal towers, torsion loads caused by the unbalanced longitudinal working tension due to one circuit conductors and overhead grounding wire strung shall be considered at EDS tensions.

(2) Tensioning Loading

All overhead grounding wires and conductors are loaded on tower. Vertical and transverse loads of all conductors and grounding wires shall be applied. In addition, longitudinal loads of every two earth wires, top two phases, middle two phases or bottom two phases of conductors as well as vertical load derived from guy wires installed for back tension shall be applied. The conductor and overhead grounding wire tensions for calculation of transverse loads and longitudinal loads shall be based on the tensions of 10% and 50% of maximum tensions for suspension towers and tension towers respectively.

22.4.9.4. Cascading Condition

Apart from abovementioned cases, cascading loading case should be considered as well.

22.4.9.5. Factor of safety of towers

- a. All towers shall be designed so that no failure or permanent distortion shall occur when tested with applied forces equivalent to 2.0 times the maximum simultaneous working loading specified in the chapter before.
- b. All towers shall also be designed so that no failure or permanent distortion occurs when tested with applied forces equivalent to 1.5 times the maximum simultaneous working loading resulting from the assumed breakage of conductor (s) specified in the chapter before.
- c. All crossarms shall be designed so that no failure or permanent distortion shall occur when tested with applied forces equivalent to 2.0 times for each types of suspension towers and 2.0 times for each type of tension and terminal or special towers under the broken wire condition specified in the chapter before.

- d. Design tests on tower types selected by the Employer/ Employer's Representative shall be carried out and all costs shall be deemed considered in the Contractor's price (tower price) and no additional cost will be paid by the client.
- e. Each tower shall be tested in accordance with IEC 60652 and subjected to such test loads as the Employer/ Employer's Representative may specify in order to prove compliance with the ultimate loading conditions including the overload factor, applied in an approved manner without showing signs of failure or permanent distortion in any part.
- f. Tower type tests shall be performed for at least seven (7) load cases. Tests to destruction shall then be carried out up to 120% loadings in an approved manner on all tower types. No tower or parts of any tower submitted for destruction test shall be used on the contract Works, and steel members shall be destroyed or marked in an approved manner.
- g. Tests to ultimate loading shall be carried out in an approved manner on tension tower types.
- h. Steel towers submitted for test shall be galvanized unless specific approval is obtained. Towers shall be provided with anti-climbing devices on at least 1 leg to facilitate inspection of the proposed devices.
- i. After type test, the Employer's representative has the right to choose some tower members, bolt, and nuts for sample tests. All sample tests results must be submitted to Employer for review.

22.4.10. Construction of tower steelwork

All designs shall be such that no trouble shall arise in service from vibration or excessive deflection due to the use of too light section. Rolled steel section, flats, plates and bars shall, unless otherwise approved, consist of steel grade E 275 and E 355 of ISO 630.

Bolts and nuts shall meet to property class 5.8 of ISO 898-1 of 520 N/mm² of minimum tensile strength or higher grade.

Steel shall be free from blisters, scale or other defects and shall be smooth on surface finish.

High strength steel, when stored in the fabricators stockyard prior to fabrication and galvanizing, shall be marked continuously throughout its length with a light blue water paint line. In addition the grade number of the steel shall be painted on and ringed round with paint.

All steel members and bolts and nuts shall be hot dip galvanized. Galvanize shall be 600g/m² (85μm) average and 500g/m² (70μm) minimum for members and 376g/m² (53μm) average and 305g/m² (43μm) minimum for bolts and nuts.

The standard rolled steel sections used for all main members including legs, tower top verticals, crossarm members (except bracing), shall be not less than 6mm thick.

No standard rolled steel section shall be less than 4.75mm thick. Bolt-holes shall not be more than 1.5mm larger in diameter than the corresponding bolt diameter. The design shall be such as to keep the number of different parts as small as possible, and shall facilitate transport, erection and inspection.

Bracing shall be symmetrical in each face.

The ultimate design stress in tensile members shall not exceed the elastic limit strength of the material. The ultimate stress in the compression members shall not exceed a figure obtained from an approved formula.

The crossarm tips of tension towers shall be so arranged that two holes for the attachment of conductor erection and maintenance tackle are provided adjacent to each hole for tension set shackles. It shall be possible to apply full conductor tension safely to either additional attachment point.

The maximum allowable slenderness ratio (L/R) for various classes of member shall not exceed the values given in the following table.

Table: Maximum Slenderness Ratio

	Members	L/R
a)	Main members in the crossarm in compression and legs	120
b)	Bracing carrying compression stress	200
c)	Redundant members	250
d)	Bracing loaded in tension only	500

At locations with steeply sloping ground one or more of the tower legs shall be extended in lattice steel framework, in 1 m intervals in an approved manner to give minimum interference with standard or extended body design. Independent single leg extensions shall be designed and provided where necessary for both standard and extended towers.

Minor modification may be made to standard tower design where the Employer directs that such are required to suit special loading conditions.

22.4.11. Workmanship

All steel lattice members shall be cut to jig and all holes in steelwork shall be drilled or punched to jig. All steel parts shall be carefully cut and holes located so that when the members are in position the holes will be opposite each other before being bolted up. The drilling, cutting, punching 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 structures on the site. High tensile steel members shall be bent hot. All bends made by cutting and welding shall be to the Employer approval. Care shall be taken not to punch holes too close to edges of metal.

Means shall be provided to enable the Employer to carry out such checking of members as he may consider necessary. Built-up sections, when finished, shall be true and free from all links, twists and open joints and the materials shall not be strained in any way.

In order to check the workmanship, not less than 1 per cent of the members corresponding to each type of tower or crossarm shall be selected at random and assembled to form complete latticed towers or crossarms in the presence of the Employer at the manufacture's works.

If the towers are fabricated or galvanized by subcontractors, the Contractor shall, if required by the Employer, provide a resident inspector at the works of each subcontractor during the time that the bulk of the steelwork is being fabricated or galvanized.

22.4.12. Anti-climbing devices, step bolts, anti-theft bolts and bird guards

Each tower shall be fitted with an anti-climbing device of an approved design fixed at a height of between 3.0 and 5.0 metres above ground. The anti-climbing device should be the best available construction to prevent unaided access up the tower, lockable gates shall be provided. No barbed wire is to be used on towers within national park boundaries. The position of the anti-climbing device on the tower should preferably be such that a standard device is used regardless of the tower body or leg extensions that may be employed. The suitability of such devices shall be checked by assembly on towers erected for test or assembled as part of the check erection process.

On each double circuit tower, two diagonally opposite legs, shall be provided with step bolts of approved type fixed at equal centres of between 300 mm and 380 mm throughout the height of the tower starting immediately above the anti-climbing device and continuing to the earth conductor peak. Where, for structural reasons, it is not possible to maintain the equal centres it shall be acceptable to change the centres by not more than 30 mm. Below the anti-climbing devices, holes shall be provided for removable step bolts at the centres stated above. Sets of step bolts to fit these holes shall be provided where required by the Engineer.

Step bolts shall not be permitted in stressed connections.

Anti-theft bolts shall be provided from ground level to 2m above the anti-climbing device.

Towers shall be equipped with approved devices immediately above each suspension insulator attachment point to prevent birds perching above the insulators. The devices shall be easily removed and replaced to facilitate maintenance work.

22.4.13. Notice plates

Conspicuous danger and tower number plates, circuit number and phase sequence plates of approved types, vitreous enamelled and resistant to fading under the climatic conditions at Site, shall be provided and fixed in approved positions on all towers.

Plate and lettering sizes are to be the same as for the existing towers. The back of the plates shall be coloured black.

The danger and tower number plate shall be fixed above the anti-climbing device.

The line code identification plate shall be attached centrally immediately below the danger plate.

Phase sequence plates of approved types coloured red, yellow and blue respectively to indicate the line conductor phases shall be provided for each circuit and fixed in approved positions on all towers.

Circuit number plates shall be coloured in accordance with KETRACO's standard requirements. The first plate is to be fixed just below the anti-climbing device, the second halfway up and the third just below the lowest crossarm.

Aerial tower number plates shall be provided and fixed in an approved position on the earth conductor peak of every tenth tower. The plates shall have yellow numbers on a black background.

Enamelled plates shall be provided with fibre washers, front and back, at the securing screws or bolts.

All inscriptions shall be in the Swahili and English language.

Flags are utilised during maintenance works to identify specific circuits. Flag fixing brackets are therefore to be fitted to each step bolt leg of the tower, one immediately above the anti-climbing device and one on the climbing leg adjacent to each crossarm.

25 wristlets shall be provided. A wristlet shall consist of a curved stainless steel disc 34 mm diameter and 2 mm thick fitted to a good quality 12 mm wide nylon strap, with buckle, suitable for all sizes of wrist diameter. The steel disc shall be colour coded for line identification finished in vitreous enamel.

22.4.14. Aircraft warning markers, obstruction lights and tower painting

In restricted areas and pipeline crossings Aircraft Warning Markers (AWM) shall be fitted to the earth conductors and Air Traffic Obstruction Lights (ATOL) on the towers in order to satisfy requirements of Authorities. Where required by KETRACO, ATOL shall also be installed on the highest phase line conductor(s) and the towers shall be painted as specified.

a. Aircraft Warning Markers

Where required AWM shall be spherical of 600 mm diameter and manufactured in fibreglass. The spheres shall be coloured International Orange which shall not fade when subjected to the direct rays of the sun. They shall be manufactured in two halves and designed such that assembly and attachment to the earth conductor is simple.

Provision for drainage shall be provided. Suitable clamping devices shall be provided which will not damage the conductor but will prevent the sphere from twisting or slipping on the conductor. All metal parts used for holding the spheres in position shall be of mild steel and galvanized.

The warning spheres shall be fixed on the earth conductor in any required span and shall be erected, as required by Chapter 6 of Annex 14 to the ICAO Regulations, at intervals of not more than 30 metres on the overall earth conductor system.

The first and last spheres in any span shall be approximately 10 meters from the towers defining the span.

With twin earth conductors, provided the spacing of the spheres on either earth conductor is suitably staggered to provide the above requirements, the placing of the spheres can be alternated between the two earth conductors at uniform spacing.

It shall be noted that the supply of equipment shall include the necessary spare parts as per the manufacturer's recommendations, for a service period of five years, the cost of which is to be included in the price quoted.

The tower obstruction light system shall be to the approval of the Engineer.

b. Air Traffic Obstruction Lights on Towers

Where required ATOLs shall be installed on the towers defining the span, of International Standard red in colour, and having the following general features:

conforming to Chapter 6 of Annex 14 to the ICAO Regulations

two lamps per tower of which only one may be lit at a time (by utilizing a switch-over relay)

having minimum luminous flux of approximately 10 candela, steady aviation red light

having minimum lamp life time of approximately 20 000 hours

all components shall be corrosion-proof for use in marine and damp tropical climate conditions.

The system offered shall be comprehensive and complete in every respect. If a system fed by cables is proposed, it shall be designed to withstand the induced high voltage that can occur during earth fault conditions. It shall consist of a constant current regulator, high voltage cable, dimmer switch, protection equipment, insulating transformers, lightning arresters, etc. The connection and cabling to the nearest available safe mains supply shall be deemed to be included.

Should a solar powered system be proposed, the battery supplied shall be able to maintain the minimum luminous flux of 10 candela under the condition of dusty solar cells. A battery maintenance interval of 5 years minimum shall be guaranteed. Photovoltaic panel output shall be de-rated, over and above age de-rating, by 40%, on account of dust accumulation on the panel surface. The upper edges of the solar panels shall be fitted with stainless steel needle strips, effectively preventing birds from sitting in these locations.

It shall be noted that the supply of equipment shall include the necessary spare parts as per the manufacturer's recommendations, for a service period of five years, the cost of which is to be included in the price quoted.

The tower obstruction light system shall be to the approval of the Employer's representative .

c. Tower Painting

Where required and to comply with requirements of Authorities certain towers may need to be painted with two coats of approved epoxy resin type paint with red and white strips of widths complying with ICAO Regulations. The life span of the paint system shall be not less than 10 years and the colours shall not fade within this time under strong sun radiation.

22.5. Foundations

22.5.1. Applicable standards

The equipment or components supplied shall be in accordance with the standards specified below or later editions and/or amendments thereof.

Offers of Items manufactured to any other internationally recognized standards or specifications, provided they are not less rigid shall accompany an English version of such standards.

BS 8004 - Code of Practice for Foundations.

BS 8110 - Structural use of concrete.

BS 4449 - Carbon steel bars for the reinforcement of Concrete

22.5.2. Foundation types

Soil types to be applied for foundation design are classified as shown in the following table.

Table: Classification of Soil Type

Soil Type	Particular of Soil
Class 1	Homogeneous rock
Class 2	Fractured rock/hard clay/ very dense sand
Class 3	Stiff clay/ dense sand
Class 4	Firm clay/ medium dense sand
Class 4W	Firm clay/ medium dense sand
Class 5	Soft clay/ silt/ loose sand
Class 5W	Soft clay/ silt/ loose sand

The foundation design particulars are given in clause 22.5.3.

22.5.3. Foundation design

All types of foundations shall be designed to withstand compression, uplift, settlement, overturning and sliding when subjected to the specified conditions of tower loading. Allowance shall be made in foundation design for hydrostatic pressure where this may occur and the effects of seasonal rains, drying out, cyclic loading and wind induced vibration of tower members.

The Contractor shall be responsible at his own cost for identifying and classifying at an early stage of the Contract the types and nature of ground and subsoil encountered along the line route. Investigations shall be carried out to confirm or adjust the parameters given in below table. Subject to the approval of the Employer the parameters obtained from the Contractor's soil tests shall be classified into typical groups and employed in the designs of all foundations.

The type of foundation to be used at each tower location shall be subject to approval and shall normally be decided on the most economical solution.

The designs for foundation class 6, pile foundations shall consider the actual maximum loading to which the particular tower under consideration will be subject in service due to its position on the transmission line profile. The specified unbalanced loading and the assumptions of temperature and wind pressure shall otherwise apply together with the specified factors of safety.

Where necessary concrete shall be reinforced and designed, detailed and constructed in accordance with BS 8110 using grade 25 concrete. Test cubes shall be provided whenever requested.

Reinforcement bars for concrete shall conform to Grade 460 of BS 4449.

As far as practicable the set of foundation stub shall be identical for anybody extensions and any leg extensions of the same tower type.

All steelwork below ground level, except reinforcement bars, shall be galvanized and completely covered with encasing concrete not less than 75 mm thick from a point 300 mm above ground down to the main foundation block or, for rock foundations, down to the rock. In water logged areas, above mentioned 300 mm should be extended up to 1000 mm above maximum water level. Where necessary, the encasing concrete shall be keyed to the steelwork or to the main foundation in an approved manner. Cover over the reinforcement bars shall not be less than 50 mm.

Single footings of each standard class of tower foundations and any special foundations when instructed by the Employer shall be tested.

As an addition to the main quotation which shall be completed in full and shall be based on the foundation types specified, alternative types of foundation differing from those specified may be considered subject to the approval by the Employer of design principles, parameters, and all relevant factors affecting the performance of the proposed foundations over the service life of the transmission line.

Foundations shall conform to the following general requirements:-

(i) Rock foundation.

The holes for stubs shall be made in such a manner to eliminate the possibility of serious cracking of the rock. The dimensions of hole shall be approved and shall ensure the stubs are firmly keyed and grouted and in no case shall the stub be embedded less than 1 meter into the rock. The stubs shall be encased as for other types of foundation with the exception that the encasing concrete shall extend down to the upper surface of the rock.

Where the use of embedded stubs is not economical, other types of rock foundation consisting of grouted anchors may be used. The construction methods and design detail for grouted anchors shall be proposed by the Contractor and approved by the Employer.

(ii) Pad and chimney foundation.

The main concrete block will be pyramidal in shape. The tower stub shall extend into the main concrete block. Stubs shall be provided with bolt-on cleat.

Where the soils are stiff or dense and are free from standing water and will permit a satisfactory undercut without risk of collapse, concrete pad and chimney foundations may be employed with undercut excavations subject to approval of Employer. The undercut will extend to a minimum of 300 mm outside the excavated walls. The outer edge of the undercut shall be vertical for a minimum of 100 mm and the upper surface sloped to an angle of 50° from the horizontal. All undercutting of excavations shall be carried out by hand tools and use of excavators will not be permitted. Care shall be taken to ensure inclusions of foreign matter do not occur during concreting and the sides of the 'undercut' shall be lined with waterproof paper or similar material to prevent migration of fine aggregate and cement.

Undercut concrete pad and chimney foundations shall be designed for the Soil type S1 and S2 given in table above Schedule of foundation design particulars. In order to distinguish from standard pad and chimney foundation, the word 'undercut' shall be appended to the foundation description.

(iii) Pile Foundation

In addition to the standard foundations where the investigation of subsoil according to the Employer's Requirement have indicated ground of very low bearing capacity and/or high water table in granular soils or other special circumstances, pile foundations are to be provided. These foundations shall be designed in accordance with established principles of soil mechanics and shall be of one of the following types: - either concrete pad and chimney with enlarged pad, concrete raft or deep reinforced concrete piles (bored or driven) with reinforced concrete cap. AN-steel and wooden piles are not accepted.

To enable the type and size of a special foundation to be determined the Employer may require a special soil investigation to be undertaken and a report and recommendation submitted. The report shall include soil cohesion and/or friction values obtained by means of tri-axial compression tests from undisturbed bore hole samples together with other complementary laboratory test results.

The static analysis and pile design shall normally be in accordance with BS-8004, BS-8110 and/ or equivalent as approved by the Employer.

Pile foundations shall comprise reinforced concrete piles bored or driven to a depth determined by the Site soil investigation. Driven reinforced concrete piles will normally be preferred if access costs are not prohibitive. Unless otherwise agreed with the Employer where bored piles are employed a minimum of two piles shall be constructed for each tower leg footing. The diameter to length ratio of any bored pile shall not exceed 1:50. Where the subsoil conditions dictate, steel casings may be left in the bore as a precaution against the formation of voids. Wherever possible bores terminating in stiff clay or other suitable strata are to be provided with a bulb end or undercut. Piles may be raked or vertical. To resist horizontal shear forces piles shall normally be connected by collar beams extending between the tower legs at the surface of the ground. The tower stub or anchor plate shall be grouted into a concrete block extending over the pile group and the whole shall be properly reinforced to ensure no rupture of the concrete when subjected to simultaneous ultimate applied loading.

Bearing for pile foundations shall be the sum of pile end bearing and shear resistance of the soils developed over the effective surface area of the piles. The under-surface of the pile cap shall be considered as not contributing to the bearing surface of the foundation.

The pile foundation resistance to uplift shall be the sum of the skin friction developed over the effective surface area of the piles and the weight of the concrete piles including the pile cap. The minimum weight of any pile cap shall not be less than the uplift developed under the conditions of "everyday" temperature and zero wind. Due allowance shall be made in all calculations for hydrostatic pressure where the water table occurs above the base of the piles. The loading capacity of a pile group shall be reduced by a factor appropriate to the configuration of the group. The soil sub grade reaction to horizontal forces shall also be evaluated and the pile and/or collar beams reinforced as found necessary.

To allow for shrinkage due to seasonal changes in soil water content it shall be assumed that a minimum of the top 3 meters of each pile has no contact with surrounding soils. The effective surface area of the pile shall be calculated accordingly.

Subject to the approval of the Employer, additional piles may be installed at a tower site for the purpose of tests to confirm the uplift and/or bearing capacity of the installed piles. Where possible such tests shall be carried out before concreting of the pile caps for the tower foundations thus allowing for additional piles to be installed if necessary. Piles shall be excavated to a minimum of 3 meters or suitably sleeved during construction to ensure no soil adhesion during testing.

The pile shall have the minimum dimensions of 300 mm x 300 mm for square cross section or 300 mm in diameter for circular cross section in case of driven reinforced concrete piles, or 460 mm in diameter for bored piles.

Minimum number of piles is 3 per leg in case of driven piles and 2 for bored piles.

The piling system proposed should be provided for convenient adjustment of depth over a wide range but for the purposes of bidding, basic designs should be submitted and prices entered using the following assumptions:

- The Bidder shall state kind, size and number of piles per leg for each tower type.
- The depth of pile from ground level is 15m.

All pile foundations shall be designed in accordance with the requirements of the following table.

Table: Foundation Design Particulars

Foundation Class	1	2	3	4	4W	5	5W	6
Foundation types	Rock anchor	Concrete pad and chimney	Concrete pad and chimney	Concrete pad and chimney	Concrete pad and chimney	Concrete pad and chimney	Concrete pad and chimney	Special: Piling, raft, enlarged concrete pad and chimney
Approximate soil description	Homogeneous rock	Fractured rock/hard clay/very dense sand	Stiff clay/dense sand	Firm clay/medium dense sand	Firm clay/medium dense sand	Soft clay/silt/ loose sand	Soft clay/ silt/ loose sand	Subject to detailed soil investigation
Net allowable design bearing capacity under ultimate load (kN/m ²)	>750	>400	>250	>150	>100	>50	>50	Subject to detailed soil investigation
Design uplift frustum angle	30°	25°	20°	15°	10°	10°	0°	As above
Approximate sub-soil investigation parameters:#								
Cohesive soil, N (blows/300mm)	-	>30	>19	>12	>8	>4	>4	As above
Cohesive soil, qc (kg/cm ²)	-	>80	>50	>30	>20	>10	>10	
Frictional soil, N (blows/300mm)	-	>40	>25	>17	>12	>7	>7	As above
Frictional soil, qc (kg/cm ²)	-	>160	>100	>60	>40	>20	>20	
Allowable lateral earth pressure # to (kN/m ²)								
Backfilled/disturbed soil:	Nil	Nil	Nil	Nil	Nil	Nil	Nil	As above
Undisturbed soil:	400	50 + 50H	50 + 25H	Nil	Nil	Nil	Nil	As above
Water table level	>0.5 m below Fdn level	>0.5 m below Fdn level	>0.5 m below Fdn level	>0.5 m below Fdn level	Grd level to <0.5 m below Fdn level	>0.5 m below Fdn level	Grd level to <0.5 m below Fdn level	As above
Concrete density kg/m ³	2240	2240	2240	2240	2240/1200*	2240	2240/1200*	As above

Foundation Class	1	2	3	4	4W	5	5W	6
Undisturbed Soil density kg/m ³	>2000	>1800	>1600	>1500	>1500/1000*	>1400	>1400/960*	As above
Backfill Soil Density kg/m ³	>1600	>1600	>1500	>1400	>1400/960*	>1400	>1400/960*	As above

* Submerged density is subject to verification by foundation test

Notes:

1. Allowable toe pressures for concrete mono block foundations may be 25 per cent higher than the specified bearing pressures shown.
2. Sub-soil investigation limits based upon results of Standard Penetration Test or Dutch Cone penetrometer tests use correlations between N (blows/300mm) or cone resistance q_c (kg/cm²) and allowable bearing capacity generally accepted for most soils.
3. Lateral earth pressure to be considered ignoring first 1.0 m below ground level. H = depth below ground level.
4. Fdn : Foundation. Grd : Ground.
5. For augered shaft foundations the maximum ultimate friction/adhesion stress assumed between concrete and soil, averaged over the depth of the foundation, shall be 60 kN/m².
6. Plain concrete density shall be 2240 Kg/m³, and Reinforced concrete density shall be 2400 Kg/m³.
7. Minimum concrete compressive strength (f'_c) shall be 300 Kg/cm² on Standard Cylinder Sample, or 350 Kg/cm² on Standard Cubic Sample.
8. Minimum rebar yield point (F_y) shall be 4000 Kg/cm².

22.5.4. Support Structure Earthing

(1) Earthing Angle Set

Each leg of foundations shall be earthed by earthing angle. A set of earthing angle consists of a galvanized steel angle of 45 mm wide and 5 mm thick and 1 m long, stranded copper conductor of 38 mm² and compression terminals at both ends. The steel angle shall be driven into ground underneath the concrete block before concreting and electrically connected to tower stub member or cleat by means of copper conductor.

(2) Counterpoise

Counterpoise shall be 7/4.0mm stranded galvanized steel wire. It shall be electro-galvanized to provide a coating of at least 520 grams of Zinc per square meter of surface.

The counterpoise shall be buried not less than 600 mm in the ground. Normally two counterpoise sets will be installed per tower connecting to individual leg members in an approved manner and shall run an opposite direction each other underneath the lines where possible.

The electrical resistance to earth of all structures shall be measured.

Wherever possible individual tower footing resistance shall be reduced to a value not exceeding 10 Ω (ohms), or as agreed by the Employer following resistance measurements.

22.6. Steel work detailing and manufacture

22.6.1. Detailing and fabrication

All towers shall be of self-supporting construction.

The towers shall be of approved design and construction. Unless otherwise approved, tension members, such as crossarm ties, which are liable to be set in vibration, shall consist of rolled steel sections and not flats.

The material used for main leg angles and stubs shall not be less than 6 mm thick and the material used for all other tower steelwork shall have a minimum thickness of 4 mm.

Welding shall not be used in the fabrication of any component used to form the tower structure.

Stub steelwork used to connect the tower to the foundation shall be at least the same section and steel thickness used for the lower tower leg which is attached to the stub.

The stub is considered as part of the foundation, therefore the safety factor of the foundation shall apply to the stub and cleats calculation

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

Horizontal members shall be detailed wherever possible, in such a way, as to place the horizontal flange on top.

No bolt hole shall, before galvanizing, 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 tower joints.

The distance between the centre line of any hole and the member end shall be in excess of 1.5 times the hole diameter. The distance between the centre line of any hole and the edge of the member shall be in excess of 1.25 times the hole diameter. Hole to hole distance shall not be less than 2.5 times the bolt diameter

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

The holes necessary for accommodating the specified earthing counterpoise connections shall be provided on each leg of every tower and extension and the earthwire peak.

Suspension insulator sets and earth conductor suspension assemblies shall be attached to the tower such that the point of transverse rotation is on a full bearing surface.

All attachments shall be of 'hinge' type. Ubolt/shackle attachment type shall not be allowed

Provision shall be made on all tower types for the attachment of stringing and maintenance equipment to the cross-arms.

Approved means shall be provided on all towers and extensions to avoid risk of livestock being caught and injured in the angles between tower members.

Towers shall be equipped with approved devices immediately above each suspension insulator attachment point to prevent birds perching above the insulators.

22.6.2. 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 10025 for grades S235JR and S355J0 steel or equivalent from other approved 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 or other defects. Steel sections shall preferably be ISO Standard sections chosen with a view to avoiding delays in obtaining material.

High tensile steel when stored in the fabricator's stock-yard 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.

22.6.3. Bolts and nuts

All metal parts shall be secured by means of bolts and nuts and single washers. The minimum diameter shall be 12 mm.

All bolts and nuts shall comply with BS 4190, BS EN 20898 or other approved standard and screw threads shall be to metric standards. Bolts and nuts shall be of steel, with hexagonal heads. Screw threads shall not form part of the shearing plane between members, any thread in the bearing plane shall be to the approval of the Engineer. Bolts of any given diameter shall be of one grade of steel and marked for identification.

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.

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. Galvanising shall be in accordance with this Technical Specification.

When in position all bolts or screwed rods shall project through the corresponding nuts, for a minimum of two full turns but such projection shall not exceed 10 mm. Suitable bolt grip tables shall be provided to demonstrate compliance with the above requirements.

All bolts shall be supplied with nuts and flat washers.

22.6.4. 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 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.

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 1 per cent of the members corresponding to each type of tower shall be selected at random and assembled to form complete towers in the presence of the Engineer at the Manufacturer's Works.

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

22.6.5. Erection marks

Before leaving the Manufacturer's Works all tower members shall be hard stamped 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 located on the member so that, after assembly and erection, all members can be individually identified.

The erection marks shall be stamped before galvanizing and shall be clearly legible after galvanizing. Care shall be taken to distinguish between various grades of steel.

The erection marks shall incorporate the standard tower nomenclature as given in this Technical Specification.

22.7. Galvanizing

22.7.1. General

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

Galvanizing of all material, except core wires of line conductor, earth conductor and counterpoise cable shall be in accordance with BS EN ISO 1461 and BS 7371 Part 6 and shall be applied by the hot dip process to provide thickness of zinc coating of 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.

Galvanizing of steel core wires of line conductor, earth conductor and counterpoise cable shall be in accordance with IEC 61089 and BS EN 10244-2 or other approved standard and shall be applied by either the hot dip or electrolytic process. The zinc coating shall be smooth, clean, of uniform thickness and free from defects.

All steel tower materials shall be treated with a sodium dichromate solution immediately after galvanizing.

The preparation for galvanizing and the galvanizing itself shall not adversely affect the mechanical properties of the coated material. Tests shall be carried out as specified elsewhere in this Technical Specification.

Sherardizing or other similar process shall not be used.

The Contractor shall keep available on site an instrument suitable to determine the thickness of galvanized coatings on steel members.

22.8. Temporary Bypass and Emergency Restoration System (ERS)

22.8.1. General Requirements

Construction of LILO works would surely demand for outages on the existing 400kV Suswa-Isinya double circuit (D/C) transmission line and 220kV Line in Line out to 220/66 kV Kimuka substation. Considering the importance of these lines, prolonged outages shall not be possible and as such durations of outages shall be limited. To facilitate smooth execution of LILO works and limit the outage durations on the existing lines and by extension the Country's transmission system, construction of temporary bypasses on both the transmission lines shall be required. These bypasses shall utilize Emergency Restoration System (ERS) structures with all associated accessories, whose supply and installation including recoveries shall form an integral part of this contract scope. The ERS materials inclusive of all requisite tools supplied shall be handed over to KETRACO upon recovery and at the end of the Contract.

The specific work scope shall include but not be limited to the following:

- (a) Survey and complete design for the temporary transmission line bypasses both for the 400kV Suswa-Isinya double circuit (D/C) transmission line and 220kV Line in Line out to 220/66 kV Kimuka substation. This shall include, but not limited to, survey, profiling, and design of stay-works of existing towers as maybe appropriate. Profile designs for adoption in bypass works and installations shall adopt applicable electrical clearances as specified for the 400kV work scopes.
- (b) Design, manufacture, packing, supply, and delivery to site of the complete ERS structures with all the necessary components and accessories as detailed in the ERS specifications section. Exact quantities for the ERS structures with all the requisite accessories maybe varied subject to final design of the temporary bypasses which shall be part of Contractor's scope.
- (c) Supply of complete set of conductors (Phase, ACS earthwire and OPGW) with all requisite accessories and fittings inclusive of joints etc. to realize work completion related to the scope.

- (d) Supply of all necessary tools relating ERS works as outlined herein this specification.
- (e) Installation of temporary bypass works on both the 400kV Suswa-Isinya double circuit (D/C) transmission line and 220kV Line in Line out to 220/66 kV Kimuka substation to allow for completion of the related LILO works. For the case of OPGW splicing works, the same are part of the scope.
- (f) Recovery of all ERS Structures with all the requisite accessories and bundling of the same to KETRACO's approval and packaging them in Containers for storage at the yard within the substation area or to a site as shall be directed by the Engineer. The containers shall have suitable storage systems and shall be supplied as part of the scope.
- (g) Provision of requisite training to KETRACO operations staff to impart knowledge and skills on ERS installation and recovery works to be able to undertake restoration works independently with the materials and tools supplied as part of the work scope.
- (h) Identification and acquisition of the required wayleave trace for construction of the temporary bypasses (Both for the 400kV Suswa-Isinya double circuit (D/C) transmission line and 220kV Line in Line out to 220/66 kV Kimuka substation) shall be the Contractor's responsibility and the cost of which inclusive of any compensation costs to owners of affected land parcels shall be deemed incorporated in the Contract price for the bypass works.

22.8.2. Technical Specification for ERS

This section describes the technical requirements for the supply, installation, and restoration of an Emergency Restoration System (ERS). Each ERS will consist of all necessary parts, services, and all other equipment necessary to restore a damaged or destroyed permanent transmission tower in the event of an emergency. In the context of this contract, the same shall be necessary to allow for rerouting of existing transmission lines to allow for undertaking of LILO works with minimal outages on the existing power system. The ERS towers shall be compatible for KETRACO's transmission system comprising of 132kV, 220kV and 400kV A.C as well as 500kV D.C voltage levels.

Scope of Supply

This section documents requirements necessary for the column sections, the foundations, the articulating gimbal joint, the guy plates, the anchors, the guy wire, the guy wire accessories, the insulators, the conductor hardware, construction tools, spare parts, training etc. as maybe appropriate.

The ERS supply scope shall include but not limited to the following: -

- a) Design, manufacture, packing, and delivery, training

- b) Supply of one (1) set of erection & special tools required for installation and restoration of the ERS requested by the Employer in this document.
- c) Five-day field training to cover ERS tower assembly, erection, dismantling, storage and maintenance of ERS.

As part of the scope, the Contractor shall provide comprehensive transportation, erection, storage and maintenance manuals along with requisite guidelines.

Scope defined herein is in addition to the general scope detailed in section 1 of this document relating complete bypass works scope and ERS supply.

Service Conditions

The Emergency Restoration System towers shall be suitable for continuous operation outdoors in tropical areas with the following specific characteristics in addition to what is specified for the 400kV towers:

- a) Altitude of up to 2200m above sea level
- b) Relative humidity of up to 90%
- c) Average ambient temperature of +30°C, with a minimum of -0°C and a maximum of +40°C
- d) Heavy Saline conditions along the coast.

General Technical Conditions

The following provisions shall supplement all the detailed technical specifications and requirements brought out in the accompanying technical specifications which shall be fully complied with for the scope.

Drawings

All drawings submitted for the ERS shall be in sufficient detail to indicate the type, size, arrangement, dimensions, material description, bill of materials, weight of each component, etc. for ease of assembly.

Each drawing submitted by the Contractor shall be clearly marked with the name of the KETRACO, the unit designation, the specification title and the name of the project in addition to other requisite details like manufacturer et c. All titles, notes, markings and writings on the drawing shall be in English. All dimensions should be to scale and in metric units.

Manufacturing Certification

The manufacturer of the ERS must be ISO 9001:2015 certified.

The bidders shall include in their submission a manufacturer's authorization.

Testing

The manufacturer shall document the testing process, showing results for all tests. Testing shall be in accordance to IEEE 1070-2006 and IEC 61284. Type test results for the following tests shall be submitted as part of the ERS documentation: -

- a) Compression of sections
- b) Bending of sections
- c) Torsion of sections
- d) Combined Compression and bending of sections
- e) Ultimate bending - bolts / welds
- f) Load test on Guy Wires attachment (Universal Bracket)
- g) Ultimate capacity test on bolt and nut assemblies
- h) Buckling test on sections
- i) Compression test on the Articulated Base
- j) Transverse test of the Articulated Base
- k) Capacity validation test
- l) Dimensional test

Workmanship

The following requirements shall be taken into consideration during the manufacturing process of the ERS towers.

Process	Requirements
General	<p>All works shall be performed using the best modern practices of the industry. All applicable standards shall be stated. Materials shall be new and free from any defects or irregularities.</p> <p>All components of the same design and designations should be identical; like components should be interchangeable. All corners shall be rounded, and sharp edges shall be smoothly finished.</p>

Fabrication	Fabrication shall not commence until the Employer or Employer's representative has approved the related drawings. Best modern practices to be used in manufacture and fabrication of all types of materials.
Bending	All bending shall maintain sufficient thickness of material in order to provide full strength without impairing the materials.
Cutting	Cutting of plates and structural shapes shall be guided by electrical and mechanical means to assure a neat accurate cut. Cuts shall be clean and free from sharp edges.
Welding	Any welding, if necessary, shall be to ISO 3834 for "Quality requirements for fusion welding of metallic materials". All welded points shall be completely sealed. There shall be no voids or seams between joining surfaces into which fluids may enter.
Drilling and Milling	All load bearing holes shall be drilled, and all slots shall be milled in all material thickness. Punching of the holes or slots is not allowed. The ultimate Bending strength of the welds shall be stated by the manufacturer.

Qualifying Requirements

The ERS manufacturer must have been in existence for the past ten (10) years. The type of tower offered must have been in production for a similar period and the manufacturer must have supplied at least three hundred (300) units worldwide in the past three (3) years with at least two (2) references in Africa.

The tower type on offer shall be in strict conformance to the testing requirements of IEEE 1070-2006 and IEC 61284-1997 or latest versions. A certified copy of the Design Test Report to the applicable standards shall have to be provided as part of test records.

Other codes or standards that are not relevant to Emergency Restoration Systems are not allowed for substitution.

ERS Towers

The following restoration scenarios for the respective towers should be utilized:

- (a) Single Circuit, three vertical phase, 400 kV Angle (0°-30°-line Angle) Tension Structures, and
- (b) Single Circuit, three vertical phase, 400 kV Tangent (0°-5° Line Angle) Suspension Structures.

Towers to be used at 400kV should also be suitable for use at lower voltages of 220kV and 132kV. The towers should have modular components which can be reconfigured into economical designs at the different voltages.

When restoring a downed transmission line, it is assumed that the ERS towers will bypass the fallen towers off to one side thus ensuring that the original line can be reconstructed.

For this reason, two single circuit towers cannot be replaced by a single double circuit tower. In general, a transmission line using ERS will bypass to the side of a permanent line, and it is envisioned that the ERS towers are only suitable for single circuit towers. ERS towers may replace double circuit towers by using two single-circuit ERS.

The design of ERS towers should be suitable for spans as specified for the 400kV transmission line LILO works. The loading conditions inclusive of safety factors shall be similar as those for normal 400kV towers safe for Broken Wire Condition which shall not be considered in the case of ERS tower. The basic wind speed (3sec gust) for which the ERS tower designs shall adopt shall be 40m/s for it to be applicable in other areas as well in the Kenyan context.

The towers should use a configuration which is suitable for a vertical disposition of conductors.

Structure Components – General

The ERS structure shall be made of aluminum alloy and be of modular construction allowing easy adoption to various line designs / configurations.

All components must be fully exchangeable regardless of whether they are used in suspension, angle or dead-end conditions.

To ensure uniform compatibility of the ERS supplied under the contract, all components of modular restoration structures shall be geometrically identical / mutually compatible.

The mast sections shall be lightweight, made of high strength aluminum alloy. The shape, size, dimensions, and weight of individual components shall be such that manual handling of the components is possible.

The structure column section shall not be more than 3.0m in length. Also, the weight of each section of ERS tower shall not exceed 150kg.

The structure should include an integrated rail system on each corner, which allows sliding of the gin pole and the safety devices from the bottom to the top of the tower without any interruption or disassembly.

The structure modules should have sufficient attachment points per face to allow attachment of a wide range of accessories (universal brackets, insulator brackets, platforms, etc.).

The structure column section shall be of only one size.

All materials making up the structure must be protected from corrosion and capable of outdoor and warehouse storage for a period not less than 20 years with no required maintenance.

A minimum of 20% extra connecting bolts, nuts and lock washers shall be supplied with each column section.

Foundation Plates

The foundation plates shall be made in accordance with Figure 4 in IEEE Standard 1070.

They shall be designed to rest on the ground surface with anchors or metal stakes to avoid sliding and shall be made of light weight, high strength material.

The base area of the foundation plate shall be designed to work safely on regular earth bearing capacity soils (150kPa or more).

Articulated base

The articulated base shall be designed for fixing on the foundation plate allowing assembly of structures over it and shall allow leaning as well as a rotation of 360 degrees in all directions.

It shall minimize column eccentricity and eliminate torsion loading on structures due to its rotational capability and shall be made of lightweight, high strength material.

Anchoring assembly

Depending on the prevailing soil conditions, different anchoring arrangements shall be required.

The suitable anchoring assembly for following type of soils shall be supplied:

- (a) For soft soils.
- (b) For normal or average soils
- (c) For hard rock soils.

Each anchor shall have the following characteristics: -

- (a) Terminate with a triple eye nut suitable for attachment of preformed type guy wire grips.
- (b) A minimum strength of 150kN. The actual holding strength of the anchor may be less than this depending on the soil. The anchor itself should be able to withstand 150kN of load.
- (c) Shall be hot dip galvanized as per ASTM A153 or its latest version.
- (d) These anchors shall be capable of being installed with a hydraulic jack hammer and be self-locking when set in place with the hydraulic pulling device, (i.e. a load locker).
- (e) The minimum bearing area of these anchors shall be 450cm^2
- (f) These anchors should be supplied with a 1m extension rod and a 2m extension rod.

- (g) A quantity of cross-plate anchors having a minimum bearing area of 1.6m^2 shall be provided complete with a 3m extension rod that ends in a triple eye attachment.
- (h) Rock anchors must be suitable for installation in solid rock shall be supplied with a 1 m extension rod.

Anchors with an extremely large bearing area are not required.

Insulators

The ERS shall be equipped with all necessary insulators, fittings & accessories for conductors.

Every insulator body shall have a durable and legible trademark and year of manufacture as well as the rated combined mechanical strength in kN.

The insulators shall be of the modular design so as to be able to use for all required voltages using the same size insulator in series. (1 piece for 220kV / 132kV and 2 pieces connected together for 400kV).

Guy Wire and Grips

All guy wires shall be supplied in spools of 2000 m or of 1000 m.

Preformed helical grips suitable for attachment with the above guy wires shall be provided. The strength of the preformed grip should be equal to the strength of the guy wire.

Guy wire thimbles shall be provided for effective attachment of guy wires to anchors or guy plates. The guy wire thimbles should be appropriately sized for attachment with the guy wire specified.

Anchor attachments ending in a thimble eye do not require an additional guy wire thimble.

Thirty percent (30%) additional spare guy wires and fifty percent (50%) additional compatible helical preformed grips and guy wire thimbles shall be supplied beyond the minimum required to build any of the ERS Structures specified herein this specification section.

Conductor Hardware

Ultimate strength of each hardware component shall be greater than 140kN, except as noted below.

All ferrous materials shall be galvanized in accordance with the latest revision of ASTM A153. All materials shall be free from burr, sharp edges, lumps and dross and shall be smooth so that any connecting parts may be assembled or disassembled easily. All threaded parts shall be galvanized after threading and excessive zinc shall be removed from threads. Drilling shall be made before galvanizing. All nuts and lock nuts shall be re-tapped after galvanizing and shall be capable of being turned on the bolt threads easily without using a wrench. All cotter pins shall be made of stainless steel in order to avoid oxidation.

A minimum number of different types of hardware shall be provided in order to minimize confusion during emergencies. All insulator/hardware assemblies shall be designed to attach to the structure in 1.45m increments to correspond to the column section lengths supplied in order to minimize confusion during emergencies.

Only one size of shackle shall be supplied. These shackles shall be capable of fitting all hardware and guy wire anchoring assemblies. These shackles shall have a minimum ultimate strength of 267kN and be supplied with a bolt, nut and cotter.

Bolted tension clamp shall be supplied to fit the range of conductors specified.

The conductor and overhead shield wire suspension and tension clamps shall have a minimum ultimate strength of 120kN and shall be capable of allowing a minimum 15° line angle at the suspension clamp.

A quantity of 156kN turnbuckles corresponding to at least one half the quantity of suspension insulators, shall be provided for take up of hardware assemblies. Minimum take up shall be 0.3 m.

Routine mechanical pull tests shall be applied to all hardware items in accordance with IEEE Standard C135.61-1997 or its latest version. All galvanized wire rope with swaged fittings shall be proof tested to one half (50%) their ultimate strength.

Test reports shall be prepared in detail containing all the data, number of tested samples and other necessary information as required by IEEE Standard C135.61-1997 or its latest version.

A minimum of ten percent (10%) additional spare hardware shall be supplied beyond the minimum required to build any of the ERS Structures.

Guy Strain Insulators

An additional quantity of fiberglass guy strain insulators, having a minimum length of 2.5m, shall be provided to provide electrical clearance for guy wires. These guy strain insulators shall have a minimum strength of 150kN. These guy strain insulators shall be provided with sufficient hardware for connecting them together when a greater length is required.

The quantity of guy strain insulators should be sufficient to build the structures specified. However, since these guy strain insulators are typically installed due to field variables (e.g. adjacent energized lines, proximity of down guys to conductors on tension structures a minimum of 120 guy strain shall be supplied per ERS set. More may be supplied if required by the design.

Suspension insulators may be used instead of guy strain insulators.

Gimbal Joint

The gimbal shall be made in accordance with Figure 3 in IEEE Standard 1070.

Guy Plates

The Guy plates shall be made in accordance with Figure 2 in IEEE Standard 1070.

Box Sections

The Box Sections shall be made in accordance with Figure 5 in IEEE Standard 1070.

Tools

A quantity of all necessary construction hydraulic tools and hand tools shall be provided for assembly, erection, and disassembly of a complete ERS structure.

Special tools and equipment

The supplier shall offer requisite number of special tools and equipment required for erection of the ERS towers. The items/tools to be supplied shall include but not be limited to the tools/items described as follows:

- (a) Working platform for clipping the conductors into post insulator assemblies.
- (b) Sliding gin pole capable of being attached to corner rails of the column section.
- (c) Rotation gin pole capable of rotating at least 2 sections of horizontal mast section assembly.
- (d) Grip hoist or Tirfor – 1.5 tons or more with at least 70m of cable.
- (e) Sliding linemen safety devices capable of being attached to corner rails of the column section.

In addition to the above, the Contractor shall also offer the following Anchor installation kits as part of the special tools. Each anchor installation kit shall have:

- (a) An appropriately rated petrol/Diesel hydraulic power unit, capable of delivering 20-35 lpm at a maximum pressure of 2000 PSI (13790 kPa).
- (b) A compatible hydraulic driving hammer for installing the anchors in soil
- (c) A compatible hydraulic rotary hammer for drilling holes in rocks for installing rock anchors
- (d) A compatible hydraulic proof testing unit for locking and proof testing soil anchors and proof testing rock anchors,
- (e) All necessary and compatible hydraulic hoses, rock drill bits (5 per rotary hammer), and torque installation tools for the rock anchors. Hydraulic hoses shall have quick-disconnect type couplers.

Construction Tools

Each set of construction tools shall consist of the following:

- (a) One (1) set of gin pole made from aluminum alloy will be provided to be fitted into the provision for the lifting tool described in *Structure components – General*. The gin pole shall be suitable for simultaneous lifting of a column section and a post insulator support section. All necessary snatch blocks and rigging ropes will be supplied with the gin pole. All ropes shall be polyester with a minimum diameter of 15 mm. The gin pole shall have a davit arm to keep loads clear of the structure while being raised by a capstan hydraulic power unit, and low friction bushings for rotation of the load. A slider shall clamp to the corner members of the emergency restoration structure and allow the gin pole to be raised on the structure using manpower or a pulley and the capstan winch.
- (b) A 1/2-ton hydraulic capstan winch with foot pedals shall be provided with each gin pole for controlling the speed of the capstan. This capstan shall be capable of being powered by the same hydraulic power unit used to install the soil anchors stated in *Special tools and equipment*. The capstan shall be mounted to a plate that can be anchored to the ground.
- (c) A quantity of eight (8), high-quality 2-ton Tractel Tirfor-style grip hoists will be provided with 45 m of 7/16" (11.5 mm) wire rope. Forged safety hooks shall be provided on both ends for the grip hoist body and for the 7/16" wire rope.
- (d) A quantity of twelve (12), reversible ratchet for hand installation of ERS bolts. The reversible ratchet shall be made of forged material and provided with a 1/2" square drive and socket to fit the ERS bolts used to join the tower sections. A quantity of twelve (12) forged closed box wrenches will also be provided as an assembly tool.
- (e) A quantity of six (6), three (3) ton reversible chain hoists will be provided for tensioning of guy wires and conductor. Forged safety hooks shall be provided on the reversible chain hoist. The hook throat openings shall be a minimum of 35 mm and sufficient chain shall be provided to have a standard lift of 3m.
- (f) A quantity of nine (9), pulling eyes that attach to the anchor rods and allow placement of safety hooks for either the 3-ton chain hoist or the 2-ton grip hoist shall be provided.
- (g) A quantity of nine (9), automatic wire grips suitable for gripping the 9/16 x 19 strand guy wires shall be provided. They shall have a minimum safe working load of 65kN. The grips shall be made of forged steel and have a bail suitable for attachment of the 3-ton chain hoist safety hook.
- (h) A quantity of one (1) 3m, 16mm diameter double loop 6x37 steel wire rope slings shall be provided. These slings shall have a loop eye swaged at both ends and have an ultimate strength of 100kN.
- (i) A quantity of one (1) 3m, 75mm wide, two (2) ply nylon slings shall be provided for lifting purposes. The slings shall have a twisted eye at both ends and have a rated capacity of 40kN when loaded vertically.
- (j) A quantity of eight (8) 1.8m long, round endless slings, with a rated capacity of 24kN when loaded vertically, shall be provided for temporary guying of this structure.

- (k) One (1) self-contained 6-ton hydraulic wire cutter shall be provided. This self-contained hydraulic cutter shall be capable of not only cutting the 9/16 x 19 strand guy wire but also the ACSR conductor and the overhead static wire.
- (l) For each foundation, four (4) foundation stakes of 25mm diameter and 1.2 meters in length shall be provided for staking the foundations to the ground. The stakes shall have a pulling eye at the top for retracting the stakes after use.
- (m) A quantity of six (6), aluminum conductor lifting hooks shall be provided. These lifting hooks shall be made from high strength aluminum alloy and shall a minimum ultimate strength of 45kN.

Certified Fall Arrest Device

The ERS should include a sliding linemen safety device designed to be attached on the side rails of the tower and slide from bottom to top, without interruption.

The Fall Arrest Device should be certified by an accredited testing and certification organization and be in full compliance with a relevant applicable legislation acceptable to Employer.

Containers for ERS

In addition to the usual packaging of the ERS towers and its components, tower shall be neatly placed and arranged inside a non-returnable steel container designed for ERS storage. This will prevent tower and its components from any losses due to pilferage and/or being misplaced during trans-shipment, loading and unloading at the port of entry and transporting to its final destination. Cost of this work to be done by the manufacturer shall be included in the bid price of ERS towers and its components.

In addition, a sufficient quantity of 20-foot ocean cargo storage steel containers shall be provided. These containers shall be designed or outfitted for holding all the hardware, insulators, guy plates, guy and anchor accessories, tools and equipment for erection and installation (including the gin pole and manta ray machine) and nuts and bolts. The insulators shall be held in PVC conduit tubes in order to protect them from adjacent insulators. All hardware and nuts and bolts shall be stored in ferrous metal wire containers. There shall be easy access to the containers and easy access to the parts in the containers. The 20-foot ocean cargo storage containers shall be lockable to prevent loss. All ERS components including of the large ERS structure components and guy wire shall be stored in these 20-foot containers. These containers shall be kept by KETRACO at the completion of the work.

22.8.3. Testing and Inspection

General

All materials to be supplied relating ERS shall be made available for inspection and test by KETRACO representatives during manufacture and it is the Contractor's responsibility to advise KETRACO when the materials are available for inspection. Not less than 45 days' notice of all tests shall be given to KETRACO's representative in order that he may be represented if he so desires.

The ERS Towers, accessories and fittings shall be tested in accordance with the relevant requirements of IEEE1070-2006 or its latest versions and this specification. It is the responsibility of the Contractor to perform or to have performed all the required tests as specified.

Routine and sample test reports for the ERS Towers, Accessories, and fittings to be supplied shall be submitted to KETRACO for approval before shipment/delivery of the goods. The test reports shall include Verification of Dimensions, Mechanical Type Tests and Electrical related tests.

The tests shall be witnessed by KETRACO's representatives at the factory. The manufacturer shall carry out the tests stated in the Tests section of this Technical Specification in accordance with the conditions thereof and the latest applicable Standards or Recommendations and such additional tests as in the opinion of KETRACO's representative are necessary to determine that the materials comply with the conditions of this Specification either under test conditions (in the Manufacturer's Works, on the Site, or elsewhere), or in ordinary working.

All materials to be supplied shall be subjected to and shall withstand satisfactorily such routine tests as are customary in the manufacture of the types of material included in this work scope.

All tests and inspections shall be carried out to the satisfaction of KETRACO's representative and in his presence, at such reasonable times as he may require, unless agreed otherwise.

The original and copies of test records whether or not they have been witnessed by the KETRACO's representative shall be provided.

No inspection or waiver by KETRACO shall relieve the supplier from his liability to supply the materials in accordance with the Contract or exonerate him from any of his guarantees.

Type tests necessary for proving compliance with the Specification and not specifically mentioned in the Schedules shall be undertaken at no extra cost to KETRACO.

Prior to the tests, the manufacturer shall submit an outline of the procedures and tests in its plans to demonstrate fulfilment of the requirements specified in the subsequent sections of the detailed technical specifications.

Test reports

The following test reports shall be provided.

- (a) Mechanical type test of the tower system
- (b) Insulator test reports of composite insulators

Acceptance tests

For the acceptance test regular tests, not limited to the underlisted, will be performed on the stated items below.

- (a) **Steel parts:** Factory acceptance tests; Visual inspections; Zinc thickness measurement and Dimension measurement, measurement whether all parts meet the requirements of the technical specifications.
- (b) **Insulators:** Visual inspections after delivery.
- (c) **Total guy assembly:** Tensile strength test on the total assembly.
- (d) **All components:** a total assembly test will be performed to test whether all components fit together.

Cost of Tests/Inspections

The cost of all tests and inspections shall be borne by the Contractor.

Prices for test shall include manufacture, supply, erection and dismantling of all the materials and provision of all test facilities. Witnessing costs shall be as specified in other related sections of the Employer's requirements.

Field Training

The Supplier shall be required to impart training to KETRACO personnel at site preferably at the time of installation of the ERS towers for the bypass works. The training shall include actual field training imparting firsthand knowledge about the assembly of modular structures, fixing of foundation plates, erecting of structures on the foundation, guying the tower with anchoring arrangement and stringing of conductor. Specific instructions shall be given for installation of ERS using cranes, gin pole and hydraulic hoisting equipment.

The cost for this training shall be deemed incorporated in the contract price. The cost of transport to site, and meals and refreshments for the field training shall be borne by the contractor.

23. Survey and Setting Out

23.1. General

The Contractor shall execute the works in accordance with the material schedule, provided that the works shall be subject to the modifications and variations due to the results of the survey.

23.2. Survey

The Contractor shall be responsible for the complete survey of the works. The survey shall include all necessary clearing of trees and vegetation and the setting out of the bearing for each section of line, the measuring and levelling and production of all necessary plans, profiles, route maps and tower schedules; the location of positions on the profiles in accordance with the Specification and all necessary setting out support for construction, all to the approval of the Engineer. All surveying measurements, both linear and vertical, made on the line route shall be closed on standard reference points, or, where such points are not available the measurements shall be closed by alternative reciprocal measurements, the degree of closing error to be approved by the Engineer.

Angle points are to be tied to Kenya National Local Grid (coordinates and elevations of points).

The levels along the surveyed centre lines shall be taken as follows:

1. On flat ground, at intervals not longer than 20 m.
2. At each depression, ditch or rise when the ditch is deeper than 400 mm or the rise is 200 mm high or higher.
3. On sloping ground, at points where changes of slope occur and at intervening points not more than 30 m apart.
4. On steeply sloping ground, at intervals of 20 m, if practicable.
5. At each canal crossing to the water level at each side and determined maximum water level.
6. At the centre point of each tower.

The Contractor shall survey all roads, major canals, pipelines, power lines and telecommunication lines wherever they cross the route of the proposed line and shall indicate the following:

- a. Roads:
 - i. Surface and class of road, eg first, second, paved,
 - ii. Names of adjacent towns,
 - iii. Angle of crossing,

- iv. Chainage of centre and both sides of the road,
- v. Elevation of pavement and shoulders and ditches,
- vi. If the road is curving additional data to define the curve of the road,
- vii. The location of any mile post or sign board with their description, if located within 100 m of the crossing point.
- b. Pipelines:
 - i. Crossing chainage,
 - ii. Crossing angle,
 - iii. Number and size of pipes, if exposed,
 - iv. Trench width, if buried,
 - v. Location of any identifiable mark on the pipeline route.
- c. Power and telecommunication lines:
 - i. Type of line,
 - ii. Voltage,
 - iii. Crossing angle,
 - iv. Crossing chainage,
 - v. distance to the nearest support on either side of crossing, and if one is within 50m of crossing, the support beyond it,
 - vi. The ground level and the level of the highest conductor at each of the support position above and the crossing point,
 - vii. A pole or a structure number and the line name.

If a road, a pipeline or a power line lies within 100 m of the survey centre line, chainage data and offset measurements shall be made to establish the proximity of the feature.

If a route is located along a street, full details of the street cross section at intervals of not more than 200 m and/or at places of varying street width shall be taken. Such details shall be agreed with KETRACO.

Where KETRACO or the consultant has commissioned a preliminary survey of the line route, either by aerial photography or by land based methods, the resulting data shall be made available to the Contractor. Tower sites determined by this survey shall be incorporated in the Contractor's survey and line profiles. It shall remain the

responsibility of the Contractor to satisfy himself as to the accuracy and suitability of any preliminary profile so provided.

Where the line route has been established by KETRACO, the Contractor may expect that at the time of Award of Contract KETRACO will be in a position to indicate to the Contractor sufficient firm details of the location of terminal and angle positions for the Contractor to commence his survey with reasonable continuity of operation in the major sections of the lines.

After approval of the line route, the contractor shall clearly mark the points of angle points by concrete beacons with the round steel bar in the centre. The concrete mixture shall be 1:1:4, beacon minimum sizes 200 x 200 x 600 mm and the steel bar 10 mm diameter and 500 mm long.

Intermediate beacons, of the same design, shall be embedded at the intervals of approximately 1 km between angle points.

The Contractor shall be responsible for marking in an approved manner any special trees which, in his opinion, require to be felled or lopped in order to carry out a survey.

Where the route of the line is parallel to an existing line adequate falling clearance is to be provided between adjacent supports and conductors to the approval of the Engineer. The nominal spacing between the centres of the adjacent parallel transmission lines shall be as given on the tender drawings.

23.2.1. Profiles

The existing overhead line profiles are to be obtained from the Client and updated accordingly.

The ground profiles (longitudinal) are to be prepared by the Contractor for the complete route length. Unless otherwise approved, the scale shall be 1:200 vertical and 1:2000 horizontal. In addition to showing the line route ground line and tower (centre point) location, the following features, where applicable, shall be shown;

- a. continuous longitudinal chainage
- b. ground line
- c. line of lowest conductor at the maximum still air sag specified
- d. clearance curve or clearance line
- e. indication of side slopes where these affect clearances (account being taken of conductor under 45° swing angle conditions)
- f. all the numbered pegs identifying the survey points and the towers locations. For each peg the plan will show partial and progressive distances and elevation
- g. buildings, rivers, roads, power and telecommunication lines, and other obstacles to be crossed

- h. sections unsuitable for tower locations
- i. vegetation and nature of ground
- j. tower locations, tower number and type of tower with type of extension if necessary
- k. angles of deviation, spans, equivalent spans.
- l. sag templates used.

The Contractor shall be responsible for checking the minimum weight condition on suspension and tension structures under assumed conditions of still air for any conductor temperature between the specified minimum ambient and maximum conductor operating temperature. The mass of conductors carried by any suspension insulator set shall not be less than 35 per cent of the total mass of the corresponding line conductors included in the two adjacent spans. Similarly the mass of conductors or magnitude of the uplift supported by any tower shall not exceed the specified design limitations. For supports that carry both dead weight and uplift from adjacent spans special consideration shall be given to ensure that the vertical loadings are within the support design limitations. The Contractor shall be responsible for any alternations to the Works that may be required in order to comply with requirements or to give the specified minimum clearances.

If the Contractor proposes to prepare the line route profiles and to optimize the position of the towers by means of a computer program (PLS-CADD software) and plotter the input data is to be first agreed with the Engineer. For particular conditions it may be necessary for the Engineer to restrict the employment of maximum support extensions and also to include provision in the computer program for restricting costly special foundations. The software used shall be freely accessible to KETRACO for checking the line design and profiles. A copy of the software shall be handed over to KETRACO on completion of the project.

For final records, profiles shall be provided on A0 sheets and each sheet shall represent approximately 4 km of line.

The Contractor shall provide suitable diagonal profiles to enable accurate determination of foundation setting levels, tower leg extensions and, where required, foundation chimney extensions wherever there are side slopes that require such consideration. The diagonal profiles shall be to a scale not less than 1 to 200 and shall extend beyond the limits of the assumed foundation uplift frustum. Support setting levels shall be reflected in the longitudinal profile and be selected to preclude the requirement for structural members to be encased with concrete.

The overhead line route will maintain the following minimum horizontal clearances:

- 50 m: National Road, Railway track
- 30 m: Other Roads
- 100 m: to parallel pipelines subject to discussion with pipes owners

30 m: any area classified as hazardous.

No structure will be positioned so that any excavation or erection work will be closer than 30 m to a pipeline or major road.

23.2.2. Line schedule

The existing line schedules are to be obtained from the Client and updated accordingly.

23.2.3. Route map

The existing overhead line route maps are to be obtained from the Client and updated accordingly.

23.3. Civil Works

23.3.1. Sub-surface investigation and foundation class selection

The Contractor shall be responsible at his own cost for ascertaining that the foundations to be employed are suitable for the sub-surface conditions encountered at each tower site. For this purpose he will be responsible for classifying these conditions at each tower site at an early stage of the Contract. Results of any geotechnical investigations already carried out for KETRACO will be provided as reference.

After performing the tower spotting, the Contractor shall make a terrain reconnaissance, making probe or rock drilling tests at each tower location. Additional probe tests, as well as any other tests the Contractor deems necessary, should be carried out in areas of variable ground condition where the Contractor may wish to propose selective movement of some foundation locations.

Soil probe testing will be by means of an approved type of penetrometer or borer in order to give information on ground bearing properties of the various underground strata, to provide data which will aid in checking the compression and uplift design of the foundations and to provide data on underground water levels where they exist. Where the soil probing indicates the possibility of rock due to 'refusal' of the probe test, the Contractor shall confirm by carrying out further probe tests at an adjacent location or by drilling that rock, to confirm that an isolated boulder has not been encountered. Further tests subject to the approval of the Engineer may be required to determine the rock quality.

In addition, to correlate the probe tests and to confirm or adjust the parameters for standard foundations given for tender purposes in the Schedules, one in 10 tower sites shall be investigated during the profile survey by bore hole and one or more of the following methods – SPT, Dutch static cone penetrometer, dynamic penetrometer, shear vane, rock drilling and coring, plate bearing tests, laboratory testing (including triaxial shear testing, sieve analysis, soil densities, moisture contents and plasticity and expansion indices, as well as chemical analysis of soil and water). In addition trial pits shall be excavated to a depth of 3m, photos taken and probe and/or other tests performed at 0.5m intervals. This data shall be used for comparative purposes when excavating and testing the remaining foundations. Where foundation excavations are to be of the open cut type the properties of compacted backfill are also to be examined and tested and related to undisturbed soil properties in accordance with the schedule on foundation tests. The one in 10 tests shall generally be performed at equal intervals along

the line route but this may be reduced to one in 5 sites or less where ground conditions are identified to vary significantly.

Subject to the approval of the Engineer, the parameters obtained from the bore holes and sub-surface probe tests shall be classified into typical groups and employed in the designs of all foundations.

The Contractor shall be responsible for any subsidence or failure due, in the opinion of the Engineer, to insufficient care having been taken in his examination of ground conditions or in installation of the foundations.

The results of all soils tests shall be submitted to the Engineer together with any proposals that the Contractor may consider necessary to ascertain the parameters and dimensions for standard foundations given in the Schedules or the need for special designs.

Prior to construction the Contractor shall submit for approval his proposals for correlating the results of the soil tests with the parameters employed for the foundation design. These proposals shall also consider visual and manual checks and tests to be made after excavation and will be to the Engineer's approval.

The Contractor shall prepare and update the line Schedule for construction purposes that clearly indicates the class of foundation to be installed at each site and records the soil investigation data on which the choice has been made. The Schedule will be subject to approval of the Engineer prior to commencement of foundation construction.

When required by the Engineer the Contractor will be required to make arrangements for a comprehensive soils investigation to be carried out at any specified tower site, including deep borings and laboratory analysis of undisturbed soil samples and for a report and recommendation to be submitted. The Engineer may require that this work shall be carried out by an approved subcontractor at rates to be agreed.

23.3.2. Installation of foundations

- a. **General.** Foundation construction shall always be carried out with all due regard to the mitigation of any damage to the environment and in accordance with the findings of any Environmental Impact Assessments and Management or Monitoring Plans.
- b. **Site levelling.** From consideration of the impact on the environment it is normally preferable not to level sites, but to build the structures into the land form basically as it exists, using suitable steel leg extensions on the towers or concrete extensions on the foundations. However, in exceptional cases, where tower leg foundations are located on the side of a hill or on a slope and it is decided that terracing, or cut and fill, is an option, full proposals for earthworks shall be submitted to the Engineer for approval before any excavation or filling takes place. Proposals shall show:
 - i. how rainwater run-off from the hillside is to be allowed for and diverted around the foundation;

- ii. how the exposed surfaces are to be protected against weathering and the possibility of erosion;
- iii. the full depth and details of the foundation, with particular note of the presence of fill material;
- iv. that the Contractor is aware of the possibility of slippage taking place and has taken precautions to avoid it.

Preference will be given to proposals that minimize the amount of disturbance to the terrain environment. Material that is excavated in terracing shall be spread in an appropriate manner in an area near the tower but in such a manner that no instability is caused to the terrain and the spreading causes no environmental distress.

- c. **Foundations.** A record shall be kept of each foundation installed including details of the strata of the ground throughout the depth of excavation, the presence or not of water during construction and liability to seasonal flooding, together with results of tests carried out and all other relevant information.

Where ground conditions necessitate, the foundation dimensions shall be increased and concrete added and/or reinforced as may be approved by the Engineer.

Where ground conditions are unsuitable for the installation of any standard or modified standard class of foundation the Contractor will be required to make arrangements to provide a piled or other special foundation as may be approved. The Engineer may require that such specialist foundation work shall be carried out by an approved subcontractor.

In ground which may be flooded at any time of the year and where the soil is such that enlarged pad or raft foundations may be employed economically the excavated subsoil remaining after backfilling shall be formed into a flat topped mound approximately 0.75 m high extending approximately 1 m beyond all sides of the tower base. The sides of the mound shall be battered to minimize the effects of erosion. The mass of the mound shall not be considered in the uplift capacity of the foundations. The foundation stubs shall be extended to allow for the change in ground level such that the encasing concrete extends to 300 mm above the level of the top of the mound. The cost of forming the mounds will be included in the total cost of the foundations.

In areas where black cotton is encountered the contractor shall make provision for importing backfill material.

- d. **Excavation.** During excavation, the Contractor shall take adequate precautions to prevent earth disturbances that might affect the safety of personnel, property and the Site Works.

Before excavations are commenced the Contractor shall submit his proposals with regard thereto for the Engineer's approval. Excavations shall be close timbered or sheeted, planked and strutted as and when necessary and kept free of water by pumping or other

means during the course of the work and shall ensure the safety of personnel working within them. The sides of excavations shall normally be vertical unless otherwise specifically agreed with the Engineer.

Should dewatering be necessary during excavation and concreting works due consideration shall be taken to ensure there will be no adverse influence on adjacent structures as a result of the lowered ground water table.

Written approval shall be obtained from the Engineer before explosives are used for excavating foundations in rock. The Contractor shall be responsible for complying with local regulations concerning the use of explosives and for the safekeeping and handling of explosives. Proper warning shall be given of all blasting operations. During operations involving the handling or use of explosives, the Contractor shall be responsible for the safety of personnel, Site Works and people or properties in the vicinity of the Site. The Contractor shall make good at his own expense any damage caused by the use or mishandling of explosives. No blasting is permitted near permanent work or dwellings.

Blinding concrete shall be provided under all concrete foundations at the base of the excavation for a thickness of at least 75 mm and shall be deemed to be included in the price of the foundations. In cohesive material the final 150 mm of ground above formation level shall only be removed immediately prior to placing the blinding concrete.

- e. **Stub setting.** Stubs for tower foundations shall be carefully adjusted to an approved template and shall be held in the correct position while the concrete for the foundation structure is placed. The templates shall not be struck until at least 24 hours after foundations have been completed nor before the completion of backfilling activities. The spacing and levels of the stubs after the templates have been struck shall be such as to ensure correct alignment of the towers without forcing of members during erection and shall comply with the construction tolerances stated under subclause j.
- f. **Formworks.** Formers shall normally be employed to produce the correct foundation shape and ensure no loss of aggregate or cement. All formers shall be sufficiently strong to withstand the pressure arising from the concrete during compaction and shall be capable of removal without undue disturbance to the concrete.

Formers may consist either of steel, timber or plywood elements.

The faces of the formers that are in contact with the concrete shall be cleaned and oiled or coated to prevent any concrete adherence to them and to facilitate their removal.

Formers shall not be removed before sufficient hardening of the cast-in concrete has taken place and in no case less than 24 hours after the concrete has been placed. Any concrete that has been damaged during formwork removal or is honeycombed must be removed by chipping to sound concrete and then repaired at the Contractor's expense and to the Engineer's approval.

- g. **Reinforcement.** All steel rod reinforcement shall be clean and free from loose mill scale, loose rust, oil and grease or other harmful matter and except at bends shall be truly straight before being surrounded with concrete. Evidence of steel quality, which shall be to an approved Standard such as BS 4449, shall be provided. The numbers, lengths, diameters, forms and positions of all reinforcing bars shall be in accordance with approved drawings.

The steel reinforcement shall be so connected as to form a rigid cage or mat. To prevent displacement before or during concreting, the bars shall be secured one to the other with 18-gauge soft iron wire. Sufficient precast rings or distance blocks shall be used between the reinforcement and the bottom and sides of the excavations to ensure the correct cover of concrete around the bars. The distance blocks shall be made of concrete of not less strength than that of the concrete in which they occur. The foundation reinforcement shall be bonded to the tower stub with 7/4 mm galvanized steel wire strand before concreting.

Steel rod reinforcement shall be bent cold in a manner that will not injure the material. Bending hot at a cherry red heat (i.e. not exceeding 840°C) may be allowed except for bars that depend for their strength on cold working. Bars bent hot shall not be cooled by quenching.

Bends, cranks or other operations on reinforcing bars shall be in accordance with approved drawings. Where splices or overlapping in reinforcement are required the bars shall unless otherwise approved have an overlap as specified in BS 8110.

- h. **Concrete.** Unless otherwise approved, concrete for foundations and for encasing concrete shall be to Design Mix Grade C25 to BS 5328 (BS EN 206-1 AND BS 8500) with minimum cement content of 300 kg/m³ concrete, maximum water cement ratio of 0.6 and maximum slump of 75 mm.

The concrete mix is to be designed by the Contractor and submitted to the Engineer for approval in sufficient time to permit the necessary tests on compressive strength to be carried out prior to construction commencing.

All cement used shall be of Portland or other approved composition obtained from an approved maker. Portland cement shall conform in all respects to BS 12 (BS EN 197-1). Where Portland cement concrete may be liable to chemical attack sulphate resistant cement to BS 4027 may be used where approved. Cement shall be stored in an approved manner.

All aggregates shall be obtained from sources approved by the Engineer and shall be clean and free of clay, earth, organic matter, salt or other impurities. The aggregate shall comply generally with the requirements of BS 882.

Coarse aggregate shall be gravel or broken stone of angular or rounded shape, of approved grading and shall pass a mesh not more than 40 mm square for foundation concrete or 20 mm square for encasing concrete.

Fine aggregate shall, unless otherwise approved by the Engineer, be sand, well graded from 4 mm gauge downwards. No seashore sand shall be used, and, unwashed pit or river sand shall not be used unless approved by the Engineer.

Water shall be obtained only from sources approved by the Engineer. It shall be clean, free from deleterious materials and chemically neutral.

Cement shall be measured by weight, either by use of one or more complete bags or by weighing on site. Other ingredients shall be measured by weight or by volume, and concrete shall be mixed in batches using one or more complete bags of cement. Only in exceptional circumstances shall a bag of cement be divided. When mixing by volume is adopted, suitable batch boxes of approved dimensions shall be made and used for the measurement of coarse and fine aggregates. A calibrated container for the measurement of water shall also be used.

All concrete shall be thoroughly mixed by machine, with only sufficient water to ensure a workable mix. Consistency tests shall be made when required by the Engineer by checking the maximum slump in a truncated cone 300 mm high and of standard dimensions. No concrete shall be mixed or placed when the temperature of the air or the ingredients is less than 2°C nor shall concrete be placed when its temperature is greater than 32°C. In hot conditions the initial temperature of the mix should be kept as low as possible, by shading the materials against the sun. Retarding admixtures may be used subject to the Engineer's approval. Freshly placed concrete shall be properly protected against the weather.

Test cubes of 150 mm face in accordance with BS 1881 shall be made during the progress of the works, comprising a minimum of one set of four cubes per tower or per day, or one set of four cubes for each 6 m³ of concrete placed if greater.

Cubes shall be tested in accordance with BS 1881.

Contractors shall submit plans showing where the concrete will be mixed for each tower site and how they propose to transport the concrete to the foundation location. If the concrete is being made "off-site" and transported in "ready-mix" trucks, then the journey time must be noted and approved by the Engineer. Transportation shall be such as to avoid segregation of the concrete constituents.

The concrete shall be vibrated or thoroughly rammed during placing to ensure that it is homogeneous and free from voids. Excessive vibration shall be avoided.

The upper surface of the concrete for all types of foundations shall be made by a continuous pour of foundation concrete and shall be sloped in an approved manner to prevent accumulation of water.

Unless otherwise approved, there shall be no joints in the concrete foundation. Where the construction of the foundation is such that joints are unavoidable adequate bond between the old and new concrete shall be ensured by chipping the old concrete to a rough, clean

surface free from loose particles. Immediately before placing the new concrete, this cleaned surface shall be primed with a layer approximately 15 mm thick of a wet mix of cement and fine sand in equal proportions.

Particular attention shall be paid to the need to ensure complete curing of all concrete and the Contractor shall supply information in his method statement relating to his proposed methods for curing and for protecting the concrete. Curing and protection shall start immediately after the compaction of the concrete and shall ensure adequate protection from:

- premature drying out, particularly by solar radiation and wind
- leaching out by rain and flowing water
- rapid cooling during the first few days after placing
- high internal thermal gradients
- low temperature or frost
- vibration and impact which could disrupt the concrete and interfere with its bond to the reinforcement.

- i. **Backfill.** Proper precautions shall be taken to ensure that all backfilling and compaction of earth is done thoroughly and evenly round all parts of each separate foundation block or structure. The backfill shall be placed in layers not exceeding 300 mm in thickness and shall be compacted to achieve the bulk density assumed in the design using a method of compaction included in the Contractor's method statement and approved by the Engineer. Backfilling only from one side or corner of an excavation hole shall not be allowed. In wet or flooded situations adequate provision shall be made to ensure the excavation is kept free from water whilst work is carried out. Stub setting templates shall not be removed before completion of backfilling.

Organic matter and silt shall not be used as backfill material. All temporary timbering, shuttering, etc. and all decomposable or perishable material shall be removed from the excavations prior to backfilling.

Black cotton soil or peat soil shall not be used for backfilling and it is categorised as unsuitable material. Contractor shall import suitable soil for backfilling.

- j. **Construction tolerances.** Foundation setting tolerances shall be in accordance with the requirements stated below.

The difference in elevation between the tops of any two stub angles shall not exceed 1/1000 of the horizontal distance between the stubs. The actual elevation of any stub angle shall not differ from the computed elevation by more than 1/100 of the foundation depth.

Stub rake shall be within 1 per cent of the required hip or face rake.

Back-to-back dimensions at top of stubs shall be within 10 mm on the face or within 15 mm on the diagonal.

The twist of any stub in plan shall be less than 1° about the longitudinal axis.

Tolerances for the position of the tower and excavations in relation to the tower position given on the profile shall be:

	Out of alignment	From centre line of route	From transverse centre line of tower
Suspension tower	0.25°	±25 mm	±250 mm
Tension tower	0.25°	±25 mm	±25 mm

- k. **Site clearance.** As soon as practicable at each tower site, backfilling shall be completed, surplus soil removed and the site cleared. Final site clearance will normally be carried out at the same time as fitting of anti-climbing devices and tower plates, and shall be undertaken without delay.
- l. **Protection of tower footings.** At locations where water due to flood or tidal water may affect the foundations or cause erosion of the ground near the tower foundations, protection to the foundations and to the ground surrounding them shall be provided by the Contractor. Methods include stone revetment, concrete placement, gabion structures or reinforcement of ground surfaces as well as drainage schemes as necessary. Other methods, where more suitable, are not precluded and the Contractor shall furnish recommendations for the provision of protection at such locations

23.4. Erection

23.4.1. Storage and erection of steelwork

- a. **General.** All transmission tower steelwork stored at site shall be kept clear of the ground. Contact with brackish water or other substances likely to attack galvanizing shall be avoided and all tower members shall be kept in a clean and tidy condition.
- b. **Assembly and erection.** The Contractor shall erect the towers for the transmission line in accordance with the erection diagrams, construction lists and other drawings and instructions.

Unless otherwise approved, towers with concrete foundations shall not be erected until the concrete has had 14 days in which to cure, or such longer or shorter time as may be approved, depending on the type of cement used and on local conditions.

The method of assembling and erecting a tower shall be such that during erection no member shall be subjected to any stress in excess of that for which it was designed.

Misalignment or misfit of adjacent sections or members attributable to the adopted method of erection shall be corrected by changing erection methods as necessary to eliminate the trouble.

All members shall have their joints cleaned when bolted up. As far as possible bolt heads, rather than nuts, shall be on the outer or upper faces of tower joints.

All towers assembled on the ground shall be kept off the ground with wood so as to be free of dirt, mud and other foreign materials that tend to adhere to the structure.

If erected by assembling in sections, the initial tightening of bolts shall be adequate for dead load, live load and direction stresses, but shall not be so strong as to prevent aligning and fitting adjacent sections or members. The assembled sections shall be adequately supported during erection.

Spanners used during erection shall be well shaped and shall fit closely onto the hexagon to avoid damage to nut and bolt heads. The use of any wrench that may deform the nut or cut or flake the galvanizing will not be allowed. During assembly, punching, reaming or drilling for correction of mismatched holes shall not be permitted without the authorization of the Engineer in writing.

Proper precautions shall be taken to ensure that towers are not strained or damaged in any way during erection. Suitable ladders shall be used, whenever necessary, during erection of towers. All ladders and removable step bolts shall be removed when erection work is not in progress.

If any shop errors in the steel are discovered, the Contractor shall notify the Engineer who will decide whether the error shall be corrected on site or the members shall be replaced.

All exposed steel surfaces around the holes or on cuts on which such corrective work is permitted shall be given sufficient coats of a zinc rich paint to provide sufficient protection to the steel and shall be to the approval of the Engineer.

All towers shall be vertical under the stresses set up by the overhead line after conductor erection. A tolerance of 25 mm for every 10 m height may be allowed.

After erection each tower shall be thoroughly inspected by a special crew to check the condition of the section surfaces and the correct tightness of the nuts on the bolts. The final tightening of the nuts shall be carried out using torque wrenches and the nuts shall be torqued to the values proposed by the Contractor and approved by the Engineer.

On each tower the Contractor shall install the relevant danger and identification plates as indicated in the erection drawing.

In order to prevent pilfering, all bolts and nuts from ground to two metres above of the anti-climbing device shall be secured by means of specifically designed anti-theft type bolts and nuts to the approval of the engineer on each tower.

All foreign matter and surplus materials shall be removed from the towers and from the site upon completion of erection.

- c. **Tower earthing and resistance measurements.** The Contractor shall install and test the structure grounding in accordance with Clause **Error! Reference source not found.** of the Technical Specification.

23.4.2. Earthing

The Contractor shall undertake preliminary soil resistivity measurements as soon as possible after Award of the Contract.

In the presence of the Engineer, the Contractor shall measure the electrical footing resistance to earth of the tower before the earth conductors are erected. These measurements shall be recorded by the Contractor in the form of a tower footing earth resistance profile of an approved type.

The following materials or their equivalents shall be used:

- Earthing rods shall be made of galvanised steel, with a minimum diameter of 20mm and minimum length of 3m. There shall be provision for coupling rods to extend their length if necessary. A bronze or brass bolted clamp shall be provided for connection of earthing cables to the earthing rods;
- Earthing cables (counterpoise) shall be of galvanised steel wire with 11.5mm diameter.
- Connection of the counterpoise to the tower steelwork shall be by means of a compressed lug and two galvanized bolts and nuts, washers and spring washer on the tower stub at least 500 mm above the foundation surface. The minimum diameter of the bolts shall be 12 mm. The holes in the leg/stub steelwork shall be factory drilled prior to galvanizing.

The depths of the upper ends of earthing rods and the depth of burial of earthing cables shall not be less than the following values:

- | | |
|--------------------------|--------|
| - Cultivated (soft) soil | 800 mm |
| - Normal soil | 500 mm |
| - Rocky ground | 150 mm |

Where the measured tower footing resistance is greater than 10 ohms towers shall be earthed using one of the systems detailed below.

Type A: Each tower shall be earthed at two diagonally opposed legs. The earthing rods; one per leg, shall be hammered vertically into the soil to a depth of 3 m at a minimum distance of 5 m from the footing and shall be connected to the tower legs by earthing counterpoise cables.

This type of earthing system shall be generally employed where the ground conditions are favourable, i.e. in cultivated (or soft) soil.

Type B: Installation of earthing rods as described in type A but with one 3m rod and earthing counterpoise cable connected to each tower leg.

This type of earthing system shall be used in cultivated (soft) soil where type A earthing does not provide adequate earthing.

Type C: Installation of earthing rods as described in type A but with each rod being extended to 6m long and earthing counterpoise cable connected to each tower leg.

This earthing system shall generally be used where the ground conditions are not favourable, but not rocky.

Alternatively, 30m of earthing counterpoise shall be laid to the edge of the servitude then parallel to the line from both sides of the tower. The cable shall be buried at the specified minimum depths and shall be clamped at two diagonally opposite corners of the tower to the corresponding stub as detailed above. This will be classed as Type A. Additional 2 x 30m lengths of earthing counterpoise cable connected to the first lengths shall be Type B and another additional 2 x 30m cable will be Type C.

This type of earthing system shall generally be used in rocky grounds.

Type D: Any special measures and methods (deep grounding, counterpoise connection to the adjacent tower, earth conductivity improving chemicals etc.), subject to approval of the Engineer, which shall be used in specific soils where type C earthing cannot provide sufficient reduction in resistance.

For all types of earthing system, each section of earthing cable shall be separately bolted to the tower in order that it can, if required, be disconnected for the purpose of earth resistance measurements.

At each tower connected to an earthing system the Contractor shall measure the electrical footing resistance to earth with the system connected. The measurements shall also be recorded by the Contractor on the tower footing earth resistance profile.

The terminal towers shall be connected to the substation earthing grid.

Type and thickness of galvanizing shall provide sufficient protection of steel for 20 years' service and shall not be less than 610g/mm².

Metal roofs of existing buildings constructed within 30 m of the centre of the transmission line shall be securely earthed. A minimum of two earth connections shall be made to opposite sides of the roofs by means of earthing (counterpoise) cable, which shall be led down the sides of the building to earth. The earthing cable shall be

securely fixed in cleats to the sides of the buildings and not less than 2 m of the cable shall be buried in the ground at a depth of at least 800 mm.

All metallic fences both new and existing, which cross under, or which are located near and parallel to the transmission line shall be earthed as follows:

- One earthing rod shall be used to ground each 100 m of fence that is parallel to and within 50 m of the centre line of the transmission line. One earthing rod shall be used on each side of the right of way to earth fences crossing under the line.
- Earthing rods, to which the fence wires shall be bonded, shall be driven to a depth of not less than 1.5 m. All metallic fence gates within the right of way shall be electrically bonded to the fences.

23.4.3. Erection of insulators

Insulators and insulator fittings shall be assembled and installed by the Contractor as shown on the drawings, and in accordance with the recommendations of the manufacturers.

All insulators shall be handled carefully during transportation, assembly and installation on the tower to avoid damage and shall be cleaned when installed using techniques which cause no damage to the surface of the insulator.

Proper precautions shall be taken to ensure that insulators and fittings are not strained or damaged during erection of the insulator sets, and during the pulling out and erection of conductors.

The Contractor shall take adequate precautions to ensure that dust and dirt is excluded from insulator ball and socket joints.

23.4.4. Crossing of public services

At crossings of roads, buildings, waterways, telegraph and telephone lines, over or under other power lines, the provisions of any Regulations to which KETRACO is subject shall be complied with. No additional payment will be made for any temporary guarding or scaffolding required for erection of the conductors at crossings.

When the Contractor is about to carry out erection of the conductors along or across power lines or telecommunication circuits, public roads, waterways, he shall be responsible for giving advance notice to the appropriate authorities of the date and time at which he proposes to carry out the work. Where authorities or public undertakings deem it necessary for the protection of their employees or property, or of the public, or for the regulation of traffic, to provide flagmen or watchmen, the cost of such provision shall be borne by the Contractor.

23.4.5. Erection sags and tensions

The line and earth conductors shall be erected so that the tensions at “everyday temperature” in still air shall be the figures stated in the Schedules of Technical Information and shall be equal in all spans, excepting for sections

with spans differing considerably from the basic span where compliance with the specified tensions under the assumed maximum loading conditions may necessitate a lower figure for the "everyday temperature" still air tension.

At "everyday temperature" in still air, in any span, the earth conductor sag shall be approximately 10 per cent less than the line conductor sag.

In calculating the initial sags and tensions allowance shall be made for the elasticity and coefficient of expansion of the conductor materials.

The "equivalent span" method shall be used, in which the tension in any section length is that which would apply to a single span equal to the square root of the figure arrived at by dividing the sum of the cubes of the individual span lengths, in the section considered, by their sum. Unless otherwise approved, the sag of any one conductor should not differ from the correct sag by more than 3 per cent and, in any one span, the maximum permissible difference in sag between conductors of different phases shall not exceed 150 mm.

The sag of the subconductors of any one phase shall not differ by more than 50 mm.

Employing the approved design sags and tensions as the basis the Contractor shall submit, for approval, calculations for the initial sags and tensions to be employed during stringing activities. These calculations shall take into consideration the effects of creep for each of the phase and earth conductors and also that, for instance, Aircraft Warning Markers will not be installed at the time of sagging. For sections where Aircraft Warning Markers are to be installed additional initial sag and tension data shall be provided.

23.4.6. Erection of line and Aluminium Steel Clad earth conductors

At least 3 months prior to the commencement of stringing activities the Contractor shall submit his stringing schedule identifying the stringing sections, locations of tensioner and puller, the proposed position of mid-span joints, drum identification numbers, sagging spans and, where appropriate, check sagging spans. The sagging span shall normally be the longest span within the section but consideration shall be given to establishing a line-of-sight to the puller station. In addition, details of temporary staying of towers, joints of control and other relevant information shall be submitted.

The fullest use possible shall be made of the maximum lengths of line and earth conductor in order to reduce to a minimum the number of joints. The number and span location of tension joints shall be approved. The number and span location of tension joints shall be approved. Unless otherwise approved there shall be no tension joints in adjacent spans or in sections, between tension towers, of less than three spans; there shall be no joints in spans crossing roads, navigable waterways or buildings or in the spans immediately adjacent thereto. All joints shall be at least 30 m away from structures.

The conductors, joints and clamps shall be assembled using the approved tools and shall be erected in such a manner that no bird-caging, over-tensioning of individual wires or layers, or other deformation or damage to the conductors shall occur. Running out blocks shall be of an appropriate diameter to avoid the formation of permanent "sets" in the conductor and shall be to approval. The use of midspan compression joints for the purpose of pulling out conductors during erection and the use of insulators and line materials in general for erection

purposes will not be allowed. Auxiliary erection clamps, or hauling devices shall be of approved design, and shall under erection conditions, allow no relative movement of strands or layers of the conductors. If required by the Engineer, this property shall be demonstrated by actual test. Cutting of layers of ASCR or ASC conductors shall be carried out with tools designed not to damage underlying strands. Cropping or shearing of complete conductors shall not be permitted. The cut ends of the conductors and the joints, clamps and fittings attached to the conductor themselves shall be treated in an approved manner to prevent ingress of moisture.

The Contractor shall measure by means of approved micro-ohm meter equipment the electrical resistance of all joints after completion and before erection. The resistance of the joint shall be in accordance with the requirements of the Specification and shall in no case be greater than 75 per cent of the resistance of the equivalent length of conductor. The values of resistance measured shall be recorded on a schedule that shall be submitted to the Engineer as part of the final records. Any faulty joint shall be cut out and replaced at the Contractor's expense.

All current carrying surfaces of bolted connections shall be coated, prior to erection, with an approved conducting compound in an approved manner.

In case of local damage to isolated strands of a conductor during erection the use of repair sleeves of approved type may, in exceptional circumstances, be permitted upon application to and at the discretion of the Engineer who will regard repair sleeves as joints in respect of permitted locations. Any use of repair sleeves shall not incur additional cost to KETRACO.

The Contractor shall at his own expense make suitable arrangements for temporary guying of towers, where necessary. Suitable plates (detachable or otherwise) shall be provided on the towers for the attachment of any temporary guys. The additional loads imposed on specific towers during erection by the use of temporary guys shall be calculated and approved. Attachment of the guys to the tower shall be accomplished so as not to damage to steelwork or the galvanized coating.

The line and earth conductors shall be erected employing tension stringing methods and equipment and shall not at any time during erection come into contact with the ground or any obstacle, such as walls, fences or buildings, except when the conductors are at rest. Approved means shall be provided to prevent any damage to conductors where these are run over temporary supports.

Conductor running-out blocks shall be free running and of approved materials and dimensions.

Conductors shall be clamped in, vibration dampers and spacers shall be erected, as soon as practicable but in any case within 72 hours after having been tensioned to the correct sag.

The Contractor shall make any necessary special arrangements for running out and sagging the conductors where the route crosses buildings, orchards, plantations, gardens, or other ground over which erection cannot be carried out in the normal manner. No extra charge for man-handling of material or for any special precautions or methods necessary at such positions shall be allowed.

The Contractor shall also make such special arrangements as the Engineer may approve where power lines are to be crossed. Where the conductors have to be erected whilst the power line to be crossed is energized, no additional payment to the prices stated in part 1 shall be made for any special scaffolding or equipment required.

Where required by the Engineer, prior to the issue of the taking-over certificate, the Contractor shall be responsible for checking that the relative sags of the conductors are within the specified tolerance. Such checks shall be carried out at selected points along the route as required by the Engineer.

At the end of the maintenance period stated in the Conditions of Contract, the line conductor sag adjusting devices for bundled subconductors shall be finally not more than 50 mm plus or minus, from their median position, unless otherwise approved.

The Contractor shall provide suitable dynamometers, thermometers, sighting rods and other approved apparatus necessary for the proper checking of the work. Dynamometers, if used, shall read in kilograms or Newtons and, where required by the Engineer, shall be tested and, if necessary, recalibrated.

The Contractor shall keep a record of the particulars of the sagging of conductors in each section of the route showing the mean actual sag of the line conductors and date of stringing as well as the ambient and conductor temperature. The data shall be handed to the Engineer at the conclusion of erection work.

Clearances between phase conductors and ground and between jumpers and structures shall be checked during erection and before handing over the line.

The Contractor shall submit his proposals for a test regime to the Engineer for approval prior to fieldwork commencing.

23.4.7. Erection of optical fibre (OPGW) earth conductors

The fullest use shall be made of the maximum lengths of conductor to reduce the number of joints to a minimum. The locations for joints shall be approved by the Engineer.

The conductors and clamps shall be assembled using approved tools and shall be erected in such a manner that no bird-caging, over-tensioning of individual wires or layers, over-tensioning or stressing of optical fibre elements, or any other deformation or damage to the conductors shall occur.

The conductors shall not at any time during erection come into contact with the ground or with any obstacle, including walls, fences and buildings.

The relevant clauses related to erection of line conductors shall apply also for OPGW earth conductors.

The erection of OPGW is to be effected in such a manner that neither torsion nor bending stresses on the conductor during erection, sagging, jointing or landing shall cause any damage or deterioration to the optical fibre system. Suitable precautions shall be taken, using for example torsionally stable pulling ropes, suitable running-boards, counterweights and running blocks. Special attention shall be paid to ensure that the conductor at no time is subjected to bending in excess of that permitted by the minimum bending radius specified by the manufacturer.

Running-out blocks shall be sized to conform to the minimum bending radius specified by the OPGW manufacturer.

The Contractor shall carry out tests to confirm the satisfactory condition of optical fibres prior to erection.

Once installation of OPGW earth conductor is complete a series of tests to be agreed with the Engineer shall be carried out to ensure the satisfactory operation of the cable. The tests shall be carried out in both directions.

The tests shall include but not be limited to:

1. Optical attenuation on OPGW earth conductor terminated with connectors carried out in both directions at 1550 nm.
2. Loss distribution to measure the uniformity of loss in the optical fibres and joint losses in the OPGW earth conductor using an optical time domain reflectometer (OTDR).

On completion of the tests three copies of the test report shall be supplied to the Engineer.

Optical attenuation of the OPGW earth conductor terminated with connectors shall be measured and recorded at the end of the guarantee period and it shall not be more than 102 per cent of the reading at commissioning.

The contractor shall submit his proposals for erection and test regimes to the Engineer for approval prior to fieldwork commencing.

23.4.8. Final inspection

Upon the notification by the Contractor that the work is finished on a completed section of line, the Engineer, prior to issuing the taking over certificate, will inspect the completed Works, in order to ascertain that they have all been carried out in accordance with the Specification and to the Engineer's satisfaction.

In particular it will be ascertained that at least:

- **At the Tower.** Backfilling of the excavations, ramming, levelling around foundations, draining of higher footings on sloping ground, dispersal of excess earth etc., is complete.

Concrete protruding above ground is correctly shaped, finished and sealed. Counterpoise earthing is installed where required.

Silicone, epoxy or other approved painting has been correctly applied. Steel sections are straight and not damaged. Bolts and nuts are correctly fitted with washers and are properly tightened and locked.

The line and earth conductor fittings are erected in accordance with the drawings and are complete. The line and earth conductors are correctly clamped. Electrical clearances from jumpers to tower steelwork are adequate.

All tower steelwork, bolts, nuts, lock nuts, cotter pins, washers and split pins on all fittings are properly fitted. The tower steelwork is free of all foreign matter.

Anti-climbing devices, danger and identification plates are complete and correctly fitted.

- **Along the transmission line.** The conductors and earthwires are clean, without strand damage and free of mud, foliage, loose wires, etc. The sags of all conductors and earthwires are in accordance with sagging documents and clearances are correct.

All packing and surplus materials have been removed from the site. The cutting and removal of trees and all route clearing is in accordance with the Specification.

All access and inspection tracks are completed and in good condition.

23.5. Tests

23.5.1. General

The Contractor shall supply documentation of such tests as are required by the Engineer to prove compliance with the Specification.

All equipment shall have valid type test report that is acceptable by the client/engineer; otherwise type test must be carried out with no extra cost.

In addition, routine and sample tests (acceptance tests) shall be performed on all equipment in the presents of client/engineer representative and all related cost must be paid by the contractor.

All cost related to test (type, routine and sample) deemed to be included in the contract price and no extra cost will be paid by the client.

23.6. Documentation with tender

The following is a list of documentation to be submitted with the Tender.

- a. Programme of anticipated works, to conform with completion times required.
- d. Details of the method of working to demonstrate that the specified Quality Assurance requirements will be complied with.
- e. Copies of any standards proposed in substitution for International Electro-technical Commission Standards or Recommendations or British Standards accompanied where necessary by English translations of the appropriate sections.

- f. Record of previous service experience of the fibre-optic earth wire offered.
- g. Documentary evidence of the successful service history of the proposed damping system for line and earth conductors in environments at least as hostile as that for the present project.
- h. Documentary evidence of satisfactory service history of the polymeric insulators.
- i. Other supporting documentation considered appropriate by the Bidder.
- j. Tower outlines with clearance diagrams for all the tower types
- k. Each tower outline drawing shall show a route for the step bolts, position of anti-climbing guard, bird guards and notice plates for all standard towers and extensions.
- l. Diagram of external loads
- m. Tower design booklet (stress calculation table) showing loading considerations, tower base reactions, member sizes, allowable stresses and maximum computed forces in members
- n. General arrangement of:
 - Suspension insulator sets and fittings
 - Tension insulator sets and fittings
- o. Detailed drawings of:
 - Insulator unit
 - Line conductor tension anchor clamp and midspan joint
 - Line conductor suspension clamp
 - Cross-section of the complete OPGW including the aluminium tube and fibre cable
- p. indicating the dimensions of each element, the design and make-up of the cable.
 - Earth conductor tension clamps and midspan joints
 - Earth conductor suspension clamps
 - Line conductor non-tension joint
 - Line conductor vibration damper
 - Earth conductor vibration dampers
- q. Foundation outlines for all standard designs.
- r. Testing arrangements (foundation test, pile test, tower test etc.)
- s. Layouts with proposals of line entries at the respective substations

23.7. Drawings to be submitted during the contract period.

List of drawings and documents to be submitted by the Contractor, for approval, shall include but not be limited to the following:

a. Design drawings and documents detailing:

- Calculations giving the design basis to be employed for the sags and tensions for the line and earth conductors for both final and erection conditions and calculations providing data for the manufacture of the sag templates.
- Derivation of applied loads for all towers including wind on structure.
- Detailed live metal or wire clearance diagrams for tower.
- Basis to be employed for the design of structures.
- Tower design booklet (stress calculation table) showing loading considerations, tower base reactions, member sizes, allowable stresses and maximum computed forces in members
- Analysis of maximum member and connection loads and capacities for all members in standard towers, body and leg extensions.
- Structure foundation loads for all loading cases demonstrating that the critical condition for any combination of body and leg extension has been considered.
- Foundation designs for all standard classes, including stub and cleat designs.
- Concrete mix design.

b. Arrangement drawings of:

- Tower, body and leg extension showing connection to foundations, insulator and earth conductor attachments and complete with all necessary erection information and part list including weight.
- Stubs, foundations (including details of reinforcement, excavation, stub setting).
- Special towers, extensions and foundations (as required).

c. Detail drawings of:

- Suspension and tension insulator sets, with all fittings and securing devices.
- Insulator units, showing cross section and details of securing device.
- Line conductor tension clamps and joints.
- Tension make-offs and suspension clamps for earth conductors.
- Vibration dampers for line and earth conductors including calculations to demonstrate the efficacy of the proposed system.
- All OPGW ancillary equipment.
- Tower earthing arrangements.

- Tower obstruction lighting and marking.
- Proposed live-line maintenance equipment.
- Danger and property, route and tower number, circuit colour, phase and aerial number plates.
- Curves showing the initial and final sags and tensions of the line and earth conductors at different spans and temperatures, all in accordance with the Specification (together with stringing charts)
- Route plans, schedules and profile drawings all in accordance with the Specification (in PLS-CADD software).

d. Other documents:

- Inspection test plan (ITP) for all equipment.

23.8. Final records

After completion of work on site all Contract Record drawings, as required by the Specification must be submitted as As-Built drawing and documents. The list of drawings required for final record purposes shall include but not be limited to the following list:

- a) Route maps
- b) Spotted plan and profile and structure list
- c) Line conductor and earth conductors datasheet
- d) Line conductor and earth conductors initial/final sag-tension charts
- e) Line conductor and earth conductors Stringing charts
- f) Tower footing resistance chart
- g) Earthing details
- h) Tower and foundation designs and calculations
- i) Tower and foundation details including all types of extensions
- j) Wire clearance diagrams
- k) Material lists for tower
- l) Tower notice plates and accessories
- m) Foundation installation details
- n) Foundation setting level diagrams
- o) Stub setting templates
- p) Insulator sets plus component parts
- q) Line conductor and earth conductors suspension and tension sets plus component parts and accessories
- r) All types of connectors, dampers and joints

24. Low Voltage Power and Control Cables (LV Cables)

24.1. General

This part of the specifications covers the design, manufacture, testing, marking and packing, transport, delivery, unloading and storage at site, installation, commissioning, handing over in satisfactory operating condition and defects liability of low voltage power and control cables and their accessories.

Standard designs and models from the Bidder's/ Contractor's manufacturing program are preferred, provided they meet the requirements of this Specification, and serve the intended purpose.

It is not the intent to specify completely herein all the details of design and manufacturing of the above cables and accessories. It may be noted that norms, standards specified are the bare minimum that is required. The cables and accessories shall conform in all respects to high standards of engineering design and workmanship and shall be capable of performing continuous commercial operation within the parameters guaranteed by the supplier in a manner acceptable to KETRACO. Any temporary arrangements that might be necessary shall be included.

The cables shall meet, as a minimum requirement, the latest versions of IEC and VDE/ DIN Standards. They shall be designed, manufactured, installed and tested in full compliance with all applicable sections, articles and drawings of these Tender Documents.

24.1.1. Applicable Standards

The latest issues of Recommendations of the International Electrotechnical Commission (IEC-Standards, etc.) shall apply.

The delivered equipment shall conform to the latest relevant directives of the European Community.

Supplementary standards are the international standards ISO, the German standards DIN and VDE, the European standards EN (CENELEC), the British standards BS, the American standards or specific national standards in the above mentioned sequence, if there are no relevant IEC-standards existing or if there is no sufficient information available in the IEC standards and/ or if explicitly asked for in these Tender Documents.

24.2. Technical Description

24.2.1. General

All cables shall fulfil the following characteristics:

- Halogen free according to IEC 60754-1 and EN 50267-2-1
- No emission of corrosive gases according to IEC 60754-2 and EN 50267-2-2
- Low smoke density according to IEC 61034-1/-2
- Flame retardant according to IEC 60332-1

- Minimal fire propagation according to IEC 60332-3-24 (type of test according to category C)

Outer sheath of LV cables shall be of uniform colour, even and free of outlines to achieve the appropriate tightness for the required IP degree together with the cable glands. The stranding must not become apparent.

Outer sheath of the cables shall be widely resistant to oils, greases, acids and bases.

Shore hardness of outer sheath shall be as follows:

- Halogen free material: Shore-D, 40
- Polyurethane (outdoor): Shore-A, 85

Shore hardness of core insulation shall be as follows:

- Halogen free material: Shore-D, 48
- Outdoor material: Shore-A, 89

All cables to be supplied shall be connected to the relevant equipment in an approved manner, including all necessary wiring. Their spare conductors shall be terminated and marked for future extensions. The conductors shall be connected to terminals as such that crossovers are avoided.

The dimensions of the cables shall meet the required operating currents, considering also that the permissible voltage drops are not exceeding the limit. Furthermore, the cables shall resist the expected thermic and dynamic short-circuit currents trouble-free.

The cable length of delivery shall be selected in that way that cable joints are not needed.

Minimum cross section of cable cores except telecommunication shall be 1.5 sqmm.

The maximum permissible voltage drops for all auxiliary power supply and control cable circuits up to the consumer shall be less than 5 %.

24.2.2. Power Cables

Power cables shall have copper conductor, XLPE insulation, inner covering and a flame retardant sheath.

In selecting the number of cables as well as the cable cross sections, due regard shall be paid to the appropriate de-rating factors in relation to the climatic conditions at site. All cables and wires shall continuously carry their rated currents under the worst temperature conditions, which prevail in summer, and shall also withstand maximum fault currents without damage or deterioration.

All Power cables shall have one separate conductor (TN-S system) of adequate size for protective earth. At the equipment to be supplied the protective earth is connected to the PE terminal.

The cross-section of the neutral conductor shall be the same like that of the respective phase conductors.

All appropriate cable racks, pipes, supporting structures, cable terminals, ferrules, and auxiliary equipment as necessary for proper installation, connection and operation shall be included to the satisfaction of KETRACO.

Conductor colours shall be selected according to KETRACO standard.

24.2.3. Control Cables

Multicore armoured and shielded control cables shall have standard cross section copper cores. The outer covering shall be preferably high density polyethylene, termite resistant, vermin proof, and suitable for the prevailing service conditions at site.

The printing on the cable sheath shall be repeated in intervals of at least 0.5 m and shall contain

- manufacturers name or trade mark
- cable type designation
- number and cross sectional area of the cable cores
- mark of conformity to RoHS

Control/ signalling cables shall have an overall screen with an optical covering $\geq 85\%$ and with the screen suitably earthed. In normal cases screens are earthed on both sides. For that reason they shall have the necessary ampacity. In special cases only earthing on one side might be needed, but this shall be agreed during design phase with KETRACO.

Cables running outside of a building shall be additionally armoured.

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

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

The cables shall be designed for nominal voltage of (U0/U) of 300/500 V, the test voltage (50 Hz, 1 min) shall be 3 kV.

Individual cables shall be used for current transformer secondary circuits, voltage transformer secondary circuits, control and signalling circuits and communication circuits.

Cables for telephone and data links shall be of the twisted pair wire type with an appropriate screen. The screen shall be connected to earth.

24.2.4. Battery Cables

The cables for connection of the batteries to the fuse boxes shall be single core, halogen free insulated, short-circuit safe and inherently earth-fault-proof.

24.2.5. Voltage Transformer Cables

The cable connections from the voltage transformer secondary terminals up to the mini circuit breakers shall be short-circuit safe and inherently earth-fault-proof. This unprotected cable length shall be as short as possible.

24.2.6. Temperature Resistant Cables

Control cables that are exposed to high temperatures like on transformers shall conform to an increased maximum permissible temperature (for fixed installation operation temperature up to 145 °C and temperature under short-circuit conditions up to 280 °C). For use in outdoor applications and if applicable due to the climatic conditions the cables shall additionally allow a minimum ambient temperature of -55 °C for fixed installation and they shall have good resistance to weathering, ozone and UV-rays. In areas with possible oil contact (e.g. on oil insulated transformers) the cables shall also be oil resistant. In other respects requirements specified for control cables shall apply.

24.2.7. Fire Resistant Cables

Fire resistant cables shall be used wherever personal safety has to be considered e.g. for the following applications:

- Fire protection and fire alarm systems
- Emergency and safety lighting
- Systems for emergency evacuation

The cables shall fulfil:

- Circuit integrity (FE180) in accordance with IEC 60331, VDE 0472-814
- System Circuit Integrity E90 in accordance with DIN 4102-12.

The system circuit integrity can only be reached together with appropriate cable support systems.

24.2.8. Cable Installation

24.2.8.1. General

The cable routes shall be designed/ planned by the Contractor in close coordination with KETRACO. All cables shall be laid according to a cable schedule to be prepared by the Contractor. In the cable schedule all cables will be identified by numbers, their route and length will be indicated and the points of termination will be specified. At either end of a cable and before and after each firewall a metallic legend plate or other permanent identification label shall be affixed bearing the same identification number as in the cable schedule. The identification number shall be consecutive.

Power cables shall be strictly segregated from control cables and instrument transformer cables.

All types of cable glands required for the termination of the various sizes of cables shall be part of cable supply.

Cable glands shall be made of non-corrosive material (e.g. nickel-plated brass or stainless steel) and shall be of metric size. They shall provide protection class of at least IP67 at 5 bar. Cable screens and armours shall be contacted in a circumferential manner for earthing purpose. Gasket material shall not be exposed to sunlight radiation.

Cable routes shall consider redundancy requirements like for example in case of trip circuits. Redundant cables shall be laid on different routes as far as possible.

To resist the short-circuit forces spacers shall be used as far as needed.

24.2.8.2. Consideration of Induced Voltage Requirements

Control, signalling and communication cables laid in the vicinity of power cables have to be protected against damage by induced high voltages occurring in case of asymmetrical power cable operation, e.g. during short circuits.

Thus the Contractor must prove by calculation on the induced voltages whether the sheaths and insulations of the offered cables are sufficient for the given network configuration.

24.2.9. Sealing and Drumming

Immediately after tests at the Contractor's premises, both ends of every length of cable shall be sealed with a metal cap (with pulling eye for power cables) which shall be plumbed to the sheath.

All cables and conductors shall have the inner ends brought out and suitably fixed to the drum to avoid any damage during handling or pulling operations.

The cables shall be rolled on strong wooden or steel drums provided with suitable wooden battens to protect the cables from damage. They shall also be suitable for storage in the open air without additional protection by casing or shutters for a period of at least two years.

The drums shall be marked in English to indicate the direction of rolling, and also as stipulated in the Special Conditions of Contract, Shipping Marks, plus the following:

SIZE AND TYPE OF CABLE, VOLTAGE, CABLE LENGTH

For all spare cut lengths of cable which are to be delivered to the Employer's stock, approved sealing caps of correct sizes shall be supplied and properly mounted immediately after the respective cable length is cut.

24.3. Documentation

As a minimum requirement the following documentation shall be handed over with the Bid.

- Brochures and data sheets of the typical cables Bidder intends to use.
- Brochures and data sheets of the typical cable supporting systems Bidder intends to use.

As a minimum requirement the following documentation shall be handed over during the design phase.

- Cable calculation in regard to maximum permissible voltage drop (cable length), load current (cable diameter under consideration of the de-rating factors to be applied) and the disconnection condition of the protective elements (minimum required short-circuit current).
- Layout drawings for the cable supports (plan views and sectional views)
- Cable Lists
- Cable routing diagrams

24.4. Tests

24.4.1. Type Tests

The Supplier shall carry out all type tests called for in this Specification and such tests in the Standard in accordance with criteria and to the extent specified in the Specification and on custom manufactured items as called for by the Employer to obtain required performance data.

24.4.2. Routine Tests

Routine and sample tests according to the IEC standards shall monitor the ongoing manufacturing process.

Before leaving the factory each completed cable shall undergo the following tests:

- Voltage Test
- Measurement of insulation resistance

24.4.3. Site Tests

Before energising a cable circuit, including all accessories, tests according to the IEC standards shall be performed on the complete installation. The tests shall include amongst others:

- Measurement of insulation resistance
- Measurement of loop resistance.

25. Earthing And Lightning Protection

25.1. Introduction

This Specification covers the ratings, design, equipment requirements, erection, inspection and testing of complete earthing system and lightning protection system.

Earthing system shall mean a complete copper conductor ground grid system, which includes all conductors, earthing rods, connectors, equipotential mats, equipment and other measures required to complete earthing of switchyards, indoor switchgears and buildings.

This is basically a performance specification and covers only those aspects that are required to define a minimum standard of quality and performance. Other details and specific data are contained in the Contract drawings, Technical Schedules and other documents that form part of the Tender Documents.

The Contractor is deemed to have visited the site and the area where the substation is to be located prior to submitting his Tender, making observations in order that he can assess the quantities required for earth electrodes to satisfy the specification requirements.

All materials and equipment shall be provided as required to make a complete, properly, functioning installation and shall conform to the highest standards of engineering design and workmanship.

The Contractor shall at an early stage of the Project and before the Site works commence undertake a survey of the ground all over the site in order to establish general characteristics and ascertain values of soil resistivity at various depths to a minimum of 20 m and measure the aggressiveness of soil. If a plot will be filled with a soil layer > 1 m to rise the level, two soil resistivity measurements – one before and one after the filling – shall be carried out. A report of the resistivity values measured, the effective earth resistivity, the expected resistance of the proposed grid and aggressiveness of soil shall be submitted to KETRACO/Engineer for approval.

Based on the above survey the Contractor shall prepare a detail design of the earthing system and lightning protection system for approval by Ketraco/Engineer. Thereafter the Contractor shall supply, excavate, install, erect, backfill and test the installation to the satisfaction of KETRACO /Engineer.

Calculations and designs shall be made using a latest version of earthing calculation and design software. Prior to any Earthing System calculation, the Contractor shall agree with KETRACO /Engineer what type of computer programme shall be applied for the Earthing System calculation. On completion of the work the complete datasets and outputs including drawings and designs from the software shall be provided to Ketraco for future use.

25.2. Applicable Codes and Standards

The design and installation of the earthing and lightning protection systems shall be based on the following standards:

IEEE 80	Guide for safety in AC Substation Grounding
IEEE 81	Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface potentials for Ground system
IEC 60364-5-54	Earthing arrangements and protective conductors for indoor installations up to 1000 V a.c. and 1500 V d.c.
NFPA 780	Lightning Protection Code
BS 6651	Protection of Structures against Lightning
BS 7430	Code of Practice for Earthing

The electrical equipment shall be in accordance with the requirements of IEC recommendations.

25.3. Scope of Works

The supply and services to be performed by the Contractor shall comprise the design, manufacture, shop testing, packing, transport, insurance, unloading, storage on Site, construction works and erection, corrosion protection, site testing, submission of documentation, commissioning, training of KETRACO's personnel and warranty of the works.

25.4. Main Technical Data

The 400, 220, 132, 66 and 33 kV Systems' Neutrals are solidly earthed.

25.5. Electrical Parameters for Earthing Calculation:

Parameter for	400 kV	220 kV	132 kV	33 kV
Fault current (kA)	40kA	40kA	31.5kA	25kA
Frequency (Hz)	50	50	50	50
Duration fault current for earthing conductor sizing (s)	1	1	1	3
Duration of shock for body current (s)	0.5	0.5	0.5	0.5

To ensure the lowest possible resistance to earth and to lower the surge impedance for lightning protection, buried electrodes shall be provided to bring the overall resistance to earth to less than 0.2 Ω . A value higher than 0.2 Ω shall be subject to the approval of the KETRACO/Engineer.

25.6. Earthing System

The earthing system shall mainly comprise a meshed earthing grid directly buried at a minimum depth of 0.5 m below final ground level, set of primary earth electrodes and down leads to all electrical equipment and all metallic frames to form an equi-potential bonding system capable of carrying the fault currents resulting from short circuits. Where there are other services like trenches, then the grid shall be laid below them.

The earthing system shall fulfill the following requirements:

- Maintain acceptable earth resistance to limit the ground potential rise (in accordance with IEEE 80) with respect to true earth and ensure protective relay operation in the event of an external fault. The GPR shall be less than the allowable touch voltage for 70 kg body weight.
- Provide earth connections to all electrical apparatus enclosures and structural steel works adequate to carry prospective earth faults without excessive heating or fire risk. To ensure, every structure must be connected via two different risers to two different parts of the grounding grid. Steel structures and fence shall not be used as parts of the protective earth connection of apparatus.
- Limit potential differences within the substation site in the event of earth current, originating from within or outside the station.
- Ensure the safety of personnel by limiting step and touch voltages within the building, outside building, within the perimeter fence and outside perimeter fence. In addition, within the building the transfer voltage is a key aspect which needs to be ascertained to values well within acceptable levels and eliminate interference or damage to sensitive electronic circuits.
- For Fences the induced voltage and touch voltage should be controlled and the fence should be grounded in every 10 meters or less.

The split factor may be considered in the design calculations however the worst case scenarios such as one power cable or transmission line with earth wires supplying the substation shall be used. Split factor calculation shall be subject to approval of KETRACO/Engineer. Split factor shall be confirmed during commissioning and this shall be carried out by earthing the remote end of the feeder and connecting the source at the new substation. The required source capacity shall be established prior to commissioning.

25.6.1. Outdoor Earthing System

Underneath the substation site a meshed earthing grid shall be installed to provide a common main earthing grid for the connection of equipment and structures. The mesh conductors shall be spaced in such a manner to prevent the occurrence of excessive step potentials and touch potentials on conducting parts of the installation which are not part of the main electrical circuits. Maximum mesh potential shall not be greater than the maximum tolerable touch potential, considering clearance time equal to the back-up protection earth fault clearance.

Main earth grid shall utilize fully the available site area.

The location of the main earthing electrodes shall be such to enable all items of equipment

to be connected to the earth system via the shortest practicable route.

In addition to the above, the following is considered as part of earthing grid:

- Earth ring electrodes around each individual building in the substation area,
- Reinforcing steel mesh of building foundation,
- Earth electrodes for outdoor lighting pole earthing,
- Substation fence earth electrodes,
- All interconnections,
- Vertically driven rods, etc

A continuous conductor shall be laid outside the periphery of substation site typically at a distance of 1.5 m to 2 m from the boundary fence, and at a minimum depth of 0.5 m below final ground level. The exact positioning of the perimeter conductor and the depth of burial shall be determined by the Contractor during the design process taking into account external

step and touch potentials.

The substation wall reinforcing shall be connected to the main earth system minimum once per wall panel section.

Where overhead lines enter the substation passing over the wall additional earthing shall be provided to ensure an effective earth path.

A meshed earthing grid shall be formed by interconnection of various points of the earth electrode perimeter.

Where appropriate, the earthing system shall be designed so as to include all overhead line terminal towers, which shall be earthed by extending the system so as to envelope all towers within the earthing system.

If the event of the substation resistance obtained with the foregoing installation being of a magnitude unacceptable to KETRACO/Engineer, then where practicable, the earth area enclosed by the earth system may have to be increased by installing directly in the ground earth electrodes in the form of a ring outside the site at a significant distance from the substation boundary.

Alternatively, earth rods may be approved if the earth resistivity survey indicates that their use is warranted.

In all cases the Contractor shall demonstrate by calculation that extensions of the grid outside the substation perimeter do not create a hazard for humans or animals under all conditions of operation.

Items of equipment and structures which are most likely to contribute high earth fault currents, such as AIS switchgear, instrument transformers, power transformers, towers, arrester pads etc. shall always be connected to the grid with a minimum of two fully rated spur connections. The down leads connections shall preferably run in opposite directions to eliminate common mode failure.

The lighting poles of the outdoor lighting system shall be connected with separate earth electrodes at the meshed earthing grid.

Two interconnections, if not specified otherwise in the remaining sections of document, between each of the building earthing sub-systems and the main earthing grid shall be provided, each having an accessible isolating point to enable measurement of the earthing resistance.

The lightning installations for all the buildings, structures, etc., must also be connected to the main earthing grid.

The effects of lightning strikes on the control and monitoring systems vary from faulty pulses in control and measurement to the destruction of electronic sub-assemblies and cables and must therefore be prevented by the earthing of screens. To this end the screens of the control cables leading from the signal transmitters, actuators etc. must be taken to the dedicated earthing points and from there to the indoor earthing installation. They must be insulated and terminated via the screen bars in subsidiary distribution boxes, intermediate terminal boxes, marshalling racks, control cabinets and DC main distribution boards.

As an additional safety measure, a closed mesh shall be provided below all operating positions for outdoor HV equipment manual operating mechanism boxes and local electrical control cubicles to ensure the safety of the operator. The mat shall be directly bonded to the cubicle and the conductors forming the mat and the bonding connection shall have a minimum copper cross-section area of 70 mm².

At locations with high surface resistance, where applicable, the Contractor shall install deep bore hole earthing. A hole shall be drilled into the ground, to a depth reaching permanently moist soil layers. The depth required shall be determined by KETRACO/Engineer on the basis of the soil investigation results.

At locations with rocky high surface resistance where it is proven by calculation that it will not be possible to achieve the desired earthing grid resistance to earth the Contractor may utilize the materials such as bentonite, marconite or modern earthing concrete materials however selection of materials and locations of utilization are subject to approval of KETRACO/Engineer. In no case charcoal and salt shall be used for improvement of earthing grid resistance to earth. In case of utilization of materials for reduction of the earthing grid resistance to earth, before warranty expiring, Contractor shall verify the integrity of the earthing grid by performing measurements of the earthing grid resistance to earth. In case of evident discrepancy between the first installation measurement and pre-warranty expiring measurement any required works to remedy the earthing grid resistance to earth to the desired value will be included in the supply of the contract.

Rods shall be used for the perimeter grounding mesh, in distances about 30 meters.

Gates shall be earthed by proper riser and Flexible conductors.

Each surge arrester, capacitive voltage transformer, grounding switch, power transformer neutral, auxiliary transformer neutral, shunt reactor neutral shall be connected to ground via a copper clad steel rod.

At least 15 cm gravel shall be considered in the outdoor switchyard area.

25.6.2. Indoor Earthing System

Flat bare copper sized to carry the fault current shall be installed to form one ring inside the building on the walls of each story. From the ring conductor the connections to the, cable trays, conduits, doors, steelworks, buried floor screens etc., shall be made using PVC sheathed copper stranded conductor or bare copper tape.

Connection to panels and other sensitive electrical apparatus shall be made independently to the indoor ring to minimize conducted interference. All of the electrical equipment, frames and mechanical apparatus shall be provided with designated earthing points.

An earth ring connected to the main earth grid at two or more points shall surround each item of large plant situated in the buildings.

Provision shall be made for the connection of power cable sheath bonding systems and cable accessories to the indoor earthing sub-system.

Copper conductors shall be laid and fixed at the cable trays. Where this is not possible supports for earthing conductor shall be provided and fixed in concrete or masonry.

The bare copper tape shall be also fixed and supported on walls. Care shall be taken to avoid the creation of tripping hazards due to surface mounted earthing conductors.

Cable trays and vertical runs shall be connected to earth at least 15 m intervals.

At maximum intervals of 10 m, the main earthing bus inside buildings shall be connected to the outdoor earthing system using lead-sheathed single core copper conductor.

25.6.3. Cable Trenches

A lead sheathed copper main earthing conductor shall be provided for each cable route within substation to which all steelworks shall be bonded. Metallic cable trays and conduits shall be electrically bonded at all mechanical joints and connect at intervals to main ground grid.

25.6.4. Pipelines

Where pipelines enter the site (fence / boundaries) they shall be fitted with a length of electrical insulation over the pipe on each side of the wall, and an insulating flange at the boundary. This prevents dangerous potentials occurring between the pipe and earth, both within and outside the site.

25.6.5. Earthing system materials

- **Earthing grid:**

Lead-sheathed stranded copper conductor shall be used for main grid conductors and down leads connected to them. The lead sheath shall be at least 2 mm thick. . If especially there is problem of theft in the substation so the Copper-clad steel wire with equivalent cross section can be used only by the client approval.

The cross-section of earth grid conductors shall be confirmed by calculation in accordance with the main technical data. All down leads shall be with redundant connections.

The size of lead-sheathed stranded copper conductors shall be uniform throughout the area under the Contract.

Alternatively, when the ground conditions are not chemical corrosive (Ph value greater than six (6) and less than nine (9)) copper conductors may be used (instead of Lead-sheathed).

The selection shall only be finalized after site investigation and is subject to KETRACO/Engineer approval.

The current density for lead sheathed stranded copper conductor shall not be greater than 140 A/mm² for 1 s duration.

- **Indoor earthing conductor:**

Bare copper tape shall be used for the ring inside the building on the walls at each operational level.

PVC sheathed stranded copper conductor or bare copper tape shall be used for connection of the equipment to the ring inside building.

Each connection between the equipment and the earthing system (spur connection) shall carry the total fault current, but the cross-section area of branch connections may be reduced to 60 percent of corresponding single conductor to provide for the current distribution in two or more conductors.

The current density for copper earthing conductors shall not be greater than 190 A/mm² for 1 s duration.

All earthing copper conductors for indoor installation shall be PVC sheathed, colored green and yellow.

- **Earth Leads**

All equipment within the station area shall be connected to the main grid including but not limited to the following: steel structures, hoist and motors, transformers neutral points, transformer tanks, shunt reactor, reactor tank, fences, cables armour, cable trays and conduits, AC switchboards, DC switchboards, control panels, control desks, relay panels, motor frames, lighting fixtures, lighting poles, housing of small equipment, ladders, steel reinforcing bars where it is applicable or where it is used in earth slabs for equi-potential grading, etc

Branch connections of the non-current carrying metal parts of equipment shall have a minimum conductor size as designed to carry maximum earth fault current for the fault clearance time or 1s (3 s for 33 kV) whichever is the longer time.

Jointing of conductor-to-conductor under the ground shall be performed by an exothermic welding process of cad weld type.

Exothermic welding shall be used to connect grounding grid conductors for switchyard and fence grids.

Equipment and metal structures may be connected to the ground grid by using bolted connectors.

Surge arrester ground connections must be short as possible, straight and shall not be used as ground connections for any other equipment.

Disconnect switch frames shall be directly connected to main ground grid. Hinge end of ground switch shall be directly connected to main ground grid.

Connection of the risers to steel structures shall be ended by cable lugs and the connection shall be endured forces by tension and short circuit.

All lighting poles shall be connected to ground grid by copper conductors that sectional area not less than 35 mm².

Earth bonds shall be used to bond all steel platforms operating floors, ladders, hand rails, cable tray, structural steel work, etc. which does not have a solidly welded path to the main structure/or earthing grid.

Whenever dissimilar materials are to be joined the necessary bi-metallic plates shall be inserted as required to ensure that electrolytic action is avoided.

- **Inspection Pits and Earth Rods**

Earth Rods shall be 20 mm diameter extendible type of solid copper or stainless steel, each driven into undisturbed soil as required by the calculation with minimum depth of 3 m. Each rod electrode shall be complete with approved non-ferrous clamps for the connections of earthing conductors and with a hardened steel tip and cap for driving by means of a power hammer.

The connections from earth rods to the main earth grid shall be made in a concrete inspection pit with cover, using bolted clamps. Clamping arrangements and terminations shall be submitted for review and approval.

25.7. Lightning Protection

The following lightning protection material shall be used:

lead sheathed copper tape at least 70 mm² for roof conductor and down conductor, copper or stainless steel earth rods of 20 mm in diameter driven into undisturbed soil with minimum depth of 3 m, air terminators with copper strip or tape of not less than 120 mm² cross section, etc.

25.7.1. Lightning Protection Material

Lightning protection shall be provided to give effective shielding against a lightning strike to the structures and all outdoor equipment.

Lightning protection shall be provided for all buildings & switchyard area and shall be in accordance with BS 6651.

Contractor shall prove by calculation and drawings of all constructional details and protective zones showing that all structures and equipment are properly protected from lightning.

The main components of a lightning protection system are as follows:

- Shield wire,
- Air terminations,
- Down conductors,
- Earth terminations and earth rods,
- Joints, bonds, test joints, etc.

A complete air termination network shall be installed on the surfaces of the roofs. No part of the roofs shall be more than 10 m away from the nearest horizontal protective conductor.

All metallic projections such as air conditioning cabins, vent pipes, railings, gutters, steel constructions, antenna, etc. on or above the surfaces of the roofs shall be connected to the above mentioned network, or shall be used as part of the protective system.

Down conductors shall be distributed on the surface of the outside walls of the buildings with a spacing distance of not more than 20 m and all main metal parts near the down conductors shall be connected thereto.

Each down conductor shall be provided with earth solid copper or stainless steel rod of 20 mm in diameter driven into undisturbed soil with minimum depth of 3 m with test joints placed in a position that results in easy testing. Each earth rod shall be interconnected with the main station earth grid.

The ring around a building installed as a part of main earth grid shall be used for connecting the air termination network. The connection points should be stripped of the lead sheath. The connection points are to be bitumen protected against corrosion. Nuts and bolts at the test joint or other joints, which are to remain detachable, shall be made of copper-nickel-silicon-bronze.

25.8. Inspection and Tests

Tests shall be carried out in order to determine whether the material and equipment comply with the required properties.

All tests on material and equipment shall be made in accordance with IEC Standards if not otherwise specified.

The testing of earthing system shall be in accordance with IEEE 81.

Upon completion of earthing system, the following measurement shall be effected:

- Measurement of resistance to earth,
- Measurement of touch voltage inside and outside perimeter fence
- Measurement of step voltage inside and outside perimeter fence,
- Determination of Grid Potential Rise.
- Contact resistance measurement to check the Integrity of welded/bolted joints in the internal as well as external earthing system.

All tests shall be carried out to the satisfaction of KETRACO/Engineer and in his presence, at such reasonable times as he may require, unless agreed otherwise.

Not less than one (1) week notice of all tests shall be given to KETRACO/Engineer.

25.9. Special Equipment and Tools

Works to be done under this section include the delivery of special equipment and tools for erection, installation, maintenance, setting to work and other purposes.

25.10. Documentation

The Contractor shall provide all necessary drawings, design specifications, design details, operation and maintenance manuals and other information in accordance with requirements listed in above section.

the contractor after award must submit the below documents:

Calculation, layout drawings, materials and manufacturer documents as stipulated in Sections above shall be provided. The earthing systems shall not be accepted as complete until the required information has been provided to the satisfaction of KETRACO/Engineer.

26. Environmental and Social (ES) Requirements

[The Employer's team preparing the ES requirements should include suitably qualified Environmental and Social specialist/s. The ES requirements should be prepared in manner that does not conflict with the relevant General Conditions of Contract (and the corresponding Particular Conditions if any) and other parts of the specifications.]

27. Contractor's Representative and Key Personnel

[Note: Insert in the following table, the minimum key specialists required to execute the contract, taking into account the nature, scope, complexity and risks of the contract.

Where a Project SEA risks are assessed to be substantial or high, the Employer shall include Sexual Exploitation, Abuse and Harassment expert(s)

Contractor's Representative and Key Personnel

Item No.	Position/specialization	Relevant academic qualifications	Minimum years of relevant work experience
1.	Contractor's Representative		
2.	<i>[Construction Manager]</i>		
3.	<i>[...specify other key personnel as appropriate]</i>		
4.	<i>[Environmental]</i>	<i>[e.g. degree in relevant environmental subject]</i>	<i>[e.g. [years] working on road contracts in similar work environments]</i>
5.	<i>[Health and Safety]</i>		
6.	<i>[Social]</i>		
7.	<i>Sexual Exploitation, Abuse and Harassment [Where a Project SEA risks are assessed to be substantial or high, key personnel shall include an expert/s with relevant experience in addressing sexual exploitation, sexual abuse and sexual harassment cases]</i>		<i>[e.g. 5 years of monitoring and managing risks related to gender-based violence, out of which 3 years of relevant experience in addressing issues related to sexual exploitation, sexual abuse and sexual harassment]</i>
8.	<i>[modify as appropriate]</i>		