POWER GRID COMPANY OF BANGLADESH LIMITED

Bidding Document
for

Design, Supply, Installation, Testing & Commissioning of 400/230kV, 400/520MVA Transformer with associated switchgear in existing Aminbazar 400/230/132kV grid substation

Volume 2 of 3

Issued on	**:**	**January 24, 2023**
Invitation for Bids No.	**:**	**27.21.0000.101.07.420.23.398**
OCB No.	**:**	**PGCB/400kVTx/Aminbazar SS**
Country	**:**	**People's Republic of Bangladesh**

Employer:

Power Grid Company of Bangladesh (PGCB)
PGCB Head office Building, Jahurul Islam city, Avenue-3
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1. Scope of Supply of Plant and Services

Please refer to Volume 3 of the Bidding Document.

2. Ancillary Mechanical and Electrical Apparatus

2.1 Scope

This section of the technical specifications describes the general requirements for mechanical and electrical designs of all the plant being supplied under the contract, electrical aspects being covered in another Section of the Specification. It shall be read in conjunction with the General Conditions, Drawings, the Schedules and other sections of these technical specifications covering particular aspects of the plant. In the event of conflict between the general and special contract requirements, the latter shall take precedence.

2.2 References

2.2.1 ISO Standards

- ISO 68 General Purpose Screw Threads
- ISO 261 General Purpose Metric Screw Threads
- ISO 262 Selected sizes for screws, bolts & nuts
- ISO 272 Fasteners-hexagon products-widths across flats
- ISO 274 Copper tubes of circular section.
- ISO 448 Gas cylinders for industrial use-marking.
- ISO 885 General purpose bolts and screws-metric series
- ISO 888 Bolts, screws and studs-nominal lengths, and thread lengths
- ISO 965 / 1, 2, 3 General purpose Metric screw threads
- ISO 4759-1 Tolerances for fasteners
- ISO 9000 Quality management and quality assurance standards
- ISO 9001 Quality management systems-Requirements

2.2.2 IEC Standards

- 60034 Rotating Electrical Machines
- 60038 IEC Standard Voltage
- 60044-1 Instrument transformers - Part 1: Current transformers
- 60044-2 Instrument transformers - Part 2: Inductive voltage transformers
- 60044-5 Instrument transformers - Part 5: Capacitor voltage transformers
- 60051 Direct acting indicating analogue electrical measuring instruments and their accessories
- 60055 Paper insulated metal sheathed cables up to 15 / 30 kV
- 60059 IEC Standard Current ratings
- 60072 Dimensions and output series for rotating electrical machines
- 60073 Coding of indicating devices and actuators by colours
- 60079 Electrical apparatus for explosive gas atmospheres
- 60085 Thermal evaluation and classification of electrical insulation
- 60137 Bushings for alternating voltages above 1000 V

- 60168 Tests on indoor and outdoor post insulators of ceramic material
- 60228 Conductors of insulated cables
- 60228 A first supplement. Guide to dimensional limits of circular conductors
- 62155 Tests on hollow insulators for use in electrical equipment
- 60269 Low voltage fuses
- 60273 Characteristics of indoor & outdoor post insulators above 1000 V
- 60282 High voltage fuses
- 60296 Specification for unused mineral insulating oils for transformers & switchgear
- 60305 Characteristics of string insulator units of the cap & pin type
- 60332 Tests on electrical cables under fire conditions
- 60364 Electrical installations of buildings
- 60376 Specification and acceptance of new sulphur hexafluoride
- 60383 Insulators for overhead lines above 1000 V
- 60417 Graphical symbols for use on equipment
- 60423 Conduits for electrical purposes
- 60433 Characteristics of string insulator units of the long rod type
- 60437 Radio interference test on high voltage insulators
- 60439 Low voltage switchgear and control gear assemblies
- 60455 Solventless polymersable resinous compounds used for electrical insulation
- 60502 Extruded solid dielectric insulated power cables from 1-30 kV
- 62052 Electricity metering equipment
- 60529 Degrees of protection provided by enclosures (IP Codes)
- 60587 Test methods for evaluating resistance to tracking
- 60614 Conduits for electrical installations-Specification
- 60621 Electrical installations for outdoor sites under heavy conditions
- 60644 Specification for high-voltage fuse links for motor circuit applications
- 60660 Tests on indoor post insulators of organic mats. between 1-300 kV
- 60672 Specification for ceramic & glass insulating mats.
- 60898 Circuit Breakers for overcurrent protection for households etc.
- 60947-1 Low-voltage switchgear and controlgear - Part 1: General rules
- 60947-2 Low-voltage switchgear and controlgear - Part 2: Circuit breakers
- 60947-3 Low-voltage switchgear and controlgear - Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units
- 60947-5-1 Low-voltage switchgear and controlgear - Part 5-1: Control circuit devices and witching elements
- 60981 Extra heavy duty steel conduits for electrical installations
- 61035 Specification for conduit fittings for electrical installations
- 61084 Cable trunking & ducting systems for electrical installations
- 62271-1 High-voltage switchgear & controlgear - Part 1: Common specifications
- 62271-100 High-voltage switchgear & controlgear - Part 100: High-voltage alternating-current circuit breakers
- 62271-102 High-voltage switchgear & controlgear - Part 102: Alternating current disconnectors and earthing switches
- 62271-105 High-voltage switchgear & controlgear - Part 105: Alternating current switch-fuse combinations
- 62271-200 AC metal-enclosed switchgear & control gear for 1 kV and above
- 62271-203 Gas-insulated metal-enclosed switchgear for rated voltages of 52 kV and above
- 62271-209 Cable connections for gas-insulated metal-enclosed switchgear for rated voltages of 52 kV and above

2.2.3 British Standards

- BS EN 10250-2 Specification for Carbon steel forgings
- BS 182 Specification for galvanised line wire for telephone & telegraphic purposes
- BS EN 10244-2 Specification for testing zinc coatings on steel wire
- BS 499 Welding terms & Symbols
- BS 709 Method & testing fusion welded joints
- BS 729 Specification for hot dip galvanised coatings on iron & steel articles
- BS 970 Specification for wrought steels for mechanical & allied Engineering
- BS EN 12540 Specification for electroplate coatings of nickel and chromium
- BS1710 Specification for identification of pipelines & services
- BS EN 837-1 Specification for Bordon tube pressure and vacuum gauges
- BS 1858 Specification for bitumen based filling compounds
- BS EN 60068-218 Environmental Testing
- BS 2569 Pt 2 Protection of iron & steel against corrosion at elevated temperature
- BS EN 1435 Radiographic examination of fusion welded butt joints in steel
- BS 2765 Specification for dimensions of temperature detecting elements
- BS 2910 Radiographic examination of fusion welded circumferential butt joints
- BS 3858 Specification for sleeves for electric cables & wires
- BS 3923 Pt 1 Methods of examination of fused welds and butt joints & Pt 2
- BS 4211 Specification for ladders for permanent access to chimneys, other high structures, silos and bins
- BS4395-1-2 Specification for High Strength Grip Bolts
- BS 4479 Recommendations for coatings. Pts 1-9
- BS EN 1412 Industrial type flooring, walkways and stair treads
- BS 4604 Pt 1-2 Spec for high strength friction bolts
- BS EN 10250-3 Spec for alloy steel forgings.
- BS 4800 Schedule of Paint Colours for building
- BS 4675 Pt 2 Mechanical vibration of rotating and reciprocating machinery
- BS 4872 Pt 1 Fusion welding of steel
- BS 5395-3 Code of Practice for the design of industrial type stairs, permanent ladders etc.
- BS 5493 Code of practice for protective coating of iron & steel structures against corrosion
- BS EN ISO 9934 Method for penetrant flaw detection
- BS EN 50262 Specification for metallic cable glands
- BS 6121-2 Specification for polymeric cable glands
- BS 6121-3 Specification for special corrosion resistant cable glands
- BS 6180 Code of Practice for barriers in and about buildings
- BS 6231 Specification for PVC insulated cables for switch & control wiring
- BS EN 571-1 Method of penetrant flaw detection.
- BS 7079 Preparation of steel substrates before application of paints

2.2.4 BS European Standards

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

2.3 Definition of Terms

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

2.4 Statutory Regulations

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

2.5 Design Standards and Codes

2.5.1 General Compliance with International Standards and Codes

The Contract Works shall comply with the relevant standards as specified. Provided there is no conflict with the standards, and unless otherwise stated, all parts of the Works shall comply with the relevant international standards and design codes. Where suitable international standards do not exist, internationally accepted national standards or other approved standards shall apply.

2.5.2 Standards Named in Specification

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

2.5.3 Hierarchy of Standards

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

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

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

2.5.4 Substitution of Standards and Design Codes

The Contractor may offer works that comply with international standards, or internationally recognised national codes or standards, which differ from those specified. However the Contractor may offer works, which comply with the different standards or codes, only if, when requested by the Engineer, he is able to demonstrate to the Engineer's satisfaction that the Works offered are equal or superior to

that which would have resulted had the specified code or standard been used. This substitution of codes or standards for those specified will only be acceptable if the manufacturing organisation in question has extensive experience with the alternative code or standard offered.

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

2.6 Erection Marks

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

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

2.7 Cleaning and Painting

2.7.1 General

Following award of the Contract, the Contractor shall submit the name of the proposed paint supplier and applicator, together with a quality assurance programme, for approval. All paints for the outdoor equipment on the Contract shall be provided by one Manufacturer and preferably shall be manufactured in one country to ensure compatibility. All painting of outdoor equipment shall be carried out strictly in accordance with the paint system Manufacturer's recommendations and the application shall be checked and approved, in writing, by an authorised representative of the paint Manufacturer.

The painting of the plant shall be carried out in accordance with the appropriate schedule later in this section. The work is generally covered by the schedules but where particular items are not referred to specifically, they shall be treated in a manner similar to other comparable items as agreed with the Engineer.

The Contractor shall ensure that precautions are taken in packing and crating, to avoid damage to the protective treatment during transportation to the site. Any damage to paintwork that occurs during transport shall be made good at site.

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

Steel sections and plate shall be free from surface flaws and laminations prior to blast cleaning and shall not be in worse condition than ISO 8501-01.

Where paint coatings are proposed for the protection of surfaces of equipment exposed to corrosive conditions, such as plant items exposed to brine or sea water, or immersion in liquids or wet gases, the coatings shall be formulated to be suitably corrosion resistant and shall be high voltage spark test- ed at works and at Site prior to commissioning. The test procedure shall be based on the use of a high voltage direct current. The voltage used shall be 75% of the breakdown voltage of the coating. This breakdown voltage shall first be separately determined using test plates coated with the specified coating formulation and thickness. The coating on the test plate shall also be micro-sectioned by the applicator to show that it is free from vacuoles and other defects likely to invalidate the test procedure.

If the defects revealed by the above test procedure do not exceed one per 5 m² of coating surface, the coating need not be re-tested after the defects have been repaired. If the defects exceed one per 5 m² of coating surface, the repairs shall be re-tested after any curing is complete, and this procedure shall be repeated until the defects are less than one per 5 m² of coating surface. After repair of these defects, the equipment can be placed in service without further testing.

All coatings proposed for the internal protection of domestic water storage tanks and desalination plants shall be certified as suitable for use in potable water installations by an approved independent authority and shall meet the non-tainting requirements of BS 3416.

The Engineer will consider alternative paint schemes to meet the requirements of fabrication using modern automated materials handling systems, provided that the Contractor is able to demonstrate that they offer the same standards of surface protection and service life as those intended by the Schedules.

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

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

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

Where lapped or butted joints from part of an assembly that is assembled or part assembled prior to final painting, the jointed surfaces shall be cleaned free from all scales, loose rust, dirt and grease and given one brush-applied coat of zinc phosphate primer before assembly.

Paint shall not be applied to surfaces which are superficially or structurally damp and condensation must be absent before the application of each coat. Painting shall not be carried out under adverse weather conditions, such as low temperature (below 4°C) or above 90 % relative humidity or during rain or fog, or when the surfaces are less than 3°C above dew point, except to the approval of the En- gineer or his duly appointed representative.

Priming coats of paint shall not be applied until the surfaces have been inspected and preparatory work has been approved by the Engineer or his duly appointed representative. No consecutive coats of paints, except in the case of white, shall be of the same shade. Thinners shall not be used except with the written agreement of the Engineer.

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

The schedules differentiate between "Treatment at Factory" and "Treatment at Site after Completion of Erection" but the locations at which different stages of the treatments are carried out may be modified, always providing that each change is specifically agreed to by the Engineer and the painting is fin- ished or made good at Site to the Engineer's satisfaction.

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

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

All outdoor painting shall be checked prior to issue of the final certificate and no visible corrosion or spotting shall be present. Slight loss of gloss may acceptable. In the event of visible corrosion being present, the Employer will retain the right to withhold such an amount from the Contractor as may be necessary to repaint the entire exterior part of the works.

The painting requirements shall be interpreted in accordance with the requirements and recommendations of the standards and codes of practice referred to and the paint Manufacturer's special instructions where applicable, colours being in accordance with BS 1710 and BS 4800, or equivalent material standards.

2.7.2 Schedules for Indoor Surfaces Finishes

Treatment at Factory	Treatment at Site after Completion of Erection
General	
(a) Structural and supporting steelwork, plant items above ground, tank external surfaces. All not above 95°C (or 65°C for chlorinated rubber finishes).	
Blast clean to BS 7079 2nd quality (SA 2.5) profile amplitude 40-75 µm. Then apply within 4 hours one coat (13 µm) weldable holding primer for 12 months x match protection. After fabrication is complete dress all welds, thoroughly clean to remove corrosion products, oil, grease and dirt and apply one coat (50 µm) of two pack epoxy zinc phosphate primer followed by two coats two pack epoxy micaceous iron oxide (250 µm total).	• Thoroughly clean to remove oil, grease and dirt. • Paint coats to be touched up where necessary. • Then apply one tie coat to finish (30 µm) and one coat alkyd gloss (25 µm)
(b) Steel floors, chequer plates, galleries, stairways, treads, kick stops.	
Galvanise to BS 729	Thoroughly clean to remove oil, grease and dirt. Where galvanising is damaged, wire brush to BS 7079 3rd quality (SA2) and apply 1 coat zinc rich epoxy primer (50 µm). Then apply: • 1st coat of etch primer • 2nd coat epoxy zinc chromate • 3rd coat 2-pack epoxy micaceous iron oxide (50 µm). On galleries and stairwaystop surfaces apply: • 4th coat non-skid epoxy deck paint (30 µm).

Treatment at Factory	Treatment at Site after Completion of Erection
(c) Galvanised iron and steel requiring paint finish	
Galvanise to BS 729	Thoroughly clean to remove oil, grease and dirt. Then apply: • 1st coat of etch primer • 2nd coat of zinc chromate primer (30 µm) • 3rd coat alkyd undercoat (30 µm) • 4th coat alkyd gloss (25 µm).
(d) Stainless steel, aluminium alloys and non-ferrous alloys requiring paint finish.	
Not Applicable	Thoroughly clean to remove oil, grease and dirt. Then apply: • 1st coat alkyd undercoat (30 µm) • 2nd coat alkyd gloss (25 µm).
(e) Bitumen dipped items	
Bitumen dipped.	Thoroughly clean to remove oil, grease and dirt. Then apply: • 1st coat general purpose aluminium paint (18 µm) • 2nd coat alkyd undercoat (30 µm) • 3rd coat alkyd gloss (25 µm).
Battery Rooms (open top batteries), Chlorination Plant Rooms, Electrolytic Cell Rooms	
(a) Steelwork	
Blast clean to 2nd quality BS 7079 (SA2.5) profile amplitude 40-75 µm	Thoroughly clean to remove oil, grease and dirt. Priming coat to be touched up where necessary. Then apply: • 1st coat chlorinated rubber primer to Manufacturer's instructions • 2nd coat high build chlorinated rubber (80 µm) • 3rd coat high build chlorinated rubber (80 µm).
Bright Parts	
Coat with a mixture of oil, grease or approved proprietary inhibitor.	Clean and polish
Instrument Panels, Relay Panels, Control Panels, 400V A.C. Boards, 110V D.C. Boards, Telemetry Marshalling Kiosks, Lighting and Small Power Distribution Boxes, Battery Charger Cubicles, Metal Clad Switchgear	
Acid pickle or blast clean to 1st quality BS 7079. Then apply: • 1st coat zinc chromate primer (30 µm) Stop and fill. Then apply: • 2nd coat alkyd undercoat (30 µm). Rub down with fine abrasive paper. Then apply • 3rd coat alkyd undercoat (30 µm) Rub down with fine abrasive paper. Then apply: • 4th coat alkyd matt (25 µm) • 5th coat alkyd matt (25 µm)	Touch up if necessary and burnish

Treatment at Factory	Treatment at Site after Completion of Erection
• 6th coat alkyd matt (25 µm) Total film thickness (125 µm).	

2.7.3 Schedules for Outdoor Surfaces Finishes

Treatment at Factory	Treatment at Site after Completion of Erection
General	
(a) Structural and supporting steelwork, plant items above ground, tank external surfaces. All not above 95°C (or 65°C for chlorinated rubber finishes).	
Blast-clean to BS 7079 2nd quality (SA2.5) profile amplitude 40-75 µm. Then apply within 4 hours one coat (13 µm) weldable holding primer for 6 months protection or (25 µm) weldable holding primer for 12 months protection. After the protection period, thoroughly clean to re-move oil, grease and dirt and apply one coat (50 µm) of two pack epoxy zinc phosphate primer followed by two coats two pack epoxy micaceous iron oxide (250 µm total).	Thoroughly clean to remove oil, grease and dirt. Paint coats to be touched up where necessary. Then apply one tie coat to match finish (30 µm) and one coat alkyd gloss (25 µm)
(b) Steel floors, chequer plates, galleries, stairways, treads, kick stops	
Galvanised to BS 729	Thoroughly clean to remove oil, grease and dirt. Where galvanising is damaged, wire brush to BS 7079 3rd quality (SA2) and apply one coat zinc rich epoxy pri- mer (50 µm). Then apply: • 1st coat epoxy etch primer • 2nd coat epoxy zinc chromate (30µm) • 3rd coat two pack epoxy micaceous iron oxide (100 µm) On galleries and stairways top surfaces apply: • 4th coat non-skid epoxy deck paint (30 µm).
(c) Galvanised iron and steel requiring paint finish	
Galvanised to BS 729	Thoroughly clean to remove oil, grease and dirt. Then apply: • 1st coat etch primer • 2nd coat zinc chromate primer (30µm) • 3rd coat alkyd undercoat (30 µm) • 4th coat alkyd gloss (25 µm).
(d) Stainless steel, aluminium alloys and non-ferrous alloys requiring paint finish	
Not applicable.	Thoroughly clean to remove oil, grease and dirt. Then apply: • 1st coat alkyd undercoat (30 µm) • 2nd coat alkyd gloss (25 µm).

Treatment at Factory	Treatment at Site after Completion of Erection
(e) Bitumen dipped items	
Bitumen dipped.	Thoroughly clean to remove oil, grease and dirt. Then apply: • 1st coat general purpose aluminium paint (18 µm) • 2nd coat alkyd undercoat (30 µm) • 3rd coat alkyd gloss (25 µm)
Bright Parts	
Coat with a mixture of oil, grease or approved proprietary inhibitor.	Clean and polish
Instrument Panels, Control Panels, Marshalling Kiosks, Lighting and Small Power Distribution Boxes and Junction Boxes etc.	
Blast clean, prime, undercoat and paint in accordance with the painting schedule for structural and supporting steelwork, with finish coat of paint applied at Manufacturer's works	Clean and touch up as necessary
Water and Oil Storage Tanks-Internal Surfaces	
The epoxy paint formulation shall be to the approval of the Engineer. The finished coating shall be capable of being tested with a high voltages spark tester for absence of pinholes and porosity. For oil storage tanks, solvent-free epoxy paint formulation shall be used.	
For tanks delivered to site in plate sections, the plates shall be blast cleaned to BS 7079 1st quality (SA3) profile amplitude 40-75 µm and then within 4 hours coat with a weldable holding primer dry film thickness 25 µm	Welded Construction at Site. After erection all welds shall be dressed to remove rough edges and burrs and all sharp edges shall be radiused 3 mm Prior to painting, all surfaces shall be sweep blast cleaned to a sound surface free from rust and debris. Then apply within 4 hours: • 1st coat Isocyanate or amine cured epoxy primer 25 µm • 2nd coat Isocyanate or amine cured high build epoxy (125 µm) • 3rd coat Isocyanate or amine cured high build epoxy (125 µm).
Sectional Construction: Prior to assembly, all component items to be blast cleaned to BS 7079 1st quality (SA3) profile amplitude 40-75 µm. Then apply: • 1st coat Isocyanate or amine cured epoxy primer (25 µm). After assembly, clean all surfaces free from rust, grease and dirt. Priming coat to be touched up as necessary. Then apply:	Sectional Construction: Touch up damaged areas as necessary.

Treatment at Factory	Treatment at Site after Completion of Erection
• 2nd coat Isocyanate or amine cured high build epoxy (125 µm) • 3rd coat Isocyanate or amine cured high build epoxy (125 µm).	
Radiators	
Radiators shall be thoroughly cleaned and treated externally by phosphating or other approved rust inhibiting process and given, preferably by flood painting, the same number and type of coats specified in Gen- eral Sub-Clause of this Clause. Radiators that are hot dip galvanised to BS.729, Part 1, shall be artificially weathered and given one coat of zinc chromate primer followed by the same number and type of paint coatings specified in Clause. Radiators shall be painted with Munsell colour No. 5Y 7/1.	

2.8 Rating Plates, Nameplates and Labels

2.8.1 General

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

Nameplates or labels shall be of non-hygroscopic, non-deteriorating and non-warping material with engraved lettering of a contrasting colour or, in the case of indoor circuit breakers, starters, etc., white plastic material with black lettering engraved thereon.
Items of plant such as valves, mounted outdoors or subject to harsh operating conditions, shall be provided with engraved chromium plated brass or stainless steel nameplates or labels with engraving filled with black enamel.

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

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

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

All equipment within panels and desks shall be individually identified.

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

2.8.2 Rating Plates

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

2.8.3 Circuit Labels

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

In addition, the device number allocated by the Engineer to each item of plant shall be displayed in text height 30 mm on all operating mechanisms and 60 mm or larger in height on principal items of Plant, e.g. busbars, transformers etc. The same device number shall be displayed on control cubicles in text height 10 mm or larger as may be required by the Engineer.

2.8.4 Pipe Service Identification

A colour-banding scheme shall be used to identify pipework included within this Contract. The colours employed shall be in accordance with the painting specification herein. Colour bands shall be painted on each side of all valves and items of equipment in the piping systems. The use of adhesive-backed colour bands is not permitted.

Valve labels shall be circular and fitted under the hand-wheel captive nut. For check valves and small valves, the Contractor may provide rectangular labels fitted to the valve or secured close by the valve.

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

Where the direction of flow through a valve or other device is an important requirement for correct functioning, the body of the valve or device shall be legibly marked with a cast on or a properly secured arrow, showing the direction of flow. Pipework shall be provided with plentiful large painted arrows or other secure and durable arrow markings to allow the flows of fluids around the plant to be readily understood.

2.9 Environmental Protection & Tropicalisation

2.9.1 General

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

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

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

Outdoor plant shall be rated and constructed so that its performance, operation, reliability, maintenance and or life shall meet the specified design and operating conditions.

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

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

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

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

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

2.9.2 Tropicalisation

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

- Metals: Iron and steel are generally to be painted or galvanised as appropriate. Indoor parts may alternatively have chromium or copper-nickel plating or other approved protective finish. Small iron and steel parts (other than stainless steel) of all instruments and electrical equipment, the cores of electromagnets and the metal parts of relays and mechanisms shall be treated in an approved manner to prevent rusting.
- Screws, nuts, springs, etc. The use of iron and steel shall be avoided in instruments and electrical relays wherever possible. Steel screws shall be zinc, cadmium or chromium plated, or when plating is not possible owing to tolerance limitations, shall be of corrosion-resisting steel. Instrument screws (except those forming part of a magnetic circuit) shall be of brass or bronze. Springs shall be of non-rusting material, e.g., phosphor bronze or nickel silver, as far as possible.
- Rubbers: Neoprene and similar synthetic compounds, not subject to deterioration due to the climatic conditions, shall be used for gaskets, sealing rings, diaphragms, etc.

2.10 Platforms, Stairways, Ladders and Hand-Railing

2.10.1 General

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

Galleries, platforms and stairways shall be designed generally for a load of 7.5 kN/m² but where loads in excess of this are likely to be imposed during operation or maintenance, the Contractor shall make due allowance for the increased loads in the design. Particular care shall be given to their rigidity. All the necessary supports from the floors, buildings and foundations shall be supplied under this con- tract.

Galleries and platforms around plant subject to significant expansion shall be designed to allow for such expansion and to provide safe and adequate access for both hot and cold conditions.

Platforms and galleries shall have a minimum width of 850 mm clear passageway and shall be enclosed by hand railing on both sides. In cases where there is a space not exceeding 200 mm on one side of a passageway hand-railing need be supplied for one side only but an edging strip shall be provided on the side without handrail. The minimum headroom on platforms and galleries shall be 2100 mm.

Ladders will only be permitted where stairways are impractical and access is required for mainte- nance. All platforms, stairways, ladders and other access ways, shall comply with the requirements of BS 5395 Part 3, unless otherwise stated. As far as practical the flooring, stair treads and handrails shall conform to a uniform pattern throughout the whole of the Contract Works.

2.10.2 Flooring

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

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

The open grid flooring and stair treads shall be from an approved Manufacturer and generally in accordance with BS 4592. The pattern of open grid flooring and chequer plate shall be uniform and laid with the pattern in one direction.

Open grid floor panels shall be not less than 25 mm in depth and shall be fitted neatly between kerbs and clamped with nuts and bolts in such a manner as to permit ready removal or replacement. The design of the clamps shall be for approval and only minimal protrusion above the floor level will be permitted.

Where chequer plate is supplied it shall be galvanised mild steel to an approved design. No chequer plate shall be less than 10 mm thick and all plates shall be secured to the supporting steel by galvanised countersunk screws of not less than 10 mm nominal size.

2.10.3 Hand-Railing and Protective Barriers

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

Double hand railing shall be provided unless otherwise specified. Each length shall be joined by internal ferrules and all joints shall be neatly finished by the removal of all burrs.

The top rail shall be not less than 30 mm diameter and mounted at a height of not less than 1100 mm from the gallery or platform level. The intermediate rail shall be not less than 25 mm diameter and mounted at a height of not less than 535 mm from the gallery or platform level. Handrails for stairways shall have the top rail at a height of not less than 900 mm and lower rail at not less than 420 mm above the stairway pitch line.

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

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

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

2.10.4 Stairways

Where specified, main stairways shall have a minimum stair tread width of 1100 mm; other stairways shall have a minimum width of 750 mm. Wherever possible, the angle of slope of stairways shall be standardised. Angles exceeding 42° to the horizontal shall not be used.

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

2.10.5 Fixed Access Ladders

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

2.11 Nuts, Bolts, Studs and Washers

The threads and other details of fasteners shall comply with the relevant ISO Standards for metric series fasteners. Nuts and bolts for pressure parts shall be of the best quality steel. Nuts, bolts, studs and washers shall be of materials most suitable for the service operating conditions and designed to ensure the stresses arising in normal operation shall not exceed those necessary to ensure that the specified plant life is achieved.

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

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

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

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

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

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

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

2.12 Forgings

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

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

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

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

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

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

2.13 Castings

2.13.1 General

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

All castings shall be homogeneous and free of shrinkage, pipes, under-sizing, porosity or voids. "Bum-in" repairs shall not be acceptable and no welding, filling, interlocking or plugging of defective parts shall be done without the Engineer's approval in writing. All repairs shall be subjected to non-destruct-

ive examination (ultra-sonic, X-rays, gamma-rays) after heat treatment. Welding repairs to castings that will be in contact with corrosive liquids, such as seawater or brine, will only be permitted under special circumstances.

2.13.2 Steel Castings

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

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

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

Only welders who have passed an appropriate qualification test shall be employed on the repair of castings. All repairs shall be carried out by the metal arc process. Ultrasonic inspection shall be applied to all important castings to locate the extent of sub-surface defects and to check the wall thickness.

All castings shall be identified by stamped or cast-on reference marks, which shall be entered on all relevant documents and test certificates. The Engineer may require that certain castings be examined using radiographic techniques. The Contractor shall include for this eventuality and shall comply with the Engineer's instructions when issued.

2.13.3 Iron Castings

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

Weldable grades of iron castings may be repaired by welding provided the approval of the Engineer is first obtained. The Contractor shall submit full details of the proposed weld repair procedure and weld procedure qualification test prior to making any weld repairs.

The maximum size of defect for which weld repair will be permitted is:

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

Test blocks shall be integrally cast on all medium and large castings. The Engineer may require that certain castings be checked using radiographic techniques. The Contractor shall include for this eventuality and shall comply with the Engineer's instructions when issued.

2.13.4 Aluminium Bronze Castings

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

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

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

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

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

2.14 General Welding Requirements

2.14.1 General

All welding shall conform to the relevant British Standards, or other British or National Standard Specification as agreed by the Engineer. Where there is a conflict between Codes and/or Standards the Engineer's decision will prevail.

2.14.2 General Fabrication

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

2.14.3 Weld Procedure Documents

Complete and fully detailed weld procedure documents shall be kept by the Contractor and these shall be made available to the Engineer on request. Prior to commencement of welding the Contractor shall submit to the Engineer for approval the welding procedures to be used in the fabrication of the relevant sections of work.

The weld procedure documents shall be fully detailed and each shall indicate clearly which item it is intended to cover. The procedures shall be in accordance with the requirements of BS 499 Part 1, Appendices A-G.

2.14.4 Weld Procedure Qualification Tests

Weld procedure qualification tests shall be carried out in accordance with the requirements of BS EN 288, or agreed National Standard for the item of plant under consideration. Provided that the Contractor confirms that the basic parameters of the procedure have not been changed since approval, the results of weld procedure qualification tests previously carried out under the supervision of an internationally recognised inspecting authority may be accepted by the Engineer.

The Contractor shall inform the Engineer of any proposed changes to the welding procedures before such changes are implemented. If in the opinion of the Engineer a further qualification test is required as a result of such changes, then the Contractor shall perform the required test without additional charge.

The results of all tests shall be made available, for examination by the Engineer, if required.

2.14.5 Welder's Qualification Tests

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

All welders' tests shall be witnessed and/or approved by the Engineer before the welder or operator is permitted to work. The decision of the Engineer regarding the acceptability of any test or existing qualification tests, shall be final.

Records showing the date and results of the qualification tests performed by each welder and weld operator, together with the identification number assigned to him, shall at all times be available for scrutiny by the Engineer.

2.14.6 Storage of Welding Consumables

Welding consumables shall be stored in a manner that will protect them from all forms of deterioration prior to use and shall be properly identified. Gas cylinders for use with burning or welding equipment shall be marked in accordance with the requirements of BS 349 or IS0448. Site storage procedures for gas cylinders will require the approval of the Engineer.

2.14.7 Welding Equipment

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

2.14.8 Visual Weld Inspection

Each weld shall be subjected to a stringent visual inspection and shall be free from undercut, excessive spatter, craters, cracks, porosity and other surface imperfections. Welds shall be of regular contour, even weld ripple and indicative of good workmanship. Fillet welds shall be checked for dimensional tolerance and form using a fillet weld gauge. Fillet welds should be slightly concave in form and each leg of the weld shall have equal length.

2.14.9 Internal Examination

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

2.14.10 Non-destructive Examination

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

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

2.14.11 Ultrasonic Examination

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

2.14.12 Magnetic Crack Detection

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

2.14.13 Dye Penetrant Tests

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

2.14.14 Quality Requirements for Welds

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

2.14.15 Weld Repairs

The Engineer's approval shall be obtained prior to commencement of any repair or rectification work. Weld repairs shall be made to the same procedure as for the original weld. All tests shall be repeated after the repair has been completed and reports on radiographic and ultrasonic tests shall be marked to indicate that the report refers to a repaired weld.

2.14.16 Mandatory Inspections

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

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

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

2.15 Galvanised Work

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, not less than 98% of which must be pure zinc and in accordance with BS 729 or BS 443 as applicable. No alternative process shall be used without the approval of the Engineer. Bolts shall be completely galvanised including the threads, but the threads of nuts shall be left uncoated and shall be oiled. The zinc coating shall be uniform, clean, smooth and as free from spangle as possible.

Galvanised wire shall comply with the requirements of BS 182 and the thickness of the coating and testing thereof shall comply with BS 443. Nuts and bolts and small components shall be tested in accordance with BS 729. The Engineer may select for test as many components to be weighed after pickling and before and after galvanising as he may think fit.

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

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

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

2.16 Chromium Plating

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

2.17 Pumps

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

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

Pumps shall be capable of continuous operation with minimum maintenance.

2.18 Pipework

During the contract Engineering, the Contractor shall supply to the Engineer schedules of the pipe- work provided under this contract. These schedules shall state for each pipework system or part of a pipework system the design and operating pressures and temperatures, the fluid transmitted, the pip- ing and valve materials, the types of valves, any corrosion allowance, the pipework design code, insu- lation proposals, pipe supports and any other data relevant to the mechanical design of the pipework system or part of a pipework system.

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

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

The procedure for internal cleaning of pipes adopted by the Contractor is to include the following:

- Thorough cleaning of all internal surfaces prior to erection to remove accumulations of dirt, rust, scale etc., and welding slag due to site welding before erection.
- Thorough cleaning of all pipework after erection by blowing through to atmosphere to ensure that no extraneous matter is left in the system.

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

Pipework shall be supported and anchored in an appropriate manner in accordance with the provi- sions of US Standard ANSI B31.1 or the Standard to which the pipework is designed. The whole of the

pipework and accessories included in this Contract are to be supported and mounted in an approved manner. All necessary slings, saddles, structural steelwork, foundation bolts, fixing bolts and all other attachments are to be supplied. The number and positions of all supports and the maximum weight carried by a support is to be subject to the approval of the Engineer.

2.19 Valves

All valves shall be suitable for the service conditions under which they are required to operate. The design, construction and choice of materials shall take into account all operational deviations including pressure surge and thermal shock.

All valve hand operating mechanisms shall be easily operable by one man. The mechanisms shall be such that the total force at the rim of the hand-wheel or other point of application of manual action shall not need to exceed 400 N (normally 200 N pull plus 200 N push) to exercise any valve. Special attention shall be given to the operating mechanism for large size valves with a view to ensuring that a minimum of maintenance is required and to obtaining quick and easy operation.

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

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

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

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

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

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

2.20 Pressure Vessels

All vessels shall be designed, constructed and otherwise comply with appropriate international or national pressure vessel design codes, unless the vessel in question falls into one of the following groups:

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

- hot water storage vessels heated by steam or any other indirect means when none of the following limitations is exceeded:
  - a heat input of 58kW
  - a water temperature of 93°C
  - a nominal water containment capacity of 454 litres.
- vessels having an internal or external design pressure not exceeding 1.03 bar gauge, this design pressure being not less than the maximum expected difference that may exist between the inside and outside of the vessel at any time.
- vessels having an internal diameter not exceeding 150 mm.
- vessels and equipment covered more appropriately by boiler or pipework design codes.

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

Notwithstanding the foregoing exclusions, if it is stated elsewhere in the Specification that a particular vessel shall comply with a pressure vessel design code, then a vessel complying with a suitable design code shall be provided.

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

2.21 Lubrication

The Contract is to include for the supply of flushing oil for each lubrication system when the item of plant is ready for preliminary tests and the first filling of approved lubricants for the commercial opera- tion 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 Engineer for approval. The number of different types of lubricants is to be kept to a minimum. Copies of this schedule shall be included in both the draft and final copies of the operating and maintenance instructions. In the case of grease lubricated roller type bearings for electric motors a lithium based grease is preferred.

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

2.22 Oil Level Indicators

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

2.23 Pressure Gauges

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

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

Gauges shall be calibrated to read pressure at the tapping point and a sealed pressure transmitting system shall be used. All pressure gauges are to be clearly identified by means of labels of approved type and lettering. All pressure gauge piping is to be of corrosion resistant steel or copper tube.

2.24 Thermometer Pockets

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

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

2.25 Gauge Cubicles and Panels

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

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

2.26 Locking Facilities

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

- Control position selector switches in all positions provided, except where other electrical or mechanical interlocking is approved.
- Marshalling, operating and terminal kiosks or cubicle access doors and panels.
- Isolating valves in open or closed positions.

Locking facilities shall be of an approved dead latch type. Three keys shall be supplied for each lock and all locks and keys shall be non-interchangeable. Where a set of locks is provided under a particular section of the Plant, a group master key shall be supplied in addition.

A schedule of locks and keys shall be submitted to the Engineer for approval.All locks and padlocks shall be of brass and where they are fitted to switchboards or similar cubicles shall have the visible parts chromium plated.

Where a group of locks is supplied under any part of the Contract, a rack or cabinet of approved design shall be supplied for the accommodation of all padlocks and/or keys while not in use. The padlocks and keys shall be engraved with an agreed identifying code or inscription and this shall be repeated on the racks or cabinets on engraved labels.

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

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

2.27 Electrical Equipment

2.27.1 General

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

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

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

Corresponding parts of similar equipment, and equipment liable to renewal, shall be fully interchangeable and the Contractor will be required to demonstrate this feature to the Engineer's and Employer's satisfaction.
All equipment shall operate without undue vibration and with the least practical amount of noise.

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

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

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

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

2.27.2 Electrical Equipment Enclosures

Equipment enclosures for electrical equipment shall comply with IEC 60079, IEC 60529 and IEC 60947-1 as applicable. Equipment enclosures for use in hazardous areas other than explosive gas atmosphere shall comply with National and Local Regulations relating to this application. Unless oth- erwise specified, minimum equipment enclosure classifications for non-rotating electrical equipment shall be as follows:

- Indoors only in totally enclosed rooms with provision for limiting ingress of dust: IP 31
- Indoors, except as noted otherwise: IP 54
- Outdoors, and indoors in areas subject to water spray, or heavy condensation: IP 55W

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

2.28 Current Ratings

2.28.1 Normal Current Ratings

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

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

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

2.28.2 Temperature Rise

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

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

To allow for high ambient site temperatures, the allowable temperature rise for transformers shall be reduced by a maximum of 10°C from the standard value in IEC60076.

In such cases where the Contractor is unable to guarantee the permitted maximum temperature reached under site conditions, taking account of solar heating, then sunshades shall be provided to the Engineer's approval.

The maximum temperature attained by components under the most onerous service conditions shall not cause damage or deterioration to the equipment or to any associated or adjacent components. The Contractor shall submit his calculations to the Engineer to prove that all plant has been sufficiently de-rated to suit the site conditions and any changes required by the Engineer shall be made at no ex- tra cost.

2.28.3 Short-Time Current Ratings

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

Equipment shall be so constructed as to withstand the specified maximum short-circuit currents for the time specified in the Schedules without the temperature exceeding the specified maximum short-time temperature or value stated in the relevant standard, under these conditions. The equipment shall be considered as being operated at the maximum permitted continuous temperature prior to inception of the short circuit.

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

2.29 Voltage Ratings

2.29.1 Normal Voltage Ratings

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

All electrical equipment shall, except where otherwise specified, be capable of continuous operation at a voltage in the range of ±10% of the nominal voltage and at a frequency in the range of 47 to 51 Hz coincidentally without deterioration.

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

2.29.2 Short-Time Voltage Ratings

All electrical equipment shall be so designed such as to withstand abnormal system voltages as required by the applicable BS, IEC or acceptable International Standard.

2.30 Electrical Insulation

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

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

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

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

Linseed oil and untreated materials of fibre, leatheroid, presspahn, asbestos or other similar hygroscopic types of materials shall not be used for insulation purposes. Untreated leatheroid and presspahn may be used for mechanical protection of winding insulation.

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

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

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

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

2.31 Insulating Oil

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

2.32 Control and Selector Switches

Control switches shall be of the three-position type with a spring return action to a central neutral position and without a locking feature. Circuit breakers shall have control switches which shall be labelled open/N/close or (0/N/I) and arranged to operate clockwise when closing the circuit breakers and anti-clockwise when opening them.

Control switches of the discrepancy type shall be provided where specified. Such discrepancy control switches shall be arranged in the lines of the mimic diagram. Such switches shall include lamps and be of the manually operated pattern, spring loaded such that it is necessary to push and twist the switch past its indicating position for operation.

The lamp shall be incorporated in the switch base and shall flash whenever the position of the controlled device is at variance with the position indicated by the control switch. Hand dressing of the control switch to the correct position shall cause the lamp to extinguish.

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

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

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

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

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

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

2.33 Panels, Desks and Cubicles

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

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

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

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

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

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

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

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

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

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

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

Each panel shall include rear access doors internal power sockets and door-operated internal lighting, and be clearly labelled with the circuit title at front and rear, with an additional label inside the panel. Panel sections accommodating equipment at voltages higher than 125V (nominal) shall be partitioned off and the voltage clearly labelled. Each relay and electronic card within panels shall be identified by labels permanently attached to the panel and adjacent to the equipment concerned. Where instruments are terminated in a plug and socket type connection both the plug and the socket shall have permanently attached identifying labels.
Instrument and control devices shall be easily accessible and capable of being removed from the panels for maintenance purposes.

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

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

All panels, whether individually mounted or forming part of a suite, shall incorporate a common internal copper earthing bar onto which all panel earth connections shall be made.

Suitable studs or holes to the Engineer's approval shall be left at each end of the bar for connection to the main station earthing system and possible future extension.

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

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

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

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

All cubicles, desks and panels shall be painted externally with a high gloss paint of Munsell 5Y7/1 colour. The interiors of all cubicles, desks and panels shall be painted matt white.

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

2.34 Instruments & Meters

2.34.1 Indicating Instruments

All indicating instruments shall be of the flush mounted pattern with dust and moisture proof cases complying with BS 2011, Classification 00/50/04, and shall comply with IEC 60051-1.

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

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

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

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

2.34.2 Electrical Meters

All electrical meters shall comply with IEC 62053 and other relevant IEC standards and, unless otherwise specified, shall be of accuracy Class 1, except Class 0.2 for energy meters. Three-phase power measuring instruments shall be of the three-phase unbalanced load pattern wherever the current and voltage references permit.

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

Due allowance shall be made for the errors of current and voltage transformers with which they shall work and whose accuracy class shall be Class 0.2.

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

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

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

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

Each 400 kV and 230 kV feeder shall be provided with Main 1 and Main 2 energy meters.

The energy meter shall be 3-element, 4-wire arrangement of programmable digital type and shall have proven performance and shall consist of different types, from either the same Manufacturer or different Manufacturers. The accuracy class of the energy meter shall be 0.2.

2.35 Indicating Lamps and Fittings

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

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

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

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

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

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

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

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

Red	energised or operative position
Green	de-energised or inoperative position
Amber	fault or abnormal condition
White	healthy or normal condition
Blue	other purposes, to be used with descriptive label

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

2.36 Anti-Condensation Heaters

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

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

Motor anti-condensation heaters where fitted shall be fed from an LV single phase and neutral supply bus-wired through the board. The supplies shall be individually fused and will be switched by auxiliary contacts on the contactor and isolated by auxiliary contacts on the contactor isolator.

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

2.37.1 General

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

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

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

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

- Class 1: conductors up to a maximum of 0.9 mm diameter where necessary for wire-wrapped terminations and similar techniques,
- Class 2: conductors except where specified otherwise,
- Class 5 and Class 6: conductors between points subject to relative movement.

The following minimum conductor sizes shall be used:

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

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

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

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

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

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

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

2.37.2 Identification of Wires

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

When a wire numbering system is used, it should be in accordance with IEC standards or with a functional marking system. Both ends of every wire and core in control and instrument cables shall be fitted with interlocking ring ferrules of white insulating material indelibly marked with black characters, complying with BS 3858. Heat shrink marking sleeves may be used, but adhesive markers are not acceptable.

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

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

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

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

2.37.3 Terminals and Terminal Blocks

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

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

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

Where clamp type terminals are used, Class 1 and Class 2 conductors may be terminated without lugs. Crimp lugs shall be used for Class 5 and Class 6 conductors. Means shall be provided for retain- ing the identifying ferrules of the wire end when it is disconnected.

Pinch screw type terminals shall not be permitted.

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

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

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

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

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

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

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

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

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

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

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

2.38 Cable Boxes and Glands

2.38.1 General

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

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

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

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

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

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

Flexible connections shall be provided between cable lugs and bushings for all cables of 300 mm² section and greater.

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

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

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

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

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

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

Removable gasketted steel gland plates shall be provided for multicore cables. The cable entry into the cable box shall be arranged so that there is adequate space to manipulate the cable for glanding and termination.

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

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

2.38.2 Additional Requirements for Compound-filled Cable Boxes

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

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

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

2.38.3 Cable Glands

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

All glands shall be provided with an earthing tag or equal facility. For cables having conductors not larger than 4 mm² serrated washers may be used in place of earthing tags to provide earth continuity.

Glands for armoured or screened cables greater than or equal to 240 mm² and all insulated glands for power cables shall be provided with an integral earthing lug. On cable glands up to and including 40 mm nominal size, the earthing connection shall have a short circuit rating of at least 25 kA for 1 second and of at least 40 kA for 1 second on larger sizes.

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

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

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

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

2.39 Box-Filling Compounds

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

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

The Contractor shall take particular care to adhere to the recommended topping-up procedures and to ensure that no leakage or migration of the filling compound occurs.

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

2.40 Oil or Compound-Filled Chambers

All joints of oil- or compound-filled fabricated chambers, other than those that have to be broken, shall be welded and care shall be taken to ensure that the chambers are oil-tight. Defective welded joints shall not be repaired but maybe re-welded subject to the written approval of the Engineer.

Insulating compound shall comply with BS 1858.

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

2.41 Joints and Gaskets

All joint faces are to be flat and parallel to the approval of the Engineer and arranged to prevent the ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of oil or air. Oil-resisting synthetic rubber gaskets are not permissible, unless the degree of compression is accurately controlled. For gaskets of cork or similar, oil resisting synthetic rubber may be used as a bonding medium.

2.42 Valves on Electrical Equipment Fluid Lines and Vessels

Valves shall comply with the requirements of Clause 2.19. All drain and filter valves shall be provided with gun metal adaptors suitable for connecting a flexible hose having a screwed coupling of approved size. Captive-screwed caps shall be provided for all such adaptors.

2.43 Junction and Marshalling Boxes

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

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

All outdoor kiosks, cubicles and panels shall be provided with sun/rain shades. All kiosks, cubicles and panels not in air-conditioned rooms shall be provided with thermostat controlled anti-condensation heaters. All kiosks, and cubicles shall be fitted with door operated internal illumination lamps. All necessary gland plates shall be provided undrilled.

Boxes shall be complete with suitably inscribed identification labels. Boxes for use in hazardous areas shall have all entries factory pre-drilled. Every unused screwed entry shall be sealed by means of a tamperproof screwed plug in accordance with IEC 60079. Hazardous area boxes with bolted or screwed lids shall require the use of special keys or spanners, for lid removal, protected against the ingress of moisture, by an approved means, compliant with local standards.

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

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

2.44 Conduit and Accessories

Conduit installations shall comply with IEC standards 60364, 60621, 60981 and 61035. Installations shall also be compliant with local regulations, unless otherwise approved by the Engineer.

All conduit and conduit fittings shall comply with IEC 60423 and IEC 60614. Unless otherwise approved, all conduit and conduit fittings shall be threadable steel conduit with minimum enclosure classification IP55, heavy mechanical protection and high resistance to corrosion inside and outside.

No conduit smaller than 20mm diameter shall be used.

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

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

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

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

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

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

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

Flexible metallic conduit shall be used where relative movement is required between the conduit and connected apparatus, and a separate earth continuity conductor shall be provided.

2.45 Trunking

Steel trunking may be used for running numbers of insulated cables or wires in certain positions to the approval of the Engineer. The trunking thickness shall not be less than 1.2 mm. Connection of conduit to trunking shall be with socket and male bush. All trunking shall be manufactured from hot-dip zinc coated steel sheet and conform to IEC 61084.

2.46 Electric Motors

2.46.1 General

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

2.46.2 Type and Rating

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

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

Three phase a.c. motors shall be rated for the voltages specified elsewhere in the Specification. The minimum rated output of HV motors shall comply with IEC 60034-1. The maximum rated output of LV motors shall not exceed 150 kW, except where approved by the Engineer.

2.46.3 Insulation

Motors shall be insulated with materials complying with IEC 60085. All motors shall have Class F insulation but the temperature rise shall not exceed the limits applicable to Class B.

2.46.4 Conditions of Operation

A.C. motors shall be capable of continuous operation under the service conditions within the Zone A voltage and frequency variations specified in IEC 60034-1 Figure 13 or as covered in Clause 4.1 whichever is the most onerous. Unless otherwise specified, the motors shall be capable of continued operation at 75% rated voltage and rated frequency for a period of 5 minutes without injurious heating. In the event of loss of supply, all motors shall be suitable for restarting against the full residual voltage in the motor winding during motor run-down.

2.46.5 Starting Performance

Unless otherwise specified or required, cage induction motors up to and including 40 kW shall have a starting performance better than or equal to Design N in accordance with IEC 60034 (External inertias for 50 and 60 Hz motors shall be in accordance with BS 4999 Part 112). Cage induction motors above 40 kW shall have a starting performance better or equal to Design D in accordance with BS 4999 Part 112. The starting current at full voltage shall not exceed 6 times full load current.

The starting torque at 80% voltage shall be adequate for starting the driven load under the most arduous conditions, such as open fan vane or open pump discharge valve. The accelerating torque at any speed and 80% rated voltage shall be not less than 10% of motor rated torque. In any event the motor starting torque at 100% rated voltage, and at all speeds between standstill and the speed at which

breakdown torque occurs, shall be not less than 1.7 times the torque obtained from a load curve which varies as the square of the speed and is equal to 100% motor rated torque at rated speed.

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

Electric motors shall be suitable for two successive starts with the motor already at full load working temperature, subject to the motor being permitted to decelerate to rest under operating conditions between successive starts. After a cooling period of 30 minutes at rest another starting sequence of two successive starts shall be permissible.

2.46.6 Bearings

The type of bearings used in the motor shall be fully compatible with those used in the driven equipment. The type of bearing, bearing numbers and regressing interval shall be stamped on each motor rating plate. Bearings shall comply with the applicable ISO standards. Bearings shall be designed to exclude the ingress of dust and water and sealed to prevent leakage of lubricant along the shaft.

2.46.7 Enclosures and Methods of Cooling

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

- IP54 for indoor locations not subject to hosing.
- Not less than IP 55W for outdoor locations, and indoor locations subject to hosing.
- Where motors are exposed to solar radiation, sunshades shall be fitted, if required by the Manufacturer to meet his guarantees.

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

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

Aluminium and its alloys shall only be used when the Manufacturer can demonstrate that such materials are entirely suitable for the particular application at its installation location. Fans of identical motors shall be interchangeable without affecting motor balance.

2.46.8 Anti-condensation Heaters

To minimise condensation in all outdoor 400V and intermittently used 400 V motors when out of service, heaters of an approved type and rating, suitable for operation from a 230 V a.c. single phase supply, shall be fitted inside the lower half of the stator frame.
The control of anti-condensation heaters shall be so arranged that they are normally energised when the motor is not running.

2.46.9 Terminals and Terminal Boxes

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

- Main (line) connections.
- Star point connections.
- Anti-condensation heater connections.
- Instrumentation and alarm devices.

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

Terminals and terminal leads shall be to approval and shall be substantially designed for connection to a system having the symmetrical short circuit rating of the source switchboard, as limited by fuses, where applicable. The clearances and creepage distances shall apply also to insulated terminals and connectors. Porcelain terminal bushings and insulators shall not be used.

Main and star point terminal boxes of HV motors shall be of steel. Cast iron may only be used for LV motor terminal boxes and auxiliary terminal boxes. Star point terminal boxes shall only be provided where required to accommodate neutral end current transformers and shall be positioned opposite the main terminal box.

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

Provision shall be made for earthing the cable armour and the cable insulation screens, where applicable, in accordance with the cable termination method being used. In auxiliary cable boxes either stud terminals or clamp terminals shall be provided. The anti-condensation heater terminal box shall have a warning label adjacent to it, stating "motor heater-terminals live".

2.46.10 Earth Terminal

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

2.46.11 D.C. Motors

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

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

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

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

2.47 Motor Starters and Contactors for Separate Mounting

In special cases for motors below 30 kW, and non-essential non-plant auxiliaries, such as roller shutter doors, and where approved by the Engineer, separately mounted starters for motors may be provided. Each such motor starter shall be equipped with two or three pole control gear, as appropriate, for direct-on-line starting and shall be complete with a fully shrouded lockable isolating switch, mechanically interlocked with the means of access. All starters shall be supplied by one Manufacturer, except where otherwise approved by the Engineer.

Contactors shall be of robust design and shall comply with IEC 60947. All contactors and their associated apparatus for minor motors shall be capable of operating without overheating for all specified motor operating conditions, and including for a period of five minutes at normal frequency if the supply voltage falls to 80% of nominal voltage.

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

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

2.48 Pushbuttons and Separately Mounted Pushbutton Stations

Pushbuttons, which may be of the illuminated or non-illuminated type, shall be shrouded or well recessed in their housings in such a way as to minimise the risk of inadvertent operation. In instances where "enable" pushbuttons are required they shall be electrically interlocked with the normal control such that deliberate operation of the "enable" push-button is required before the normal control can take place.

The colour of pushbuttons shall be as follows:

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

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

Loose pushbutton stations, unless supplied as weatherproof free standing enclosures, shall be of the metalclad weatherproof type suitable for wall or bracket mounting with a minimum enclosure classification of IP55.

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

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

Any necessary pushbuttons used on covered desks, panels etc. have to be of special types (e.g. miniature, illuminated). The specifications and requirements for these special pushbuttons shall be agreed with the Engineer.

Emergency stop pushbuttons shall be provided adjacent to all motors and machinery with exposed moving parts, couplings etc. to prevent danger, and on main and local control panels. These pushbuttons shall have a large "mushroom" head, be coloured red and incorporate a protective cover or guard to avoid accidental operation. These buttons shall automatically lock in the depressed position, requiring twist or key resetting. Contacts shall be provided to cause tripping of the associated circuit, prevent restart of the circuit and bring up an alarm in the Central Control Room.

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

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

2.49 Miniature Circuit Breakers, Fuses and Links

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

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

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

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

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

2.50 Earthing and Bonding

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

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

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

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

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

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

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

The size of the copper earth bar in control panels, control desks or similar enclosures containing low voltage apparatus shall be such as to comply with the specified requirements for withstanding prospective short-circuit currents. The size of this bar shall be a minimum of 100 mm² cross-sectional area, providing that sufficient mechanical integrity is provided by adequate supports and terminals, and also providing this size is not less than the size of the largest incoming power supply conductor.

The metal cases of all instruments, relays and the like shall be connected to the panel earth bars by copper conductors of not less than 1.5 mm² cross-sectional area, or by other means to the approval of the Engineer.

If the plant contains electronic equipment that is vulnerable to possible conductive interference, or if the equipment generates electrical noise, which could interfere with other plant or equipment, then separate earths may be supplied and the actual means of interconnecting with the station earth sys- tem shall be agreed with the Engineer.

3. HV Switchgear and Neutral Earthing Equipment

3.1 Scope

These clauses describe the general technical requirements for the new 400, 230 kV and 33 kV Air Insulated Switchgear (AIS) and shall be read in conjunction with the project requirements, schedules and drawings in the specification.

The Contractor shall demonstrate that the switchgear has been designed, built and installed in accordance with the relevant international standards and the specification. It shall also operate and perform on a site in accordance with the requirements of the specification and in the environment defined therein.

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

The requirement for switchgear spares, tools and appliances, including test, maintenance and handling equipment shall be as stated in the Bid document. All devices necessary for operation and earthing shall be provided within the contract price.

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

3.2 References

3.2.1 IEC Standards

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

- IEC 60044 Instrument transformers
- IEC 60060 High voltage test techniques
- IEC 60071 Insulation coordination
- IEC 60099 Surge arresters
- IEC 60137 Bushings for alternating voltages
- IEC 60265-1 High-voltage switches - Part 1: Switches for rated voltages above 1 kV and less than 52 kV
- IEC 60265-2 High-voltage switches. Part 2: High-voltage switches for rated voltages of 52 kV and above
- IEC 60269 Low voltage fuses
- IEC 60273 Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000V
- IEC 60282 High voltage fuses.

- IEC 60305 Insulators for overhead lines with a nominal voltage above 1000V - Ceramic or glass insulator units for ac systems - Characteristics of insulator units of the cap and pin type.
- IEC 60358 Coupling capacitors and capacitor dividers
- IEC 60364 Electrical installation of buildings
- IEC 60376 Specification of technical grade sulphur hexafluoride (SF6) for use in electrical equipment
- IEC 60383 Insulators for overhead lines with a nominal voltage above 1000V
- IEC 60815 Guide for the selection of insulators in respect of polluted conditions
- IEC 60865-1 Short-circuit currents - Calculation of effects
- IEC 61639 Direct connection between power transformers and gas insulated metal enclosed switchgear for rated voltages of 72.5 kV and above
- IEC 62155 Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1000 V
- IEC 62271-1 HV switchgear and controlgear - part 1: common specifications
- IEC 62271-100 HV switchgear and controlgear - part 100: AC circuit breakers
- IEC 62271-103 Switches for rated voltage above 1 kV and less than 52 kV
- IEC 62271-104 Switches for rated voltage of 52 kV and above
- IEC 62271-102 HV switchgear and controlgear - part 102: AC disconnectors and earthing switches
- IEC 62271-200 HV switchgear and controlgear - part 200: A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
- IEC 62271-203 HV switchgear and controlgear - part 203: Gas insulated metal-enclosed switchgear for rated voltages 52 kV and above
- IEC 62271-209 HV switchgear and controlgear - part 209: Cable connections for gas insulated metal-enclosed switchgear for rated voltages of 52 kV and above

3.2.2 British Standards

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

3.3 Design Principles

3.3.1 General Requirement

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

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

The following provisions shall be made for control and indications:

- Local control cubicle to equipment - control of circuit breakers, disconnectors and earthing switches where power operated, complete with electrical indications, mimic diagram, gauges and alarm annunciator.
- Remote control panel in the control room on each substation site - control of circuit breakers, disconnectors and earthing switches where power operated, complete with electrical position indications, mimic diagram in each instance.
- Supervisory control from NLDC - provision of control of circuit breakers and disconnectors switches where power operated, with position indication in each instance.

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

Circuit identifying labels shall be fitted at the front and rear of each individual circuit assembly and on the local control cubicle. In case of labels not visible when standing on the floor, additional name plate shall be fixed at a suitable location.

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

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

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

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

3.3.2 Availability for Maintenance, Repair, Extensions, Testing

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

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

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

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

3.4 Outdoor HV Switchgear

3.4.1 Switchgear - Design and Performance

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

It shall be designed to comply with this Specification and relevant IEC and British Standards where applicable. Deviations from these Specifications and Standards shall be stated in Schedule F of Departures in Volume 3.

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

The disposition of plant in any substation is to be such that the operation of any item of plant under the specified service conditions, shall in no way create a condition that could adversely affect the performance of adjacent circuit breakers or any associated equipment.

The Contractor is to ensure that the complete substation installation will satisfy the requirements of this Specification and the appropriate Standards in respect of insulation, fault levels, mechanical stress etc., and any additional equipment found to be necessary to meet these requirements shall be deemed to have been included in the Contract Price.

The layout and design of plant and equipment on substation sites shall make provision for the future extensions shown on the layout drawings and shall provide for ready access for operation, maintenance and extension whilst the remaining sections of equipment are alive.

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

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

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

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

3.4.2 Current Ratings

Every current-carrying part of the switchgear including circuit breakers, disconnectors, current transformers, busbars, connections, contacts and joints shall be capable of carrying its specified rated cur-

rent at rated frequency continuously, and in no part shall its temperature rise exceed that specified in relevant standards.

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

3.4.3 Corona

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

3.4.4 Local, Remote and Supervisory Control

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

Position indication of these devices shall be provided on their operating mechanisms and the Contractor shall include the supply and fitting of the necessary auxiliary switches for remote position indication.

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

3.4.5 HVAC Circuit Breakers not require

3.4.6 HV Instrument Transformers not require

3.4.7 Surge Arresters

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

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

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

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

High-Voltage Terminals
High-voltage terminals shall be as it is defined in a technical schedule:
- Vertical,
- Flat,
- For aluminium conductor,
- Minimum area of 200 or 100 x 100 mm
- With at least eight or four holes 14 mm diameter, at 50 mm distance between each other

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

Earthing
Surge arresters will be equipped with appropriate earthing connector.

Surge Arresters Housing
Housing shall be made from silicon and/or composite material in accordance with Technical specification. The connection itself shall be handled with such manner so as to prevent retaining or intrusion of moisture. Minimum creepage distance is 25 mm/kV.

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

Nameplates
Nameplates should have data written in a English language:
- Manufacturer name
- Type of surge arrester
- Rated voltage of surge arrester Ur
- Continuous operating voltage of surge arrester Uc
- Nominal discharge current of an arrester (8/20 μs)
- Rated short circuit current

- Rated frequency
- Line discharge class
- Number of a unit position in a set (for multi units surge arrester)
- Mass of surge arrester
- Year of production
- Serial number

Special Equipment, Tools and Drawings

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

Spare Parts

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

Packing, Shipment and Transportation

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

Inspection and Tests

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

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

Type Tests

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

- Dielectric tests
  - Power frequency withstand voltage test of arrester housing
  - Lightning impulse voltage tests of arrester housing
  - Power frequency voltage wet and dry test of arrester housing
- Residual voltage test
  - Steep current
  - Lightning impulse
  - Switching impulse
- Test to verify long term stability under continuous operating voltage
- Repetitive change behaviour verification
- Operating duty tests
- Power frequency voltage versus time
- Short circuit test
- Weather aging test

- Long duration current impulse withstand test
- Pressure relief test.
- Artificial pollution test
- Partial discharge test
- Seal leakage test

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

Routine Tests
The following routine tests shall be conducted on each piece the equipment to be supplied for the purpose of revealing faults in material or construction:
- Measurement of reference voltage
- Residual voltage test
- Partial discharge and contact noise tests
- Seal leakage test

Documentation
Documentation attached to the bid shall include minimum the following:
- Manufacturer's Authorization
- Manufacturer's Quality control certificate
- Detailed list of type test for each type and class of the specified equipment
- Copies of type test reports
- Equipment-related catalogues
- Reference list for previous five years
- Drawings

For each surge arrester, the following documentation shall be delivered:
- Drawings
- Instruction manuals for installation, testing and maintenance
- Test protocol of acceptance testing

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

3.4.8 Post Insulators

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

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

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

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

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

Insulator Material

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

RIV

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

Fittings

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

Cementing

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

Insulation Level

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

Dimensions

Rated dimensions of insulator shall be in accordance with values defined in the Technical Data Schedules, with appropriate tolerances referring to parallelism, eccentric and angle deviation, in accordance with standard IEC 60272. Minimum creepage distance is 25 mm/kV.

Packing, Shipment and Transportation

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

Inspection and Tests

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

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

Type Tests

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

- Dielectric tests
  - Lightning impulse voltage tests
  - Power frequency voltage wet and dry test
  - Power frequency withstand voltage test of arrester housing
    Residual voltage test
    Mechanical failing load test+

Special Tests

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

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

Routine Tests

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

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

Acceptance Tests

The following tests shall be conducted:

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

Documentation

Documentation attached to the bid shall include minimum the following:

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

Following documentation shall be delivered together with the equipment:

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

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

4. Power Transformers

4.1 Scope

These clauses describe the general technical requirements for power transformers and shall be read in conjunction with the attached GTP,GA,NAMEPLATE,BCT ,NIFPS system ,foundation drawing in the document.

Installation, testing and commissioning of power transformers shall be done by the Manufacturer(s)' Engineer(s).

4.2 References

4.2.1 IEC Standards

IEC 60076	Power transformers
IEC 60137	Insulated bushings for ac voltages above 1000V
IEC 60044-2	Voltage transformers
IEC 60044-5	- ditto -
IEC 60214-1	On load tap changers
IEC 60228	Conductors of insulated cables
IEC 62155	Tests on hollow insulators for use in electrical equipment
IEC 60289	Reactors and Earthing Transformers
IEC 60296	Specification for unused mineral insulating oils for transformers and switchgear
IEC 60354	Loading guide for oil immersed power transformers
IEC 60422	Supervision and maintenance guide for mineral insulating oils in electrical equipment
IEC 60529	Degrees of protection provided by enclosures
IEC 60551	Determination of transformer and reactor sound levels

4.2.2 British Standards

BS61	Specification for threads for light gauge copper tubes and fittings
BS EN 10220	Specification for dimensions and masses per unit length of welded and seamless steel pipes and tubes for pressure purposes
BS EN 1092	Circular flanges for pipes, valves and fittings (PN designated)
BS 6121	Mechanical cable glands
BS 6346	Specification for PVC insulated cables for electricity supply
BS 6435	Specification for unfilled enclosures for the dry termination of HV cables for transformers and reactors
BS 7354	Code of practice for design of HV open terminal stations
BS EN 10137	Specification for hot rolled quenched and tempered weldable plates

4.2.3 BS European Standards

BS EN 10029 Specification for tolerances on dimensions, shape and mass for hot rolledsteel plates 3mm thick and above

4.3 Power Transformers

4.3.1 Types of Transformers and Operating Conditions

General

The transformers shall be oil immersed and suitable for outdoor installation and shall comply with IEC 60076, Parts 1 to 5 inclusive.

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

Cooling

The types of cooling shall be as stated in the Schedule A of Requirements, Appendix A2 in Schedule A of Volume 1 of 3 and the letters relating to the method of cooling used in this Specification and Schedules shall be in accordance with IEC 60076.

Where a combination of two methods of cooling is applied to one transformer, as for ONAN/ONAF units, the transformer shall be capable of operating under the ONAN condition up to half full load or more as stated in the Schedule of Requirements, after which the cooling equipment is to come into operation and the Transformer will operate as an ONAF unit.

Transformers shall be fitted with at least two coolers or two banks of radiators each capable of dissipating 50 per cent of the losses at continuous maximum rating. They shall be capable of remaining in operation at full load for 20 minutes in the event of failure of blowers associated with one half of coolers or radiators, without the calculated winding hot spot temperature exceeding 140°C.

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

Parallel Operation

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

Handling on Site

For installation purposes and to permit the moving of any three phase unit, the transformers are to be equipped with castors (rail wheels). A permanent rail transfer track system shall be provided, integrated with the transformer foundations. The castors should be able to swivel in both the longitudinal and transverse directions.

A system of wedges shall be included to stop any unwanted movement of the transformer during its operating life. The distance between rails must be compatible with the transformer dimensions and also the rail gauge prevailing at existing substation sites.

4.3.2 Continuous Maximum Rating

Transformers shall have the rating stated in the Schedule of Requirements and shall comply with the requirements as regards temperature rise and overloads on all tapings, irrespective of the direction of power flow and with the voltage of the lower voltage winding at the normal voltage stated in the

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

The overload capability shall be in accordance with IEC 60354.

4.3.3 Electrical Connections

Transformer windings shall be connected in accordance with the IEC 60076 group symbol specified in the Schedule of Requirements.

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

4.3.4 Ability to Withstand Short Circuit

General
All transformers shall be capable of withstanding, on any tappings and without damage, the thermal and dynamic effects of external short circuits under the conditions stated in IEC 60076 Part 5. For this purpose the design short circuit level for each system voltage is stated in the Schedule of Requirements.

Calculations and Tests
Evidence shall be submitted with the Bid as to the extent to which the Manufacturer has proved, or is able to prove, either by calculation or test, the ability of the specified Transformers to withstand short circuit.
The Bidder shall provide with his bid a brief description of those transformers, or parts thereof, which have been subjected to short circuit test or for which short circuit calculations are available. It is preferred that this information relates to designs comparable with the transformers offered, but, in the event this is not so, the Engineer reserves the fight to require calculations to prove that the design of transformers offered will satisfactorily comply with this clause.

4.3.5 Stabilizing Windings

Unless otherwise specified in the Schedule of Requirements, the product of the number of turns of the stabilizing windings and the cross- sectional area of one such turn must not be less than 33 per- cent of the corresponding product for the untapped main winding.

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

4.3.6 Losses and Evaluation of Losses

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

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

For each unit of the three-phase transformers,

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

Where

N= average No-load loss (core-loss) at rated voltage in kW
L= average Load loss (copper-loss) at 75°C, 50 Hz maximum continuous rating in kW
M= Total load of transformer cooling fans at transformer maximum continuous rating in kW (when all the cooling fans are in operation)
a= Cost/kW of no load loss (core-loss) valued at 600,000 BDT
b= Cost/kW of load loss (copper-loss) valued at 300,000 BDT
c= Cost/kW of auxiliary power valued at 300,000 BDT

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

(a) Component losses in excess of guaranteed values but within the tolerance permitted under IEC 60076 Part 1.
Transformers shall be acceptable subject to full compliance with all technical particulars, including temperature rises at CMR and subject to the Bidder accepting deduction from the contract Price of charges for each kW or part thereof of component losses in excess of the guaranteed values, at the above evaluation rates.

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

The acceptance or rejection of transformers shall be entirely at the discretion of the Employer and subject to the Bidder accepting the deduction from the contract Price of charges for each kW or part thereof of component losses in excess of the guaranteed values, at the above loss evaluation rates.

In the event of transformers yielding component and total losses that are either equal to or below the guaranteed values, the Bidder will not be entitled to any premium in respect of reduction in losses below the guaranteed values.

4.3.7 Impedance

The value of impedance measured on normal and extreme tappings shall be as stated in the attached nameplate for the power transformer in the document.

4.3.8 Noise

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

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

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

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

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

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

4.3.9 Harmonic Suppression

Transformers shall be designed with particular attention to the suppression of harmonic voltages, especially the third, fifth and seventh harmonics, and to minimise the detrimental effects resulting therefrom.

4.4 Magnetic Circuit and Windings

4.4.1 Magnetic Circuit

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

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

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

4.4.2 Flux Density

Cores shall be constructed from cold rolled grain oriented steel sheets. Design shall be such that there will be no adverse effects due to core or stray flux heating with the quality of steel employed, and that when operating under the most onerous conditions envisaged in IEC 60076 and IEC 60354, flux density in any part of the magnetic circuit does not exceed 1.9 Tesla.

4.4.3 Windings

Transformer 400 kV and 230 kV star connected windings shall have graded insulation as defined in IEC 60076. For 33kV and below they shall have uniform insulation as defined in IEC 60076. All neutral points shall be insulated to withstand the applied test voltage specified in the Schedule of Require- ments.

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

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

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

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

4.4.4 Internal Earthing

General
All metal parts of the transformer, with the exception of the individual core laminations, core bolts and associated individual clamping plates, shall be maintained at some fixed potential.

Earthing of Core Clamping Structure
The top main core clamping structure shall be connected to the tank body by a copper strap. The bottom main core clamping structure shall be earthed by one or more of the following methods:

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

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

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

Earthing of Coil Clamping Rings
Where coil clamping rings are of metal at earth potential, each ring shall be connected to the adjacent core clamping structure on the same side of the Transformer as the main earth connection.

Size of Earthing Connections
Main earthing connections shall have a cross-sectional area of not less than 80 sq.mm but connections inserted between laminations may have cross-sectional areas reduced to 20 sq.mm when in close thermal contact with the core.

4.5 Tanks and Ancillary Equipment

4.5.1 Transformer Tanks

Each transformer shall be enclosed in a suitably stiffened welded steel tank such that the transformer can be lifted and transported without permanent deformation or oil leakage. The construction shall employ weldable structural steel of an approved grade to BS 7613 and BS EN 10029. The final coat colour of transformers shall be to Munsell notation N5Y-7/1.

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

The base of each tank shall be so designed that it is possible to move the complete transformer unit in any direction without injury when using rollers, plates, or rails.

Transformers shall have wheel bases, unless otherwise specifically approved by the Engineer.

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

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

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

Each tank cover shall be of adequate strength, must not distort when lifted and shall be provided with suitable flanges having sufficient and properly spaced bolts. Inspection openings shall be provided to give access to the internal connections of bushings, winding connections and earthing links. Each opening shall be correctly located and must be of ample size for the purpose for which it is intended. All inspection covers shall be provided with lifting handles.

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

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

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

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

4.5.2 Conservator Tanks, Breathers and Air Dryers

Each transformer shall be provided with an overhead conservator tank formed of substantial steel plates and arranged above the highest point of the oil circulating system (see also Clause 4.6. 1). Connections into the main tank shall be at the highest point to prevent the trapping of air or gas under the main tank cover.

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

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

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

Each conservator shall be fitted with an air cell that shall be connected to a silica gel breather of a type that permits the silica gel content to be removed for drying. Due to the climatic conditions at site, this breather shall be larger than would be fitted for use in a temperate climate. All breathers shall be mounted at a height of approximately 1400 mm above ground level.

4.5.3 Valves

Each transformer shall be fitted with the following valves as a minimum requirement and inconjuction of the attached required valve schedule.

Main Tank

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

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

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

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

Conservator

(E) One valve between the conservator and gas actuated relay for the main tank and, where appropriate, for the tap change diverter switch tank complete with bypass pipework for Buchholz relay to facilitate maintenance of the relay.

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

Tap Changer

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

Diverter Switch

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

Radiators and Cooler Banks

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

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

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

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

4.5.4 Joints and Gaskets

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

Oil resisting synthetic rubber gaskets are not permissible except where the synthetic rubber is used as a bonding medium for cork, or similar material, or where metal inserts are provided to limit compression.

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

4.5.5 Pressure Relief Device

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

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

4.5.6 Earthing Terminals

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

4.5.7 Rating, Diagram and Valve Plates

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

(A) A rating plate bearing the data specified in IEC 60076 Part 1. This plate shall also include the short-circuit current rating and time-factor for each winding.
(B) A diagram plate showing in an approved manner the internal connections and the voltage vector relationship of the several windings, in accordance with IEC 60076 Part I with the transformer voltage ratio for each tap and, in addition, a plan view of the transformer giving the correct physical relationship of the terminals.
(C) A plate showing the location and function of all valves and air release cocks or plugs. This plate shall also if necessary warn operators to refer to the Maintenance Instructions before applying vacuum.

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

4.6 Cooling Plant

4.6.1 Cooling Plant General

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

The clearance between any oil or other pipework and live parts shall be not less than the minimum clearances stated in the Schedule of Requirements.

4.6.2 Radiators Connected Directly to Tank

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

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

4.6.3 Cooler Banks

Each cooler bank shall be provided with:

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

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

4.6.4 Forced Cooling

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

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

4.6.5 Oil Pipes and Flanges

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

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

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

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

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

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

4.6.6 Air Blowers

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

To reduce noise to the practical minimum, motors shall be mounted independently from the coolers or, alternatively, an approved form of anti-vibration mounting shall be provided.

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

Blades shall be of material subject to approval.

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

Galvanised wire guards with mesh not exceeding 12.5mm shall be provided to prevent accidental contact with the blades. Guards shall also be provided over all moving parts. Guards shall be designed such that blades and other moving parts cannot be touched by test fingers to IEC 60529.

4.6.7 Cooler Control

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

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

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

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

The control arrangements are to be designed to prevent the starting of motors totalling more than 15kW simultaneously, either manually or automatically. Phase failure relays are to be provided in the main cooler supply circuit.

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

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

An alarm of indicating "Transformer Cooling Fault" is to be provided and initiated in the event of any ventilation/cooling motor trip, or failure of either main or control supplies.

4.7 Voltage Control

4.7.1 General

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

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

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

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

4.7.2 On-Load Tap Changers

General

on-load tap changers shall be from MR Germany or ABB Sweden make,oil immersed or vacuum type, and comply with IEC 60214-1 and shall besuitable for power flow in both directionS. Only de-signs that have been type-testedin accordance with these standards will be accepted. Tap changersin auto-transformers shall belocated between the HV and LV windings. The OLTC shall be installed inside the main tank.
Current making and breaking switches associated with the tap selectors or otherwise where combined with tap selectors shall be contained in a tank in which the head of oil is maintained by means completely independent of that on the transformer itself. Details of maintaining oil separation, oil levels, detection of oil surges and provision of alarm or trip contacts will be dependent on the design of tap-changer and be to the approval of the Engineer.

Mechanisms

The tap change mechanism shall be designed such that when a tap change has been initiated, it will be completed independently of the operation of the control relays and switches. If a failure of the auxiliary supply during tap change or any other contingency would result in that movement not being completed an approved means shall be provided to safeguard the transformer and its auxiliary equipment.
The driving motor shall be rated 400/230V ac and shall be equipped with thermal and over load protection located in the motor drive cubicle. Proper working of the drive motor shall be ensured up to 25% below the rated voltage.
Limit switches shall be provided to prevent over-running of the tap changing mechanism. These shall be directly connected in the operating motor circuit. In addition, mechanical stops shall be fitted to prevent over-running of the mechanism under any conditions. For on-load tap change equipment these stops shall withstand the full torque of the driving mechanism without damage to the tap change equipment.
Thermal devices or other approved means shall be provided to protect the motor and control circuit.
A permanently legible lubrication chart shall be provided and fitted inside the tap change mechanism chamber.

Local and Remote Control

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

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

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

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

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

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

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

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

Indications

Apparatus of an approved type shall be provided on each transformer:

(A) To give indication mechanically at the transformer and electrically at the remote control point of the number of the tapping in use.

(B) To give electrical indication, separate from that specified above, of tap position at the remote supervisory point.

(C) To give indication at the remote control point and at the supervisory control point that a tap change is in progress; this indication to continue until the tap change is completed.

(D) To give indication at the remote control point and at the supervisory control point when the transformers operating in parallel are operating out of step.

(E) To indicate at the tap change mechanism the number of operations completed by the equipment.

Oil Treatment

Each tap changer is to be equipped with a stationary on-line oil filter facility, complete with time switch control in case of oil type switches used.

4.7.3 Automatic Voltage Control

Automatic control shall be suitable for control of transformers in parallel. In addition to the methods of control covered by Clause 4.7.2, the following methods shall also be provided.

(A) Automatic Independent - It shall be possible to select automatic independent control for each transformer irrespective of the method of control selected for any other of the associated transformers.

(B) Automatic parallel - It shall be possible to select any transformer for master or follower control.

It must not be possible to operate any tap changer by supervisory, remote or local electrical hand control while the equipment is switched for automatic operation.

4.7.4 Voltage Regulating Relays

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

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

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

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

4.7.5 Remote Control Panels

The remote control panels specified in the Schedule A of Requirements shall be floor mounted sheet steel cubicles of approved type, layout and colour to Munsell notation 5Y-7/1 and shall be provided for each transformer. Each shall form a complete enclosure with lockable rear doors and shall be fitted with interior lamp, door switch, heaters, cable gland plates for bottom entry of cables and all other equipment to provide the features specified, the standard requirements (which may be varied to suit Manufacturer's design) being as follows:

- Instruments:
  - Voltmeter (voltage at the low voltage terminals of the transformer)
  - Tap position indicator with integral or separate scale to indicate the no-load (LV) Voltage in kV appropriate to each winding tap.
- Relays:
  - Automatic voltage control
- Controls:
  - Automatic/Non-automatic voltage control selector switch
  - Remote/Supervisory tap change control selector switch
  - Pistol grip selector switch with centre zero
  - Independent/Master/Follower selector switch
  - AVR voltage reference adjuster
- Indications and Alarms:
  - Tap change in progress - white lamp
  - Tap change out of step - amber lamp
  - Tap change incomplete - amber
  - Tap change control on "local"
  - Tap change control on auto/manual
  - Group 1 Air forced cooling equipment running - white

- Group 1 Air forced cooling overcurrent alarm - amber
- Group 2 Air forced cooling equipment running - white
- Group 2 Air forced cooling overcurrent alarm - amber
- Forced cooling failure-amber lamp
- VT Fail alarm - amber
- Supply voltage to OLTC failure - amber lamp

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

4.7.6 Off-Load Tap Changers

The off-circuit tappings as specified in the schedule of requirements shall be provided on the higher voltage windings for a variation of no-load primary voltage as specified.

Off-load tap-changing shall be carried out by means of an external hand-operated tapping switch mounted on the side of the tank. All phases of the tapping switch must be operated by one hand wheel.

The tapping switch shall have a spring-loaded captive bolt or other approved means on the moving part that positively locates the switch correctly at each tapping position. This bolt must be lockable at each tapping position and shall be provided with a suitable padlock and keys. Moving the switch from one tapping position to another shall require that the bolt be withdrawn by hand from its locating sock- et on the transformer tank against the spring pressure.

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

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

4.8 Supervisory Control

4.8.1 Requirements

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

The following supervisory facilities are required:

Controls:

i) Supervisory selection of auto/non-auto voltage control.
ii) Tap change raise/lower by direct operation of tap changer.
iii) Tap change blocking on/off.
iv) Remote/supervisory selection "override".
v) Parallel/independent control.

Indications and Alarms:

i) Tap position indication by means of transducer with 4-20 mA d.c. output range proportional to step increment.
ii) Tap change out of step alarm.
iii) Buchholz and winding temperature non-trip alarm.
iv) Tap change control on Local/Supervisory.
v) Parallel/independent, master/follower.
vi) Tap change blocking on/off.
vii) Tap change control on automatic/manual.

All contacts for supervisory alarms and indications shall be potential free.

4.9 Terminal Bushings and Connections

4.9.1 General

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

All bushings shall comply with IEC 60137 and the minimum creepage distance for outdoor bushings shall not be less than 25mm per kV of rated voltage between phases.

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

Bushings shall be of sealed construction suitable for service under the very humid conditions at Site and, addition, for the very rapid cooling of equipment exposed to direct sunlight when this is followed by sudden heavy rainstorms.
Typical sections of bushing insulators showing the internal construction, method of securing the top cap and methods of sealing shall be included in the Bid.

The 400 &230kV outdoor bushings shall be oil impregnated paper insulated condenser type and have no communication with the oil in the transformer. An oil gauge shall be provided to indicate that the correct level is maintained. 33kV bushings shall be oil filled or solid type.

Completely immersed bushings and lower voltage outdoor immersed bushings may be of other type of construction, subject to the approval of the Engineer but bushings of resin bonded paper construction are not permitted.

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

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

4.9.2 Porcelain

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

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

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

All porcelain insulators shall be designed to facilitate cleaning.

4.9.3 Marking

Each porcelain insulator shall have marked upon it the Manufacturer's name or identification mark and year of manufacture. These marks shall be clearly legible after assembly of fittings and shall be imprinted before firing, not impressed.

When a batch of insulators bearing a certain identification mark has been rejected, no further insulators bearing this mark shall be submitted and the Contractor shall satisfy the Engineer that adequate steps will be taken to mark or segregate the insulators constituting the rejected batch in such a way that there can be no possibility of the insulators being re-submitted for the test or supplied for the use of the Employer.

Each complete bushing shall be marked with the Manufacturer's name or identification mark, year of manufacture, serial number, electrical and mechanical characteristics in accordance with IEC 60137:1973.

4.9.4 Mounting of Bushings

Bushing insulators shall be mounted on the tank in a manner such that the external connections can be taken away clear of all obstacles. Neutral bushings shall be mounted in a position from which a connection can be taken to a neutral current transformer mounted on a bracket secured to the transformer tank. The current transformer will be supplied by the switchgear Manufacturer but provision shall be made on the tank for mounting to the Engineer's requirements.

The clearances from phase to earth must not be less than those stated in the Schedule A of Requirements.

A flexible pull-through lead suitably sweated to the end of the winding copper shall be provided for the bushings and is to be continuous to the connector that is housed in the helmet of the bushings.When bushings with an under-oil end of a re-entrant type are used the associated flexible pull-through lead is to be fitted with a suitably designed gas bubble deflector.

The bushing flanges must not be of re-entrant shape that may trap air.

Clamps and fittings made of steel or malleable iron shall be galvanised and all bolt threads are to be greased before erection.

4.10 Auxiliary Power and Control Cables

4.10.1 Scope of Supply

This Contract includes the supply, installation and termination of the necessary auxiliary power and control cables within items of plant supplied under the contract.

The Contractor shall produce, during the currency of the contract and in any case, before shipment of plant commences, detailed cable core schedules for each transformer.

4.10.2 General

Auxiliary power and control cables shall have copper conductors, PVC insulated, armoured and PVC sheathed overall. The cable design shall generally be in accordance with BS 6346 and Section 6 of this Specification.

All cables installed under the contract shall utilise compression glands of type EI to BS.6121 or otherwise designed to secure armour wires and bond them to earthed metal and to provide seals between sheath and gland and between inner sheath and threaded fixing component.

The Contractor shall supply and fit the compression gland and make off individual cores on to the terminal boards, including the supply and fitting of numbered markers on each core.

4.11 Temperature and Alarm Devices

4.11.1 Temperature-Indicating Devices and Alarms

The transformers shall be provided with approved devices of Kilhstrom or equivalent for indicating the top oil temperature and hottest spot winding temperatures. The devices shall have a dial type indicator and, in addition, a pointer to register the highest temperature reached. Each winding temperature device shall have four separate contacts fitted, two of which shall be used to control the two groups of cooling plant motors (i.e. AF1 and AF2), one to give an alarm and one to trip the associated circuit breakers.

To simulate indication of the hottest spot temperature of the winding the device shall comprise a current transformer associated with one phase only and a heating device designed to operate continuously at 130 percent of transformer CMR current and for 30 minutes at 150 percent of CMR current, associated with a sensing bulb installed in an oil tight pocket in the transformer top oil.

The winding temperature indicators (WTI) shall be housed in the marshalling cubicle. The tripping contacts of the winding temperature indicators shall be adjustable to close between 80˚C and 150˚C and to re-open when the temperature has fallen by not more than 5˚C.

The alarm contacts and the contacts used to control the cooling plant motors on the above devices shall be adjustable to close between 50˚C and 100˚C and to re-open when the temperature has fallen by a desired amount between 5˚C and 10˚C.

All contacts shall be adjustable to a scale and must be accessible on removal of the relay cover. Alarm and trip circuit contacts shall be suitable for making or breaking 150 VA between the limits of 30 volts and 250 volts AC or DC and of making 500 VA between the limits of 110 and 250V DC. Cooler motor control contacts shall be suitable for operating the cooler contactors direct or, if necessary, through an interposing relay.

The temperature indicators in the marshalling kiosk shall be so designed that it is possible to move the pointers by hand for the purpose of checking the operation of the contacts and associated equipment.

The working parts of the instrument shall be made visible by the provision of cut-away dials and glass-fronted covers and all setting and error adjustment devices shall be easily accessible.

Connections shall be brought from the device to terminal boards placed inside the marshalling cubicle.

Terminals, links and a moving iron ammeter shall be provided in the marshalling kiosk for each WTI for:

(A) Checking the output of the current transformer.
(B) Testing the current transformer and thermal image characteristics.
(C) Disconnecting the bulb heaters from the current transformer secondary circuit to enable the instrument to be used as an oil temperature indicator. Links shall be provided as shown on the drawing enclosed with this Specification.

4.11.2 Gas and Oil-Actuated Relays

Each transformer shall be fitted with gas and oil-actuated relay equipment having alarm contacts that close on collection of gas or low oil level, and tripping contacts that close following oil surge condi- tions.

Each gas and oil-actuated relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay.

Each relay shall be fitted with a calibrated glass window for indication of gas volume.

To allow gas to be collected at ground level, a small bore pipe shall be connected to the gas release cock of the gas and oil-actuated relay and brought down to a point approximately 1400MM above

ground level, where it shall be terminated by a cock which shall have provision for locking to prevent unauthorised operation.

The design of the relay mounting arrangements, the associated pipework and the cooling plant shall be such that mal-operation of the relay will not take place under normal service conditions, including starting or stopping of oil circulating pumps, whether by manual or automatic control under all operating temperatures.

The pipework shall be so arranged that all gas arising from the transformer will pass into the gas and oil-actuated relay. The oil circuit through the relay must not form a delivery path in parallel with any circulating oil pipe, nor is it to be teed into or connected through the pressure relief vent. Sharp bends in the pipework shall be avoided.

When a transformer is provided with two conservators, the gas and oil-actuated relays shall be arranged as follows:

a) If the two conservators are connected to the transformer by a common oil pipe, one relay shall be installed in the common pipe.
b) If the two conservators are piped separately to the transformer, two relays shall be installed, one in each pipe connection.

The clearance between oil pipework and live metal shall be not less than the minimum clearances stated in the Project Requirements of Section 1.

4.12 Shipment and Drying Out

4.12.1 Shipment

Each transformer, when prepared for shipment, shall be fitted with a shock indicator or recorder that shall remain in situ until the transformer is delivered to site. In the event that the transformer is found to have been subjected to excessive shock in transit, such examination as is necessary shall be made in the presence of the Engineer.

Where practicable, transformers shall be shipped with oil filling to cover core and windings but, when shipped under pressure of gas, shall be fitted for the duration of delivery to Site and for such time thereafter as is necessary, with a gauge and gas cylinder adequate to maintain internal pressure above atmospheric.

All earthing transformers shall be shipped full of oil.

4.12.2 Drying Out

All transformers shall be dried out by an approved method at the Manufacturer's works and so arranged that they might be put into service without further drying out on site.

Clear instructions shall be included in the Maintenance Instructions regarding any special precautionary measures (e.g. strutting of tap changer barriers or tank cover) which must be taken before the specified vacuum treatment can be carried out. Any special equipment necessary to enable the transformer to withstand the treatment shall be provided with each transformer.

4.12.3 Fire Protection System

4.12.3.1 General

The new 400/230/33kV, 400/520 MVA, ONAN/ONAF autotransformers shall be provided with Nitrogen Injection Fire Protection System (NIFPS).existing NIFPS system drawing is attached in the document . bidder have to consider this for the adaptation with the transformer.
General description, design and performance requirements of the NIFPS is given below. It is not intended to completely specify all details of design and construc- tion. Nevertheless, the system design and equipment shall conform in all respects to high standard of engineering, design and workmanship.

The system design shall also conform to TAC / NFPA norms. The offered system shall comply with the relevant international standards.Reference standards are listed below. Relevant international standards other than BS standards shall be subject to approval by the Employer:

4.12.3.2 BS Standards

BS 381 C	Colours for Identification, Coding & Special Purpose
BS 7629-1	Specification for 300/500 V fire resistant electric cables having low emission of smoke and corrosive gases when affected by fire.

BS 8434-1 Methods of test for assessment for power integrity of electric cables

BS 5839-1	Code of practice system design, installation, commissioning and maintenance for fire detection and fire alarm system
BS EN50267-2-1	Common Test Methods for Cables Under Fire Conditions

The fire protection system shall have been in successful operation in for at least last three years for protection of transformers of 400/230/33 kV and higher voltage class. The reference list along with performance certificate from end users of the system shall be submitted with the bid.

The system shall be reliable without making any mal operation. Even if undesirable nitrogen gas injection is made into the transformer tank under normal transformer condition without the internal faults, restoration of transformer by vacuum oil purification up to re-energizing shall complete as soon as possible after the undesired gas injection.

In case of an event of the control power failure, the system shall be able to be operated manually.Various equipment to perform the required fire protection shall be provided under this contract.

4.12.3.3 Nitrogen Fire Fighting System

The Contractor has to make necessary provisions (in consultation with the Supplier of the NIFPS) for the satisfactory operation of the nitrogen fire-fighting system without affecting the overall performance of the transformer. Oil filled autotransformers shall be provided with an appropriate NIFPS for the following ratings: 400/230/33kV, 400/520 MVA, ONAN/ONAF.

The fire protective system shall prevent the explosion of the transformer oil tank and a possible fire in case of internal faults. In the event of fire by external causes such as bushing fire, OLTC fires, fire from surrounding equipment etc., it shall act as a fast and effective fire fighter. It shall accomplish its role as fire preventer and extinguisher without employing water and/or carbon dioxide.

Fire shall be extinguished within 3 minutes (maximum) of system activation and within 30 seconds (maximum) of commencement of nitrogen injection.

4.12.3.4 Activation of the Fire Protective System

Mal-functioning of fire prevention/ extinguishing system could lead to an interruption in power supply. The Bidder shall ensure that the probability of malfunctioning of the fire protective system is practically zero. To achieve this objective, the Bidder shall plan out his scheme of activating signals which should not be too complicated to make the fire protective system inoperative in case of actual need. The system shall be provided with automatic control for fire prevention and fire extinction. Besides automatic control, remote electrical push button control at the control box and local manual control in the fire extinguishing cubicle shall also be provided. The following electrical signals are required for activating the fire protective system under prevention mode / fire extinguishing mode:

Auto Mode

- For prevention of fire:
  - differential relay operation
  - Buchholz relay paralleled with pressure relief valve or RPRR (rapid pressure rise relay)
  - tripping of all circuit breakers (on HV &LV/IV side) associated with transformer is the pre-requisite for activation of system
- For extinguishing fire
  - fire detector

- Buchholz relay paralleled with pressure relief valve or RPRR (rapid pressure rise relay)
- tripping of all circuit breakers (on HV &LV/IV side) associated with transformer is the pre-requisite for activation of system.

Manual Mode (Local / Remote)

- Tripping of all circuit breakers (on HV &LV/IV side) associated with transformer is the pre-requisite for activation of system

Manual Mode (Mechanical)

- The system shall be designed to be operated manually in case of failure of the power supply to the fire protection system

4.12.3.5 Description

The nitrogen injection fire protection system should be a dedicated system for each oil-immersed transformer. It should have a fire extinguishing cubicle (FEC) placed on a plinth at a distance of 5-10 m from transformer / reactor or placed next to the fire wall (if a fire-fighting wall exists).

The FEC shall be connected to the top of the transformer/reactor oil tank for depressurization of the tank and to the oil pit (capacity is approximately equal to 10% of the total volume of the oil in the transformer /reactor tank) from its bottom through oil pipes.

The fire extinguishing cubicle should house a pressurized nitrogen cylinder(s) which is connected at to the bottom of the transformer oil tank. The transformer conservator isolation valve (TCIV) is fitted between the conservator tank and the Buchholz relay. Cable connections are to be provided from the signal box to the control box in the control room, from the control box to the fire extinguishing cubicle and from the TCIV to the signal box. Fire detectors placed on the top of the transformer/reactor tank are to be connected in parallel to the signal box by fire-survival cables. The control box is also to be connected to the relay panel in the control room for receiving system activation signals.

4.12.3.6 Operation

On receipt of all activating signals, the system shall drain a pre-determined volume of hot oil from the top of the tank (i.e. top oil layer) through an outlet valve to reduce the tank's pressure by removing top oil and should simultaneously inject nitrogen gas at high pressure for stirring the oil at a pre-set rate, thus bringing down the temperature of the top oil layer.

The transformer conservator isolation valve blocks the flow of oil from the conservator tank in case of tank rupture / explosion or bushing bursting. Nitrogen occupies the space created by the drained out oil and acts as an insulating layer over the oil in the tank, thus preventing an aggravation of the fire.

4.12.3.7 System Components

The nitrogen injection fire protection system shall broadly consist of the components mentioned below. However, all other components which are necessary for fast, reliableand effective operation of the fire protection system are deemed to be included in the scope of supply.

- Fire Extinguishing Cubicle (FEC)
  The FEC shall be made of CRCA sheets of a minimum thickness of 3 mm, complete with the base frame, painted inside and outside with post office red colour (shade to be in line with BS: 381 C: 1988 -Colours for Identification, Coding and Special Purposes). It shall have hugged split doors fitted with high-quality tamper proof lock. The degree of protection shall be IP55. The following items shall be provided in the FEC.
  - a nitrogen gas cylinder with regulator and falling pressure electrical contact manometer
  - oil drain pipe with mechanical quick drain valve
  - electro-mechanical control equipment for draining of a pre-set volume of oil and for injecting a regulated volume of nitrogen gas
  - a pressure monitoring switch for back-up protection for nitrogen release
  - limit switches for monitoring of the system
  - a butterfly valve with flanges on the top of the panel for connecting the oil drain pipe and the nitrogen injection pipes for transformers
  - panel lighting (CFL type)
  - oil drain pipe extensions of suitable sizes for connecting the pipes to the oil pit
  - space heater
  - other items, if necessary

- Control box
  The control box shall be placed in the control room for monitoring system operation, automatic control and remote operation. The following alarms, indications, switches, push buttons, audio signal etc. shall be provided.
  - system on
  - TCIV open
  - oil drain valve closed
  - gas inlet valve closed
  - TCIV closed*
  - fire detector trip *
  - Buchholz relay trip
  - oil drain valve open*
  - extinction in progress *
  - cylinder pressure low *
  - differential relay trip
  - PRV / RPRR trip
  - transformer/reactor trip
  - system out of service *
  - fault in cable connecting fault fire detector
  - fault in cable connecting differential relay
  - fault in cable connecting Buchholz relay
  - fault in cable connecting PRV / RPRR
  - fault in cable connecting transformer /reactor trip
  - fault in cable connecting TCIV
  - auto/ manual / off
  - extinction release on / off
  - lamp test
  - visual/ audio alarm*
  - visual/ audio alarm for DC supply fail *
  - space heater
  - others, if necessary

Suitable provisions shall be made in the control box for monitoring of the system from a remote substation using the substation automation system.

- Transformer Conservator Isolation Valve
  A transformer conservator isolation valve (TCIV) shall be fitted in the conservator pipeline, between the conservator and the Buchholz relay.It shall isolate the conservator during abnormal flow of oil due to rupture / explosion of tank or bursting of bushing. The valve shall not isolate the conservator during normal flow of oil during filtration or filling or refilling. Locking plates shall be provided with handle for pad locking. It shall have a proximity switch for remote alarm; indication shall be with visual position indicator.

- Fire Detectors
  The system shall be complete with an adequate number of fire detectors (quartz bulb) fitted on the top cover of the transformer / reactor oil tank.

- Signal Box
  The signal box shall be mounted away from the transformer's main tank, preferably near the transformer marshalling box, for terminating cable connections from TCIV & fire detectors and for further connecting them to the control box. The degree of protection shall be IP55.

- Cables
  Fire-survival cables (capable to withstand 750°C) of 4 core x 1.5 mm² size for parallel connection of the fire detectors shall be used. They shall conform to BS 7629-1, BS 8434-1 and BS 5839-1, BS EN 50267-2-1 or relevant International standards.
  Fire-retardant low smoke (FRLS) cables of 12 core x 1.5 mm² size shall be used for connection of the signal box / marshalling box near the transformer and the FEC mounted near the transformer with the control box mounted in the control room. Such cables shall also be used for the connection between the control box and the DC and AC supply source, the fire extinguishing cubicle and the AC supply source, the signal box/ marshalling box and the transformer conservator isolation valve connection on the transformer.

- Pipes
  Pipes complete with connections, flanges, bends and tees etc. shall be supplied alongwith the system.

- Other items
  - Oil drain and nitrogen injection openings with gate valves on transformer tank at suitable locations.
  - Flanges with dummy piece in conservator pipe between Buchholz relay and conservator tank for fixing TCIV.
  - Fire detector brackets on transformer / reactor tank top cover.
  - Spare potential free contacts for activating the system i.e. in differential relay, Buchholz relay, Pressure Relief Device / RPRR, Circuit Breaker of transformer/reactor
  - Pipe connections between transformer / reactor and FEC and between FEC and oil pit required for collecting top oil.
  - Cabling for fire detectors mounted on transformer /reactor top cover
  - Inter cabling between signal box, control box and Fire Extinguishing Cubicle (FEC).
  - Butterfly valves /Gate valves on oil drain pipe and nitrogen injection pipe which should be able to withstand full vacuum.
  - Supports, signal box etc. which are to be painted with enamelled paint.

4.12.3.8 Technical Particulars

• Fire extinction period from commencement of nitrogen injection:	30 s. (max.)
• Total duration from activation of fire protection system to complete cooling:	30 minutes (max.)
• Fire detectors' heat sensing temperature:	141 °C
• Heat sensing area per detector:	Up to R = 800 mm
• Transformer Conservator Isolation valve setting (minimum):	60 litre / min
• Capacity of nitrogen cylinder (minimum water capacity):	68 litre
• Capacity of nitrogen cylinder (minimum gas capacity, at 150 kg/cm² pressure:	10 m³
• Power supply, for control box and for fire extinguishing cubicle for lighting:	110 V DC / 240 V AC

4.12.3.9 Mandatory Spare Partsper Substation

• Cylinder filled with nitrogen of required capacity per substation:	1 piece
• Fire detectors:	3 pieces
• Regulator assembly:	1 piece

4.12.3.10 Tests

Reports of all type tests conducted as per relevant IEC standards including test reports for the degree of protection for FEC / control box / signal box shall be submitted with the bid.

The performance test of the complete system shall be carried out after installation of the system on site. Detailed layout drawings, equipment drawing along with 4 sets of the operation and maintenance manual along with soft copies (on CDs) shall be submitted by the Contractor.

4.12.4 Fire Wall

A fire wall of suitable height shall be installed between the transformers to prevent transformers from the spread fire. The wall shall be made of reinforced concrete.

4.13 Transformer Oil and Treatment

4.13.1 Transformer Oil

The transformer oil shall be new, inhibited, naphthenic based mineral oil, free from additives. It shall be acid-refined and pre-treated and shall have properties complying with IEC 60296-class II. The Contractor shall supply the first filling of all insulating oil required for the operation of the Plant and, after treatment, a test shall be made in the Engineer's presence to prove that the breakdown voltage is at least 50kV at 2.5mm electrode gap.

4.13.2 Oil Treatment Plant

The Contractor shall supply oil treatment plant for the treatment of insulating oil for the initial filling of transformers at Site and handed over the same to Employer at the end of work.

The oil treatment plant is to be mounted on a steerable trailer equipped with pneumatic types, over-run and parking brakes and weatherproof canopy. The plant shall be capable of treatment of oil to IEC 60296 and IEC 60422, shall be of the replaceable paper filter type and shall have the following facilities:

(A) Oil treatment rate not less than 6000 litres per hour.
(B) Water extraction capability down to 5 ppm.
(C) Reduction of dissolved gas content to 1% by volume or less.
(D) Filtration level less than 1 micron.
(E) Oil transfer, vacuum pumps and heaters suitable for 40OV, 3 phase 50Hz, 4 wire, supply.
(F) Vacuum capability approximately 1 Torr.
(G) Facility to apply vacuum to transformer tank during oil filling.
(H) Two 15m lengths of wire reinforced hose coloured differently for clean and dirty oil.
(I) Facility for "closed loop" operation.
(J) One 20m length of power supply cable with plug and socket at the filter end only.

4.13.3 Oil Storage

As required by Clause 4.13. 1, the Contractor shall supply the first filling of transformer oil. It is envisaged that the oil will be supplied to site in 200kg drums and filtered by use of the plant described in the preceding paragraph into a storage tank prior to transfer again via filter plant into the transformer.

Storage tanks shall be painted internally and externally and shall be equipped with:

- 50mm top inlet and bottom outlets with blank flanges.
- 50mm drain valve.
- Oil level indicator.
- Manhole.
- Silica gel breather.

4.14 Earthing/Auxiliary Transformers

4.14.1 General

Earthing transformers shall comply with IEC 60289 and shall be of the oil immersed ONAN type suitable for outdoor installation. They are to have a main interconnected star winding brought out via oil/air terminal bushings, which will be directly connected to the lower voltage terminals of the associated system transformer.

The neutral point of the interconnected star winding shall be brought out of the tank through a bushing insulator. This point maybe isolated or connected to earth directly or through a resistance in order to provide an earthing point for the neutral of the system.

The earthing transformers shall have a secondary winding to supply the substation auxiliary load. The voltage ratio shall be 33/0.415kV. The star-connected secondary windings shall be arranged to give a three-phase, four wire supply with the star point solidly earthed. The secondary winding shall have a continuous rating of 200kVA as stated in the Schedule of Requirements and shall conform to IEC 60076.

4.14.2 Electrical and Short Circuit Characteristics

Earthing transformers will normally have their neutral points connected to earth via a resistance which limits earth fault current to the full load current at the associated power transformer. However, provision is made for solidly earthing the neutral points and, under this condition, the earthing transformers shall be capable of withstanding, both thermally and mechanically without damage, for a period of 2 seconds the application of normal three phase line voltage to the terminals of the interconnected star winding with one line terminal earthed. The current density of the winding under this condition shall not exceed 50A/mm².

In addition, the interconnected star winding of each earthing transformer, when at its maximum temperature due to continuous full load on the auxiliary winding, shall be designed to carry for 10 seconds without injurious heating an earth fault current in the neutral connection as specified. The current density under such conditions shall not exceed 23A/mm².

4.14.3 Tanks and Fittings

Earthing transformers shall be provided with the following fittings:

(A) Conservator vessel with removable end cover and prismatic oil gauge.
(B) Buchholz relay.
(C) One thermometer pocket with captive screw cap.
(D) Silica gel breather of the oil seal type with a minimum capacity of 1 kg.
(E) Pressure relief device.
(F) Filter valve and combined filter and drain valves.
(G) Oil sampling device.
(H) Rating plate.
(I) Tank earth terminals.
(J) Lifting lugs.

4.14.4 Secondary Windings

The three-phase, four-wire secondary windings shall be terminated at a three-pole MCCB unit with bolted neutral link and gland entry for a four-core solid dielectric cable. This shall be accommodated in a lockable, fully weatherproof compartment together with a neutral earthing link. The purpose of the neutral earthing link is to connect the 400V system neutral to earth. It shall be connected between the transformer winding end and a suitably located earthing terminal to which the system earth can be connected.

The windings shall be fitted with off-load tap changer to vary the voltage ±5 percent of the nominal open circuit value in 2.5 percent steps.

4.14.5 Terminal Connections

The 33 kV side of the earthing transformers shall be fitted with oil/air terminal bushings. The earth point connection to the neutral shall be via a 33 kV conductor.

4.15 Inspection and Testing

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

4.15.1 Factory Acceptance Tests

Factory acceptance tests shall be carried out at the Manufacturer's laboratory, following a mutually agreed programme, in presence of Employer's authorized representatives, according to clause SCC23 of section-8 of volume-I.

Type Tests

The following type tests shall be conducted on the first power transformer of each type:

- Temperature rise test.
  The temperature rise test must be carried out in a manner that the highest losses are generated (tap changer in the highest loss position) and the reserve cooling unit is not in operation.

Routine Tests

Routine tests will be performed to detect defects in material or construction. They shall not impair the properties and reliability of any part being tested or reduce its lifetime. The following routine tests shall be performed:

- Visual inspection and dimension verification
- Power transformer tank oil leakage test
- Corrosion protection check
- Autotransformer tank vibration test
- Jacking pad test -checking of tank by lifting of power transformer
- Welding check after jacking pad test
- Oil dielectric strength
- Winding resistance measurement
- Transformation ratio measurements and winding connection verification
- Measurement of winding insulation resistance (before and after dielectric tests)
- Core insulation measurement (before and after dielectric tests)
- Switching impulse withstand voltage (SI)
- Impulse voltage test; primary voltage, secondary voltage, tertiary, including neutral point (LI)
- Impulse chopped voltage (LIC)
- Power frequency withstand voltage test, 50 Hz , 1 min (winding, core and secondary equipment)
- Short-duration induced AC withstand voltage test (ACSD) with monitoring of partial discharges.
- Long-duration induced AC withstand voltage test (ACLD) with measurement of partial discharges.
- Measurement of no load losses and no-load current at rated frequency before and after impulse test.

- Dissolved gas-in-oil analysis by chromatography prior to dielectric tests, after completion of dielectric tests and prior and after the temperature rise tests.
- Tap changer test for no load and short circuit conditions.
- Functional tests of protection devices and related equipment.

Special Tests

Within the factory acceptance test, the following special tests shall be performed:

- Noise level measurements, in line with the specifications of NEMA TR-1.
- Measurement of zero-sequence impedance.
- Measurement of no-load current harmonics.
- Measurement of magnetizing current.
- Measurement of power consumption for cooling system.
- Measurement of capacitance (C), factor of dielectric losses (tgδ), (before and after dielectric testing).
- Measurement of the mutual inductance of the winding.
- Sweep frequency response analysis (SFRA).
- Measurement of transferred overvoltages.

Note: The transformer's capability to withstand thermal and dynamic effects of short circuit without any damage should be presented by design analysis and calculation.

4.15.2 Site Tests

Tests During Installation

The following tests shall be performed during and after installation on the entire equipment in order to ensure correct assembly of the equipment as well as to prove that the equipment has been correctly installed:

- Verification of proper and complete erection
- Verification of the proper condition of porcelains, sealing and external surfaces
- Verification of proper connection to the earthing system
- Verification of transformer bolted connections by torque spanner
- Voltage tests of all electrical LV circuits
- Verification of the proper cabling and operation of all electrical LV equipment
- Verification of control and protection circuits and wiring.

Commissioning Tests

Main objective of the commissioning tests is to check proper and safe operation of the equipment, and in particular to verify and confirm the factory acceptance test results.

The following commissioning tests will be performed before putting the transformers into operation:

- Measurements of insulation resistances of windings and magnetic core.
- Capacitance (C), dielectric losses (tgδ) and winding inductance.
- Measurement of winding resistance at all tap changer positions.
- Measurement of voltage ratio at all tap changer positions and check of winding connection.
- Operation test of all protection units, measuring and alarm (signalling) units, Buchholz relay, contact thermometer, thermal image unit, etc.
- Operation test of cooling-system controls and alarms.
- Operation test of tap changer controls and alarms.
- Oil dielectric strength.
- Physical, chemical and electrical characteristics of oil.

5. Protection, Metering and Control

5.1 General

This specification covers the, setting, parameterisation and architecture configuration, field testing, commissioning, warranty and lifetime support of 400/230/33kV substation automation system including protection, metering and control in- cluded in the contract works.

Relay panels are available with protective relays within the guide line of Grid code.protection systems, schematic are to be tested and commission under this scope for ATR _BAY by OEM Engr. Or their certified Engineer.

Testing of protection functions, including the full schemes involving control, communication, supervision, etc., shall be performed at the site.

The protection, metering and control facilities shall be suitable for the power system arrangement as shown on the bid drawings.

From operational experience, including -system stability, protection condition, integration with existing protection and control equipment, capitalizing of staff experience and familiarization with equipment, protection settings calculation mechanism and methodology of operation, standardization of operation performance, facilities and spare requirements, the protection relays, control & automation systems including complete panel are being rationalized to specific types. The system operator is making every effort to ensure smooth operation and better reliability of the system and to avoid serious system malfunctioning

All relays shall operate correctly within system frequency limits of 47Hz to 51Hz.

, testing and Commissioning of Control, protection and metering system shall be done by OEM Engr. Or OEM certified Engineer.

5.2

400 kV, 230 kV and 33 kV systems' overall fault clearance times (i.e. from fault initiation to arc extinction) shall not exceed the following:

Type of Fault	**Maximum Fault Clearance Time**			
Nominal system voltage between phases	kV	400	230	33
Substation and transformer fault	msec.	80	100	160
Line faults:				
Up to 72% of the line length (i.e. 90% of a distance relay zone 1 reach setting of 80% of the line impedance)	msec.	80	100	160
72% of 100% of the line length where (@) plus protection signalling time	msec.	100	130	190

5.3 Cubicles, Panels and Wiring

All cubicles and enclosures with their auxiliaries described in this specification are intended for continuous duty at the specified ratings under the climatic conditions prevailing at the location where the relevant equipment will be installed.

5.3.1 Terminal Blocks

All internal wiring to be connected to the external equipment shall terminate on terminal blocks consisting of a clamping yoke system, preferably vertically mounted on the side of the cubicle.

The terminal block design shall be such that various types and sizes can be mounted on TS 35 rails to profile details in DIN 46277/EN. The surface protection of the mounting rail has to be zink plated and

yellow cremated. 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.

The moulding design shall ensure that all metal parts are shrouded to meet the requirements of the IEC finger test (finger-safe) and to BS 3042 without the need for additional covers.

The rated current of the terminal blocks shall be according to DIN VDE 0611-1 with reference to the rated cross-sections. The current bar shall be of a suitable electrical conducting material like copper /alloy or copper plated with tin lead combination to guarantee the best connection between the conductor and the current bar. The current bar shall be designed to retain high clamping pressure.
The rated voltage of the terminal block shall be based on the insulation tests and creepage distances according to VDE 0110-1.

The terminals shall be such that the maximum contact area is achieved when a cable is terminat- ed.The terminal shall have locking characteristics to prevent cable from escaping from the terminal clamp unless it is done intentionally.

The terminal blocks shall be feed through clamping yoke type.

The terminal blocks shall be extendible design.

The terminal blocks shall have a self-locking arrangement to prevent its escape from the mounting rails.

The terminal blocks shall be fully enclosed with removable covers of transparent, non-inflammable, non-deteriorating type plastic material.Insulating barriers Partition plate? shall be provided between the terminal blocks.These barriers shall not hinder the operator from carrying out the wiring without removing the barriers.

The terminals shall be provided with the marking tags for wiring identification on both sides.

The arrangements shall be such that it is possible to safely connect or disconnect terminals on live circuits and replace fuse links when the cabinet is live.

Terminal blocks shall be numbered consecutively, preferably beginning with 1, from left to right or top to bottom.

All terminals shall have two separate pressure clamping points suitable for connection of incoming or outgoing stranded or solid conductors, respectively, however only one wire per terminal will be accepted. Terminals with clamping screws in direct contact with the conductor and soldering are not acceptable. If stranded or fine stranded wire are in use the wire-end have to be prepared with wire-end-ferrules made from copper und has to be crimped on the wire according DIN 46228 T 1 & T 4.

The following minimum categories of terminals shall be used:

- Terminals for power circuits of 10 mm^2, 6 mm^2 and 2.5 mm^2 wire size
- Terminals utilised in the secondary circuit of CTs (4mm^2 wire size), VTs and measuring transducers shall be supplied with a terminal with the following characteristics:
  - sliding link disconnect function
  - cross connecting disconnecting facilities
  - short circuit facilities for CT and instruments

- two integrated test sockets for test instruments per terminal, colored yellow, green & lilac
- it shall be possible to cross-connect the K-point of the CT by a fixed cross connecting link on the terminal, not by a wire link. A locking mechanism shall be included.

- Terminals for wiring of 1.5 mm² and 0.5 mm² wire size with bridging facilities to the neighbouring terminals.

Terminal blocks for protective conductors shall be designed to pollution severity category 3, rated to DIN VDE 0110-1, VDE 0611, part 3 and IEC 60947-7-2 and coloured green/yellow. They shall be fixed onto the mounting rail by means of a separate screw and clamping foot mechanism or by independent, self-locking metal foot clamping directly onto the assembly rail and shall have the ability to be arranged in the relevant sequences to match the phase circuits.

5.3.2 Labels

The boards shall be clearly labelled with the name of the circuit on the front, at the rear and inside the board. All labels shall be in English.

Each relay and electronic card in the board shall be identified by labels fixed permanently to the board next to the equipment concerned. If the equipment is connected to a terminal and to a socket, the terminal and the socket shall have permanent identification labels.

The labels shall be solidly fixed using screws. The use of adhesive tape to fix labels will not be acceptable.

5.3.3 Miscellaneous Accessories

Plug Point
240V, single phase 50Hz, AC socket shall be provided in the interior of each cubicle with ON-OFF switch.

Interior Lighting
Each panel shall be provided with a fluorescent lighting fixture rated for 240 V, single phase, 50 Hz supply for the interior illumination of the panel controlled by the respective panel door switch.

Space Heater
Each panel shall be provided with a thermostatically connected space heater rated for 240V, single phase, 50Hz AC supply for the internal heating of the panel to prevent condensation of moisture.

5.3.4 Earthing

All panels shall be equipped with an earthbus securely fixed. The material and sizes of the busbar shall be at least 25x6 mm² copper with threaded holes at a gap of 50 mm with provision of bolts and nuts for connection with cable armours and mounted equipment etc. for effective earthing. When sev- eral panels are mounted adjoining each other, the earth bus shall be made continuous, and necessary connectors and clamps for this purpose shall be provided. Provision shall be made for extending the earth busbars to future adjoining panels on either side.

All metallic cases of relays, instruments and other panel mounted equipment including gland plate, shall be connected to the earth bus by yellow/green copper wire of not less than 2.5 mm².

5.3.5 Testing Facilities

Software for testing the protection and control devices shall be included in the scope of supply. In addition, for secondary injection testing of the protection & control devices, provision shall be made in the panel for current & voltage injection using standard test set and disconnecting type terminal blocks with facility for short circuiting of current transformer secondary circuit etc. by means of movement of links from their normal operating position, or any other testing arrangement approved by the Engineer.

5.4 Relays and Scheme

5.4.1 General

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Relays shall be of approved construction and shall be arranged so that adjustments, testing and replacement can be effected with the minimum of time and labour. Relays of the hand reset type shall be capable of being reset without opening the case. ***Relays and BCU to be supplied shall be fully complied with attached GTP . REB 500 relays shall be preconfigured as per annexure A1 and annexure A2***

Relay contacts shall be suitable for making and breaking the maximum currents that they may be required to control in normal service but where contacts of the protective relays are unable to deal directly with the tripping currents, approved auxiliary contacts, relays or auxiliary switches shall be provided. In such cases the number of auxiliary contacts or tripping relays operating in tandem shall be kept to the minimum in order to achieve fast fault clearance times. Separate contacts shall be provided for alarm and tripping functions. Relay contacts shall make firmly without bounce and the whole of the relay mechanisms shall be as far as possible unaffected by vibration or external magnetic fields.

Relays, where appropriate, shall be provided with LED or flag indicators, phase coloured where applicable. LED or Flag indicators shall be of the hand reset pattern and shall be capable of being reset without opening the case. Where two or more phase elements are included in one case, separate indicators shall be provided for each element.

All Relay settings shall be visible and readable without having to remove the relay front cover. It shall not be possible to amend relay settings with the front cover in place; other than over a serial link.

If a connector for local use is provided this shall be accessible only after removing the front cover. Where a port is provided for permanent connection to a modem or other peripheral equipment, remote access shall be password protected.

Relays which rely for their operation on an external DC supply shall utilise for this purpose the trip supply of the associated circuit breaker trip coil. This supply shall be monitored and an alarm provided in the event of failure.

Any auxiliary supplies needed shall be drawn from the main station batteries and not from separate internal batteries in the protection equipment.

Relays, whether mounted in panels or not, shall be provided with clearly inscribed labels describing their function and designation in addition to the general purpose labels.

Attention is practically drawn to the tropical climate and relay designs should be entirely suitable for duty under full tropical conditions.

To minimise the effect of electrolysis, relay coils operating on DC shall be so connected that the coils are not continuously energised from the positive pole of the battery.

Relay shall be suitable for operation on 110 V nominal, 121 V float DC systems without the use of voltage dropping resistors or diodes

Numerical protection shall be designed in such a way that in case of a failure of DC auxiliary infeed, the full information needs to be maintained at least 24 hrs. After a recovery of DC auxiliary infeed the last information and alarms will be displayed and the alarm "failure of DC auxiliary infeed" released. The relay reset shall not erase the relay memory.

The Numerical protection functions shall be in the form of software such that additional or different functions, application specific logic etc. can be readily implemented without changes to the existing hardware. It shall be possible to programme/ parameterize by a portable computer (PC) all the numerical protective relays and the entire relay operating and configuring software and the portable computers and other accessory equipment needed to communicate with the relays shall be provided.

All numerical relays shall be adequately protected against damage from incoming surge and shall meet relevant IEC, BS and ANSI SWC test standards. Relays shall utilise a DC-DC converter type regulated power supply to provide transient surge isolation between the station battery and protection equipment. Each DC supply shall be designed to protect it from high voltage and surge and provide electrically isolated contacts for annunciation.

In addition, to all equipment and components, the Contractor shall supply documents and calculations to prove the correct functioning of the equipment and he shall ensure and demonstrate that the setting range of relays and the operating limits of all equipment is suitable for the intended applications.

5.4.2 Scheme

Existing in built system shall be tested and commission

5.4.2.1 Trip Relays

Existing in built system shall be tested and commission

5.4.2.2 Trip Circuit Supervision

Existing system as per CRP scheme shall be tested and rectified.

5.4.2.3 Protection Supply Supervision Relays

Existing system as per CRP scheme shall be tested and rectified.

5.4.2.4 VT Supervision Relays

Existing system as per CRP scheme shall be tested and rectified.

5.5 Overhead Line Protection not require

5.6 Busbar Protection

5.6.1 Existing Busbar Protection

The busbar protection have the following features:

(a) Two independent measurement & tripping criteria. One based on stabilized current differential algorithm and the other on directional current comparison and shall be capable of detecting three phase, phase-phase and phase to earth faults, under all system generation plant condi- tions. They shall meet the fault clearance time of 80 ms under all conditions.

(b) Two independent hand or electrically reset busbar protection trip relays shall be associated with each circuit breaker. These trip relays may also be employed for circuit breaker failure. Operation of either of these relays shall block closing of the associated circuit breaker.

(c) Each trip relay shall trip the circuit breaker via both trip coils. Both relays on the 220 kV transformer circuits shall trip the associated circuit breakers.

(d) The operating time of the measuring relays shall not exceed 30 msec. at five times the relay current setting.

(e) Continuous supervision of CT secondary against any possible open circuit; if it occurs, it shall render the relevant protection zone inoperative and shall initiate an alarm.

The busbar protection will be supplied from multi-ratio current transformers. The working ratio will be selected on the basis of maximum load transfer in the same manner as the line current transformer ratios.

The overall fault setting shall be between 10% and 30% of the minimum fault current available for any type of fault, unless otherwise specified. The minimum fault current for 230 kV busbar faults will be advised at a later stage.

The rated stability limit of the protection shall not be less than the switchgear short circuit rating.

Automatic and continuous supervision of current transformer circuits shall be provided to give an alarm when the out-of-balance current reaches an undesirable value. Operation of current transformer supervision equipment should take the defective protection zone out-of-service.

The contract shall include for all necessary current transformers, relay panels, marshalling boxes, isolating and shorting links, etc. A lockable busbar protection ON/OFF switch shall be provided. Lockable maintenance switches shall be provided for each bay unit of busbar protection.
Test terminal blocks to be provided shall be fully enclosed with removable covers. All terminals shall be clearly marked with identification numbers. Test terminal blocks shall have shorting, disconnecting and testing facilities for CT circuits.

Current transformer secondary bus wiring should be suitably dimensioned to reduce current transformer burdens to a minimum.

Suitable voltage limiting devices shall be provided as necessary, including across the unused part of the CT secondary when tappings are employed.

Full details of the scheme offered, together with performance figures for stability and sensitivity, shall be provided in accordance with Clause 5.10.2.

The numerical busbar protection shall be multi-processor in structure, with extensive self-supervision, 16 bit analogue to digital converters, together with appropriate algorithms to provide phase segregated measuring principles and multi criteria evaluations before initialisation of trip commands. The busbar protection shall be of decentralised, with redundant DC/DC supplies type and the bay units shall be fixed as close to the CTs as possible reducing the copper wiring to a bare minimum and thereby also reducing the CT burden and CT dimension.

If the intercommunication between the bay unit and central unit by fibre optic cables, the required fibre optic cable and all necessary items shall be supplied, connected and commissioned by the Contractor.

Busbar protection shall be tested and commission by OEM Engr. Or OEM certified Engr.

5.7 Circuit Breaker Failure Protection not require

5.8 Auto-Reclosing Scheme not require

5.9 Overcurrent and Earth Fault Protection

The overcurrent and earth fault relays shall be fully Numerical and have multi characteristics (inverse, very inverse, extremely inverse) to IEC 60255.

Overcurrent relays shall have a current setting range from at least 50% - 200% in 25% setting steps.

Earth fault relays shall have a current setting range from at least 20% - 80% in 10% setting steps.

Time multiplier settings shall be continuously adjustable from 0 to 1 or, as an alternative in steps of 0.025 from 0.05 to 1.0.

In the case of transformer circuits relays shall be provided with high set instantaneous units which can be set to 1.25 times the fault current in the HV winding for a fault on the LV terminals computed using the transformer minimum impedance and assuming negligible source impedance. The instantaneous unit shall have a low transient overreach (less than 5% for system X/R ratio of 10) and an operating time of less than 40 msec. at two times the current setting.

In the case of underground line circuits relays should have a reset ratio greater than 95% to enable settings to be made which are close to the circuit emergency rating. The relay contacts must close at a current equivalent to 110% of the setting and relay overshoot must not exceed 50 msec.

Overcurrent and earth fault relays shall trip via the CB duplicate trip coils and initiate duplicated direct intertripping to the remote line end CB.

Relays shall be thermally rated such that the operating time of the relay at the highest practical current levels on any combination of current and time multiplier settings shall not exceed the thermal with- stand time of the relay. The Contractor shall provide copies of type test reports to show that this re- quirement has been met.

Directional back up overcurrent and earth fault relays shall be provided for underground Cable feeders and the directional elements shall be voltage polarised.
Directional units for directional overcurrent protection shall be quadrature connected with a relay characteristic angle setting of 30° or 45° current leading voltage.

Directional units for directional earth fault back up protection shall employ residual voltage quantities and the relay characteristic angle be variable 0°, 45° and 60°, current lag.

The nominal operating boundary shall be ±90° from the relay characteristic angle and the operating time of the directional unit shall not exceed 20 ms at the relay characteristic angle.

The relay shall be capable of operating correctly when both the operating current and polarising voltage quantities are 1% of rated values at an angle equal to the relay characteristic angle.

The residual polarising voltage for earth faults may reach 190.5 volts and therefore it should withstand this value continuously. The continuous withstand current should be no less than twice rated current.

5.10 Transformer Protection

The 400/230/33kV auto transformers shall be provided with dual biased differential protection and restricted earth fault relay as a main protection. Redundant biased differential relays shall be provided as shown in the protection block diagram for transformer protection. Directional overcurrent relays and over current relays shall also be installed for back-up protection. Additionally, over flux (V/Hz) relays shall be provided in order to avoid any overheating. **For relay and protection connections, refer to the drawing.The detailed protection scheme shall be approved by the Employer**.

5.10.1 Biased Differential Protection

The transformer differential protection shall be of fully numerical design, with 16 bit analogue to digital converters, powerful digital signal processors, CPU, etc. The relay should have continuous self-supervision and diagnosis. A local display unit shall be provided on the front of the relay for measure and display, trip indications, diagnostics, etc., and also for acknowledging and resetting latched outputs. The required software for setting and configuring the relay shall be provided with the relay, and this human machine interface (HMI) shall be user-friendly and should not require any special pro-

gramming knowledge. It should be possible to do the settings offline and load the settings on to the relay with a standard portable PC with a fibre optic connection.

Overall differential protection shall be of the biased differential type and be capable of detecting phase and earth faults.

Separate facilities shall be provided to enable adjustment of bias and operating settings. The minimum operating setting shall not be higher than 20 % of the rated full load current of the transformer.

The protection shall be designed to ensure stability on any transformer tap position under maximum through fault conditions with maximum d.c. offset. An infinite source is to be assumed, and the through fault current shall be calculated using the transformer impedance only.

Correction for matching transformer vector groups and main CT ratios for transformer differential protection shall be performed within the relay without the use of external interposingtransformer.
The relay shall have second harmonic or other inrush proof features. The relays shall have magnetising inrush current restraints of the second harmonic or other approved means. All necessary interposing current transformers shall be provided under the contract.

Where specified in the drawings, two biased transformer differential protection relays shall be provided for each transformer.

The relays shall have an inbuilt event, fault and disturbance recorder. All binary inputs, binary outputsand analogue channels available in the relay shall be recorded in case of fault.

5.10.2 Restricted or Balanced Earth Fault Protection

Where specified, or shown on drawings, transformer windings and connections shall be protected by restricted earth fault protection. Delta connected windings shall be protected by balanced earth fault protection. Relays shall be of identical numerical design as the main protection and of the high impedance type with necessary protection against over voltages. For reliability reasons the restricted earth fault relay shall be separate from the transformer differential relay.

Relays shall have maximum sensitivity and minimum operating times consistent with stability for faults outside the protected zone and on magnetising inrush surges.

The rated stability limit shall not be less than the maximum current available for an external fault. This shall be taken as 16 times the rated current of the protected winding of the power transformer, or any other value agreed by the Engineer.

For the purpose of calculations it shall be assumed that any neutral earthing impedance is short circuited.

The Contractor shall prepare for approval calculated performance for instantaneous high impedance restricted earth fault protection in lieu of heavy current tests, subject to the conditions in Clause 5.10.2 except:

i) The rated stability limit shall be as specified above.
ii) The fault setting shall be as specified below.

(a) When the transformer winding is connected to a solidly earthed power system, the fault setting shall be between 10% and 60% of the rated current of the winding. When the transformer winding has more than one rating, the setting shall be based on the lower rating.

(b) When the protected transformer is not connected to a solidly earthed power system the fault setting shall be between 10% and 25% of the minimum current available for an earth fault at the transformer terminals.

5.10.3 Transformer Back-up Overcurrent Protection

Three-pole inverse time back up overcurrent and earth fault protection shall be provided as shown on the drawings. This shall comply generally with Clause 5.12 but in addition the overcurrent elements shall also be a two stage device. Stage 1 will comprise the inverse time unit and stage 2 will comprise an additional definite time unit with a setting range of 50 msec. - 5 secs.

5.10.4 Gas Pressure (Buchholz) Protection

Power transformers and earthing transformers shall be fitted with Buchholz devices under this contract. The Buchholz device will be of the two element type giving operation under gassing and under surge conditions.

All necessary flag indication, tripping relays and alarm relays associated with this protection shall be provided, mounted and connected under this contract.

5.10.5 Oil and/or Winding Temperature

Transformers will be provided with oil and/or winding temperature protection under this contract. These will be of the two stage type with adjustable settings giving alarm and trip facilities.

All necessary flag indication, tripping relays and alarm relays associated with this protection shall be supplied and connected under this contract.

5.10.6 Low Oil Level and Pressure Relief Devices

Transformers shall be provided with low oil level with contacts for the purpose of providing remote alarm. Transformers shall also be provided with a pressure relief device with contacts for purposes of remote alarm and trip function.

The alarm relays associated with these devices shall be supplied and connected under this contract.

5.10.7 Tap Changer Oil Surge

Transformers will be provided with an oil surge or pressure operated device having contacts for purposes of remote alarm and trip.

A relay associated with this device shall be supplied and connected under this contract.

All necessary flag indication, tripping and alarm relays associated with tap change oil surge shall be provided.

5.10.8 Standby Earth Fault Protection

Standby earth fault protection shall be provided for all earthing transformers/resistors, fed from a current transformer in the transformer/resistor neutral connection.

The operating current shall be adjustable between 10 and 40 per cent of the resistor value. The time delay shall be adjustable between 1 and 10 secs. As an alternative to a definite time relay, a long inverse time relay may be offered.

5.10.9 Tripping Relays

All tripping relays, where specified shall be of the heavy duty type suitable for panel mounting. The trip relays of the offered numerical protections shall be directly capable of tripping the breaker coils. It shall not be required to add additional trip relays

Trip relay contacts shall be suitably rated to satisfactorily perform their required duty and relay operating time shall not exceed 10 ms. from initiation of trip relay operating coil to contact close.

Where specified latching type relays shall have hand or electrically reset contacts and hand reset flag indicators. Resetting of the flag indicator and the contacts shall be possible without having to open the relay case.

Tripping relays shall operate when the supply voltage is reduced to not higher than 30% of nominal battery voltage. It shall not operate for wiring leakage currents and discharge of wiring capacitance

400 kV and 230 kV circuit breakers are equipped with two trip coils. One tripping relay shall initiate tripping via one trip coil and the other tripping relay via the second trip coil.

5.11 DC Auxiliary Voltage Operating Range

DC operated relays, coils, elements, etc. will be operated from a 110V rated dc. battery, which under float charging conditions operates at about 125V. DC operated relays coils elements etc. shall be suitable for operation over a voltage range of 66V to 143V. i-e. 110 - 40% + 20%.

5.12 Teleprotection Signalling

Details of protection initiation and various permissive and direct intertripping signals are as specified in Section-14, of Vol. 2 of 3.

5.13 Protection Settings

Relay settings with calculation for all unit-type protective schemes shall be submitted to the Engineer and Employer prior to commissioning of any plant for approval. Settings shall also be provided for those relays and other equipment provided under this section of the contract which do not require an intimate knowledge of existing relay settings e.g. circuit breaker fail relays. Detailed calculations shall be provided supporting all recommended settings.

Any additional information needed by Contractors should be requested.

5.14 Testing and Inspection

5.14.1 General

All relays (including panels) shall be tested in the Manufacturer's work. The Bidder/Contractor may be required to carry out any or all of the tests stated in this specification in presence of PGCB or its representatives according to clause SCC23 of section-8 of volume-I.

Testing of relays and their components shall be performed in line with this specification and in accordance with the relevant IEC standards (as minimum requirement) and other standards as may be approved by PGCB.

Acceptance by PGCB's Representative of any relay tests shall not relieve the Manufacturer from any of his performance guarantees or from any other obligations.

PGCB reserves the right to perform checks during the manufacturing process at any time or all the times. It shall be at the discretion of PGCB to witness tests on 100% or any percentage of each lot for routine tests, apart from the type tests, wherever called for.

Tests of relays shall comprise factory tests and site tests.

5.15 Factory Tests

5.15.1 Type Tests

Evidence shall be given that the proposed relays to be supplied under the contract had already been subjected to all type tests (including transient and steady-state tests) at an internationally recognised testing station like KEMA or equivalent. If deemed necessary, PGCB will decide whether the Bidder/Contractor shall perform additional tests.

An internationally recognised laboratory shall certify the type test reports.

The Bidder/Contractor shall submit certified copies of type test certificates covering the proposed relay components.

Type test certificates/reports shall be considered acceptable if they are in compliance with the relevant standards and the following:

- Type tests conducted at an internationally recognised laboratory acceptable to PGCB.
- Type tests conducted at the Manufacturer's laboratory and witnessed by representatives from an internationally recognised laboratory acceptable to PGCB.

If the presented type test reports are not in accordance with the above requirements, PGCB may decide to ask for the type tests to be carried out afresh in the Manufacturer's premises or other places subject to the approval of PGCB and at no additional cost. These tests shall be performed in the presence of an internationally recognised laboratory, which should issue the relevant type test certificates upon successful completion of all tests.

5.15.2 Routine Tests

Protection relays and their components shall be subjected to routine tests as per the relevant IEC standards. Protection relays mounted in cubicles shall be completely wired, tested and inspected at the relay Manufacturer's factory.

Factory tests shall cover a subset of the following:

- Secondary injection, scheme checks, relay logic, performance of engineer interface, functional-trip tests, setting ranges and calibration accuracy, response(trip) times, functional availability and ap-

The Contractor have the option to choose different types of communication networks for the bay level and the process level based on IEC 61850. However, network topology and access mode shall be clearly indicated. The availability shall be maintained with suitable topology of ring, star or bus. The physical medium of those shall be glass fibre optics.

The IEDs for protection and control functions maintain high availability and reliability together with bay independence through extensive self-supervision and state-of-the-art technology. All IEDs shall be directly connected to the IEC 61850 bus and shall use only the IEC 61850 protocol for com- munication. No proprietary protocols shall be used.

The system capable of having its computing power increased in the future through the addi- tion of additional computing systems.
The system design life shall be not less than 20 years.

The capacity of the SA system sufficient for the ultimate development of the substation as set out in the project requirements.

The SA Supplier demonstrate that the proposed system has been designed, installed and commissioned in accordance with the IEC 61850 standard and shall provide evidence of satisfactory service experience during the past 5 years.

For detailed technical data, please refer to the technical data schedules.

These specifications describe the functional requirements of the substation control and supervisory system. The frame structure of these systems is also defined. For implementation of these requirements, the Contractor shall use standard hardware and software to the maximum possibleextent.

The optimum solution of the substation control and monitoring system for the considered substation is realized by three functionally independent subsystems:

- the substation control system
- the protection system and protection supervision system
- the switchyard interlocking system

The protection system is described in a separate section of these specifications.

Both substation control and interlocking system should a have hierarchical structure, which best suits the substation design, functions and its importance for the power system. The Contractor has to propose such a particular, his own, optimal solution and confirm its advantages and give the related references confirmed by the Employer. The Contractor shall confirm continuity of his preferable philosophy of the proposed solutions, utilization and compatibility of new products in the next 15 years after commissioning.
The system between the bay control level and the substation control level and linked with higher level control centre shall be of the "open" system design, i.e.:

- it must be possible that equipment from different manufacturers works together,
- easy extension shall be possible,
- future upgrades (hardware and software) must be easily possible without changing existing equipment or interfaces. Implemented protocols should also be replaceable without major modifications (e.g. future IEC standards).

For the purpose of the cooperation of equipment from different manufacturers, the internationally recognized and approved standard communication protocol shall be applied. The substation control and supervision system shall have minimum 2 (two) interfaces for communication with the control centre.

5.19.2 Compliance with Standards

For design and type-testing of the protection and control equipment, the following standards shall apply:

5.19.2.1 Standards for Environment

- IEC 60068-2-1/2: Environmental testing: Temperature
- IEC 60068-2-3: Environmental testing: Humidity
- IEC 60654: operating conditions: climatic conditions
- IEC 60870-2-2: telecontrol equipment and system: environment conditions

5.19.2.2 Standards for Equipment

- IEC 60044-1: current transformer
- IEC 60056: earthing switch
- IEC 60185: low voltage switchgear
- IEC 60186: voltage transformer
- IEC 60688: electrical measuring transducers
- IEC 60227: polyvinyl insulated cables
- IEC 60228: conductors of insulated cables
- IEC 60297: dimensions of mechanical structures (19" panel, racks, cabinets etc.)
- IEC 60309: plugs, socket-outlets and couplers
- IEC 60352: solderless connections
- IEC 60529: degrees of protection provided by enclosures
- IEC 62271-100: high voltage alternating circuit breaker
- IEC 62271-102: Alternating current disconnectors and earthing switches
- IEC 60129: high voltage switchgear and control gear. Alternating current disconnectors and earthing switches.
- IEC 60146: Rectifiers, converters, stabilized power supply.

5.19.2.3 Standards for Tests, Safety, Definitions

- IEC 60605-7: Equipment reliability testing
- IEC 60271÷ tests
- IEC 60073: Basic and safety principles for man-machine interface
- IEC 60050: international electrotechnical vocabulary
- IEC 60038: IEC standard voltages

5.19.2.4 Standards for EMC

- IEC 61000-4-2: Electromagnetic compatibility - electrostatic discharges
- IEC 61000-4-3: Electromagnetic compatibility - electromagnetic field

- IEC 61000-4-4: Electromagnetic compatibility - fast transient (burst)
- IEC 61000-4-5: Electromagnetic compatibility - impulse voltage immunity requirements (lightning)
- IEC 61000-4-6: Electromagnetic compatibility - continuous wave (CW) current injection.
- IEC60801: Electromagnetic compatibility for electrical and electronic equipment
- IEC 60255-6: electrical relays: HF interference test.
- IEC 60255-22: electrical relays: electrical disturbance tests
- IEC 60255-3: electrical relays: surge voltage test
- IEC 60255-5: electrical relays: HF interference test
- IEC 60870-2-1: telecontrol equipment and system: power supply and electromagnetic compatibility

5.19.2.5 Standards for Interfaces

- IEC 61850 Edition 2: communication networks and systems in substations.
- IEC 60870-5-101: telecontrol equipment and system: transmission protocol (telecontrol tasks)
- IEC 60870-5-102: telecontrol equipment and system: transmission protocol (integrated total in electric power systems)
- IEC 60870-5-103: telecontrol equipment and system: transmission protocol (informative interface for protection equipment)
- IEC 60870-5-104: telecontrol equipment and system: transmission protocol: network access
- IEC 60870-3: telecontrol equipment and system: Interfaces (electrical characteristics)
- IEEE 803: Ethernet LAN

5.19.2.6 International Standards Organisation

The Manufacturer of the substation control and supervision system shall submit a certificate of a quality assurance system according to ISO 9001 in design, development, production, installation and servicing.

- ISO 9001: Quality system model for quality assurance in design/development manufacture and testing.
- ISO 9002: Quality system model for quality assurance in production, installation and servicing.

5.19.3 General System Design

The SAS contain the following main functional parts:

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

The main process information of the station shall be stored in distributed databases. The system shall be based on a decentralised concept with bay-oriented distributed intelligence for safety and availabil-

ity reasons. Functions shall be decentralised, object-oriented and located as close as possible to the process.

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

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

The monitoring system shall be suitable for the supervision and monitoring of all the secondary (IED) and primary devices in a substation including future extensions.

Maintenance, modification or extension of components shall not cause a shut-off of the whole station monitoring system. Self-monitoring of single components, modules and communication shall be incorporated to increase the availability and the reliability of the equipment and to minimise maintenance.

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

One remote computer should be provided with access to the SMS and with different access levels. The required SMS software and application-specific firmware (for relay parameterisation) shall be pro- vided with associated tools and equipment. The required engineering tools and analysing software shall also be provided/installed both in the station PC and the remote master analysis station. A back- up copy of all the software shall be provided on CDs.

The SAS shall be capable of communicating with the remote master analysis station at the protection development branch through a modem over a dedicated or dial-up voice grade telephone line or microwave channel.

5.19.4 Flexibility and Scalability

The offered SAS concept shall be flexible and shall permit future extensions to be implemented easily. Preference will be given to those Suppliers who are in a position to provide protection and control devices that can be freely adapted to the requiredapplication functions.

5.19.5 System Hardware

5.19.5.1 Bay Control Level

5.19.5.1.1 Bay Control Units (BCU)

For detailed technical data, please refer to the Technical Data Schedules.

5.19.5.1.2 Voltage Regulation

Control of the transformer tap changer (rise and lower) from the substation computer keyboard shall be provided with simultaneous indication on screen. The tap changers (OLTC) control and indication from the control centre shall also be provided.

Each transformer (with OLTC) shall be equipped with its own voltage regulator or shall be controlled by complex joint voltage regulation system provided by third party. Selection of automatic or manual initiated tap changer control shall be provided. Parallel regulation is not foreseen, and such operation must produce a warning but shall be an allowed operation.

5.19.5.1.3 Protection Monitoring System

The Contractor shall propose the protection monitoring system which is (as a function) independent from the station control system for the remote relay monitoring and fault analysis. It shall have the possibility to be used for station diagnostics. This system shall allow for:

- Monitoring and diagnostic of protective equipment,
- Access to the relays and overview of relay setting from a local and remote location,
- Protection performance analysis,
- Fault recording and fault location determination,
- Analogue fault data acquisition and storage,
- Transmission of fault data to remote location for analysis,
- Reports,
- Communication with control system connection of the HMI for diagnostic functions of the primary equipment,
- Remote parameter reading/setting for protection devices is welcomed.

At the substation level, an expert system / advanced help utility should be provided with facilities for transmission data to the control centre.

5.19.5.1.4 Data Security

Substation control and supervision system shall provide the security and diagnostic functions of the individual system elements especially for:

- Monitoring and diagnostic of auxiliary equipment:
  - Auxiliary supply,
  - Auxiliary air conditioning systems,
  - UPS systems.
- Monitoring and diagnostics of the air conditioning system,
- Monitoring and diagnostics of the firefighting system,
- Monitoring and diagnostics of the alarm system,
- Access to the files,
- Transmission and execution of commands,
- Serial data communication,
- Data storage,
- Coordination of functions,
- Conformity of the substation equipment with the single line diagram.

To achieve high reliability of the system operation, actual faults shall be time tagged in the moment they occur but not in the cycle time of the process. Software data and parameters shall be stored in solid-state memory, which does no lose its contents in a case of loss of supply. The software and da- tabase shall automatically restore after recovery of voltage.

5.19.5.2 System Design

5.19.5.2.1 Hardware

The system hardware designed as interchangeable elements of the standard formats or as compact modules (according to IEC 60297). It shall have an "open" structure and design so that ex- tension of the system should be easy. The hardware shall meet the following specifications.

5.20 Busbar Voltage Selection

Where required, selected voltage references, one for each busbar, shall be employed for all indications, metering, protection and synchronizing where appropriate. The correct voltage selection for the requirements of each circuit according to the busbar to which it is connected shall be obtained by direct use of auxiliary contacts on busbar selector switches.

5.21 Energy Meter (Tariff Metering)

5.21.1 Normal Display List

Scroll Order	Display Item Name
1	Complete LCD test
2	Present date
3	Present time
4	Current billing total kWh-Del
5	Current billing total kWh-Rec
6	Current billing total kVARh-(Q1+Q4)
7	Current billing total kVARh-(Q2+Q3)
8	Current billing maximum kW-Del
9	Current billing maximum kW-Del Date
10	Current billing maximum kW-Del Time
11	Current billing cumulative kW-Del
12	Current billing maximum-Rec
13	Current billing maximum kW-Rec Date

Scroll Order	Display Item Name
14	Current billing maximum kW-Rec Time
15	Current billing cumulative kW-Rec
16	Phase A Voltage
17	Phase B Voltage
18	Phase C Voltage
19	Phase A Current
20	Phase B Current
21	Phase C Current
22	Phase A voltage angle
23	Phase B voltage angle
24	Phase C voltage angle
25	Phase A current angle
26	Phase B current angle
27	Phase C current angle
28	System PF-arithmetic
29	Line frequency

5.21.2 Alternate Mode Display List

Scroll Order	Display Item Name
1	Complete LCD test
2	Present date
3	Present time
4	Current billing total kWh-Del
5	Current billing total kWh-Rec
6	Current billing total kVARh-(Q1+Q4)
7	Current billing total kVARh-(Q2+Q3)
8	System PF-arithmetic
9	Line frequency

Load profile (cumulative meter reading) and Instrumentation profile data in the following format should be stored in intervals of 30 min for at least 100 days:

5.21.3 Interval Date (Load Profile)

Interval Data Mode: Cumulative Engineering Units

Time	kWh-Del	kWh-Rec	KVARh-(Q1+Q4)	kVARh-(Q2+Q3)
Date: 1/31/2015				
00:00	0	0	0	0
00:30	0	0	0	0
01:00	0	0	0	0
01:30	0	0	0	0

5.21.4 Interval Date (Instrumentation)

Set-1

Time	End Phase A Voltage	End Phase A Voltage	End Phase A Voltage	Average System kW
Date: 1/31/2015				
13:45	61.0544	61.1424	61.072	0

Set-2

Time	End Phase A Current	End Phase A Current	End Phase A Current	Average System PF-Arithmetic
Date: 1/31/2015				
13:45	0.0008	0.0004	0.0004	-0.7002

Self-read feature for at least 12 months' billing history.

6. Auxiliary Power and Control Cables

6.1 Scope

A complete cabling system for the substation auxiliary power requirements and the control and protection multicore cabling shall be designed, provided, installed and commissioned by the Contractor as specified in the Project Requirements and schedules. All ducts, cable racking and supports are to be supplied under the Contract. The Contractor shall, furnish satisfactory evidence as to the competence of the electricians and jointers, he proposes to employ on the cable installation and jointing works.

6.2 General Description of Installation

The complete cabling installation, including that associated with control and instrumentation, shall be managed by the Contractor, who shall be responsible for design, procurement, installation and works/site testing of the whole installation.

The Contractor shall employ a cabling computer program to facilitate the above and the Bidder shall describe in his Tender the cabling management procedures he will adopt. A cable scheduling system will be imposed by the Engineer.

The Contractor shall provide an installation in accordance with the best modem practice and complete in every detail for continuous operation.

Cabling areas will include those which have natural ventilation. Cabling shall therefore be designed for the maximum ambient temperatures expected.

To cater for future requirements, adequate provision shall be made for the associated cables in respect of trench sizes, space for future racks or trays and numbers of cables permitted in areas or spaces required for future equipment.

The Contractor shall submit to the Engineer drawings for approval showing the proposed cable routes, cross-sections of the trenches and arrangements of the cable racks and trays.

The Contractor shall prepare and provide all necessary cable schedules. The cable numbering system to be used shall be advised to the Contractor and this system shall be followed.

The Contractor shall provide all necessary power, multicore and communications cables required as required and specified in the Project Requirements.

6.3 Standards

The cables shall comply with British Standards or IEC standards and recommendations, or any other Internationally recognised standards, subject to the approval and acceptance of the Engineer.

6.4 Cable Installation

6.4.1 General

The cabling system shall be designed to incorporate maximum practical security, to ensure that an incident such as fire causing loss of cable circuits in any one route would at worst result in the interruption in operation of one unit only. Cables with reduced fire propagation characteristics shall be provided.

Cables shall be satisfactory for operation under the atmospheric and climatic conditions prevailing at the site and under such variations of current, voltage and frequency as may be met under fault and surge conditions on the system.

Cables shall be derated to allow for the likely number of cables following a given route.

The methods of installation shall be as follows:

(a) directly buried
(b) in concrete trenches (on racks or trays)
(c) in ducts
(d) in air

Control and instrumentation cables shall be screened/shielded to minimise interference, where necessary.

6.4.2 Installation Criteria

Specific requirements shall be as detailed in the project requirements.

System security shall be achieved by ensuring that cables are segregated or separated from each other as appropriate. Segregation shall be achieved by laying cables associated with any one high voltage circuit of a pair on separate trays or racks at least 600mm apart from the cables of the other of the pair with an airspace, but not necessarily a physical barrier, between them.

In general, to minimise interference, control cables and instrumentation cables shall be separated from power cables.

The following group classifications will be allocated for each cable:

- Group A: Single core power cables,
- Group B: Multicore power cables,
- Group C: Multicore control cables and protection cables,
- Group D: Multi-pair control and instrumentation or indication cables.

In general, single core (Group A) and multicore (Group B) power cables shall be allocated to separate racks. In a similar manner, multicore control (Group C) and multi-pair (Group D) instrumentation cables shall generally be allocated to separate trays.

There shall generally be a minimum separation of 600 mm between instrumentation cables (Group D) and power cables (Groups A and B), and a minimum separation of 300 mm between control cables (Group C) and power cables (Groups A and B). However, both these separation distances may be reduced where the two types of cable only run in parallel for a limited distance, provided the Contractor demonstrates that the level of interference resulting will not be detrimental to the operation of the equipment concerned.

6.4.3 Reduced Fire Propagation

A cable installation with reduced fire propagation characteristics shall be provided, utilising cables with organic compounds which are capable of extinguishing or considerably reducing the spread of flame along the cable.

Consideration shall also be given to ensuring that the minimum toxic or corrosive products are given off on combustion of any organic component used in cable construction.

6.4.4 Type Approval

Cables and accessories for use at all voltages shall have satisfactorily passed type approval tests equal to those required by the International Electro technical Commission or equivalent, and details for the cable designs offered shall be given in Schedule E of Particulars and Guarantees.

The Contractor is to certify that the cables and/or accessories offered will be identical in all essential particulars in respect of design, materials and workmanship with the cables and/or accessories for which type approval certificates are offered in support of his tender. The Contractor shall also ensure that all materials used will be subjected to and shall have satisfactorily withstood such tests as are customary in the manufacture of the types of cables specified. Records of such tests shall be available for inspection, if required by the Engineer.

6.4.5 Cable Sizing and Routing

The Contractor shall be responsible for all cable sizing and routing design, procurement, installation and testing.

Proposals for the following aspects of cable design shall be submitted for approval:

- Routing cables along the shortest route compatible with segregation/separation and capacity limitations
- Sizing cables in accordance with length grouping, ambient temperature and current rating
- Recording estimated lengths and later measured lengths for each cable
- Progressing the cable installation
- Producing and progressing cable schedules, cable termination schedules, and support steelwork schedules and drawings

All necessary de-rating factors shall be applied when sizing cables, to allow for maximum ambient temperatures, soil temperatures, values of thermal resistivity of soil, and grouping as necessary.

Due allowance shall be made for the method of installation, depth of laying, spacing and grouping factors.

All power cables shall be adequately rated to withstand the thermal and magnetic effects of short- circuit fault currents equivalent to the short circuit fault rating of the associated switchgear, except when advantage can be taken of the peak current limiting effects of MCCB's and fuses. Screens and /or outer sheaths shall be designed to carry the full ground fault current.

The short-time rating of all transformer and interconnector feeders shall correspond to the maximum short-circuit conditions and be based on the previous maximum continuous rating operating temperature, followed by the initial asymmetric peak current, followed by the thermal steady state r.m.s. fault current for the total duration required for the associated main and back-up protection to operate and isolate the circuit. When protected by a circuit breaker which is not of the current limiting type, the cable shall withstand the maximum fault current, including asymmetric peak, for at least 3 seconds without damage.

For 400V motor supply cables the rating shall be based upon the duration of the let-through current of the associated main circuit breaker or fuse protection. The fault currents considered shall not include for the reduction due to the impedance of the cables concerned.

Maximum conductor temperatures permissible during the passage of short-circuit current shall be in accordance with cable Manufacturer's recommendations and joints and terminations shall be designed to match the cable characteristics.

For all alarm, control, indication, instrumentation, metering and protection cables, the Contractor shall determine the impedances, load burdens and other requirements of the cabling and associated equipment and shall provide cabling for satisfactory operation. Particular attention shall be given to protection circuits and the Contractor shall ensure that satisfactory operation will be achieved under overload or short circuit conditions on the system.

The Contractor shall furnish copies of calculations and other details to show how the ratings and cross-section areas of all cables have been obtained and the de-rating factors for which allowance has been made. Where a cable is routed through differing types of installation conditions, the condition giv- ing the lowest cable rating shall determine the cable size.

The sizes of all cables shall be submitted to the Engineer for approval and the Engineer may require the Contractor to increase the cross-sectional area of the conductor to ensure that the required current carrying capacity and performance is obtained. All such changes shall be made by the Contractor without extra cost.

6.5 Cable Construction

6.5.1 Oversheaths

All cables shall have a black flame retardant low smoke PVC oversheath material, to meet the fire retardant characteristics of BS 4066 and IEC 60332.

PVC sheathing shall comply with IEC 60540 and shall have flame retardant properties such that the Oxygen Index is not less than 30 when tested in accordance with A.S.T.M. D2863-77. Test certificates stating measurement values for sample drum lengths of cable shall be provided.

The external surface of the oversheath shall be embossed along two or more lines approximately equally spaced around the circumference with the words "ELECTRIC CABLE" in English. Figures for the relevant voltage grade, together with Manufacturer's name, shall be embossed on the oversheath.

The letters and figures shall be raised and shall consist of upright block characters. The maximum size of the character shall be 13 mm and the minimum size 15% of the approximate overall diameter of the cable. The gap between the end of one set of embossed characters and the beginning of the next shall not be greater than 150mm.

The minimum thickness of oversheath shall not fall below the Manufacturer's stated value by more than 0.2mm plus 20 percent.

A means of identifying the Manufacturer shall be provided throughout the length of the cable.

6.5.2 Armouring

All multicore cables shall be provided with galvanised steel wire armour. Single-core cables shall have copper or aluminium wire or tape armouring.

The armour shall be protected by an overall PVC or plastic sheath.

6.5.3 Laying Up

The cores of multicore cables shall be laid up with a right hand direction of lay. Where necessary, non-hygroscopic fillers, which may be applied integrally with the bedding, shall be used to form a compact and circular cable.

6.5.4 Cable Drums

Cable drums shall be non-returnable and shall be made of timber, pressure impregnated against fungal and insect attack, or made of steel suitably protected against corrosion. They shall be lagged with closely fitting battens.

Each cable drum shall bear a distinguishing number on the outside of one flange. Particulars of the cable, i.e. voltage, conductor size and material, number of cores, type, length, gross and net weights

shall also be clearly shown on one flange. The direction of rolling shall be indicated by an arrow on both flanges. The method of drum marking shall be to the Engineer's approval.

Cable spare lengths shall be wound on to steel drums before they are handed over to the Employer's stores.

6.5.5 Sealing and Drumming

Immediately after the Works tests, both ends of each cable length shall be sealed by means of a shrinkable cap and the end projecting from the drum shall be adequately protected against mechanical damage during handling. The ends of each drum length of multicore cables shall be masked red and green in accordance with BS 6346 or BS 5467.

6.5.6 Spare Cable

Spare cable and accessories, as detailed in the schedules, are required to be included in the Contract.

6.5.7 Jointing Accessories

Cables shall be installed in continuous lengths and straight through jointing between shorter lengths will not be permitted.

Jointing accessories shall include all necessary internal and external fittings, insulating materials, soldering metal, glands, filling and drain plugs, armour clamps, earth bonding terminals and filling compounds as appropriate.

Mechanical glands for the termination of elastomeric or thermoplastic insulated cables into straight-through joints and termination accessories shall meet the requirements of BS 6121 and shall be correctly designed for the termination of the armouring. The gland shall not only adequately secure the armour to provide efficient electrical continuity but shall also provide a watertight seal between the oversheath and the inner extruded or taped bedding to prevent the ingress of moisture. All glands shall be fitted with a substantial earth bond terminal.

The armour clamping device shall be capable of clamping the cable armour so that the clamp withstands any short circuit current from the armour wires, through the gland body to the integral bonding connector.

Sealing end porcelains shall be free from defects and thoroughly vitrified so that the glaze is not depended upon for insulation. The glaze shall be smooth and hard, completely cover all exposed parts of the porcelain and for outdoor types shall be a uniform shade of brown.

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

Outdoor sealing ends and fittings shall be unaffected by atmospheric conditions, proximity to the coast, fumes, ozone, acids, alkalis, dust or rapid changes of air temperature between 15°C and 65°C under working conditions.

6.6 Types of Cable

6.6.1 Low Voltage Cables

These cables shall be in accordance with IEC 60502 with a voltage rating of 0.6/ 1 kV. They cables shall have stranded copper conductors.Insulation shall be XLPE with an operating temperature of 90˚C.

6.6.2 Control Cables and Instrumentation Cables

6.6.2.1 General

Two types of cable shall be provided for the control and instrumentation cabling.

The first is multicore cable with stranded (7/0.67mm wires) copper conductors of min 2.5sq.mm which is suitable for voltages up to 300V to ground a.c. or d.c. and currents up to 5A. These cables shall be used where a low impedance is essential i.e. the secondary wiring of current or voltage transformers and for circuit breaker or contactor controls.

The second type designated "SIGNAL CABLE" is defined as those cables carrying milliamp, analogue or digital signals at low voltage levels (110V d.c. maximum) used on instrument and Logic Transmission Systems. These cables shall be multiple twisted pairs, screened and PVC covered with conductors sized 1.5mm²minimum. The use of cable cores shall be such that each plant analogue signal is transmitted in a twisted pair. Under no circumstances shall the signal positive be in a different twisted pair to the negative. 20% spare capacity shall be included in all multiple twisted pair cables. The combinations of multiple twisted pair cables used throughout the plant shall be restricted to 2, 5, 10, 20, 30, 50 and 100 pairs.

Inductive interference between primary and secondary cables due to load, switching or unbalanced fault conditions associated with the primary circuit shall be avoided. The more sensitive telephone, communication, analogue and digital circuit cables shall be spaced at least 600mm from power ca- bles.

6.6.2.2 Multicore Control Cables

Cables shall comply with the construction here above and shall have cross-linked polyethylene (XLPE) insulation.

All cables shall be provided with a low smoke PVC oversheath.

Multicore control cables shall be generally in accordance with IEC 60502 with a voltage rating of 0.6/1 kV, except that 2.5 mm² copper conductors shall be stranded (7/0.67mm wires). Standard designs shall be for cables with 2, 3, 4, 8, 12, 16, 24 and 36 cores, and single strand conductors will be accepted at 1.5 mm².

All these cables shall have galvanised steel wire armouring.

These cables shall be used where a low impedance is essential, e.g. for the secondary wiring of current and voltage transformers and for circuit breaker and contactor control circuits.

6.6.2.3 Multi-Pair Instrumentation Cables

Multi-pair instrumentation cables shall be provided in accordance with industry standards.These cables shall have solid copper conductors, typically of 0.9 mm diameter laid in twisted pairs, triplets or quads. The cables shall be polyethylene or XLPE insulated. They shall have galvanised steel wire armouring.

Cables shall be provided with either an overall metallic tape screen or individual tape screens round each conductor bundle to reduce interference from adjacent circuits.

These cables shall be used for circuits with a voltage rating not exceeding 125 V to earth and a current rating not exceeding 20 mA, where considerations of interference and cross-talk are of great importance. Typical applications include communications, computer signals, transducer circuits and alarms.

6.6.2.4 Oversheaths

All the cable types above shall have a black flame-retardant low smoke PVC oversheath. In normally manned locations, especially the control building, cables shall have a low smoke, zero halogen oversheath, so as to minimise the generation of smoke and corrosive acid gases in the event of a fire.

6.7 Straight-through Joints

Each cable shall be run in one continuous length. Straight-through joints will not be permitted.

6.8 General Methods of Cable Installation

The arrangement of cables and the methods of laying shall be approved by the Engineer. Cables shall be installed by the following methods only:

- in concrete trenches
- in ducts
- on cable racks or trays.

Concrete trenches shall be provided in switchrooms. Cables shall be installed in a manner which permits the required ratings and with due regard to the number of cables following a given route, including future plant extensions.

All cables routed under roads and access ways usable by vehicular traffic shall be installed in ducts.

At all such crossings spare ducts shall be installed; the number of spare ducts shall be two, or 20% of the total number of ducts installed at each crossing, whichever is greater.

Mechanical protection to the Engineer's approval shall be installed at all, points where the cable is vulnerable to mechanical damage. Locations where this protection shall be installed shall include all points where cables pass through a wall, floor, side or top of a cable trench. In outdoor locations ca- bles shall be provided with mechanical protection from ground level to a minimum height of 1 metre or the cable box on the apparatus, whichever is lower.

Cables shall be installed in such a manner as to avoid undue risk of damage during installation. The Contractor shall provide all necessary rollers and supports, and bending radii shall comply with the recommendations of cable specifications and be to the approval of the Engineer.

Sunshields shall be provided in all locations where the cable would otherwise be subjected to direct sunlight.

6.9 Cables laid directly in the Ground

The method of installation shall be as follows:

Trenches shall be excavated to the minimum depth shown in Drawing for cable trench. Covers shall be provided over cables laid in the trench.

Filling in of trenches shall not be commenced before inspection and approval by the Engineer of the cables and accessories in-situ.

The Contractor shall lay the cables direct in the ground in the following manner:

70mm minimum of builders fine and graded and washed sand or other approved material shall be placed to form a bed for the cables.

After the cables have been laid they shall be covered with additional riddled sand well punned over and around the cables. No mechanical punners shall be used for this work. Protective covers of con- crete shall be provided and installed.

Where, in the opinion of the Engineer, the soil on the site is unsuitable for backfilling, the Contractor shall arrange for the importation of suitable material.

Where three single core cables are laid direct in the ground and form one three phase circuit, they shall unless otherwise stated, be laid touching one another in trefoil formation, with one cable upper- most. In order to maintain a trefoil formation the three cables shall be tied together with tarred twine or by other approved means at intervals of 1.5m.

Unless otherwise approved, auxiliary control cables shall be laid under the same covers as the power cables and there shall be at least 50mm of riddled sand between the two types of cable.Above the protective covers (tiles) there shall be provided 150mm wide Teri-tape in yellow with "CAUTION - ELECTRIC CABLE" in English.

After any cable has been laid and until all of the cables to be laid in the trench have been covered with their protective covers, no sharp metal tools, such as spades or fencing stakes, shall be used in the trench or placed in such a position that they may fall into the trench. Rollers used during the laying of cables shall have no sharp projecting parts liable to damage the cables.

6.10 Cables drawn into Ducts

Ducts and pipes 35mm minimum in excess of cable diameter shall be supplied and installed by the Contractor in accordance with the building and civil works section.

Ducts shall be of rigid PVC and shall be surrounded by concrete of minimum thickness of 150.

Before pulling cables through ducts, the Contractor shall remove any loose material from the ducts, and prove them by drawing through a mandrel of slightly less diameter than the duct. Any lubricant used shall have no deleterious effect on the cables.

Any ducts or pipes not used shall be sealed by plugs (detail subject to approval) supplied by the Contractor before backfilling.

The ducts shall be water and vermin proof sealed, after completion of cable installation.

6.11 Cables installed in Concrete Trenches

The cable trench system shall be designed by the Contractor to the approval of the Engineer. It shall be complete with removable covers and shall comply with the building and civil works Section.

All cables routed in concrete trenches shall be suitably supported by means of cleats or racks and raised from the trench floor by means of suitable spacers. All cables shall be run in a neat and orderly manner and the crossing of cables within the trench shall not be acceptable without the prior approval of the Engineer.

The Contractor shall be responsible for removing and replacing the trench covers free of charge during the execution of his work as directed by the Engineer.

6.12 Cables Supported on Racks, Trays, etc.

6.12.1 General

All single core and multicore main power cables shall be installed in cleats or saddles fixed at intervals. Multicore power cables shall be installed on trays or racks but segregated from other cables on the same tray by a space of 300 mm.

All control cables shall be installed on racks or trays with adequate clamps, cleats or ties to avoid excessive sagging. The Contractor shall include for the preparation and provision of single line cable routing drawings and detailed cable supporting steelwork drawings, necessary to enable the Engineer to give his approval for all main and subsidiary routes before installation commences.

Ample allowance shall be made in the design for additional cabling for future extensions.

Racks and trays shall be secured to channel or similar inserts installed in accordance with Building and Civil works section.

All cables shall be run with a particular regard to neatness of appearance. Multiple runs shall be arranged so that cables entering or leaving the run do so in a logical manner.

Trays and supporting steelwork shall be securely bonded and grounded to the main earthing/grounding system. Bonding and grounding connections shall be adequate to carry prospective fault currents without exceeding thermal or voltage limits.

6.12.2 Supporting Steelwork

All supporting steelwork shall be hot dip galvanised after manufacture and shall be to the approval of the Engineer.

Steelwork section shall not be less than 50 x 50 x 6 mm for steel channels and 50 x 50 x 5 mm for angles.

On all main cable runs, supporting structures shall be designed and drilled to accommodate additional cable racks or cleats to the extent of 20% of cables installed under the Contract and those required for known future extensions. The spacing between supporting structures shall be not greater than 1 m unless otherwise approved by the Engineer.

In cases where cables or their supports must be fixed to structural metal work, care shall be taken to avoid eccentric load transfer to beams or other structural metal. Also, local overloading or deformation of structures shall be avoided. The Contractor shall, if required, demonstrate that the loading resulting from the attachment of cabling steelwork has been taken into account in the steelwork design.

6.12.3 Cable Clamps, Cleats, Saddles and Ties

For single core cables carrying three phase alternating current, non-magnetic trefoil cleats shall be used and for other single core and three core cables claw type single or multicore unit cleats shall be used. The cleating arrangements for single core cables shall be adequate to withstand all short circuit forces.

Cable clamps shall be used at any change of direction of cable laying, but at agreed intervals on straight runs cable ties of approved design may be used.

Every non-flexible type cable shall be securely supported at a point not more than 1 m from its terminal gland to prevent stressing the termination, and on vertical runs passing through floors, immediately above the floor.

6.12.4 Trays and Racks

The Contractor shall provide all necessary trays or racks which shall be fixed at not more than 1 m centres. On all main runs trays or racks shall be installed to accommodate additional cables to the extent of 50% of those installed under the Contract or known future requirements.

Cables shall be installed on trays, in general as follows:

- Up to 16 mm² - double layer touching.
- 25 to 70 mm² - single layer touching.
- Above 70 mm² - single layer with 25mm (minimum) spacing.

All cable trays shall be perforated.

All trays and racks shall be galvanised to a thickness not less than 1.6 mm and shall be PVC coated in exposed areas. The erection of steelwork, trays or racks shall not proceed until the Engineer's approval for such has been obtained.

Where cables are run on trays or racks, they shall be tied to the tray at 1 m intervals using materials approved by the Engineer.

The cable tray system shall have minimum of 20% spare cable capacity throughout.

6.13 Cables Installed on Structural Steelwork and Brickwork or Concrete

The majority of cables shall be routed on steel racks or trays but where cables have to be installed on buildings and building framework the cables shall be held by spacer saddles or cleats screwed or welded in position. The Contractor shall supply all necessary spacer saddles or cleats and fix these in position in the least obtrusive manner possible, copper cleats being used for copper sheathed MICS cable.

Cables shall not be routed on tiled, lagged or other special finished surfaces.

6.14 Terminations

6.14.1 General

The Contractor shall be responsible for making all terminations, checking and setting-to-work the completed installation. All cables provided as part of the Contract shall be terminated at both ends.

For control wiring the cable tails shall be so bound that each wire may be traced back to its associated cable without difficulty. Cores in twisted pairs or groups shall be kept together. Any spare cores shall be numbered and terminated in the spare terminals furthest away from the cable gland. All cables shall be long enough to permit a second termination if necessary at a future date to the remotest ter- mination location in the panel.

Cable glands shall be used at all equipment to support the weight of cable from the terminations and to seal the cable to the equipment, unless otherwise approved by the Engineer.PVC, XLPE, silicone rubber and PTFE insulated cables shall be terminated via glands to BS 6121.

Glands in all outdoor locations and within the Substation and other areas where water may impinge on cables shall be type EIU, with inner and outer seals and armour clamp. Unarmoured single core cables in these areas shall have type A2 glands.

Glands in indoor locations with the exceptions as noted above shall be type C for armoured cables and type A2 for unarmoured single core cables.

PVC shrouds shall be supplied and installed over each gland.

6.14.2 Power Cables

The Contractor shall ensure that the correct phase rotation and connections are achieved. Particular care shall be taken in the case of heavy cables, where subsequent correction may be difficult. Phase

tests will be witnessed by the Engineer and, if found necessary, the Contractor shall carry out the reversal of phase connections. Connections to electric motors shall be made as specified. Where motors have tails rather than bushings, a heat shrink or equivalent PVC tube for insulation of the crimp joint shall be provided.

Where insulated glands are provided, the Contractor shall ensure that the insulation is maintained after jointing the cable and shall, if required, demonstrate this to the satisfaction of the Engineer. The tails of two or three or four core cables in air insulated terminations shall be identified by a band of ap- proved tape of appropriate colour over the self-sealing tape.

Single core cables shall be similarly identified by coloured tape over the cable beneath the gland.

6.15 Terminating and Jointing Conductors

Compression (indentation) type cable lugs and ferrules shall be provided and all necessary tools, including dies and other materials for making compression joints, shall be provided by the Contractor, who shall comply with the recommendations of the supplier of cables and lugs in the preparation and execution of each termination.

For stud type terminals approved crimping lugs shall be used.

Where clamp type terminals are used, the conductor shall be terminated without lugs, with the exception of flexible conductors having wires of 0.3mm or smaller which shall be fitted with crimps to more than one conductor shall be terminated in each clamp.

6.16 Core Identification

A uniform core identification system shall be used throughout the Station. The following clauses outline the broad requirements but the exact implementation shall be agreed with the Engineer.

Approved numbered ferrules shall be supplied and fitted to every cable core of control and instrument cables at each termination. The ferrules or sleeves shall be of interlocking ring insulating materials such as plastic which shall be black engraved on yellow background and have a glossy finish. The fer- rules or sleeves shall be unaffected by oil or damp. Identification marks on self-sticking cloth shall not be used. The ferrules shall be of "O" or "D" cross section. Ferrules of "C" type cross section shall not be used.

Single d.c. wires shall be identified by a red or blue coloured ring (positive or negative polarity) followed by the identification of the polarity concerned (instrumentation, klaxon, alarm, etc.).

Direct a.c. circuits shall be identified by a yellow end piece followed by an identification of the phase concerned.

Wiring for secondary circuits of voltage transformers shall be identified by a grey end piece and wires in current transformer secondary circuits shall be identified by a green end piece. This identification shall be completed by a terminal index.

All markings for terminal blocks, cables, cable conductors and wiring shall be located on the corresponding fault finding drawing.

Characters suitably marked "TRIP" in white shall be fitted on all wires associated with trip circuits.

A common system of ferrule numbering shall be adopted such that ferrule numbers at terminations shall agree with ferrule numbers on the internal wiring of equipment.

6.17 Cable Identification and Schedules

The Contractor shall prepare and submit computerised cable schedules, the content and style of which shall be to the general approval of the Engineer. These shall include cable identification num- bers for all cables except those provided for lighting and small power circuits and those which are connected to the load side of distribution boards for lighting and small power circuits.

The cable identification number system shall be such as to give a brief general indication of the type and function of individual cables and shall be approved by the Engineer.

The Contractor may use a fully computerised system for rating, and routing of cables, but shall provide a system that readily permits the cables to be scheduled on the following basis in sequence of cable identification number:

a) By cable identification number only
b) By type and size of cables
c) By function of cable
d) By main LV AC and DC,switchboard, actuator boards.
e) By agreed electrical and mechanical plant functional groups.

The Contractor shall provide copies of the cable schedule in an approved format. The Contractor shall provide a standard software package together with a suitable personal computer to permit the Engineer to access, display, print and edit the schedules. The schedules shall be accessed by simple interactive dialogue using 'menu-selection' or other approved procedure.

In addition, the Contractor shall provide selected copies of the above schedules in a computer print- out format agreed intervals.

Each end of every cable, except those provided for lighting and small power circuits and which are connected to the load sides of distribution fuse boards, shall be identified with a separate cable reference number fitted in a suitable position under the cable termination.

Where cables enter and leave ducts or pipes, suitable identification markers shall be fitted.

The materials of the markers and fastenings shall be such as to avoid corrosion or deterioration due to incompatibility of materials and shall ensure permanent legibility.

7. Earthing System and Lightning Protection

7.1 Scope

These chapters describe the general requirements for the earthing and lightning protection and shall be read in conjunction with the project requirements and schedules.

7.2 References

7.2.1 American Standards

- ANSI/IEEE/std 80 IEEE Guide for Safety in AC Substation Grounding
- ANSI/IEEE/std 81 IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potential of a Grounding System

7.2.2 German Standards

- VDE 0140 Earthing Systems for Power Installations with Rated Voltages above 1 kV

7.2.3 British Standards

- BS EN 13601 Specification for copper for electrical purposes: high conductivity copper rectangular conductors withdrawn or rolled edges.
- BS EN 13601 Specification for copper for electrical purposes. Rod and bars
- BS EN 12449 Specification for copper and copper alloys. Tubes
- BS 2874 Specification for copper and copper alloy rods and sections (other than forging stock).
- BS 4360 Specification for weldable structural steel
- BS 6360: Specification for conductors in insulated cables and cords.
- BS 6651 Protection of Structures against Lightning
- BS 6746 Specification for PVC insulation and sheath of electric cables.
- BS 7430 Code of Practice for Earthing

7.3 General

An earthing system generally in accordance with the requirements of IEEE 80 and BS 7430 shall be designed under this Contract. The earthing system shall include earth electrodes to provide the connection to the general body of the earth, all earthing conductors and connections to all electrical equipment and metallic structures on the site. The earth electrodes shall limit the potential rise under fault conditions and buried conductors shall be provided to limit potential differences on the site and adjacent to the site to ensure safety to people and animals.

Protection for all electrical equipment against lightning shall also be provided.

7.4 Extent of Work

The Work under this Section comprises the design, supply and installation including excavation, back-filling and site testing of earthing systems and connections to electrical apparatus at 400 kV and 230kV substation. Also included is the lightning protection scheme and the provision of portable earth- ing devices.

The Contractor shall be required to undertake all necessary earth resistivity tests at the substation sites and, from these tests, to undertake the design of the earthing systems. These designs, as well as providing safe passage to earth for the stated earth fault currents, shall also include calculation of step, touch and mesh potentials, which shall be within the allowable limits of the standards quoted in this specification.

The design calculations of step, touch and mesh potentials, accompanied by full installation drawings and material requirement schedules, shall be submitted to, and receive the approval of, the Engineer before materials procurement or installation commences.

7.5 Soil Survey

Not later than one month after the site has been handed over for access, the Contractor shall carry out an earth resistivity survey of the sites and report in writing to the Engineer in accordance with the approved programme. The report shall detail the methods and instruments used and the results of the surveys. Based on the results the Contractor shall include in the report his proposals for the resistivities to be used in the design of the earthing system.

The surveys shall show the variation of resistivity across the site and with the depth below the site. The Contractor shall consider if there is a need to model the resistivity in two layers and if there is any advantage in the use of deep rod electrodes.

The surveys shall also determine the depth and nature of any underlying rock, which may limit the depth for driving earth rods or if boring will be necessary for installing earth rods.

The weather conditions prior to and at the time of the surveys shall be recorded in the report and an assessment made of the seasonal variations in resistivity based on meteorological data for the area. The programme for the project should, as far as possible, time the resistivity surveys to take place during a dry season.

The report should also state if there are any indications that the ground is corrosive to bare copper.

The report shall be approved by the Engineer before proceeding with the design of the earthing system.

7.6 Fault Current and Duration

Each site shall be provided with an earth grid of buried conductors designed for an earth fault current of 63 kA one second for 400 kV and 50kA one second for 230 kV. The preliminary earthing design shall be such that the potential rise shall not exceed 5 kV.

7.7 Earth Electrode System Design

7.7.1 Design Calculations not require

As per existing mesh and layout, earthing shall be completed .

7.7.2 Earth Electrode

As per existing mesh and layout, earthing shall be completed .

7.7.3 Mesh System

As per existing mesh and layout, earthing shall be completed .

7.7.4 Earthing Rods

As per existing mesh and layout, earthing shall be completed

7.7.5 Connection of System Neutrals and Earth

The system neutral points within a substation shall have duplicate connections to the closest earthing point.

The earth electrodes of a neutral earthing point shall be arranged in two groups with a conductor from each group to a test link and there shall be duplicate bare copper conductors of cross sectional area not less than 150 mm² from each test link to the earth grid. The duplicate connection may be in the form of a ring.

Neutral earthing connections between the substation system (transformer) neutral and the test links shall be of bare copper tape, secured and supported on stand-off insulators so that there is no contact between copper tape and transformer tank.

Neutral earthing conductors shall normally be buried directly in the ground but where necessary, they may be cleated to walls, fixed to cable racks or laid in the cable trenches.

7.7.6 Electrical Equipment and Structure Connections to Earth

Connections between: (a) all HV electrical equipment and (b) LV electrical equipment comprising substantial multi-cubicle switchboards and the main earth bar shall be duplicated. ***The bare copperconductor size shall have a minimum cross section area of 240 mm².***

All substation equipment, including disconnectors, earthing switches, main transformer tanks, current and voltage transformer tanks, switchgear, electrical supporting steelwork and gantries etc. shall all be connected with the earth grid.

Surge arresters installed for the protection of transformers and reactors shall be connected by low reactance paths both to the transformer tanks and to the earthing system.

Capacitor voltage transformers used in connection with line traps shall be connected by direct low reactance paths to a single earth rod for each arrester, in addition to the earth grid.

Where necessary an earthing mat shall be installed at all operating positions for outdoor HV equipment manual operating mechanism boxes and local electrical control cubicles to ensure the safety of the operator. The mat shall be directly bonded to the cubicle and the conductors forming the mat and the bonding connection shall have a minimum copper cross-section area of 75 mm².

Galvanised structures comprising bolted lattice components shall not be used as the sole earth connection path to post and strain insulators or to overhead line earth conductors.

Buildings containing electrical equipment shall be provided, at each level, with a ring of earthing conductors which shall have duplicate connections to the earth grid outside the building. The frames of all switchgear, control and relay panels and other electrical equipment and exposed structural metal work shall be connected by branches to a ring. The ring and branch conductors shall be of the same material as the earth grid. Strip run within buildings, inside cable trenches or above ground level on apparatus shall be neatly supported in non-ferrous clamps.

Fixed earthing connectors for use with portable earthing devices specified below shall be provided on each busbar and on both sides of high voltage equipment.

Rigid loops in the copper earthing strip branch bond between the equipment and the earthing grid shall be provided adjacent to each item of high voltage equipment for use with the portable earthing devices. The rigid loops shall be marked green.

Connections between other LV electrical equipment and the earth bar need not be duplicated. The single conductor shall be rated to withstand the fault rating of the equipment.

7.7.7 Connections to Non-Electrical Structural Metalwork and Equipment

All metalwork within the project area which does not form part of the electrical equipment shall be bonded to the main earth bar except where otherwise specified. The bonding conductor size shall be not less than 240 mm².

Individual components of metallic structures of plant shall be bonded to adjacent components to form an electrically continuous metallic path to the bonding conductor.

Small electrically isolated metallic components mounted on non-conducting building fabric need not be bonded to the main earth bar.

7.7.8 Fittings

Clips for supporting strip conductors not buried in the ground shall be of the direct contact type and clips for circular conductors shall be of the cable saddle type. The clips shall support the conductors clear of the structure.

Conductors shall be connected to earth rods by a bolted clamp to facilitate removal of the conductor for testing the rod.

Disconnecting links shall comprise a high conductivity copper link supported on two insulators mounted on a galvanised steel base for bolting to the supporting structure. The two conductors shall be in direct contact with the link and shall not be disturbed by the removal of the link. Links for mounting at

ground level shall be mounted on bolts embedded in a concrete base.

Disconnecting links mounted at ground level and the connections at the earth rods shall be enclosed in concrete inspection pits, with concrete lids, installed flush with the ground level.

All conductor fittings shall be manufactured from high strength copper alloys with phosphor bronze nuts, bolts, washers and screws. Binary brass copper alloys will not be acceptable. All fittings shall be designed for the specific application and shall not be permanently deformed when correctly installed.

Sheathed conductor support fittings may be of silicon aluminium, glass-filled nylon or other tough non-hygroscopic material for indoor installations.

Fittings not in direct contact with bare or sheathed conductors may be of hot-dip galvanised steel. Bi-metallic connectors shall be used between conductors of dissimilar materials and insulating material shall be interposed between metallic fittings and structures of dissimilar materials to prevent corrosion.

7.7.9 Joints

Permanent joints shall be made by exothermic welding below ground, or crimping for above ground connections.

Detachable joints shall be bolted and stranded conductors at bolted joints shall be terminated in exothermically welded lugs or a crimped cable socket. The diameter of any holes drilled in strip conductors shall not be greater than half the width of the strip.

Connections to electrical equipment shall be detachable and made at the earthing studs or bolts provided on the equipment by the Manufacturer. When an earthing point is not provided, the point and method of connection shall be agreed with the Engineer.

Connections to metallic structures for earthing conductors and bonding conductors between electrically separate parts of a structure shall be either by direct exothermic welding or by bolting using a stud welded to the structure. Drilling of a structural member for a directly bolted connection shall only be carried out to the approval of the Engineer.

Bolted joints in metallic structures, including pipework and which do not provide direct metallic contact, shall either be bridged by a bonding conductor or both sides of the joint shall be separately bonded to earth, unless the joint is intended to be an insulated joint for cathodic protection or other purposes.

When the reinforcing in concrete is used as a part of the earthing system, the fittings used to provide a connection point at the surface of the concrete shall be exothermically welded to a reinforcing bar. This fitting shall be provided with a bolted connection for an earthing conductor. The main bars in the reinforcing shall be welded together at intervals to ensure electrical continuity throughout the reinforcing.

No connections shall be made to reinforcing bars and other steelwork which do not form part of the earthing system and are completely encased in concrete.

7.8 Lightning Protection

Overhead earthwire shall be provided to protect the equipment from direct lightning strikes. The screens shall be of aluminium clad steel wires of not less than 50 mm². total section, and connected to provide low impedance paths to earth.

The layout of the earth wires shall be such that equipment to be protected generally lies within areas bounded by two or more conductors, in which case the protected angle shall not exceed 45°. Where equipment is protected by a single earth wire, the protective angle shall not exceed 35° to the vertical.

The overhead earthwire shall be suitable for extension to protect the substation equipment to be installed in future stages of development.

7.8.1 Conductors

All conductors used for earthing and bonding the fences and components and for outer rings shall have a cross-sectional area of not less than 70 mm²

Connections shall be made of copper strip of 30mm x 5mm. cross section between the overhead earthed screen wire and the main substation earthing system at each support unless the galvanised steel support structure has sufficient area and current carrying capacity.

Earth wires shall be held in clamps with free pin type joints between clamps and supports.

Connections shall be provided for the terminations of the earth wires of the overhead lines, including bimetal connectors where necessary.

The design of all structures shall generally comply with Section 11 of the specification and in addition is to ensure that in the event of breakage of one earth wire, the Factor of Safety is not less than 1.5.

8. Supporting Structures for Outdoor Equipment

8.1 Scope

Where specified structures shall be provided under this contract for supporting the conductors, busbars, insulators, isolating switches, circuit breakers, current and voltage transformers, surge arresters, line traps, coupling capacitors, sealing ends or cable boxes and cables where necessary and other items of plant generally as shown on the relevant drawings. Facilities shall also be provided where specified for the termination of the incoming transmission lines.

All structure designs shall be such as to facilitate inspection, painting, maintenance, repairs and operation with the continuity of supply being the prime consideration.

8.2 Structure Arrangement

The arrangement of the high level structures supporting conductors and/or busbars shall be either lattice structures primarily composed of angle sections, or low visual impact A-frame type structures primarily composed of welded hollow or composite sections. Angle, hollow or composite sections shall be either steel or aluminium as specified. For lattice structures a fully triangulated system of bracings shall preferably be adopted. For A-frame structures the primary connections between major compo- nents shall be bolted, for ease of transportation and erection.

Low level support structures shall be either lattice structures primarily composed of angle sections or 'moment' type structures primarily composed of welded hollow or composite sections.

The design and arrangement of supporting structures shall be subject to approval by the Engineer.

The type of arrangement of high-level structures and acceptable materials for both high and low level structures shall be as specified in the Schedule of Technical Requirements.

8.3 Design

8.3.1 General

The supporting structures shall be designed to ensure that the specified minimum phase, earth and section clearances are maintained under all conditions. Where applicable special attention shall be paid to the design of the line termination structures to ensure minimum phase clearance is obtained for the complete range of angles of entry specified.

The strength and rigidity of structures shall be such that the alignment of the equipment which they carry shall not be affected by the static and dynamic loads to which the structures are subjected.

The assumptions made in the overall structural design especially in the load transfer between the gantry beam and column shall be adequately reflected in the design and detailing of the beam-column connection.

8.3.2 Assumed Loading Combinations

The supporting structures shall be designed to resist the ultimate applied loading, determined in accordance with the following load combinations:

Load Combination 1 - Design Wind, Coincident Temperature, (Ice)

(a) The wind pressure specified in Table 11-1 below applied to the projected area of all conductors and electrical equipment;
(b) The wind pressure specified in the Schedule of Technical Requirements applied to the projected area of all members of the windward face of structure;
(c) Where appropriate the conductor and/or earthwire tensions or busbar forces, including due allowance for both horizontal and vertical deviations / inclinations;
(d) Self weight of the conductor, earthware, insulator, equipment and structure;
(e) When stated in the Schedule of Technical Requirements the effects of the specified radial ice thickness shall be taken into account in the determination of the wind area of the conductor, earthwire, busbar, electrical equipment and the supporting structure, the conductor and earthwire tensions and the self-weight of the equipment and the structure.

The wind directions considered shall include transverse, longitudinal and if appropriate 45° to the major axis of the structure.

Table 11-1: Wind Pressures

Line	Description			
1.	**Structure Arrangement [clause 11.2]**			
	• High level • Low level • Primary material		• Lattice or A-Frame • Lattice or Moment • Steel	
2.	**Load Combination 1 [clause 11.3.2]**		**Structures only**	**Conductor, Insulator, Equipment, Busbars, etc..**
	• Wind pressure at 10 m above G.L. q_{ref}	kN/m^2	3.54	1.21
	• Power law factor	α	0	0.095
	• Coincident temperature	°C	5	
	• Radial ice thickness	mm	0	
	• Density of ice	kg/m^3	-	
	Load combination 2			
	• Minimum temperature	°C	5	
	• Maximum operating temperature	°C	80	
	Load combination 3			
	• Seismic coefficient	g	0.1	
	• Coincidence temperature	°C	5	

Line	Description			
3.	**Line Termination Structure [clause 11.3.3]**		**Phase**	**Earthwire**
	Conductor designation		Mallard	7 x 4.0
	Type		ACSR/SA	GSW
	Number of sub-conductors		2	-
	Maximum working horizontal tension per sub-conductor	kN	20.0	4.5
	Wind pressure	kN/m²	1.40	1.76
	Radial ice thickness	mm	0	0
	Maximum downlead span	m	75	75
	Maximum angle of entry horizontal	deg.	45	45
	Vertical	deg.	30	30
	Low duty tension set wind area	m²	0.7	-
	Mass	kg	100	-
4.	**Partial Load Factors [clause 11.3.4]**		**Steel**	**Aluminium**
	Load combination			
	• 1		1.35	n.a.
	• 2		1.0	n.a.
	• 3		1.0	n.a.
	• 4		1.5	1.5
5.	**Safety and Access Requirements [clause 11.3.7]**		**High Level**	**Low Level**
	Step bolts		Yes	No
	Ladders:		Yes	No
	• Cage protection		No	No
	• Fall arrest system		No	No
6.	**Partial Material Factors [clause 11.3.8]**			
	Steel		0.85	
	Aluminium		-	
	Foundations		0.76	
7.	**Minimum Member Thickness [clause 11.3.8]**		**Steel**	**Aluminium**
	Main member	mm	6.0	n.a.
	Other bracing members	mm	5.0	n.a.
	Secondary (redundant) members	mm	5.0	n.a.
	Plates	mm	6.0	n.a.
	Bolt diameters	mm	16.0	n.a.
	Minimum thickness specified shall apply to both hot rolled and hollow sections			
8.	**Protective treatment (clause 11.6)**			
	Galvanising thickness	µn	85	n.a.
	Protection procedure		BS 729	no

Load Combination 2 - Still Air, Short Circuit, Minimum Temperature or Maximum Operating Temperature

(a) Conductor and/or earthwire tensions or busbar forces including the dynamic affects calculated in accordance with IEC 865-1.
(b) Self weight of the conductor, earthware, insulator, equipment and structure;

Unless agreed to the contrary, the "resultant spring constant" (s) of both supports of one span for strained conductors shall be taken as 10^7 N/m for steel structures.

Load Combination 3 - Still Air, Seismic, Coincident Temperature (Ice)

(a) Conductor and/or earthwire tensions or busbar forces;
(b) Seismic forces;
(c) Self weight of the conductor, earthware, insulator, equipment and structure;
(d) When stated in the Schedule of Requirements the effects of the specified radial ice thickness.

Seismic forces shall be applied as a static horizontal force transversely and alternatively longitudinally to the major axis of the structure, and shall be equal in value to the seismic coefficient stated in the Schedule of Technical Particulars multiplied by the self-weight of the conductor, earthwire, busbar, electrical equipment and structure, and applied at the centre of gravity of the equipment and structure as appropriate.

Load Combination 4 - Still Air, Erection, Coincident Temperature

(a) Conductor and/or earthwire tensions or busbar forces;
(b) Self weight of the conductor, earthware, insulator, equipment and structure.

For erection conditions any one complete phase conductor bundle or busbar or earthwire shall be assumed not to be erected in any one span.

For the purposes of design all high level structures shall be considered as terminal structures. For multi-bay continuous structures, central columns shall be designed for the most onerous condition of adjacent bays being loaded or unloaded.

8.3.3 Line Termination Structures

For details of the incoming transmission line phase conductor and earthwire details, and angles of entry reference should be made to the Schedule of Technical Requirements.

8.3.4 Partial Load Factors

The partial load factors to be applied to the loading combinations determined in accordance with Clause 11.3.2 shall be as specified in the Schedule of Technical Requirements.

8.3.5 Wind Loading

The reference wind pressure to be adopted for the design of the outdoor supporting structures shall be based upon the value specified in the Schedule of Technical Requirements. The reference wind pressure q_{ref} N/m^2 at a height of 10m above ground level shall be subjected to variation for height and shape of the structure or equipment under consideration to give the total wind load.

The total wind load on the structure or equipment surface shall be determined from the expression:

The total wind load on the structure or equipment surface shall be determined from the expression:

$$F_w = q_{ref} \left(\frac{H}{10}\right)^{2a} C_{shp} W_A$$

Where

F_w =	The calculated total wind load on the structure or equipment:
q_{ref} =	reference wind pressure
H =	Height to top of the panel under consideration
α =	power law index
C_{shp} =	aerodynamic shape factor
W_A =	windward face area of the structure or equipment

The aerodynamic shape factor C_{shp} shall be as specified:

• Flexible conductors	1.0	
• Earthwires	1.2	
• Tubular busbars Re < 4.1 x 105	1.2	[1]
• 4.1 x 105< Re < 8.2 x 105	0.6	
• Support insulators, porcelain for apparatus or cap & pin insulator strings	1.2	[2]
• Flat truss structures consisting of profiles	1.6	
• Square & rectangular lattice towers & supports consisting of profiles	2.8	
• Sharp edged structures & components other than above	2.0	
• Flat truss structures consisting of tubes	1.2	
• Square & rectangular lattice towers & supports consisting of tubes	2.1	

Notes: [1] Re = Reynolds Number [2] Based on external diameter of insulator.

8.3.6 Equipment and Conductor Terminations

All supporting structures shall be provided with such holes, bolts and fittings as may be necessary to accommodate insulators, isolating switches and other equipment provided under the Contract.

Where incoming transmission lines and/or conductors and/or earthwires are terminated at structures with tension sets, approved shackle or swivel attachments shall be provided. To facilitate maintenance and erection, additional attachment points shall be provided adjacent to the main termination attachment. The supply and connection of the incoming transmission line will be undertaken under a separate contract.

Structures required to support cable sealing ends shall be provided with arrangements for supporting the cables. Attachment holes for the connection of earthwire bonds shall be provided adjacent to the

earthwire attachment point. Attachment holes for the connection of the substation earthing grid shall be provided on the vertical face of the structure, approximately 300mm above the top of concrete. Foundation holding-down bolts shall not be used for the attachment of earth connections.

8.3.7 Safety and Access Requirements

To facilitate safe inspection and maintenance all supporting structures which cannot be maintained from ground level shall be provided with climbing facilities, inter-circuit screens, guards etc. in appro- priate positions as agreed with the Engineer.

All members inclined at 40° or less to the horizontal, shall be designed to resist a mid-point load of 1.5 kN, with no other loading being considered.

Where specified step bolts of an approved type shall be fitted to supporting structures at not more than 450 mm centres starting as near as practicable to the base and continuing to within 1m below the top of the structure. It shall be noted on the erection drawings that all step bolts are to be removed after construction for a distance of 2.0m above ground level. Adequate clearance shall be provided be- tween the step bolts and any obstructions which might interfere with their use. Step bolts shall not be less than 16mm diameter, project not less than 150mm, and be fixed with nut, washer and nut.

Where specified ladders of an approved type generally in accordance with the requirements of BS 4211, 450mm wide and 350mm rung spacing shall be fitted to supporting structures. They shall be in- corporated into the structure either integrally or separately. Where specified cage protection or fall ar- rest systems shall be fitted to the ladder. Means shall be provided to prevent unauthorised access of ladders.

Inter-circuit screens shall be provided where necessary to prevent access between adjacent circuits on multi-bay structures. Inter-circuit screens shall be fabricated from a 50mm x 50mm mesh formed from 3mm diameter galvanised steel wire.

All structures shall be fitted with identification/notice plates as appropriate.

8.3.8 Structural Design

The allowable ultimate unit stresses used in the determination of the nominal member strength of sup- porting structures shall be based on the following:

Lattice steel structures	ASCE 10-97
Steel A frame or moment structures	BS 5950
Aluminium structures	BS 8118: Part I

Partial factors to be applied to member nominal strength determined in accordance with the above stated codes shall be as specified in the Schedule of Technical Requirements. For ASCE 10-97 the appropriate reference stress levels shall be based on the values specified in BS 5950.

The maximum allowable slenderness ratios shall not exceed the following:

Steel/Aluminium

- For column or support leg members, beam chords 120

- For other load bearing compression members 200
- For secondary (redundant bracings) 250
- For tension only members 350

Members shall be of such shape, size and length to preclude damage or failure from vibration or stress reversal, including the detailing of connections.

Minimum member thickness and diameter of bolts shall be as specified in the Schedule of Technical Requirements
Holding down bolts shall be used to connect the structures to their foundations. The design of holding down bolts shall make adequate provision for combined axial and shear forces.

The nuts of all bolts attaching conductors, busbars or earthwire tension sets etc., shall be locked with a locknut. No screwed threads shall form part of a shearing plane between members, and bolts shall not project more than 10mm beyond the nut.

8.3.9 Design Submissions

The Contractor shall submit all design calculations, drawings and method statements as required. All sets of calculations shall be complete, bound, properly titled and given a unique drawing number. An agreed system of identification of the structure design reference, fabrication drawings and substation general arrangement drawings shall be used.

Calculations shall contain a Design Information sheet, derivation of all applied loadings including sag and tension and dynamic tension calculations, the design load for each member group under the critical loading case, member size, slenderness ratio, allowable load, end connection detail and foundation load schedule. Codes or standard references should be quoted and where computer programs are used, a full explanation in the English language shall be provided to assist the Engineer's approval of the calculation.

8.4 Materials

All steel shall comply with BS EN 10025 or BS EN 10210 as appropriate and shall be suitable for all usual fabrication processes including hot and cold working within the specified ranges. The Contractor must take due cognisance of the minimum ambient temperature, quality of steel, charpy impact value and stress relieving.

The quality of finished steel shall be in accordance with BS EN 10163. All steel shall be free from blisters, scale, lamination, segregation's and other defects. There shall be no rolling laps at toes of angles or rolled in mill scale.

Hot rolled steel plate 3mm thick or above shall be in accordance with the requirements of BS EN 10029.

Bolts and nuts shall be ISO Metric Black Hexagon to BS 4190 and shall be threaded ISO Metric

Course Pitch to BS 3643: Part 2, Tolerance Class 7H/8g. Only one grade of steel shall be used per bolt diameter. Washers shall be in accordance with BS 4320 Grade E and BS 4464 Type B as appro- priate.

Consumables used in metal arc welding shall be in accordance with the relevant standard.

All materials for aluminium. structures shall be in accordance with BS 8118: Part 2.

8.5 Workmanship

The Contractor shall submit panel assembly (fabrication) drawings which shall show all materials in place, complete with all fabrication and connection details. A complete tabulation listing all pieces, bolts, nuts, washers etc. shall also be shown on the drawings. The Contractor shall make changes to the fabrication details which the Engineer determines necessary to make the finished structure con- form to the requirements and intent of the specification.

The Contractor shall submit a detailed Method Statement of his proposed fabrication procedures in- cluding quality control procedures to ensure satisfactory assembly and erection, interchangeability of similar members, accuracy of dimensions, position and alignment of holes.

All welding shall be carried in accordance with BS 5135 for steel structures and BS 8118 Part 2 for al- uminium structures. All members shall be stamped on before galvanising or other protective coatings, using characters 10mm high and shall be clearly legible after galvanising.

8.6 Protective Treatment

Unless otherwise specified after fabrication, all structural steelwork, including bolts, nuts and washers shall be hot dipped galvanised to meet the requirements of BS 729. Bolt threads shall be cleaned of surplus spelter by spinning or brushing. Dies shall not be used for cleaning threads other than on nuts. Nuts shall be galvanised and tapped 0.4mm oversize and threads shall be oiled.

Excessively thick or brittle coatings due to high levels of silicon or phosphorous in steel, which may re- sult in an increased risk of coating damage and/or other features that make the final product non-fit-for purpose shall be cause for rejection. Protective treatment for aluminium shall be in accordance with the requirements of BS 8118.

Galvanising thickness and aluminium protection procedure shall be as specified in the Schedule of Technical Requirements

8.7 Quality Control

8.7.1 General

Routine tests on raw materials and fabricated individual members shall be undertaken in accordance with BS EN 10025, BS EN 10210 and BS 8118 as appropriate.

All steel ex-mills or received from merchant's stock shall be marked to identify the cast or casts from which it was rolled in accordance with Section 9 of BS EN 10025 and Section 10 of BS 102 10, and shall be covered by the appropriate (mill) certificate. The optional impact test BS EN 10210 option 1.6 for quality JO is required.

The material grades or alloy categories of individual pieces of steel/aluminium shall be capable of positive identification at all stages of the fabrication process.

Bolts and nuts shall be covered by the appropriate test certificate to prove compliance with BS 4190.

8.7.2 Welding

Unless specified to the contrary all structural welds shall be undertaken using approved welding procedures in accordance with BS EN 288. All welders shall be tested to the requirements of BS EN 287.

All welding shall be subject to a non-destructive testing (NDT) programme, which shall include visual, ultrasonic and magnetic particle testing as appropriate. Visual inspection shall be in accordance with BS 5289, ultrasonic to BS 3923 and magnetic particle to BS 6072. Acceptance criteria shall be in accordance with BS 5135, except for porosity and BS 8118: Part 2. All welds especially butt welds must be continuous to ensure a pickle-tight connection when galvanised.

The Contractor's NDT programme shall be submitted to the Engineer for approval prior to the commencement of fabrication.

8.7.3 Check Erection

Prototype structures shall be check erected in order to verify the accuracy of detailing and fabrication.

The degree of check erection shall be sufficient to verify not only the main structure, but all auxiliary steelwork. Sufficient blocking and support shall be provided to prevent distortion and overstressing of members to ensure proper fit. Assembly shall be accomplished without extraordinary effort to align bolt holes, or to force pieces into position. Bolt holes shall not be reamed or enlarged. Any damage to protective coatings during check erection if the check erection is undertaken on coated structures, shall be recoated at the fabricator's cost.

8.7.4 Galvanising

Tests on galvanised members and components shall be carried out at the works to ensure compliance with the requirements of BS 729.

8.7.5 Tolerances

The fabrication tolerances after galvanising for steel members, which are not to be considered cumulative shall be as follows:

a)	On linear dimensions of nominal sections as per BS 4, BS 4848, BS EN 10024, BS EN 10034 & BS EN 10056-2.	
b)	On overall length of member	± 1 mm
c)	On centres of holes	± 1 mm
d)	On groups of holes	± 2 mm
e)	On back-gauges	± 1 mm
f)	On corresponding holes in opposite faces of a member	± 1 mm
g)	On specified hole diameter on the punch side (in the black), or when drilled	± 0.3% - 0 mm
h)	Taper on the punched holes as measured between the specified hole diameter on the punch side and the hole diameter on the die's side (in the black)	± 1.0 mm
i)	On specified bends, open and closed flanges	± 0.02%

The permitted tolerances for straightness after galvanising shall not exceed an offset of 1: 1000.

Tolerances for aluminium structures shall be in accordance with BS 8118: **Part 2**.

8.7.6 Erection

The Contractor shall when requested provide the Engineer with a Method Statement detailing his proposed erection methods. Due cognisance shall be taken of the relevant parts of BS 5531 and current health and safety legislation.

All structural members stored on site shall be kept clear of the ground where possible. Contact with substances likely to attack the protective coatings shall be avoided and all members kept in a clean and tidy condition. Care shall be taken to prevent damage/deterioration of any protective coating dur- ing transportation, storage and erection. Unless otherwise agreed damaged members shall be re- placed. The renovation of damaged areas of protective coatings shall be carried out using techniques agreed with the Engineer.

The Contractor shall ensure that the structures are not strained or damaged in any way during erection. Structures shall be erected vertically within a tolerance at the top, or the centre of the beam of 0.5% of the overall structure height before equipment installation or conductor/busbar stringing.

9. Buildings and Civil Engineering Works

9.1 General

This section covers all earth work, foundations and buildings associated with the project together with roads, surfacing, cable trenches and tunnels, boundary walls, guard houses, foul and storm drainage and water supply.

9.1.1 Scope of Work

The work includes the design, detailing, construction and maintenance of the following:

1. performance of site investigation
2. foundations for all equipment to be installed in outdoor switchyards, control buildings, indoor switchgear and any other building required for the project
3. complete buildings consisting of structural reinforced concrete frames, brick walls, concrete roof and floor slabs.
4. roadways generally within sites, surfacing the entire area within site boundary and surface water drainage.
5. cable trenches, cable tunnels, cable ducts and pipe ducts

Included in the scope of work is the detailing, construction and maintenance of the following items which shall generally be constructed to the Employer's standards but full working drawings shall be prepared by the Contractor:

a. guardhouses
b. the relay houses
c. auxiliary control building

Guardhouse, as stated in item (a) shall be designed as per enclosed drawing.

The Bidder shall state which approved local building Contractor(s) he proposes to employ to carry out the work.

9.1.2 Contractor to Satisfy himself as to all Conditions

The Contractor shall assess:

a. access conditions at all sites, plus ground conditions and ground bearing capacity
b. transport costs, materials costs and restrictions of availability of supply of materials locally
c. importation restrictions and delay due to customs controls
d. restrictions imposed by existing equipment on sequence of construction, access etc.
e. restrictions caused by cable laying and overhead line Contractors
f. ground conditions and temporary works required to provide support during excavation

9.1.3 Way Leaves, Land Purchase and Planning Permission

The Employer will be responsible for the purchase of all land within the permanent site boundary and the purchase of all land required to the base of the fill of any batter slopes. The Employer will also be responsible for obtaining land to provide a permanent single access to each site from a nearby road or waterway.

The land development is not in the Contractor's scope.

During the construction period the Contractor shall be responsible for maintaining this access in a reasonable condition by reinstating damage caused by his construction traffic and Employer traffic. The Contractor shall provide durable surface to access road.

Should the Contractor require more than one single access to a site or require additional land for construction activities outside the permanent site boundary, he shall be responsible for the purchase or way leave of the required land.

The Employer will be responsible for applying for planning permission. The Contractor shall be responsible for completing the approved site survey and the approved site layout plan, together with the approved architectural elevations of all facades of any buildings, by the key date given in the programme for each site so that the Employer may use these drawings to apply for planning permission.

9.1.4 Site Survey Drawings

For each site the Contractor shall prepare a survey at 1:200 scale showing existing ground levels on a minimum 10 metre grid and details of all features above and below the ground within the site boundary and up to 15 metres beyond it by the key date stated in the programme. Levels shall be related to bench marks clearly indicated on the plan. The plan shall be submit to approval by the Engineer and the agreed substation building floor levels shall be given on each site plan.

The Contractor shall propose the building floor level to the Engineer. It shall generally be 1000mm above the crown of the nearest public road or final site level or the highest known flood level, whichever is the greater.

9.1.5 Earth Works

Cut and fill where required shall be carried out by the Contractor. Source of fill material shall be planned and approved by the Employer. The Contractor shall be responsible for providing a level or uniform sloping site to suit his substation layout design. The final soil levels (i.e. the level below the brick surfacing) shall be stated on the site survey plan to be prepared by the Contractor.

Earth works to make the substation land suitable for installation of supporting structures and equipment, for extinction of the control building and related dependencies, with drainage to evacuate water in all conditions and of sufficient size to allow access to maintenance equipment and gravelling of switchyard surface.

Access road and switchyard internal circulation ways shall be extended. Extend drainage network made of perimeter trenches, switchyard internal sub soil drainage trenches or pipes.

All fill shall be compacted in layers not exceeding 150mm deep to a minimum of 90% optimum density as defined by the Proctor Test.

9.1.6 Engineer's and Employer's Accommodation/Surveying Equipment

On each major site the Contractor shall provide an office of approx. size 5 x 6m equipped with desk, 2 chairs, light and fan for the sole use of the Engineer and his inspectors. Similar facilities are to be provided for the Employer.

The Contractor shall also provide in the Engineer's site office one set of personal computer. The PC shall be fully equipped with all peripherals.

The Contractor shall loan his surveying instruments to the Engineer and his staff when required. Instrument checks shall be carried out at monthly intervals.

9.1.7 Programme

The Contractor's programme shall at Bid stage define the following key dates for each site. Where drawings are to be submitted for approval, they shall be submitted at least 6 weeks before the key dates to allow for the Engineer to comment and his comments to be incorporated in the drawings:

1. Issue of approved site survey drawing complete with soil levels and floor levels
2. Issue of approved electrical layout drawings
3. Completion of site investigation field work
4. Issue of approved Site Investigation Final report
5. Completion of loading tests on a foundation on each fill site and any other site where settlement is likely to be a problem
6. Issue of approved drawings required for planning permission
7. Issue of a full complete set of civil building drawings
8. Construction start date
9. Date access will be given for:
    a) Installation of equipment in buildings
    b) Installation of outdoor plant
10. Construction finish date

The Contractor's programme shall outline the number of sites he proposes to build at any time and shall show the order of completion of sites and how crews will move from site to site. This information shall be used to establish the number of expatriate site supervisors required.

The drawing programme shall ensure that complete set of approved civil building drawings will be issued at least 21 days before construction start at any site, in accordance with the Project Requirements in Schedule A of Volume 3 of 3.

The Construction programme shall be expressed in an 'S' curve for the whole project, with the percentage (of the total value of work in the schedules) given for each site each month. The overall percentage completion of the project each month shall also be given.

9.1.8 Monthly Progress Certificates/Progress Reports

In accordance with the Project Requirements in Volume I the Contractor shall submit agreed progress certificates for each site before the seventh day of the next month. These certificates shall state the percentage completion of each item in the schedules and shall state the overall percentage completion of each site and that site's contribution to overall project percentage completion. An updated 'S' curve shall be submitted with the progress certificates.

In addition, the Contractor shall provide a monthly

- Environmental and Social and Compensation Inspection Report
- Health & Safety Report

9.1.9 Temporary Facilities

The Contractor shall provide all temporary buildings, workshops, cement and lime stores and latrines required for his use. The Contractor shall agree the location of these buildings with the Engineer, after submitting a drawing showing their proposed location.

When a Contractor is placed in possession of a site, or part of a site, he shall erect temporary fencing immediately to protect the site until the boundary wall shall be erected.

9.1.10 Site Supervision

Although the civil and building works may be let as a sub-contract to an approved local Contractor, the main Contractor shall ensure that an expatriate supervisor in his direct employ is continuously available at each site during construction. This supervisor shall have at least a working command of spoken English and be able to read, understand and discuss specifications and drawings.

The Contractor shall notify the Employer and Engineer in writing of every concrete pour and foundation casting the day before the work starts.

9.1.11 Designs and Drawings

The Contractor shall obtain the Engineer's approval for the use of all design codes and standards before design work starts. All design and drawing work shall be completed in the Contractor's own country, in direct coordination with the electrical plant design.
The Contractor shall supply one copy of all of codes for the Engineer in Dhaka. If non-English equivalent National codes are adopted, the Contractor shall supply English translations of these Codes to the Engineer.

One copy of calculations shall be submitted together with drawings. To avoid possible misunderstandings, calculations will not be approved separately from drawings.

The Contractor shall generally submit a complete set of drawings for each substation for approval after initially getting the electrical layout of each substation approved. Where possible, drawings shall be standardized and general drawings (00) issued covering several sites.

For each substation the Contractor shall provide a co-ordination plan at scale 1:200 showing bus bar sizes, structure types, foundation types, cable trenches, roads, ducts, buildings, boundary walls, earthing, drainage and all services in this Contract.

9.2 References

9.2.1 General

The design and construction shall conform to the latest edition of the relevant Codes and Standards. Any proposed substitution for the listed Standards by an equivalent Standard will be subject to approval by the Engineer. Relevant Standards include, but are not limited to, those listed in subsection 2.2 below.

9.2.2 Design and Construction Standards

- BS12 Portland Cement
- BS EN 124 Gully and Manhole tops for vehicular and pedestrian areas
- BS 812 Testing aggregates
- BS 882 Aggregates from natural sources for concrete
- BS 1377 Methods of test for soils for civil engineering purposes
- BS 1722 Part 10: Anti-intruder fences
- BS 1881 Testing concrete
- BS 2853 Design and testing of overhead runway beams
- BS 3148 Methods of test for water for making concrete
- BS 3921 Clay bricks
- BS 4449 Steel bars for the reinforcement of concrete
- BS 5262 External renderings
- BS 5395 Stairs, ladders and walkways
- BS 5572 Sanitary pipework
- BS 5628 Code of practice for use of masonry
- BS 5930 Code of practice for site investigations
- BS 6031 Code of practice for earthworks
- BS 6367 Code of practice for drainage of roofs and paved areas
- BS 6399 Part 1: Code of practice for dead and imposed loads
- BS 6399 Part 2: Code of practice for wind loads
- BS 6465 Sanitary installations
- BS 6651 Code of practice for protection of structures against lightning
- BS 6700 Design, installation, testing and maintenance of services supplying water for domestic use
- BS 8004 Code of practice for foundations
- BS 8005 Sewerage
- BS 8100 Lattice towers and masts
- BS 8102 Code of practice for protection of structures against water from the ground
- BS 8110 Structural use of concrete
- BS 8206 Lighting for buildings
- BS 8215 Code of practice for design and installation of damp-proof courses in masonry
- BS 8290 Suspended ceilings
- BS 8301 Code of practice for building drainage

9.3 Design

9.3.1 Architectural and Structural Requirements of Buildings

All new buildings shall be designed to be architecturally pleasing in appearance and to withstand the tropical climate with minimal maintenance.

Architectural elevations of all elevations of buildings shall be agreed before other detail plans are prepared.

Air conditioning units shall be provided in rooms listed in Section 13. Air conditioned rooms shall have a false ceiling such that the overall thermal transmittance of the roof shall be below 0.45 Watts/m^2°C.

The false ceiling shall be made from non-combustible materials, and shall be easily removable to provide easy access to small power cables.

All buildings shall be reinforced by a reinforced concrete frame which shall be capable of resisting a horizontal earthquake force of 0.2G.

Two storey buildings shall be designed. First storey is cable basement. Second storey shall be designed to have at least 3.5 metres high with an imposed load of 2.5 kN/m^2 floor loading. An external concrete open staircase shall be provided. The roof shall be a flat in situ concrete slab designed for 2.5 kN/m^2 live load and galvanised steel shall be provided up to the roof.

The roof shall be waterproofed with lime terracing 2:2:7 lime, shurki (powdered brick) and brick chips 0.75" down, which shall be beaten in accordance with local practice. The entire roof area shall be laid in one continuous operation. The minimum compacted thickness of terracing shall be 25mm at the low points of the roof with a 1: 150 slope to those points formed by a layer of terracing of increasing thickness. Once laid, the terracing shall be covered with a layer of bitumen emulsion and the edge of the terracing shall be protected against erosion into the downpipes. Downpipes shall be 100mm diameter cast iron pipe placed outside the wall but shall be enclosed in a facing brick buttress. There shall be at least one downpipe per 100m² of roof. The Contractor shall guarantee the roof against leaks for a period of 5 years from the Taking Over Certificate date. The roof shall project at least 450mm beyond the face of all walls to form a sunshade and rain shelter to the walls below. The upper surface of this projection shall be sloped and a drip provided.

The main entrance to all buildings shall be shaded, either by a projection of the roof over the entrance veranda or by a separate roof at a lower level. This area of roof shall also be lime terraced and drained by rainwater pipes.

The roof parapet wall shall be about 0.8 metre high with an in situ concrete coping with DPC below it. Where facing bricks are used below the roof level, they shall also be used above roof level. An architectural feature shall be provided by panels of open decorative blockwork (Mirpur ceramics or similar approved) to ensure good air circulation over the roof. Air bricks shall be provided at 750 mm centres in solid portions of parapet wall.

The head of each downpipe shall be fitted with an enlarged hopper and purpose made cast iron grill set into a recess in the roof projection.

Window openings shall be fitted with protruding concrete sunshades above and at the sides of the openings.

All external walls shall be 230mm first class brickwork plus a 50mm thick layer of Mirpur Ceramics facing bricks or similar approved, or rendered with cement render and painted as required by the architectural plan. The internal walls shall also be generally of 105mm thick first class brickwork. Internal walls shall all be rendered and receive one sealer coat plus two finishing coats of emulsion paint. All brickwork shall be tied into the concrete frame by galvanised ties. Externally, rendered walls shall receive primer plus two finishing coats of PEP acrylic external quality paint or similar approved. At least two air bricks shall be provided to each room in which staff work/rest.

Particular attention must be given in the design of buildings and layouts to fire prevention and safety of personnel at all times. Buildings housing switchgear and control equipment shall be designed as far as practicable to exclude pollution under all likely weather conditions. Fire-proof or flame-retarding materials are to be used for floor, wall and ceiling finishes. Where areas are designed as having a fire resistance rating then materials shall be shown to have passed approved standard tests for that class of fire resistance.

The height of control rooms shall provide about 1 metre clearance over the top of the cabinets to the underside of the false ceiling. In the switchgear rooms, about 1 metre clearance shall be provided over the switchgear to the underside of the roof slab but the Contractor shall provide a greater clearance if it is required to remove equipment. The clearance maybe reduced below downstand beams provided no equipment is required to be removed from the top of the switchgear. All rooms in any building shall be one height.

Rooms shall have walls and roof slabs adequately insulated. Maximum thermal transmittance values for all rooms shall be 0.7 watts/m²/°C for walls and 0.57 for roofs. Air conditioning units shall be provided in rooms listed in Section 13. Air-conditioned rooms shall have a false ceiling such that the overall thermal transmittance of the roof shall be below 0.45 Watts/m^2/°C. The false ceiling shall be made from non-combustible materials, and shall be easily removable to provide easy access to small power cables. Suspended ceilings, with acoustic tiling and incorporating lighting and air-conditioning fixtures shall be used in corridors, offices, control room and SCADA rooms of the buildings and as per sched- ule of finishes

All structures shall be designed to carry the loads imposed by the structure itself, together with live loads in accordance with an approved standard or code of practice. The roof shall be designed for 2.5 kN/m² live load.

All doors opening outwards from the buildings shall be provided with panic latches or bolts which override any locking device, for escape in the event of fire. All doors shall be provided with overhead door closures of adequate capacity. Door labels incorporating electrical hazard warning in Bangla and English shall be fixed to each entry door. Vision panels shall be provided to frequently used doors.
Window openings shall be fitted with protruding concrete sunshades above and at the sides of the openings.

Float operated submersible pump of capacity 25 cum/hour at a head of 8 meters to be provided for sump of basements. The pumps shall be fixed in all respect ready for operation and discharge into storm water drainage system.

The domestic water supply system shall include all plumbing, underground pipework, high and low level storage tanks, valves, fittings and pumps (including the provision of a standby pump) for the pro-

vision of a pressurized water supply system for the static water tank and all buildings within the compounds.

On completion of the installation and prior to putting to use, the system shall be sterilized in accordance with an approved Code of Practice.

The Contractor shall be responsible for the provision and installation of a water supply serving the substation buildings. Every cistern, sink, basin, etc., shall be provided with as stop-cock in the supply pipe adjacent to the fitting. Each basin, sink and shower unit is to be provided with both hot and cold water. Provision shall be made for connection to the drinking water supply.

Toilets shall be provided with 1 no. western type WC, 1 no. Asiatic, type WC, 1 no. wash-hand basin, and 1 no. wall mounted mirror.All necessary fittings and accessories shall be provided.

Battery rooms shall be supplied with sink and drainer.

Control buildings housing switchgear and control equipment shall include a cable basement to facilitate connection to the equipment. Basements shall be constructed so as to protect the building substructure from water in accordance with BS 8102.

9.3.2 Ground Conditions, Foundations and Site Investigation

(a) Fill Sites

Fill will be placed by the Contractor. On fill sites where the depth of fill exceeds 3 metres the Contract assumes piled foundations shall be installed below buildings. If piled foundations are found to be unnecessary in the Final Site Investigation Report, a reduction in Contract value shall be agreed on the basis of schedule rates.

Piles shall be concrete (cast in situ or precast) complying with BS 8004.

On every fill site the Contractor shall prove that his switchyard foundation will not suffer settlement greater than 20 mm by constructing a foundation and load testing this to twice the design bearing pressure for a minimum of 20 days.

Outdoor equipment shall be provided with spread footings or pile foundation depending on the sub-soil investigation report. The bearing capacity of the proposed soil level for outdoor equipment shall be checked by the plate bearing test. The Contractor shall impose the site layout on the survey to check for uneven depth of fill below any foundation and where uneven depth of fill exists his foundation proposals shall restrict final differential settlement to a 1 in 400 slope.

If a fill site has not been exposed to one wet season before foundation work starts, the Contractor shall flood the site to a depth of 50mm for 10 daysat the Contractor's own cost (not required on hy- draulic fill sites). The reason for this is that silty sands generally compact to a denser condition on first time flooding.

On all fill sites the Contractor shall pipe rainwater from down pipes down to paddy level and shall prevent water ponding in open foundations and backfill all foundations as soon as possible.

The Contractor shall monitor settlement of the fill (by placing concrete posts 50 x 50 x 750mm deep on a 10 metre grid and taking readings) at 30 day intervals from the time he is given access to each fill site.

When a fill site is handed over to the Contractor, the Contractor shall become responsible for maintaining the entirety of the fill in good condition, including all better slopes.

(b) Unfilled Sites

Original delta levels are generally below road level. Therefore most sites are historically fill sites but fill settlement can sensibly be considered complete, where fill is over 3 years old.

(c) Site Investigation

Detailed methodology for subsoil investigation shall be submitted before implementing the subsoil investigation. All laboratory tests shall be done at the test facility approved by the Employer.

The Contractor may appoint a Subcontractor to carry out the site investigation but all work and all lab work shall be witnessed by one of his own staff who shall countersign all recorded data.

Boreholes shall be taken on a 25 metre grid with at least three additional boreholes inside each building. Additional boreholes may also be required where uneven fill depth is encountered.

The number and location of boreholes shall be approved with the site survey drawing showing existing ground levels specified in the section 12.1.4. The boreholes shall be located to an accuracy of + 0.5m and shall be located to site layout considering existing obstacles at the field.

Boreholes shall be a minimum of 30 metres depth or twice building footing width, whichever is greater.

All boreholes shall be backfilled with compacted sand.

Borehole log together with a summary of all required laboratory tests is required to be prepared. Soil test locations are required to be indicated on the geographical map.

In each borehole the following tests shall be carried out:

- Standard penetration tests at 1.5 metre intervals.
- Undisturbed samples shall be taken at around 2.0 metres depth and 3.0 metres depth and tested by unconfined compression tests.
- One-dimensional consolidation tests shall also be carried out on undisturbed samples taken at 2, 3 and 4 metres depth. The samples shall be saturated and the range of applied pressure shall fully reflect the in situ conditions. Graphs showing void ratio (e) and applied pressure shall be submitted along with the coefficient of compressibility for the range of loading anticipated.Mv shall be given in m^2/MN and shall be recorded at each stress increment. The coefficient of consolidation, cv, shall be given in m^2/year.
- Particle size analysis shall be carried out for each stratum and specific gravity, moisture content, liquid limit and plastic limit determined.
- Ground water level shall be determined by dipping the boreholes. Where collapse of the boreholes occurs, casing shall be used and left in until the water level remains constant for two days.

- In cohesive soils a vane tests to BS 1377: Part 9 shall be carried out at three different depths. The Contractor shall check the sensitivity of soil and ground water at each site to concrete and take all measures necessary to ensure the long term durability of concrete.

(d) Site Investigation Report

The site investigation and analysis of the data in a final report giving full details of foundation pro- posals shall be completed at each site by the programmed date. During site investigation, Geograph- ical map shall be prepared indicating the locations of soil test.

The report shall be submitted by the key date at each site given in the programme. The Contractor shall submit 2 copies of the report to the Engineer. The report shall propose full details of foundations and loading thereon and shall provide estimates of likely settlements and differential settlements. The report shall be the work of the Contractor's own foundation engineers.

If the Contractor uses a local site investigation Contractor, he shall appoint one of his own staff to oversee the entire operation and each piece of data shall be countersigned by this person.

Where estimated settlement exceeds 25mm, the Contractor shall construct one foundation at an early stage an test load this foundation to confirm settlement predictions.

(e) Foundations

Regardless of the result of soil investigation report, the foundations of control building, transformer foundations, gantry structures for terminating lines and for transformers shall be provided with piles.

The minimum depth of all foundations shall be:

a)	Transformer bases and bund	1.5 m
b)	All other switchyard foundations	1.1 m
c)	Control building foundations, including all wall foundations and internal wall foundations	1.5 m
d)	Boundary wall foundations	1.1 m

All formations shall be hand rammed or mechanically compacted before placing 70mm minimum thickness of Class B concrete blinding, within 24 hours of bottoming excavation, which blinding shall project 75 mm minimum distance beyond all footings. Each footing shall be inspected by the Engineer. Where soil condition is poor (on fill sites or already filled sites) or where the Contractor leaves founda- tions exposed and soil conditions deteriorate, one of the following measures shall be carried out as agreed with the Engineer:

i) Blinding depth and projection shall be increased

ii) If any soft soil layer found below any shallow foundation the soft soil shall be removed and re- placed with compacted viti sand and top 200mm of the fill viti sand khoa compaction (sand:khoa=2:3) shall be placed. All fill shall be compacted in layers not exceeding 150mm deep to a minimum of 90% optimum density as defined by the Proctor Test. The cost of this work shall be borne by the Contractor and deem to be included in civil works price.

The Contractor shall propose the allowable bearing pressure for all foundations based on soil strength parameters only and shall not be increased while wind loads exceeds 25% of dead load as well as shall not exceed 125kN/m^2. Between column footings all walls, including all internal walls, shall be provided with a reinforced concrete strip footing of minimum dimension 800mm wide by 250mm deep placed at the same level as column footings and linked structurally to the footings. In addition column footings shall be tied at foundation level and also floor level by beams to every adjacent column in both orthogonal directions.

These beams shall be designed to resist 1 in 200 differential settlements without distress and shall be capable of resisting the earthquake load of 0.1G.

The deepest parts of any foundations shall be completed first. All foundations shall be completed and backfilled, including all cable tunnel and cable trench work inside buildings, before walls are raised above floor levels. All other foundations shall be backfilled within 7 days of completing concreting.

All exposed concrete and the outer surfaces of cable trenches and cable tunnels shall receive two coats of bitumen mastic paint before backfilling to reduce ingress of water. The Concrete surface shall be ground smooth and all air holes etc. filled (rubbed down with a cement slurry) before painting.

The Contractor shall monitor settlement of all foundations each month and report this settlement to the Engineer until settlement has reduced to less than 1.5mm in 3 months.

The tops of all foundations shall terminate 200mm. above site average finished surface level for new Substation & for existing substation the level should be as per existing. All exposed edges shall have 20 mm x 20 mm. chamfers.

Excavation shall only be carried out when the ground water table is at least 1000mm below foundation level. The excavation shall be kept dry during the construction period by providing sumps and pumps as required. During the rain season, shelters shall be erected over all open excavations.

Any over excavation shall be filled with Class B concrete.

All backfill shall be compacted to 95% maximum dry density as defined by BS 1377 test method, part 4, 2.5 kg rammer.

Before starting foundation work the Contractor shall clear all sites of trees, tree roots, shrubs, debris, surplus soil, and any buildings.

Foundations shall be designed to resist uplift, assuming the water table is at ground level and the weight of soil resting on a foundation is that included within a 15° frustum.

On fill sites where the depth of fill exceeds 3 metres, the Contractor shall provide piled foundations in accordance with BS 8004 for control buildings. The design of foundations for transformer, gantry, equipment support structure, etc. shall be as per requirement of subsoil investigation report. One working pile chosen by the Engineer shall be load tested at each site to 150% of design load in accordance with BS 8004.

9.3.3 Drainage

The entire surface within boundary walls shall be of uniform sloping site, sloping at 1 in 150 minimum slopes to open channels around the entire perimeter. These channels shall be designed for a rainfall intensity of 60mm per hour. Outside the boundary wall the Contractor shall be responsible for drainage up to 20 metres from the wall and will at some sites need to construct outlets with suitable erosion protection down to paddy level.

The concrete wall of cable trenches shall project at least 70mm. above brick paving level to prevent run off entering the cable trench. The floors of all cable trenches/tunnels shall be sloped to soakway as described in 12.3.16.

The cable trenches will thus form barriers to surface water drainage. If the cut-off area exceeds 30 m² it shall be drained by a 200mm minimum diameter concrete pipe to the boundary drain. The Contractor's drainage design shall avoid all ponded water to avoid forming a mosquito breeding ground.

All drainage pipework within buildings shall be ductile iron, generally of 100mm diameter. Floor drains shall be placed in each battery room and toilet.

External pipework shall be 150mm. minimum diameter concrete pipes at a minimum depth of invert of 700mm. Where pipes, including existing pipes alongside site, are less than 400mm above adjacent foundations they shall be surrounded in concrete. Where required, drainage pipes shall be kept below cables, allowing 1.1 m cover to top of pipes.

Manholes shall be of brick construction with 600mm. x 600mm clear openings and airtight ductile iron covers to BS EN 124. Manholes shall be located at each change of direction. Minimum fall on all pipelines shall be 1 in 80. Manholes shall not be located in roads.

The Contractor shall be responsible for all negotiations with local authority WASA where a connection to a public sewer is proposed. Where high water levels in public sewers may cause effluent to back up into a site, non-return valves shall be fitted. The Contractor shall provide all protection required to existing sewers and shall deepen foundations, including boundary wall foundations, where required to ensure all foundations are below adjacent sewers. The Contractor shall draw longitudinal sections of all pipelines.

Each control building shall be provided with **a septic tank** designed for 10 users and a soak away of open brick construction 11m deep by 2.2m diameter filled with broken bricks. The septic tank shall be located at least 15 metres from buildings. Other buildings shall have septic tanks designed for the required number of users. All foul drains shall be vented by a vent pipe to above roof level. The inner surface of all manholes and septic tanks shall be painted with 2 coats of bitumen mastic paint to protect it against sulphate attack. The septic tank shall have access holes directly over the inlet pipes and outlet pipes. Where public sewers exist alongside a site, the Contractor shall connect directly to the foul sewer, provided effluent from the sewer is treated.

The Contractor shall construct the drainage first to ensure that at no stage is rainwater ponded on any part of the site. All rainwater shall be able to run off the site or shall be immediately pumped off site by the Contractor. The Contractor shall complete all necessary drains before casting any roof and large concrete area which will create large run off. The condensate drains for the air conditioning shall also be connected to the drainage. Two vents of minimum height 2.2m shall be provided on each septic tank.

If a town's water supply is unreliable, the roof rain water shall be collected in an underground tank of standard Employer's design. Scope of this work shall be agreed at Bid stage.

9.3.4 Surfacing

For the whole of the switchyard outdoor equipment area the ground shall be surfaced with gravel or other readily available local stone as approved by the Engineer. The switchyard surfacing shall be clean, thoroughly washed when necessary, and free from clay, soil or contaminating material and shall be graded from 20 - 45mm, laid and lightly compacted to a finished thickness of 175mm. Below the gravel layer there shall be a 75mm brick layer with cement mortar (1:6), laid over a 75mm level of fine sand spread over the finished fill site.

The substation plot, outside of the designated switchgear equipment areas, shall be turfed. Turf shall be of good quality, free from weeds and shall be a minimum of 40mm thick. Samples of the turf which is proposed to use shall be submitted to the Engineer for his approval. The turfs shall be laid to even surfaces on a bed of vegetable soil, which shall be raked and consolidated to provide a suitable bed.

On sloping surfaces the Contractor shall provide and fix wooden pegs to retain turfs.

All areas to be surfaced shall first be treated with a total weed killer in accordance with the Manufacturer's instructions. Weed killer shall only be applied in dry weather when there is no risk of it being washed out to adjacent agricultural areas.

9.3.5 Roads

All roads within the site boundary shall be provided by the Contractor, plus access road outside the site boundary to connect to any adjacent public road or waterway. The extent of roads required is shown approximately on Bid drawings but the scope of the work may change.

The road surface shall be finished by concrete paving or equivalent. All roads shall be of reinforced slabs of approximately 25 cm thickness fitted with construction joints. Paving schedule and methodology shall be approved by the Employer.

Road layout shall generally permit vehicles to turn easily to avoid having to reverse out. Road layout shall be designed by the Contractor. The Contractor's Liability for roads outside the site shall be as stated in the Project Requirements of Volume 1.

The width of access road from outside the site boundary to connect to any adjacent public road shall be 6 meters. All roads within the site boundary shall be generally 6 metres wide between the outer edges of kerbs for main road and 3 meters wide for sub road.

The road edge shall be formed by a flush Class B concrete kerb 300mm wide by 250mm deep, placed over one layer of bricks laid flat. The road shall be a Class A concrete slab 150mm deep with 1:50 cross fall and stiff broom concrete finish reinforced with 6mm bars at 125mm centres longitudinally and 6mm bars at 400mm centres transversely placed 60mm below the upper surface. Expansion and con- traction joins shall be detailed on site plans. Expansion joints shall have oil resisting grade polysul- phide sealant. Below the slab shall be a layer of polythene 0.5mm thick laid over one layer of 1st class bricks laid on edge in herringbone fashion in and on cement mortar (mortar designation iv) laid over one layer of 1st class bricks laid flat in and on a layer of sand laid on in situ soil which shall be com- pacted as agreed with the Engineer. If the soil is clay a 75mm drainage layer of broken bricks shall additionally be placed over the soil.

The radius of the road edge at comers shall not be less than 3 metres and 1.2 metres either side of the road shall be kept clear of obstacles. Bollards or raised kerbs shall be provided where required to protect items alongside a road from vehicles. Ducts shall be provided below roads for all services in this Contract and for all future services.

Where mortar designations are referred to see BS 5628 Mortar designation iv is 1 cement: 2 Lime: 8 to 9 sand.

At each new substation site a two bay hard standing car port, complete with sun shades, is to be provided adjacent to the control building.

9.3.6 Water Supply

The Contractor shall be responsible for providing a water supply both for construction and for operation of the completed sites. If a town's water supply is not available, the Contractor shall install a tube well of 40mm minimum diameter and 100m minimum depth but in that case guideline specified by WHO for drinking water is required to be satisfied. The Contractor shall supply and commission power supplies and all pumps required by tube wells.

If a town's water supply is available, the Contractor shall be responsible for making all necessary arrangements with WASA to connect a supply. If the pressure in the supply is inadequate to supply the roof tank continuously, the Contractor shall install an 1800 litre low level tank and pumps. This tank shall be below ground with a 200mm minimum air void around the tank to protect it from contamination. The pump control panel shall be located in the building. Water levels shall be controlled by float switches but the panel shall provide also for manual operation.

The supply shall be connected to an 1800 litre roof tank of 16 gauge galvanised steel plate with a lid secured by bolts. The tank shall be raised 400mm clear of the line terracing on four brick piers of minimum 350mm square. All supplies in buildings shall be fed from the roof tank. The supply to the tank shall have a valve at waist height. The tank shall have an overflow returning to the location of this valve. No pipes shall pass through the roof directly over any room. Pipework shall be routed up the outside of the building and return pipes shall return down the outside of the building before entering through the wall. Pipework shall be galvanised steel secured by clamps at 1-5 metre intervals and painted with alkyd paint to match walls.

shall have function to easily accommodate cables, communication wiring, etc. on its lower part. The floor material shall include the shock-absorbing material and finishing stuff.

Panel elements shall be produced without fading or peeling on the finishing stuffs and trim by the injection moulding of finishing stuff with panel elements at the same time. By the injection moulding, the panel's thickness and the other standard (width, length, thickness, opposite angle, right angle, flatness angle, etc.) should be precise.

Pedestal elements shall have the function of support for the panel element of raised floor material.

Shock-absorbing material shall be installed on the top of pedestal elements and prevent any vibration or impact of the panel elements.

The materials for raised floor shall be as shown below or similar. The details should be approved by the Employer.

- Panel stuff: polyurethane
- Panel dimension: 600 x 600 ± 0.5mm (including finishing stuff, trim)
- Panel thickness: 40 ± 0.5mm (including finishing stuff)
- Panel inside core: particle board 35mm
- Panel frame: width 3mm poly-urethane
- Finishing stuff: anti-static laminate tile
- Under structure: zinc electric galvanizing
- Central concentrated load transformation: less than 2.5 mm with 4,900 N

The materials should be kept on the well-ventilated places against rain and direct ray of light. When transporting and handling the stuffs, the handler should be alert not to be damaged. The damaged materials have to be taken out. The finishes of stuff have to be stuck in the panel element.

The floor surface must be dry before construction; also the impurities like dirt and other obstruction should be removed. The under-structures (Pedestal set) are installed at intervals of 600mm from the starting point of construction like radial shape. At this time, the under-structure is fixed strongly on the floor surface by using an adhesive. When each supporting structure is connected to the frame (stringer), the levelling work shall be done together. Horizontal angle shall be checked again after the construction is finished.

Panel lifter and other accessories necessary for maintenance shall be provided by the Contractor.

9.3.7 Site Clearance, Obstructions and Adjacent Structures

The Contractor shall be responsible for clearance of:

(1) Trees, shrubs and any vegetation including the extraction of all roots and compaction of backfill where roots have been extracted.
(2) The removal of all buildings, sheds or any other structures above or below ground including the removal of any septic tanks, drains or other underground services.
(3) The removal of any existing surfacing, roads, foundations or any other obstruction.

All material cleared away by the Contractor shall be the property of the Employer and shall be re- moved by the Contractor to a site in the Project area upon instructions of the Employer. The Employer may remove any buildings or structures himself from sites before the commencement of site works.

Where an existing service, existing equipment or adjacent building is to be retained, the Contractor shall take all necessary measures to protect the item concerned from damage and shall be responsi- ble for ensuring that no movement of foundations occurs during or after completion of construction.
Any existing electrical equipment/cables which have to be modified or repositioned shall be included in the works at no extra cost. Any buried gas or water main services which require to be diverted shall be deviated by the Employer at his cost. However, where it is possible to retain these existing services and build new structures around them, the Contractor shall take all necessary measures to build in the service at no extra cost.

9.3.8 Expansion Joints, Joint Fillers and Sealants

Expansion joints shall be placed in floors beside all ground floor walls. All filler board shall be bitumen bound fibre board. Any expansion joints on roofs shall be raised and protected by a metal flashing.

All expansion joints shall be sealed by polysulphide sealants, applied in accordance with the Manufac- turer's instructions. Sealants shall be oil resisting grade where required. Sealant colours shall match or blend with adjacent wall colours.

Longitudinal fire separation walls and transverse fire separation walls as required by the cable section, may be of brick or reinforced concrete.

Any beams used to support large span covers shall be removable. All metal work shall be painted as specified in the paint section.

All covers shall bed down evenly. Full detailed fabrication drawings shall be provided for all covers.

9.3.9 Switchyard Foundations

The tops of all foundations shall be set at the same level, which shall be raised above the general switchyard level for the purpose of preventing surface water coming into contact with the equipment structures and holding-down bolts. The distance between the general surface level and the top of foundations shall be at least 200mm. All exposed concrete surfaces shall be painted with an acrylic

weatherproofed or bituminous paint, and flat areas shall be sloped to shed water. No base shall permit ponding of water in any way, and free drainage shall also be possible from all areas inside any grouting.

Bases shall generally be of Class A reinforced concrete.

Bases shall have all recesses for cables and earthing detailed on drawings. The drawings shall clearly show the orientation of each base and the location of all recesses. Where new foundations are adjacent to existing foundations; the Contractor shall be responsible for verifying the extent of the existing foundation and ensuring its stability.

For anchorage design of switchyard foundations shear force, vertical accelerations, overturning moments and torsion due to mass eccentricities of the equipment for the earthquake load of 0.2G are required to be considered. Mild steel ductile bolts and headed studs cast-in-place anchor bolts shall be used. Thick plate washer is required to be welded to the equipment base plate. Normal washer shall be used under a nut in all cases.

9.3.10 Transformer Bases

The transformer base, together with its surrounding bund shall form a raft to distribute the load from the transformer over the entire area within the bund wall. The bund shall extend at least 700mm be- yond any part of the transformer and its radiators. The level of the top of the bund and the skids shall be 200mm above general switchyard level. Skids shall extend to the edge of the bund.

50mm below the top of the wall shall be placed a layer of stone 225mm deep set on a galvanised grill painted with two coats of bitumen mastic paint. The volume of the bund below the stone shall equal 125% of the total volume of oil in the transformer and its radiators.

Rainwater will tend to collect in the bund. To evacuate rainwater a fixed submersible pump controlled by sensors and switches (Aqua Sentry or equal) shall be provided at each bund with power supplies and drainage manhole conveniently located. The bund water control system shall differentiate be- tween water and oil to ensure that the pump will not be activated while oil is present in the bund.

The transformer base and the bund shall be founded a minimum 1.0 metres below average switchyard finished level.

Below the skids the walls shall be at least 600mm wide. Piers shall be provided below the jacking points. Each base shall be provided with two galvanised steel removable pulling posts on the other side of the access road to the bund and also at the back of the transformer bund.

The entire concrete surface of the bund and the transformer base which is not buried shall receive two coats of bitumen mastic paint. Skids shall receive 3 coats of bitumen mastic paint before being cast in.

A carriage way shall be provided with rail connected with all transformer bases.

Transformers shall be anchored to resist the earthquake load of 0.2G.

9.3.11 Blast Walls not require

9.3.12 Paints and Painting

All paints shall be of approved makes and colours and proven suitability for the prevailing climate and shall be approved by the Engineer. All surfaces for painting shall be cleaned down prior to being painted and rubbed down to a smooth finish.

All externally exposed concrete and render of the control buildings, boundary walls, blast walls and guard posts shall be painted with a fungicide, Snowcem primer and two coats of Snowcem. All exposed facing bricks and Snowcern painted surfaces shall be treated with one coat of clear silicone (5%) water proofing solution.

All exposed parts of foundations, the outer faces of cable trenches and cable tunnels shall be painted with two coats of bitumen mastic paint.

All ungalvanized metalwork shall receive two coats of red oxide paint at least 4 days before installation and shall receive two finishing coats of paint after installation, each coat being of different colour. Surface preparation before painting shall be SA 2.5 or an agreed rust convertor acid shall be used. All galvanized steel, including all brick ties, boundary wall wire supports, crane beams, and baseplates and holding down bolts and concrete plinths shall receive two coats of bitumen mastic paint. Galva- nized steel shall not be painted until the surface has weathered.

Internal walls when fully dry shall have the surface rubbed down with sandpaper and be painted with a sealer and 2 finishing coats of plastic emulsion paint before equipment is installed. A further finishing coat shall be applied after completion of installation.

One day shall be allowed for drying of each coat before the next coat is applied.The interior of all septic tanks and manholes carrying foul sewage shall receive two coats of bitumen mastic paint.

The full details and specification of these materials shall be agreed before purchase. The Contractor shall arrange for a list of items to be handed over to the Employer, who will sign for receipt of a complete set as stated on the list.

Furniture shall be provided for new substations only.

9.3.13 Concrete

Only two grades of concrete shall be used. Class A shall be used for all structural work, piling and for all foundations which are not unreinforced massive blocks. Class B concrete shall be used for blinding, pipe surround and unreinforced or nominally reinforced concrete. Road slabs and floor slabs shall all be reinforced Class A concrete.

	Class A	Class B
Minimum cement content	360 kg/m³	170 kg/m³

Maximum water/cement ratio	0.55	-
Coarse aggregate type	broken stone	Jhama brick
Max. coarse aggregate size	200 mm (40 mm piling)	25 mm
Method of batching	volume batching	volume batching
Minimum characteristic of trial:		
• Mix at 28 days	30 N/mm²	-
• Minimum characteristic strength of trial mix at 7 days	14 N/mm²	-
• Minimum characteristic strength of works cubes at 28 days	20 N/mm²	-
Slump range (minimum / maximum)	30 mm / 100 mm	min. 50 mm
Slump for concrete placed below water in piling (minimum / maximum)	150 mm / 200 mm	

It should be noted that minimum specified cement content will produce significantly stronger concrete.

The Contractor's design shall be based on a 28 day crushing strength of 30N/mm². Design shall be in accordance with this Contract and BS 8110 or other agreed standard.

Minimum cover to rebar shall be 60mm where concrete is in contact with backfilled soil against a shuttered face, 100mm where concrete is cast against soil, and 30mm for all above ground concrete. In detailing bars which traverse a member, a reduction of 5mm shall be made for a bent bar and 10mm for a straight bar to ensure adequate cover. Exposed ends of sunshades and roof projection shall have 70mm minimum cover.

All concrete design shall ensure easy access for vibrators of 50mm. minimum diameter. Because of the slowness of concreting using local methods of transport, congested reinforcement details and shapes which are difficult to concrete should not be used. The location of all cold joints shall be agreed in writing with the Engineer and all joint surfaces shall be scabbled. All joints shall be horizon- tal or formed against vertical stop ends. All cold joints shall be indicated on drawings. Roof slabs shall generally be cast in one continuous operation.

9.3.14 Concrete Reinforcement

The Contractor may use locally available mild steel bars from approved sources or import steel bars to any agreed standard. No bar or stirrup shall be smaller than 6mm diameter to ensure adequate rigidity during concreting.

If locally purchased bars are used, bending tests and tensile tests shall be carried out to ensure the bars meet the design standard adopted and weight per unit length shall be tested regularly.
Bar bending lists shall generally be shown on drawings, where possible with a diagrammatic representation of each bar to ensure clarity and ease site communication. The Engineer will not systematically check the accuracy of every bar on bar lists when approving drawings. The Contractor shall therefore arrange to check all bar lists. Drawings shall detail all chairs and ties and include these on bar lists.

Bars shall be tied at every intersection and the ends of tie wire bent away from concrete surfaces.

Anti-crack bars shall be provided at changes in slab or wall thickness and at the comers of every rectangular opening.

9.3.15 External Render

All brickwork which is not faced with facing bricks shall be rendered. Concrete columns and walls shall be rendered and painted in accordance with BS 5262 with a 3mm spatter dash coat a 12mm undercoat followed by a 9mm finishing coat. Surface preparation shall be as described in BS 5262. Joints shall be provided in all render where brickwork panels abut concrete columns and grade beams, as required by BS 5262.

A mix type II or III shall generally be used. The finishing coat shall be weaker than the undercoat.

The tops of all foundation blocks and all protruding concrete foundations shall also be rendered where required by the Engineer.

PVA Bonding agents shall not be used because of the risk of early drying in the tropics. All concrete surfaces to be rendered shall have the entire surface scrabbled and brushed with a stiff brush to remove all loose material. The surface of the undercoat shall be roughened to ensure bonding of the finishing coat.

All render once completed shall be kept continuously damp for 10 days, after which if shall be treated with a fungicide. Any existing backgrounds shall be treated with a fungicide and all growth cleaned after 5 days of contact with the fungicide.

9.4 Concrete Workmanship

9.4.1 General

At all stages in the production, mixing, placing and curing of concrete, the work will be inspected by the

Engineer's representative. If any material, dimension or practice is not at least equal to the stand- ards set out herein, it shall be rejected and alternatives compliant with the said standards, and in addi- tion to the satisfaction of the Engineer, shall be implemented.

9.4.2 Aggregates

Coarse aggregate shall be capable of passing through a 20mm sieve and be retained on a 5mm sieve. Fine aggregate shall be not larger than 5mm and not smaller than 0.06mm and shall be sharp in texture.

All aggregates shall be free of harmful quantities of organic impurities, clay, silt, salt or unsound parti- cles. The amount of clay, silt and fine dust present in aggregate, whether as coatings or separate par- ticles, may not be more than:

- 15% by weight in crushed sand
- 3% by weight in natural or crushed gravel sand
- 1% by weight in coarse aggregate.

If the Engineer considers that any aggregate which the Contractor proposes to use contains an excess of fine particles or any harmful substances, the Contractor shall either replace the aggregate or, at his option and entirely at his expense, institute a series of approved tests at an approved laboratory to determine the nature and extent of the fine particles and harmful substances. Following receipt by the Engineer of the results of the analysis and tests, he will advise the Contractor in writing whether the proposed aggregate may or may not be used. The Engineer's decision in this respect shall be final.

Tests to determine the extent of impurities or fine particles shall include (but shall not be restricted to) the relevant tests specified in BS 882:1992, ASTM. C40-79 (Colorimetric test) and ASTM. C33-82.

9.4.3 Sampling

At least four weeks before he envisages first receiving aggregate from any source the Contractor, in the presence of the Engineer, shall obtain samples for testing. Samples shall be taken in accordance with the procedure quantities laid down in BS 812 and shall be subjected to those tests which the Engineer considers necessary to demonstrate the soundness of the material.

Such tests shall be carried out in an approved manner at the Contractor's expense and may include the manufacture, both in the laboratory and at site, of test cubes or cylinders to determine crushing strength.

9.4.4 Grading

The Contractor shall ensure that his offer includes the full cost of obtaining and transporting suitably graded stone aggregates to site.

Grading of aggregates should, together with the required minimum cement content and water cement ratio, ensure adequate durability, density and characteristic strength of the finished concrete. The

Contractor shall submit in writing to the Engineer the make-up of the mix he proposes to use, together with the grading analysis for the particular material and any details concerning his or others' experience with the use of aggregate obtained from the same source.

9.4.5 Cement

Ordinary Portland Cement shall comply with BS 12. The Contractor may obtain cement, bagged or in bulk, from any approved source in Bangladesh but shall always submit sufficient samples from each delivery, as required by the Engineer, to ensure that all cement complies with the minimum requirements of BS 12. All cement shall be stored in a weather tight shed at least 300mm off the floor. Regular checks shall be made on the weight of cement in each bag.

9.4.6 Water

All water used in the preparation of concrete for foundations shall be clean, fit for drinking and free from all earth, vegetable matter and alkaline substances, whetherin solution or in suspension, and shall comply with BS 3148.

9.4.7 Reinforcing

Where reinforcing is specified in any foundation design, it shall comply with BS 4449 or an approved similar standard. Before any reinforcing is used, the Contractor shall provide the Engineer with a certified mill certificate, verifying its grade and quality, and proof test such samples as the Engineer considers necessary. All reinforcement shall be clean and free from loose mill scale, dust, loose rust and paint, oil or any other coating which in the opinion of the Engineer may destroy or reduce bond.

9.4.8 Storage

The Contractor shall ensure that all the materials he provides for the preparation of concrete shall be stored in a manner which prevents contamination by dust, clay, water or any other harmful material. Heaps of coarse and fine aggregate shall be separated by at least one metre.Where aggregate is tipped directly onto the ground, the bottom 20cm of the heaps shall not be used.

Bagged cement shall be protected from rain, mixing water or damp soil during storage/transport. Cement from accidentally split or damaged bags shall not be used.

Where the Engineer considers it necessary, special precautions shall be taken to ensure that aggregate stored on site shall remain dust free. Such precautions may include the bagging of aggregate at the pit if sites are adjacent to dusty roads or if heavy rain is liable to wash out fine material or saturate the aggregate to an extent which might influence the water content of a mix.

Where the Contractor establishes central depots for receiving cement prior to despatch to individual sites, he shall ensure that the cement storage areas are sufficiently raised above the surrounding ground to prevent contamination of the cement by surface water. The material from which storage plinths are made shall be approved by the Engineer.

9.4.9 Design Mix

Prior to ordering any aggregate the Contractor shall inform the Engineer of the source(s) of his aggregates and deliver samples to the Engineer. The Contractor will authorise at an approved laboratory tests to show the sieve analyses, relative densities, moisture content of the samples of aggregate from each source. At least four test specimens of concrete shall be mixed at an approved laboratory and tested after 7 and 28 days.

Depending on the moisture content of the samples of aggregate the Contractor will report to the Engineer on the expected water/cement ratio and the aggregate/cement ratio of concrete to be produced on site.

Following the successful testing of the laboratory samples the Contractor shall make trial mixes at site (from which he will take at least 4 test specimens) using the proportions advised to the Engineer (and in the presence of the Engineer) and using the equipment he intends to use in the normal day to day manufacturing of concrete. The minimum 28 day crushing strength of any such test specimen shall be not less than 20.7 N/mm^2.

After successful testing of the test specimens made at site, the Engineer may then approve the source(s) of aggregate and the mix design.

No changes to the approved mix design will be permitted unless the type or source of aggregate differs from those already tested, in which case further tests at both the laboratory and at site will be made.

Any concrete placed which does not conform to the approved mix designs, shall be removed and replaced by the Contractor at his own cost.

9.4.10 Mixing and Placing of Concrete

Proportions of aggregates and cement and the quantity of water for each batch of concrete shall be closely monitored by an experienced mixer operator. Aggregate shall preferably be weight batched but, where this is not possible, volume batching shall be permitted, provided that the net volumes of the loading equipment are approved by the Engineer. Containers for measuring quantities of water shall be clearly marked and only approved quantities of water shall be used in the manufacture of concrete.

Mechanical mixers shall be in good condition and well maintained. After loading, the constituent parts of the concrete shall be mixed together for a period of not less than two minutes or 30 revolutions of the barrel, whichever is the greater. For mixers with a capacity greater than 1.5m^3 these periods may be increased if the Engineer so requires.

When the constituents are adequately mixed, the fresh concrete shall be discharged from the mixer and placed in the foundation with the minimum of delay. Chutes shall be used to ensure that fresh concrete is not dropped by more than 1.5 metres.

No concrete shall be placed until all form work, installation of parts to be embedded, and preparation of surfaces involved in the placing have been approved. No concrete shall be placed in or through wa- ter, except with the written permission of the Engineer, and the method of depositing such concrete shall be approved by the Engineer.

Concrete shall not be placed in running water and shall not be subjected to the action of running water until after the concrete has hardened for seven days. All surfaces of forms and embedded materials that have become encrusted with dried mortar or grout from concrete previously placed, mud or other foreign material, shall be cleaned of all such refuse before the surrounding or adjacent concrete is placed. Immediately before placing concrete, all surfaces of foundations upon or against which the concrete is to be placed shall be free from standing water, mud and other foreign matter. The surfaces of concrete which have set, and against which new concrete is to be poured, shall be thoroughly cleaned to remove all foreign material and laitance, and be saturated with water immediately before placing concrete. Concrete shall be deposited continuously and as rapidly as possible until the unit be- ing poured is complete. If for any reason the work is stopped before completing the unit of operation, a construction joint shall be installed in accordance with the instructions of the Engineer. Concrete shall be so deposited as to maintain, until the completion of a unit, a plastic surface approximately horizontal.

The method and equipment used for transporting concrete shall be such that concrete having the required composition and consistency will be delivered as near as practical to its final position without segregation or loss of slump. All concrete mixing and placing equipment and methods shall be subject to approval by the Engineer. Concrete placement will not be permitted when, in the opinion of the Engineer, weather conditions or other pertinent factors prevent proper placement and consolidation.

Bidders are reminded that, as a minimum standard, the following series of inspections should be carried out by the Contractor before concreting can begin:

1 Formwork coated with mould oil and correct in type, quantity and condition
2 Centre lines of template to coincide at the centre peg
3 Formwork to be well strutted and correctly located
4 Vibrator to be in working order
5 Mixer to be in working order
6 There is provision to maintain continuous mixing and pouring, by hand if necessary, in the event of a mixer breaking down
7 Where necessary, re-bar is on site ready bent and complete with tie wire, stirrups and concrete or plastic preformed spacer packs
8 A reliable level is at hand
9 There is sufficient aggregate, cement and water to complete the pour
10 Excavations are safe and not cluttered around the top edges
11 The mixer barrel is clean, and the paddles are complete and in place and the barrel will rotate at the speed specified by the Manufacturer
12 A suitable chute is in place
13 Both an air thermometer and concrete thermometer are on site
14 There is a large quantity of hessian sacking at hand

Where any of the above items are not complied with, the Engineer may suspend concreting pending their implementation.

9.4.11 Testing of Concrete

Samples shall be taken and tested in accordance with BS 1881. Testing shall be carried out by an approved laboratory, who shall arrange to immediately notify the Contractor and the Employer in writing of any cube failure. Failed cubes shall be kept for reference.

Concrete for the test specimens shall be taken at the point of deposit. To ensure that the specimens are representative of the concrete, a number of samples shall be taken from different points. Each sample shall be large enough to make one test specimen and shall be taken from one point in the work.

The tests specimens shall be stored at the site at a place free from vibration, under damp sacks for 24 hours $\pm$ 1/2 hour, after which time they shall be removed from the moulds, marked and stored in water at a temperature of 10° to 21°C until the test date. Specimens which are to be sent to a laborato- ry for testing shall be packed for transit in damp sand or other suitable damp material, and shall reach the laboratory at least 24 hours before test. On arrival at the laboratory, they shall be similarly stored in water until the date of the test.

One compression plate of the testing machine shall be provided with a ball seating in the form of a portion of a sphere, the centre of which coincides with the central point of the face of the plate. Test specimens shall be placed in the machine in such a manner that the load is applied to the sides of the specimen as cast.

Cube strengths for concrete are to be not less than 14.8N/mm^2 within seven days after mixing and 20.7N/mm^2 within 28 days after mixing.

One cube shall be tested at 7 days to obtain an indication of the concrete strength. The remaining three cubes shall be tested at 28 days and the average of their strengths shall be calculated. Should the average of the cube strengths fall below the specified 28 days cube strength, the Engineer may order the affected concrete to be removed and replaced at the Contractor's expense, or the Engineer may allow the Contractor to take a cylinder for further testing in accordance with BS 1881, if Schmidt Hammer readings indicate below strength concrete.

The diameter of the cylinder shall be not less than three times the size of the maximum aggregate and its length will be at least double the diameter, after allowing for preparation and facing prior to the test.

Both a report and compression test will be completed for the sample in accordance with BS 1881. Only one such test will be permitted from any one sample and if the crushing strength of the sample is in excess of that required by the design the Engineer may, after the Contractor has made suitable re- pairs to the part disturbed by taking the sample, accept the concrete.

In addition to cube sampling, 30% of concrete pours shall be tested by Schmidt Hammer. The Contractor is to pay for all remedial work and testing. Readings shall be taken at locations agreed with the Engineer and shall be witnessed by the Engineer. At least 15 readings shall be taken such that, after discarding the highest and lowest, some 12 readings remain from which the mean shall be calculated.

Readings shall be restricted to the middle third of a beam, slab or column and shall not be closer than 50mm to an edge or closer than 50mm. to any other readings. Immediately on completion of hammer testing, the concrete surface shall be painted to seal it with two coats of snowcem primer.

9.4.12 Formwork

Formwork shall conform to the shape, lines and dimensions of the concrete as called for on the Plans and shall be sufficiently strong to carry the dead weight of the concrete without undue deflection or bulging, and sufficiently tight to prevent leakage of mortar. It shall be properly braced and tied together so as to maintain position and shape. Members used in forms at exposed surfaces shall be dressed to uniform thickness and shall be free from loose knots or other defects. Joints in forms shall be horizontal or vertical. At all unexposed surfaces and rough work, undressed timber may be used. Timber reused in shutters shall have nails withdrawn and surfaces to be in contact with concrete thoroughly cleaned before being reused. Formwork shall not be disturbed until a minimum of 48 hours has passed from time of placement and concrete has hardened sufficiently to support any construction loads that may be imposed when stripping forms, metal wedges or tools shall not be used to pry pan- els loose. If wedging is necessary, it shall be done with wood wedges lightly tapped to break adhesion.

All columns and beams will have exposed edges chamfered 20 mm x 20mm.

9.4.13 Reinforcing Steel

Steel reinforcing bars shall be positioned in the concrete at the places shown on the drawings, or where reasonably directed by the Engineer.

Before reinforcing bars are placed in position, surfaces shall be cleaned of heavy flaky rust, loose mill scale, dirt, grease and all foreign matter. Once in position, reinforcing bars shall be maintained in a clean condition until they are completely embedded in concrete. Reinforcing bars shall have at least the minimum concrete cover shown on the drawings. Reinforcing bars shall be accurately placed and

secured in position, such that they will not move during placing of concrete. Precast concrete block spacers may be used for supporting reinforcing bars.

9.4.14 Consolidation of Concrete

Concrete shall be consolidated to maximum practical density, without segregation, by vibration so that it is free from pockets of coarse aggregate and closes against all surfaces and embedded materials. Vibration of concrete in structures shall be by electric or pneumatic-driven immersion type vibrators of 50mm minimum diameter, operating at speeds of at least 8,000rpm when immersed in concrete. The vibrator shall be inserted vertically at close enough intervals so that the zones of influence overlap.

The vibrator shall be inserted to the full depth of the layer being treated and withdrawn slowly. When concrete is being placed in layers, the tip of the vibrator shall extend approximately I 00mm. into the underlying layer. Vibrators shall not be used to move concrete horizontally. Care shall be exercised to avoid over-vibration of the concrete and direct contact between the vibrator and reinforcing shall be avoided.

9.4.15 Curing of Concrete

For foundations where excavations are to be backfilled immediately following the striking of shutters, the concrete is to be thoroughly wetted before backfilling commences. Where shutters are to be struck and backfilling of the excavation is not to take place immediately, the concrete is to be covered with wetted hessian sacking and be enclosed in polythene sheeting to avoid rapid drying of the concrete.

9.4.16 Hot Weather Concreting

In hot weather the following additional precautions shall be taken.

(a) In hot weather suitable means shall be provided to shield the aggregate stockpiles from the direct rays of the sun or to cool the mixing water/aggregates to ensure that the temperature of the concrete when deposited shall not exceed 32°C.

(b) In hot dry weather suitable means shall be provided to avoid premature stiffening of concrete placed in contact with hot dry surfaces. Where necessary the surfaces, including reinforcement, against which the concrete is to be placed shall be shielded from the rays of the sun and shall be sprayed with water to prevent excessive absorption by the surfaces of water from the final concrete.

9.5 Workmanship of all Other Materials

This specification only describes concrete work in detail. All other materials workmanship shall be in accordance with an agreed standard. Before starting any new item of work the Contractor shall submit samples of the materials to the Engineer for approval in writing and the method of installation shall also be approved. The first item of any type to be installed shall be inspected and checked in detail by the Engineer before other items are constructed.

ical constraints. then the number of different sources of origin shall. be kept to a minimum. Local service facilities shall be available for the equipment proposed.

The Contractor shall provide, with his submission, illustrated technical literature covering all plant and equipment offered.

9.5.1 Standards

All air conditioning and ventilation equipment shall conform to British Standards, Chartered Institution of Building Services or ASHRAE recommendations or other recognised International Standards.

9.5.2 Approval

The Contractor shall submit to the Engineer for approval copies of all his calculations forming the basis for the selection of all air conditioning and ventilating plant, plant selection details and full working drawings. Such approval shall not relieve the Contractor of his contractual responsibilities.

9.5.3 Maintenance

The Contractor shall be responsible for the maintenance of all installations covered by this section of the Specifications for the period stated elsewhere in the Specification.

9.6 Earthing and Bonding

All equipment being supplied under this Section shall be effectively bonded to ensure earth continuity throughout the system. Continuity may be provided by means of cable armouring but a separate earth continuity conductor shall be included with all wiring in conduits. No reliance shall be placed on metal to metal joints in conduits for earth continuity. The earth continuity conductors shall as far as possible be in one continuous length to the furthest part of the installation from the controlling switchboard. The earth conductor shall connect all metal cases housing electrical equipment. The branches shall be connected to the main conductor by permanently soldered on mechanically clamped joints.

9.7 Testing and Commissioning

The Contractor shall be required to prove that the installed system meets the design requirements and Specification to the satisfaction of the Engineer.

10. Quality Assurance, Inspection, Testing, Commissioning and Warranty

10.1 Scope of Section

The whole of the plant covered by this Contract will be subject to inspection and witnessing the tests by the Employer during manufacture, erection and on completion. The inspection and witnessing the tests at Manufacturer's works may be done by the Employer or an Independent Inspection agency.

The approval of the Employer/Engineer or the passing of any such inspection or test will not, however, prejudice the right of the Employer to reject the plant if it does not comply with the specification when erected or when in service.

The Employer/Engineer or their designated representatives are entitled to attend the **factory acceptance tests**, according to clause SCC23 of section-8 of volume-I, which shall be performed at the Manufacturer's works/testing laboratories. Factory acceptance tests shall be performed for the following equipment:

- power transformer 400/230 kV,
- circuit breaker 400 kV,
- disconnectors 400 kV,
- instrument transformers 400 kV,
- surge arresters 400 kV
- substation automation system and protection relays, and
- communication equipment

The Contractor shall be responsible for bearing the costs for the above mentioned witnessing of factory acceptance tests by two (2)Employer's engineers in each visit, considering visa fees and health insurance to cover all medical costs that may be required during visit, the return air fare, hotel charges, travelling expensesfrom airport to hotel and hotel to place of testing and return, , together with a per diem allowance of USD 100 for actual working days, excluding travelling time, for each visit and for each of the Employer's Engineers.

The Contractor shall provide **training** for of 4 (four) Employer's Engineers at the Manufacturer's premises, for installation, testing, operation and maintenance of the following equipment:

- Operation and maintenance of HV switchgear equipment including power transformer
- Basic and design of substation automation system & protection equipment

The Contractor shall be responsible for bearing the costs for the above mentioned trainings for four Employer's Engineers in each training, considering visa fees and health insurance to cover all medical costs that may be required during visit, the return air fare, hotel charges, travelling expenses from airport to hotel and hotel to place of testing and return, food, laundry, together with a per diem allowance of USD 100 for minimum 10 (ten) working days, excluding travelling time, (as per the necessary and agreed training schedule) for each training and for each of the Employer's Engineers.

The Contractor shall provide, during and after the installation, **on-site training** for operation and maintenance of the works, for 10 (ten) Employer's staff, in the duration of minimum 1 (one) weeks.

The Contractor shall be responsible for bearing all costs for the above mentioned training. All costs are deemed to be included in the contract price.

For notification of testing, four weeks shall be deemed as reasonable advance notice.

Within 45 days of the letter of acceptance for the contract the contractor shall submit a quality assurance programme and a work quality programme for the Engineer's approval.

The Contractor shall have an approved quality management system.

After the award of Contract, the Engineer shall have the right to carry out a review of the quality assurance procedures operated by the Contractor. The Engineer's review may consider quality assurance in relation to the design and manufacture of plant items, but may equally investigate the Contractor's quality assurance procedures for the overall control of the wide range of design activities necessary for a complex project of this type, and the dissemination of paperwork, design drawings and data amongst the various design and manufacturing organisations within the Contract. The Contractor shall give all necessary help and assistance to the Engineer in carrying out such a quality assurance review. The Contractor shall consider and discuss the results of the review and make any reasonable improvements in his procedures.

Before any plant is packed or despatched from the Main or Sub- Contractors' works, all tests called for shall have been successfully carried out in the presence of the Engineer unless otherwise agreed.

30 days' notice shall be given when the plant is ready for inspection or tests and every facility shall be provided by the Contractor and his Subcontractors to enable the Engineer and Employer to carry out the necessary inspection and witnessing of tests.

In the cases where tests or inspection are specified as being carried out on only a sample of the total quantity of items in the Works, and where one or more items of the sample fail the test or inspection, a further batch of the items, at least equal in quantity to the proportion originally specified, shall be tested or inspected. This process shall continue until a sample proves completely acceptable.

10.2 Subcontracts

Within two months of acceptance of the Bid and in order to facilitate the inspection of bought-out materials and plant, the Contractor shall submit to the Engineer for approval three copies of all sub-orders placed by him as soon as they are issued. One copy of any drawing or schedule referred to in the sub-order shall be submitted simultaneously unless agreed otherwise with the Engineer. Any reference to price may be deleted from the copies so submitted.

The sub-orders and drawings submitted to the Engineer shall cover all components which are subject to electrical and mechanical pressure or stress when the plant is in operation and also auxiliaries and spares which are to be despatched to Site direct from the Subcontractor's factory.

Sub-orders are to include a statement advising the Subcontractor that the items being ordered will be subject to inspection and test by the Engineer and Employer.
The Contractor shall advise his Subcontractors of all the pertinent clauses in the Specification when ordering bought out plant, equipment or materials.

Every suborder or subcontract shall contain the following information:

- Main Contractor's name and sub-order or sub-contract number.
- Quantities and description of work.
- Delivery requirements.
- Delivery consignment instructions.
- Details of Employer and/or main Contractor's applicable drawing or schedule numbers.
- Name of the Engineer.
- A note advising that the plant or equipment which is the subject of the order shall comply in every respect with the Engineer's, Specification and shall be subject to inspection by the Engineer, Employer and the Contractor.
- A reference, particularised in the accompanying Specification, covering the following information:
  - Employer's name
  - Project title
  - Contract No.
  - Engineer's reference number

Subcontractors shall comply with all the applicable requirements of this Specification and the onus is upon the Contractor to ensure that Subcontractors comply with these requirements.

For the purposes of this clause, interworks orders shall be treated as sub-orders.

10.3 Guarantees

The Contractor shall state and guarantee the technical particulars listed in the Technical Schedules and other sections as specified by the Contract for testing procedures. These guarantees and particu- lars shall be binding and shall not be departed from without the written permission of the Engineer.

The Contractor shall further guarantee that all equipment supplied complies with the Contract Documents.

The tolerances permitted in the IEC and British Standards shall apply unless otherwise stated.

10.4 Quality Audit

The quality programme established by the Contractor shall be followed for all inspection and testing procedures.

The Engineer and Employer may, from time to time, visit the Manufacturer to carry out a quality audit of the Manufacturer's organisation.

10.5 Measuring and Testing Equipment

At prescribed intervals, or prior to each use, all measuring and testing equipment used in inspection shall be calibrated and adjusted against certified equipment having a known valid relationship to internationally recognised standards.

The Manufacturer shall prepare a calibration schedule showing equipment type, identification number, location, frequency of checks, method of checking and action to take when results are unsatisfactory.

10.6 Inspection Plan and Procedure

The Inspection Plan, as submitted by the Contractor to the Engineer for approval, shall cover the following:

- Relevant International Standard. For each of the following stages of the work, the acceptance criteria shall be stated.
- The stages of inspection which shall include but not be limited to the following:
  - Tests to review or approve certification of material;
  - Review and approval of manufacturing procedures;
  - Witnessing tests or review and approval of certification of operator's qualification to carry out the work required;
  - Visual and dimensional examination of components;
  - Pressure tests on casings and vessels;
  - Non-destructive examination of materials in progress;
  - Functional tests on sub-assemblies, performance tests, type tests on complete units;
  - Examination of painting, packing and documentation for shipment.

The Engineer will indicate the inspection requirements on the agreed inspection programme in accordance with the following.

Hold point - Requires a mandatory inspection by the Engineer. This inspection or test shall be witnessed by the Engineer and Employer and further progress in manufacture shall not be made until the plant is approved by the Engineer.

Witness point - Inspection or test of material may be carried out by the Engineer and Employer at their discretion.

Document review - Certification of material and functional test shall be approved by the Engineer before despatch from the works.

10.7 Test Certificates

Triplicate sets of all test records, test certificates and performance curves, whether or not they have been witnessed by the Engineer and Employer, shall be supplied to the Engineer for all tests carried out in accordance with the provisions of this Contract.

Sets of all test certificates shall be endorsed with sufficient information to identify the material or equipment to which the certificates refer, and shall carry in the top right hand comer the following reference:

- Employer's name
- Project title
- Contract No.
- Engineer's reference number

All test documentation shall be in the English language.

10.8 Material Tests

The Contractor shall provide test pieces as required by the Engineer to enable him to confirm the quality of the material supplied under the Contract. Such test pieces shall be prepared and supplied free of charge and any cost of the tests shall be borne by the Contractor.

If any test piece fails to comply with the requirements of the appropriate specifications for the material in question, the Engineer may reject the whole of the material represented by that test piece; the Contractor's or Subcontractor's designers and metallurgists will be consulted before any material is so rejected.

If the Engineer is furnished with certified particulars of tests which have been carried out for the Contractor by the suppliers of material, he may, at his own discretion, dispense with the previously mentioned tests.

10.9 General Requirements for Tests at Manufacturers' Works

10.9.1 Testing of Plant

Tests at Manufacturers' works shall include mechanical, electrical and hydraulic tests to ensure that the plant being supplied complies with the requirements of the Specification.

Works tests shall include all routine electrical, mechanical and hydraulic tests in accordance with the relevant IEC or British Standards, except where departures therefrom and modifications thereto are embodied in this Specification.

Should the plant or any portion thereof fail under test to give the required performance, further tests which are considered necessary by the Engineer shall be carried out by the Contractor and the whole cost of the repeated tests borne by the Contractor. This also applies to tests carried out at the Subcontractors' works.

The Employer or its representative or independent inspection agency may witness the tests. Sufficient notice (minimum of 30 working days) shall be given to enable the necessary arrangements to be made.

If the plant, or any portion thereof, fails under test to give the required performance, such further tests which are considered necessary by the Engineer shall be carried out by the Contractor and the whole cost of the repeated tests shall be borne by the Contractor. This also applies to tests carried out at Subcontractors' works.

Tests shall be conducted in accordance with the specified standards. When no standards are specified, the test procedure shall be agreed between the Employer and the Contractor.

Specific details of tests to be carried out at the Manufacturers' works are defined elsewhere in this Specification.

10.9.2 Rejection of Plant

If any item fails to comply with the requirements of this Specification in any respect whatsoever at any stage of manufacture, test, erection or on completion at Site, the Engineer may reject the item, or defective component thereof, whichever he considers necessary, and after adjustment or modification as directed by the Engineer, the Contractor shall submit the item for further inspection and/or test.

In the event of a defect on any item being of such a nature that the requirements of this Specification cannot be fulfilled by adjustment or modification, such item is to be replaced by the Contractor, at his own expense, to the entire satisfaction of the Employer.

10.10 Specific Requirements for Tests at Manufacturers' Factories

10.10.1 Pressure Vessels

a) All pressure vessels shall be designed, fabricated, inspected and tested in accordance with an approved pressure vessel code or standard.
b) An approved method of radiographic or other non-destructive testing shall be used for proving all welding, at all positions of possible high stress concentration, such as large branch welds, and their vicinities after all heat treatment is completed. This shall be done whatever the pro- gramme of non-destructive testing before heat treatment.
c) Hydrostatic test shall be conducted in accordance with BS 5500.

10.10.2 Substation Automation System, Control, Relay Protection and Meter- ing

All equipment for substation automation system, control, relay protection and metering shall be fully assembled at the Manufacturer's works and subject to the complete routine and functional test

For **factory acceptance test** all equipment for substation automation system, control, relay protection and metering, for each substation, shall be fully assembled at the Manufacturer's works and subjected to visual and functional tests

All control and relays and associated equipment shall be routine tested to prove the quality and accuracy. Routine tests shall be in accordance with relevant IEC Recommendations supplemented by ad-

ditional tests as are considered necessary by the Employer. Routine test reports shall be submitted for each relay and piece of equipment. The reports shall record all measurements taken during the tests. All relays shall be subjected to the appropriate routine tests as listed below, the individual tests being as detailed in IEC 60255 or as otherwise agreed with the Employer.

- Accuracy of calibrated pick-up and drop-off levels over the effective range of settings
- Insulation tests
- Accuracy of timing elements
- Correct operation of flag (or other) indicators
- Mechanical requirements, integrity/safety of draw-out units, check of contact pressure and alignment.

10.10.2.1 Wiring

All circuits shall be subjected to the high voltage test specified in the relevant IEC or approved standard. The insulation resistance of all circuits shall be measured before and after any high voltage tests. For AC secondary injection tests a substantially sinusoidal test supply shall be used.

The operating and resetting level (current and/or voltage) and timing of all relays shall be measured over an agreed range of settings for all relays.

For directional relays phase-shifting transformers shall be used to determine the maximum torque angle and the boundaries of operation/restraint.

Other relays shall be fully tested in accordance with the Manufacturer's recommendations.

All DC elements of protection relays shall be tested for operation at 70% rated voltage.

All DC supplies shall be checked for severity of current inrush when energised by switching on or inserting fuses or links.

10.10.2.2 Mechanical Inspection

All panel equipment is to be examined to ensure that it is in proper working condition and correctly adjusted, correctly labelled and that cases, covers, glass and gaskets are in good order and properly fitting.

10.10.2.3 General

Sufficient tests shall be performed on the relays and protection schemes to:

- establish that the correct equipment has been supplied and installed.
- confirm that the various items of equipment have been correctly interconnected.
- confirm performance of schemes designed on the bases of calculation e.g. differential protection.
- to provide a set of figures for comparison with future maintenance values allowing the condition of the equipment to be determined.

10.10.2.4 Secondary Injection

Secondary injection shall be carried out on all AC relays, using voltage and current of sinusoidal wave form and rated power frequency to confirm satisfactory operation and range adjustment.

The polar characteristic of all distance protections shall be recorded at a minimum of 30 degree intervals.

For circulating current protection employing high impedance voltage operated relays, the points of injection for relay voltage setting tests shall be across the relay and stabilizing resistance.

The fault setting for the type of protection is to be established by secondary injection, where it is impracticable to ascertain this value by primary injection. Injection is to be made across the appropriate relay bus wires with all associated relays, setting resistors, and CT's connected.

10.10.2.5 Primary Injection

All current operated relays shall be tested by injection of primary current to record the actual relay setting and as a final proof of the integrity of all secondary connections.

The stability of all differential schemes shall be checked by injection of primary current.

Primary current injection tests are to be carried out by the Contractor and the methods employed for a particular installation are to be agreed with the Engineer.

Tests are to be carried out as follows:

- Local primary injection to establish the ratio and polarity of current transformers as a group, care being taken to prove the identity of current transformers of similar ratio.
- Overall primary injection to prove correct interconnection between current transformer groups and associated relays.
- Fault setting tests, where possible, to establish the value of current necessary to produce operation of the relays.

10.10.2.6 DC Operations

Tests are to be carried out to prove the correctness of all DC polarities, the operating levels of DC relays and the correct functioning of DC relay schemes, selection and control switching, indications and alarms. The correct functioning of all isolation links and fuses shall also be checked.

10.10.2.7 Tests on Load

Tests on load shall also be done to demonstrate stability and operation of protection relays as required by the Engineer.

All tripping, control, alarm and interlocking circuits shall be functionally tested to prove satisfactory and fool-proof operation and/or resetting. The functional and safety aspects of all shorting and/or isolation links, fuses and switches devices shall be proved.

The total burdens connected to all voltage transformer circuits shall be measured and recorded.

The total capacitance of all wiring and apparatus connected to the negative pole of each main tripping battery shall be measured and recorded; the value shall not exceed 10 microfarad.

The continuous current drain of all trip circuit supervision relays shall be measured and shall not be greater than half the minimum current required for tripping. The supervision current shall be measured with the circuit breaker (or other device) both open and closed.

10.10.3 Relays

All relays and associated equipment shall be routine tested to prove the quality and accuracy. Routine tests shall be in accordance with relevant IEC Recommendations supplemented by additional tests as are considered necessary by the Employer. Routine test reports shall be submitted for each relay and piece of equipment. The reports shall record all measurements taken during the tests.

All relays shall be subjected to the appropriate routine tests as listed below, the individual tests being as detailed in IEC 60255 or as otherwise agreed with the Employer.

- Accuracy of calibrated pick-up and drop-off levels over the effective range of settings
- Insulation tests
- Accuracy of timing elements
- Correct operation of flag (or other) indicators
- Mechanical requirements, integrity/safety of draw-out units, check of contact pressure and alignment.

10.10.4 Electrical Instruments and Meters

One instrument and meter of each type and rating shall be subjected to the tests as specified in IEC 60051.

10.10.5 AC Switchboards

Routine tests shall include general inspection and electrical operation tests.

10.10.6 Contactors

One contactor of each type and rating shall be subjected to type tests as specified in IEC 60292-1.

10.10.7 PVC Cable

Each size and rating of PVC cable shall be subjected to type tests as specified in BS 6346. Routine tests are detailed in Section 5 of this document.

10.10.8 Switchgear (Other than GIS)

All circuit breakers shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 62271-100.

For **factory acceptance test** one or at least 20% of the circuit breakers of each type, shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 62271-100.

10.10.9 Disconnectors and Earth Switches

All disconnectors and earthing switches shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 62271-102.

For **factory acceptance test** one or at least 10 % of the disconnectors and earthing switches of each type, shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 62271-102.

10.10.10 Current and Voltage Transformers

All current transformers and voltage transformers shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 60044.

For **factory acceptance test** three or at least 20 % of the current transformers and voltage transformers of each type, shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 60044.

10.10.11 Structures of Electrical Equipment

Sample tests on the assembly and galvanising of the structures shall be carried out. A mechanical type test with the structure loaded with working load multiplied by the appropriate factor of safety shall be carried out.

10.10.12 Surge Arresters

All surge arresters shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 60099-4.

For **factory acceptance test** three or at least 20 % of the surge arresters of each type, shall be fully assembled at the Manufacturer's works and subjected to routine testes according to the IEC 60044.

10.10.13 Batteries and Battery Chargers

Battery:	The Contractor shall demonstrate that the battery will perform the duties specified.
Battery charger:	Routine tests according to IEC 60146 (BS 4417)
DC Switchboard:	Routine tests according to IEC 60439 (BS 5486:Part 1)

Complete charge and discharge tests on each of the combined batteries and chargers shall be conducted and results recorded so as to permit verification of the ampere-hour capacity of the battery.

During these tests the Engineer shall select at random reference cells and the voltage curves thereof shall be checked when the battery is discharged over three and ten hour periods. The alarm levels and the automatic voltage control feature of the charger shall be demonstrated over the specified load range. Where load changeover facilities are included, integrity of the changeover system without break or voltage variations during loading of the standby or test charger shall be demonstrated.

10.10.14 Control Panels

Routine operation tests and insulation resistance tests shall be carried out.

10.10.15 Busbars

Routine tests including millivolt drop tests shall be carried out in accordance with the specified standard.

10.10.16 Instruments

Calibration tests shall be witnessed on all important pressure gauges and other instruments as required by the Engineer.

10.10.17 Power Transformers

Inspection and testing during manufacture shall be in accordance with the General Conditions of Contract and this section of the Specification.

Works tests shall include all routine electrical, mechanical and hydraulic tests in accordance with the relevant IEC Standard, except where departures therefrom and modifications thereto are embodied in this Specification. For Plant not covered by any IEC Standard or specifically mentioned in this Specification, such tests as are relevant shall be agreed with the Engineer.

Should the Plant, or any portion thereof, fail under test to give the required performance, further tests which are considered necessary by the Engineer shall be carried out by the Contractor and the whole costs of the repeated tests borne by the Contractor. This also applies to tests carried out at the Subcontractors' works.

After satisfactory completion of the witnessed tests at the Works, the Plant shall be submitted for the Employer's approval during dismantling preparatory to shipment. No item of Plant is to be despatched to Site until the Employer has given his approval in writing.

All power transformers shall be fully assembled at the Manufacturer's works and subjected to routine testes and special tests

For **factory acceptance test** all power transformers shall be fully assembled at the Manufacturer's works and subjected to repetition of the all routine testes and special tests

10.10.17.1 Main Transformers

Routine Tests
All transformers shall be subject to the following routine tests in accordance with IEC 60076 and the requirements of this Specification.

- Measurement of winding resistance on all tap positions and phases.
- Ratio, polarity and phase relationship.
- Impedance voltage.
- Load loss at normal, maximum and minimum taps.
- No load loss and no load current at normal voltage Un and at +5% Un and at +10% Un.
- Magnetising current at nominal voltage Un and at -5% Un and +5% Un and at +10% Un.
- Insulation resistance.
- Dielectric withstand tests:
  - On uniformly insulated windings with highest voltage Um = 36kV, tests shall comprise:
    - induced over voltage withstand.
    - short duration power frequency voltage withstand.
    - full wave lightning impulse withstand for line terminals.
    - lightning impulse chopped wave at 115% of the full wave level.
  - On non-uniformly insulated windings with highest voltage Um 145 W, tests shall comprise:
    - induced over voltage withstand combined with partial discharge.
    - short duration power frequency voltage withstand.
    - full wave lightning impulse withstand for line terminals.
    - lightning impulse chopped wave at 115% of the full wave level.
  - On non-uniformly insulated windings with highest voltage Um = 245kV, tests shall be carried out according to a combination of methods 1 and 2 and comprise:
    - short duration power frequency voltage withstand.
    - induced line to earth overvoltage withstand test at 460kV (method one routine test).
    - full wave lightning impulse withstand for line terminals.
    - lightning impulse chopped wave, at 115% of the full wave level.
    - induced power frequency overvoltage withstand test with partial discharge measurement.
- Insulation Resistance

Type Tests

- Temperature rise test:
  The test shall be in accordance with IEC 60076-2, and shall be carried out on one transformer of each size and type. Temperature-rise tests shall be conducted on the tapping corresponding to the maximum losses.
- Noise level tests:
  A noise level test to IEC 60076 shall be carried out on one transformer of each type specified under items 1 and 2 in accordance with IEC 60551.

Special Tests

- Measurement of Zero Phase - Sequence Impedance
  The test shall be in accordance with IEC 60076-1 Clause 8.7 and shall be carried out on one transformer of each type.

10.10.17.2 Voltage Control Equipment

Routine Tests

Each finished tap changer shall be subjected to the routine tests specified in JEC.214 but in addition the mechanical test shall be carried out at rated voltage and no load.

Type Tests

Shall be carried out entirely in accordance with IEC 60214 except that evidence of the service duty type test shall be in excess of 100,000 operations.

10.10.17.3 Magnetic Circuit

Routine Tests

Each core completely assembled shall be tested for one minute at 2,000V AC between core bolts, side plates, structural steelwork and core at the core and coil stage. After the transformer is tanked and completely assembled, a further test shall be applied between the core and the earthed structural steelwork to prove that the core is earthed through the removable link, at one point only.

10.10.18 Outdoor Bushing Assemblies with Porcelain Insulators

Hollow insulators tested in accordance with IEC 60233, complete bushings in accordance with IEC 60137.

Routine Tests

Routine tests shall include:

- Oil leakage test
- 50Hz dry withstand test
- Power factor/voltage test
- Partial discharge test on all bushings of which the major insulation is either oil impregnated paper or resin impregnated paper.

10.10.19 Tanks

Routine Tests

Oil Leakage:All tanks, conservators and oil filled compartments, which are subjected in service or during maintenance to oil pressure, shall withstand without leakage a hydraulic pressure test equal to69 kN/m² or the normal pressure plus 34kN/m² whichever is the greater, for 24 hours during which time no leakage or oil ingress into normally oil free spaces shall occur.

10.10.20 Cooling Plant

Routine Tests

- Coolers: Pressure test to be as specified above.
- Motors and Control Gear: To the requirements as specified.

10.10.21 Gas and Oil-Actuated Relays

Routine Tests

- Oil leakage:When subject to an internal oil pressure of 207kN/m² for fifteen minutes.
- Gas collection
- Oil surge
- Performance test under service conditions.Voltage: 2kV for one minute between electrical circuits and casing.

10.10.22 Galvanizing

Routine Tests

To the requirements of BS 443 or BS 729 whichever is applicable

10.10.23 Earthing Transformers

Routine Tests

- Measurement of winding resistance
- Ratio, polarity and phase relationships
- Measurement of impedance voltage
- Measurement of loss
- Short duration power frequency voltage-withstand test
- Induced overvoltage withstand test
- Insulation resistance of each winding

Special Tests

- Measurement of zero-phase sequence impedance

10.10.24 Fibre Optic Multiplexer Equipment

Works tests shall be in accordance with the IEC standard.

10.10.25 Deleted

10.10.26 Telephone Equipment

Comprehensive system testing including subscriber to subscriber tests with transit working shall be carried out with the exchanges fed from normal, high and low volts. Hunting, alternative routing and priority facilities, etc., shall be checked.

10.10.27 Teleprotection Equipment

Back to back tests shall be carried out to determine the satisfactory operation of the teleprotection equipment.

These tests shall be via fibre optic multiplexer equipment links, simulated lines or communication channels dependent on the actual application.

Random tests shall be performed which demonstrate to the Engineer the ability of the equipment to operate satisfactory (reliability) and within the specified time limits (speed) in the presence of interfering signals or noise and also the ability not to malfunction (security) in the presence of interfering signals or noise at levels likely to occur when the equipment is installed in the power system substations.

10.10.28 Transducers

Transducers shall be tested in accordance with IEC 60688-1.

10.11 Dismantling Prior to Shipment

After the satisfactory completion of all tests at the factory, the plant shall be submitted for the Engineer's approval during dismantling preparatory to shipping. No item of plant shall be despatched to site until the Engineer has given approval in writing.

10.12 Inspection and Testing during Site Erection

10.12.1 General

The Contractor shall be responsible for the submission to the Engineer of all plant supplied under the Contract for inspection and testing during site erection, to ensure correct erection and compliance with the Specification.

During the course of erection, the Contractor shall provide access as required by the Engineer for inspecting the progress of the works and checking its accuracy to any extent that may be required.

The Contractor shall provide, at his own cost, all labour, materials, stores, and apparatus as may be requisite and as may be reasonably demanded to carry out all tests during erection, whether or not the tests are specifically referred to in this specification.

Tests on completion of erection shall be carried out by the Contractor in accordance with the General Conditions of Contract. The Contractor shall provide all necessary test equipment to carry out the site tests, but where required in the Schedule of Prices, shall include the cost of the equipment so that the Employer may have the option to buy the equipment on completion of the Contract.

The Contractor shall submit a written programme of tests and checks according to this Clause for the approval of the Engineer.

A brief description of all tests and testing procedures shall be provided before tests commence and the method of testing, unless otherwise specified, shall be agreed with the Engineer.

The Contractor shall provide experienced test personnel and testing shall be carried out during normal working hours as far as is practicable. Tests which involve existing apparatus and outages may be carried out outside normal working hours. The Contractor shall give sufficient notice to allow for the necessary outage arrangements to be made in conformity with the testing programme.

The Contractor shall advise the Engineer in writing, at the time of commencement of site erection, of the site supplies which will be required for the operation of the test equipment, to enable the Engineer to arrange accordingly or to agree alternative arrangements should this be necessary.

The Contractor shall record the results of the tests clearly, on an approved form and with clear reference to the equipment and items to which they refer, so that the record can be used as the basis for maintenance tests during the working life of the equipment. The required number of site test result records shall be provided by the Contractor to the Engineer as soon as possible after completion of the tests.

No tests as agreed under the programme of tests shall be waived except upon the instruction or agreement of the Engineer in writing.

The Contractor's test equipment shall be of satisfactory quality and condition and, where necessary, shall be appropriately calibrated by an approved authority at the Contractor's expense. Details of the test equipment and instruments used shall be noted in the test sheets in cases where the instrument or equipment characteristics can have a beating on the test results.

The testing requirements detailed under this Specification may be subject to some variation upon the instruction or agreement of the Engineer where necessitated by changed conditions at Site or by differing design, manufacture, or construction techniques.

The Bidder is required to submit proposals for site dielectric tests and to include in his price the costs of such tests and of such equipment as deemed necessary.

10.12.2 Mechanical Equipment

The extent of testing during erection shall include, but not be limited to, the following:

a) Checking the accuracy and alignment of plant erected. The accuracy shall comply with the relevant standards, the specification or the plant Manufacturer's requirements as may be applicable or, where no requirements exist, to a standard to be agreed between the Engineer and the Contractor.

b) Checking the alignment of rotating equipment to the Manufacturer's requirements.

c) Non-destructive testing of site welds as required by the relevant standard and as detailed in this specification.

d) Hydrostatic testing of pipework systems at a pressure of 1.5 times the design pressure but not less than 4.5 bar for a period of 2 hours, or at such other conditions as may be required by the pipework design code.
Air piping shall be subjected to an air pressure test rather than a hydrostatic test.

e) Site fabricated tanks and vessels shall be subjected to hydrostatic tests in accordance with the relevant standards.

f) Hydrostatic tests shall be carried out on steam generating units in accordance with the boiler design code.
After the hydrostatic test is carried out, the complete assembly shall be drained and any non-drainable sections shall be injected with an oxygen-absorbent chemical and elements plugged.

g) Pressure vessels and other parts, including pipework, that are made up on site and are subject to pressure or vacuum under normal or abnormal working conditions, shall be subjected to a site hydraulic test at approved pressures and for approved periods in accordance with the rele- vant standard. Where no appropriate standard exists the hydraulic test pressure shall not be less than 1.5 times design pressure or at such pressure to be agreed by the Engineer.
Should, in the opinion of the Contractor and with the agreement of the Engineer, an hydraulic test be impracticable due to excessive loading on foundations other than steel, an air pressure test may be employed in accordance with requirements set out in BS 5500.
Vacuum tests shall be carried out at the maximum test vacuum obtainable and the condition maintained for a period of two hours with the system isolated. The Contractor shall state in the Schedule of Guarantees the fall in vacuum anticipated during this period but the rate of fall shall not exceed that which would occur due to the designed air leakage rate being attained.

h) Calibration checks on all instrumentation.

i) Tests to demonstrate the correct functioning of the control loops, protective devices, interlocks and alarms.
Flushing out of all pipework systems which have not been fully cleaned and sealed before shipping to site.

k) Other tests as specified which have not been previously conducted.

10.12.3 Electrical Equipment

10.12.3.1 General

A general check of all the main switchgear and ancillary equipment shall be made and shall include a check of the completeness, correctness and condition of earth connections, labelling, arcing ring and horn gaps, clearances, painted surfaces, cables, wiring, pipework, valves, blanking plates and all other auxiliary and ancillary items. Checks shall be made for oil and gas leaks and that insulators are clean and free from external damage. A check shall be made that loose items which are to be handed over to the Employer e.g. blanking plates, tools, spares, are in order and are correctly stored or handed over.

The following general tests are to be carried out on electrical equipment after erection at site:

- Routine high voltage tests to the appropriate IEC Standard. Where no relevant standard exists, tests shall be agreed with the Engineer.
- Insulation resistance tests on all electrical equipment.
- Continuity and conductivity resistance tests.
- Test operation of alarm and tripping, devices to local and remote.
- Rotational tests on all motors.
- Polarity tests on CTs and VTs.
- Oil tests.
- Grounding system and electrode tests.
- Ratio, Vector Grouping and magnetising current tests on each transformer.
- Calibration of winding and oil temperature devices.
- Vector group and phasing tests on VT circuits.
- Magnetisation current/voltage tests and winding resistance tests on all current transformers.
- Primary and secondary injection tests on relays, protection devices and equipment.

10.12.3.2 Earthing System

Tests shall be made on the effectiveness of the bonding and earthing which will include conductivity tests on selected joints, on the main earthing system, and at the connections to equipment and structures. Checks shall also be made on precautions taken to avoid corrosion. attack on the earthing system.

Test probes at approximately 300 and 600 metres separation will normally be required to effectively test the earthing system. The use of transmission line conductors may be arranged to simplify these testing procedures.

The earth resistance shall be measured during the installation and on completion as follows:

- of each earth rod after driving
- of the earth grid after completion and backfilling of the trenches
- of each group of earth rods or earth point after completion of the connection from the test link terminal
- of the completed installation without any connections outside the substation

The tests shall be carried out by a method and with equipment approved by the Engineer. All tests are to be witnessed and the equipment and method used recorded with the test results.

The Contractor may also be called upon to provide assistance in the measurement of earth resistance after earth connections to the system have been completed.

10.12.3.3 Control Relays and Metering Panels, Instruments and Protective Devices

a) Wiring

- After complete erection and cabling, all circuits shall be subjected to the high voltage test specified in the relevant IEC or approved standard.

- The insulation resistance of all circuits shall be measured before and after any high voltage tests.
- For AC secondary injection tests a substantially sinusoidal test supply shall be used.
- The operating and resetting level (current and/or voltage) and timing of all relays shall be measured over an agreed range of settings for all relays.

- For directional relays phase-shifting transformers shall be used to determine the maximum torque angle and the boundaries of operation/restraint.
- Other relays shall be fully tested in accordance with the Manufacturer's recommendations.
- All DC elements of protection relays shall be tested for operation at 70% rated voltage.
- All DC supplies shall be checked for severity of current inrush when energised by switching on or inserting fuses or links.

b) Mechanical Inspection

All panel equipment is to be examined to ensure that it is in proper working condition and correctly adjusted, correctly labelled and that cases, covers, glass and gaskets are in good order and properly fitting.

c) General

Sufficient tests shall be performed on the relays and protection schemes to:

- establish that the equipment has not suffered damage during transit.
- establish that the correct equipment has been supplied and installed.
- confirm that the various items of equipment have been correctly interconnected.
- confirm performance of schemes designed on the bases of calculation e.g. differential protection.
- to provide a set of figures for comparison with future maintenance values allowing the condition of the equipment to be determined.

d) Secondary Injection

- Secondary injection shall be carried out on all AC relays, using voltage and current of sinusoidal wave form and rated power frequency to confirm satisfactory operation and range adjustment.
- The polar characteristic of all distance protections shall be recorded at a minimum of 30 degree intervals.
- For circulating current protection employing high impedance voltage operated relays, the points of injection for relay voltage setting tests shall be across the relay and stabilizing resistance.
- The fault setting for the type of protection is to be established by secondary injection, where it is impracticable to ascertain this value by primary injection. Injection is to be made across the appropriate relay bus wires with all associated relays, setting resistors, and CT's connected.

e) Primary Injection

- All current operated relays shall be tested by injection of primary current to record the actual relay setting and as a final proof of the integrity of all secondary connections.
- The stability of all differential schemes shall be checked by injection of primary current.
- Primary current injection tests are to be carried out by the Contractor and the methods employed for a particular installation are to be agreed with the Engineer.
- Tests are to be carried out as follows:
  - Local primary injection to establish the ratio and polarity of current transformers as a group, care being taken to prove the identity of current transformers of similar ratio.
  - Overall primary injection to prove correct interconnection between current transformer groups and associated relays.
  - Fault setting tests, where possible, to establish the value of current necessary to produce operation of the relays.

f) DC Operations

Tests are to be carried out to prove the correctness of all DC polarities, the operating levels of DC relays and the correct functioning of DC relay schemes, selection and control switching, indications and alarms. The correct functioning of all isolation links and fuses shall also be checked.

g) Tests on Load

- Tests on load shall also be done to demonstrate stability and operation of protection relays as required by the Engineer.
- All tripping, control, alarm and interlocking circuits shall be functionally tested to prove satisfactory and fool-proof operation and/or resetting. The functional and safety aspects of all shorting and/or isolation links, fuses and switches devices shall be proved.
- The total burdens connected to all voltage transformer circuits shall be measured and recorded.
- The total capacitance of all wiring and apparatus connected to the negative pole of each main tripping battery shall be measured and recorded; the value shall not exceed 10 microfarad.
- The continuous current drain of all trip circuit supervision relays shall be measured and shall not be greater than half the minimum current required for tripping. The supervision current shall be measured with the circuit breaker (or other device) both open and closed.

10.12.3.4 Batteries and Chargers

Tests shall be carried out on the batteries and chargers to confirm the charger ratings and adjustment, the battery and charger alarm systems and battery capacity.The open-circuit cell voltages of the batteries when fully charged shall be recorded.The insulation to earth of the complete DC installation shall be tested.

10.12.3.5 Power Cables

Each completed circuit shall be tested for continuity and insulation resistance.

10.12.3.6 Control and Instrumentation Equipment

The following general tests shall be performed on control and instrumentation equipment at site:

- High voltage testing of all circuits, as specified in the relevant IEC or approved standard.
- Insulation resistance testing of all circuits.
- Functional tests of all tripping, control, alarm and interlocking circuits.
- The testing of all equipment in accordance with the Manufacturer's instructions or as advised by the Engineer.

10.12.3.7 Transformers and Ancillary Equipment

The following tests shall be performed:

- Insulation resistance tests on bushings.
- Insulation resistance test at 500V between core and core clamping structure.
- Voltage withstand tests on insulating oil to BS 148.
- Ratio.
- Phase relationship.
- Magnetisation characteristics of current transformers of winding temperature devices.
- Calibration of winding temperature devices.
- Tap Selector and Diverter Switch alignment.
- Calibration of automatic voltage control equipment.
- Proving tests as necessary on control schemes.
- Measurement of winding resistance on all taps and phases.

Where applicable the above tests shall also be carried out on earthing transformers.

10.13 Staffing

During pre-commissioning the Contractor shall provide all necessary supervisory and operating staff.

The only involvement of the Employer's staff will be in accordance with the training and instruction as in this specification.

During the commissioning phase, the Employer's operating staff will operate plant and equipment under the supervision of the Contractor's supervisors.

The Contractor shall have satisfied himself as to the capability of the Employer's operators to carry out such operations as he may direct and shall remain responsible for the successful performance of such operations. Throughout the whole of the Commissioning Period the Contractor shall provide suitably qualified and experienced operating staff, who shall instruct the Employer's staff in the correct operating procedures.

The Contractor shall provide a team of suitably qualified and experienced engineers and technicians to pre-commission and commission the overall plant. The Contractor shall also ensure that a suitably qualified commissioning engineer from the respective Manufacturer's own service organisation shall visit the site to check the erection or installation of each significant plant item, and to supervise the commissioning of the plant item until the basic functioning of the item has been demonstrated to the Engineer's satisfaction.

At all times the Contractor shall ensure that his staff and any Subcontractor's or seconded staff, observe all prescribed safety rules and permit systems.

10.14 Taking Over

After satisfactory completion of the tests on completion, the Engineer will issue a Taking Over Certificate for the plant. The issue of any such certificate shall not however relieve the Contractor of any of his responsibilities in respect of proving that the performance of the plant meets the guaranteed values.
The Taking Over Certificate shall make reference to a schedule of outstanding minor defects and omissions which have been accepted by the Engineer as not affecting the full and safe operation of the plant. The Contractor shall rectify such defects and omissions not later than 3 months after Taking Over.

The date certified in the Taking Over Certificate shall be the date on which the tests on completion were completed.

10.15 Defects after Taking Over

In accordance with the General Conditions of Contract, the Contractor shall be responsible for making good defects or damage which may appear or occur during a 12 month guarantee period from the date

certified in the Taking Over Certificate.

Following any remedial work or replacement of any component part during the 12 months, the guarantee period for such a part shall be extended, commencing from the date at which the remedial work was completed.

Immediately prior to the completion of this period the Employer reserves the right to request the Contractor to open up for inspection the whole or any part of the Plant. The Employer will provide the labour to work under the direct supervision of the Contractor's representative for the purpose of such inspection.

The Contractor shall submit for approval the arrangements he intends making under this Contract for the making good of defects and for providing the supervisory service detailed above.

10.16 Final Acceptance Certificate

Application for the Final Certificate may be made to the Engineer after the Contractor has ceased to be under any obligation under the Contract. This shall include the submission of final contract record drawings and fully bound version of the Installation, Operation and Maintenance Manuals. If a Taking-Over Certificate has been issued in respect of any Section or Portion of the Works, only one Final Certificate will be issued after all the said obligation has ceased. Final Certificate will be issued after all the said obligation has ceased. Where the Contractor has carried out replacements or renewals to the Works, the Contractor's obligations shall continue, but the right of the Contractor to apply for a Final Certificate other than for the replacements or renewals shall not be affected by that fact.

11. Power Cables and Cable Terminating Accessories

11.1 Scope

This chapter describes the general technical requirements for the 230 kV power cables & cable terminating accessories and installation of cables and shall be read in conjunction with the project requirements, schedules and drawings in the specification.

The 230 kV cables and accessories shall be suitable for connecting the 400/230/33 kV power transformers with 230 kV AIS switchgear.

The Contractor shall demonstrate that the cables have been designed, built and installed in accordance with the relevant international standards and the specification. It shall also operate and perform on a site in accordance with the requirements of the specification and in the environment defined therein.

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

The scope of work also includes supply and installation of cable sealing ends at both ends including terminating insulators.

11.2 Standards

The cable and accessories shall comply with this specification and the latest version of relevant IEC, BS or approved equivalent.

11.3 Conditions of Operation

All cables shall be suitable for operation, at the guaranteed continuous ratings specified, throughout all seasons of the year. The nominal system voltage to which the cables will be connected is 230kV and the highest operating voltage Um will be 245kV.

Cable shall be designed to operate continuously at temperature of 90°C. Each conductor and the metal sheath/screen shall be capable of carrying the specified fault current for the specified time and its final temperature shall not exceed 250°C. Adequate measure should be taken to protect against ingress of moisture and water.

Short circuit earth fault rating of cable metal sheath or metallic screen for 230 kV cable shall be 50 kA for 1sec. respectively.

The maximum continuous current carrying capacity and maximum permissible conductor temperature, and the factors for determining such rating and temperature, shall be based on IEC recommendation

No. 287 and subsequent amendments, and all conditions obtaining on Site. The following conditions for the design of the cables shall be assumed:-

Transmission capacity for 230 kV cable circuit: 520 MVA

Other conditions for cables laid in concrete ducts/tunnels/buried pipes shall be assumed:

- Max. ambient air temperature: 45°C
- Continuous conductor temperature: 90°C
- Max. conductor temperature under fault: 250°C

The Contractor shall confirm that the cable sizes are adequate for the required circuit ratings based on the specified foregoing parameters, and he shall also confirm that the cables are adequate for the short-circuit requirements specified. The Contractor will be required to produce cable design calcula- tions to verify that the selected cable sizes are suitable for the selected cable laying conditions in con- crete cable ducts, tunnels or buried pipes.

If the Contractor considers that the conditions and the proximity to other power cables, spacing and method of installation are likely to reduce the maximum current carrying capacity he shall increase the cable conductor cross section accordingly.

The conductor section of the cable circuits shall be adequate for carrying the specified short-circuit current when operating under the specified load conditions without deterioration of the dielectric or other component materials of the cable.

11.4 Type Approval

Cables and accessories shall have satisfactorily passed type approval tests in accordance with theSpecificationanddetailsofthecabledesignsofferedshallbegiveninthe Schedule of Particulars and Guarantees. Type test reports shall include cable design details and design drawings of each jointing accessory included in the type test.

The Contractor shall certify that the cables and/or accessories offered will be identical in all essential particulars in respect of design, materials and workmanship with the cables and/or accessories for which type approval certificates are offered in support of this bid.

The Contractor shall also ensure that all materials used will be subjected to and shall have satisfactorily withstood such tests as are customary in the manufacture of the types of cable specified.

Records of such tests shall be available for inspection, if required by the Engineer.

11.5 Cable Lengths

Cables shall be supplied in maximum drum lengths bearing in mind the transport limitations in gaining access to the site. Cables shall be installed in maximum possible lengths and straight through jointing between shorter lengths will not be permitted.

The cable routes on the drawings attached to the Bidding Documents are provided for information only, and it is Contractor's responsibility to establish the exact quantities of cables and accessories required to complete the whole of the works as described in the Specification.

11.6 Cable Drums

Cable drums shall be non-returnable and shall be made of steel suitably protected against corrosion. They shall be lagged with closely fitting battens in accordance with the relevant BS or equivalent IEC standard.

Each cable drum shall bear a distinguishing number on the outside of one flange. Particulars of the cable, i.e. voltage, conductor size and material, number of cores, type, length, gross and net weights shall also be clearly shown on one flange. The direction of rolling shall be indicated by an arrow on both flanges. The method of drum marking shall be to the Engineer's approval.

Cable maintenance lengths and spare lengths shall be wound on to steel drums before they are handed over to the Employer's stores. Particulars of the cable(as stated above) shall be clearly marked on one flange.

11.7 Spare Cable

In addition to the cable maintenance lengths supplied against the Schedule of Spares the Employer shall have the option to purchase from the Contractor at the rates stated in the Schedule any spare cut lengths of cable for future maintenance purposes.

Brass or other approved sealing caps of the correct size shall be supplied for each end of spare cut cable lengths to enable them to be properly stored for future maintenance purposes. The Contractor shall be responsible for the immediate sealing of such cut lengths and the cost thereof shall be deemed to be included in the contract price.

11.8 Special Tools

Special tools used for the purpose of the cable installation, they shall be handed over to the Employer's stores after the taking over of the installation.

Price for such special tolls is to be considered as included in the price schedule.

11.9 Cable Jointing Instructions and Drawings

Copies of the instructions for the jointing of each type of cable terminating and jointing accessories supplied shall be submitted to the Engineer for approval before any work is commenced at site. One copy of each instruction shall be bound into each copy of the Operating and Maintenance Instructions to be supplied to the Engineer at the completion of the Contract for the use of the Employer.

The following drawings shall be submitted by the Contractor for approval by the Engineer. "As installed" drawings of cable routes shall be drawn to a scale of 1/200. The route shall be dimensioned in such manner that it may be used for pinpointing accurately the cables in the future. All drawings shall be submitted for approval before the issue of the Taking-Over certificate.

11.10 Cable Specification

11.10.1 General

This Specification applies to single core cables with triple extrusion type solid dielectric. They shall be generally manufactured in accordance with the relevant International Electrotechnical Commission Publication (IEC) and British Standard (BS) where applicable.

11.10.2 Conductors

Conductors shall be of stranded plain annealed copper wires to IEC or BS filled to make the cables longitudinally watertight by extrusion during stranding. This shall be to prevent ingress of water into the cable should the outer sheath become damaged. The allowable operating temperature of conductor and waterproofing shall be 90°C.

11.10.3 Conductor Screen

Semi-conductive tape for preventing ingress of semi-conductive XLPE and gluing onto the stranded conductors temperature resistance up to 250°C. Semi-conductive extruded cross-linked material to provide a smooth cylindrical equi-potential surface to which the insulation can be intimately bonded. The material shall be compatible in all respects with its conductor and insulation materials.

11.10.4 Insulation

Cross-liked polyethylene (XLPE) melted together with the conductor screen capable to operate at continuous conductor temperature of 90°C and short circuit temperature of 250°C. Cross-linking process using curing is not permitted, dry process shall be given.The insulation of the completed cable shall be substantially free from voids and contaminants.

11.10.5 Insulation Screen

Semi-conductive compound of extruded layer firmly bonded to the XLPE insulation. The conductor screen, the insulation and the insulation screen are to be extruded in a single process to keep the interface smooth.

11.10.6 Metallic Screen

Where the cable core screens are inadequate to meet the earth fault current specified, a metallic layer of adequate cross-sectional area shall be included in the design applied over the screen. The metal-

liclayer shall be Copper screen with counter helix filled with swelling powder sheathed in accordance with latest BS or IEC Publication.

11.10.7 Intermediate Layer

An intermediate layer of suitable compound shall be provided in between metallic screen and aluminium sheath if necessary.

11.10.8 Corrugated Seamless Aluminium Sheath

Metallic sheath shall consist of the extruded corrugated seamless aluminium sheath. Aluminium used for the sheath shall have the minimum purity of 99.5% and shall be of best quality metal free from pinhole flaws and other imperfections. The minimum thickness at any point shall not fall below 85% of the specified nominal thickness by more than 0.1 mm.

11.10.9 MDPE Outer Sheath

After applying the bitumen compound over the aluminium sheath, the extruded MDPE outer sheath shall be applied.

The nominal thickness of outer sheath shall be not less the specified value. The minimum thickness at any point shall not fall below 85% of the specified nominal thickness by more than 0.1mm.

An outer graphite coating shall be applied to outer sheath as an electrode for the voltage test on the extruded outer sheath.

11.10.10 Identification of Cable

The outer PVC sheath of all cables shall carry the following identification marks in three meter intervals approximately.

"Electric Cables- 230000 Volts/33000 Volts and cross section in mm² cu. PGCB, the name of the manufacture and the year of fabrication."

The letters and numerals shall comply with IEC or BS Publication.

11.11 Sealing and Drumming

Immediately after the works tests, both ends of the cable shall be sealed against the ingress of moisture, dirt and insects and the end projecting from the drum shall be adequately protected against mechanical damage during handling. The cable drums shall be arranged to take a round spindle and be lagged with strong, closely fitting so as to take a round spindle and be lagged with strong, closely fitting battens so to prevent damage to the cable. Only steel cable drum shall be used.

The complete cable shall be rolled on steel cable drums capable of withstanding the rough handling during transport without damage of the cable and enabling easy and safe unrolling of the cable during erection.

Each drum shall have marked in indelible point on both flanges, the following indications besides the shipping instructions.

- Destination
- Type of cable
- Exact length
- Net and gross weight
- Trade mark
- An arrow pointing in the direction of unrolling.

11.12 Terminating Accessories

Detailed drawings showing the types of cable sealing ends, terminal boxes and glands proposed for the installation shall be submitted at the time of Bidding. All cable sealing ends and terminal boxes shall be designed with jointing faces below compound level which will ensure the retention of the filling medium and/or cable compound under operating conditions and exclude the entry of air, dust or mois- ture. Cable sealing ends and terminal boxes designed for use with fluid or semi-fluid filling media shall have fanged joints, the faces of which shall be machined.

An earthing strip shall be provided on all boxes terminating lead sheathed cables.

The external dimensions, fixing cables and terminal arrangements for all sealing ends and terminal boxes shall be agreed with the Engineer.

Sealing ends and terminal boxes shall be provided with all necessary fittings, including external flexi- ble connections as required. The design of flexible connections shall be to approval.

Drain plugs shall be of ample size to permit the filling medium to be removed. The contact faces of the cable sockets shall be thoroughly cleaned, the lugs shall be placed in the most suitable positions and arranged as required to avoid unnecessary bending of cable cores inside the box. Provision shall be made for earthing the body of the box, and for expansion of the conductors in the box. Provision shall also be made for the expansion of the filling medium and arrangements made to prevent the formation of air spaces when filling.

11.13 Installation of Cable

11.13.1 Cable Tunnels and Trenches with Pits, Ducts and Drains

The Contractor shall design and construct cable tunnels required for connecting 230 kV power cables. Width and height of cable tunnels shall conform to required cable spacing and working spaces. The structure of cable tunnels is reinforced concrete and must be designed enough bearing capacity cause by some parts of cable tunnel are under heavy equipment.

The Contractor shall design and construct all trenches required for the work. The depth of the cable trenches shall be minimum 1.5 meter from the Substation switchyard, finished level and the width shall conform to required cable spacing and working spaces.

The thickness of cable tunnel or trench wall and floor shall be minimum 150mm and should be designed to withstand the subsoil water pressure.

Cables in cable tunnels or trenches shall be laid on cable supports at every ½ (half) meter interval.

Cable trenches shall be covered with concrete trench covers. Trenches will be built with the top edge of the walls 50mm above the finished switchyard level.

The cable tunnels and trenches shall have a suitable bed slope with sufficient number of drainage pits so that water could be drained off naturally as well as by artificial means.

The removable trench covers shall be of recast reinforced concrete adequately designed to safely withstand a load of 2,500 N at the centre of each cover. The trench covers shall be of such size as to facilitate their handling by manual labour.

11.13.2 Supports and Racks

Cable laid supports and racks together with fixing clamps, bolts,nuts and screws for outdoor installations and in outdoor concrete lined trenches shall be of hot dip galvanised steel.

Cable support and rack designs shall be submitted for the written approval of the Engineer before Manufacturer or erection.

The single core cables shall be clamped to the racks with smooth finish split packing pieces or cleats with bores of the correct size for the cable diameters. The cleats shall be of Silicon aluminium, glass filled nylon or other tough non-hygroscopic or non-magnetic material. Wooden cleats are prohibited.

11.13.3 Bonding

The cables shall be installed as an insulated sheath system. Single core cable sheaths may either be solidly bonded (single bonding).

Bonding leads shall be of sufficient cross sectional area to carry the maximum imposed short circuit current level. A schematic diagram detailing the proposed bonding systems and stating bonding leads cross section shall be submitted with the Bid.

11.14 Tests

11.14.1 Type Tests

The cable shall be tested and shall satisfy the most recent relevant IEC publications.The tests need not be carried out again if they can be provided by already existing type tests reports of recognized laboratories.If the cable is not yet type tested, the relevant tests shall be carried out.

11.14.2 Routine/Sample Tests

The cable shall be tested and shall satisfy the most recent relevant IEC Publication.

11.14.3 Tests at Site

After completion of the erection and before commissioning, each cable shall be submitted to the following test:

- Verification of the proper and complete erection of the cable and the terminals.
- Verification of the proper phase displacement.
- Verification of the proper earthing of the sheath.
- DC voltage test.
- AC voltage test.

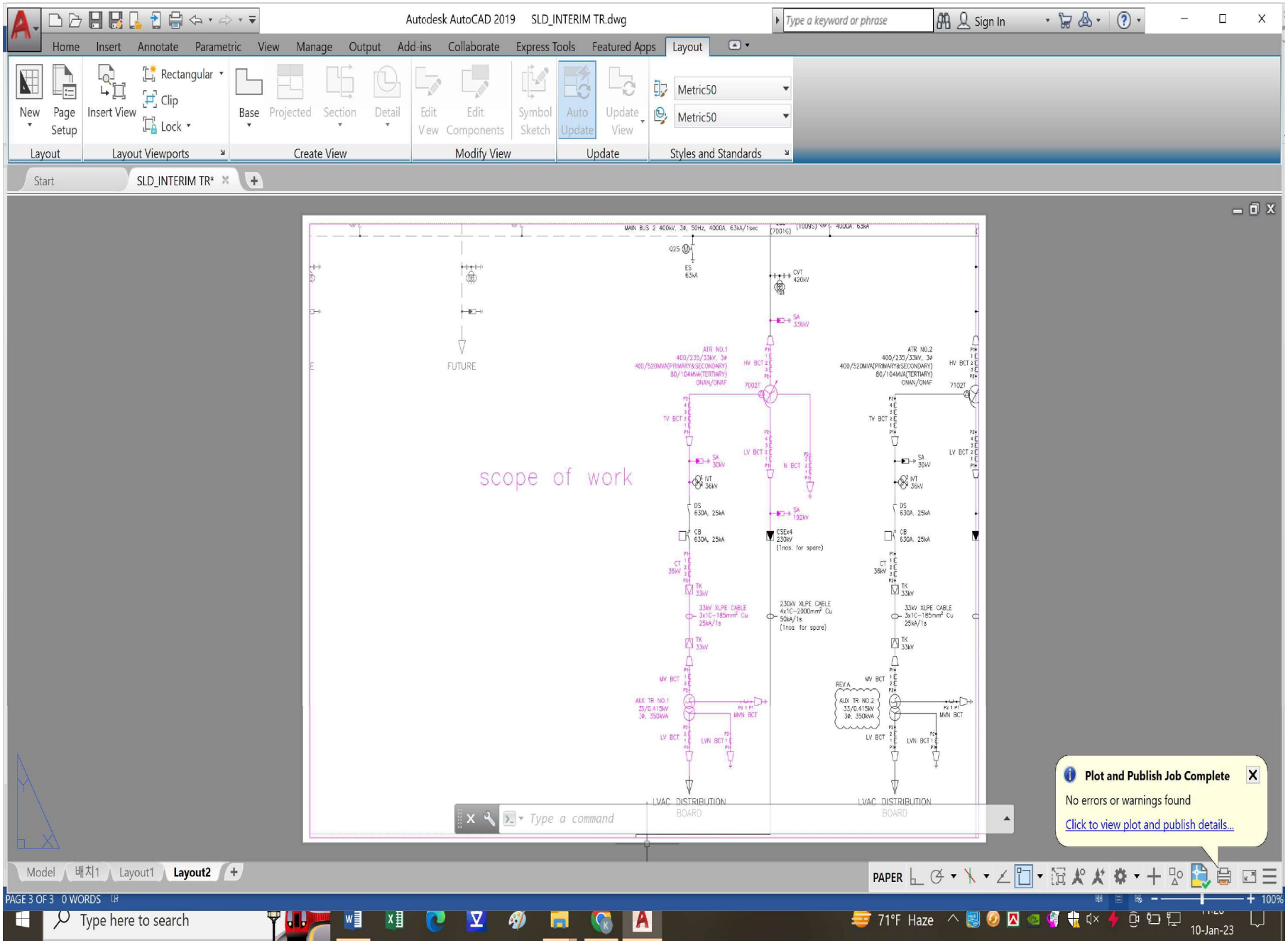
11.15 Earthing System

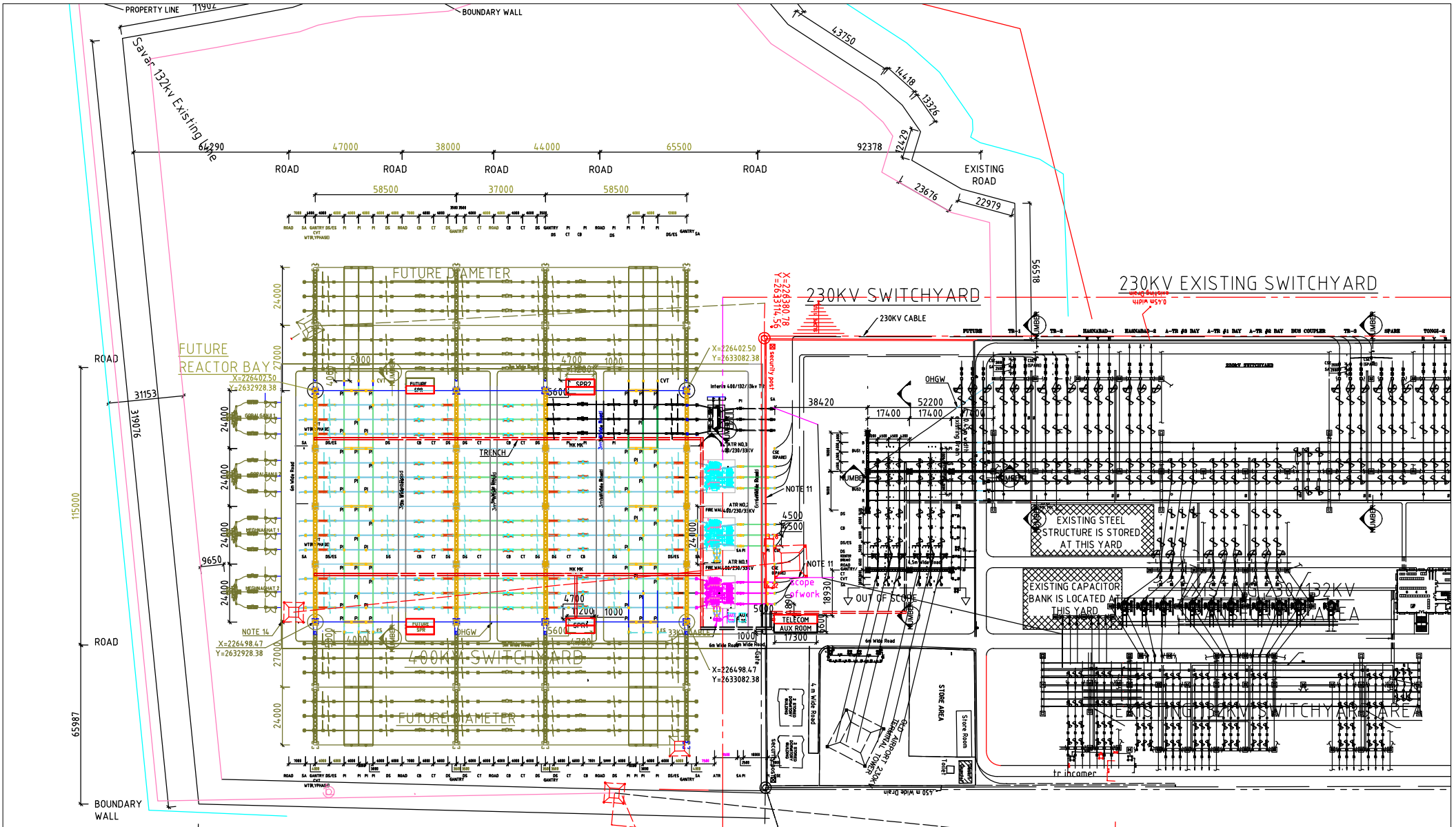
The cable sheath for single bonding of cable and cable end termination structures shall be earthed at earthing mat by extending the earthing system.

12. Drawings

The drawings provided in this section are solely for the purpose of bid information and bid preparation. They present the typical details of the project facilities and plant requirements for the following.

List of Bid Drawings in annexure _B


Autodesk AutoCAD 2019 SLD_INTERIM TR.dwg
Type a keyword or phrase
Sign In
Home Insert Annotate Parametric View Manage Output Add-ins Collaborate Express Tools Featured Apps Layout
New Page Setup Insert View Rectangular Clip Lock Base Projected Section Detail Edit View Edit Components Symbol Sketch Auto Update Update View Metric50 Metric50
Layout Layout Viewports Create View Modify View Update Styles and Standards
Start SLD_INTERIM TR*
scope of work
FUTURE
ATR NO.1
400/235/33kV, 3Φ
400/520MVA(PRIMARY&SECONDARY)
80/104MVA(TERTIARY)
ONAN/ONAF
ATR NO.2
400/235/33kV, 3Φ
400/520MVA(PRIMARY&SECONDARY)
80/104MVA(TERTIARY)
ONAN/ONAF
33kV XLPE CABLE
3x1C-185mm² Cu
25kA/1s
230kV XLPE CABLE
4x1C-2000mm² Cu
50kA/1s
(1nos. for spare)
LVAC DISTRIBUTION BOARD
LVAC DISTRIBUTION BOARD
Type a command
Plot and Publish Job Complete
No errors or warnings found
Click to view plot and publish details...
Model 배치1 Layout1 Layout2
PAPER
PAGE 3 OF 3 0 WORDS
100%
Type here to search
71°F Haze
10-Jan-23



ES

ALL DIMENSIONS ARE IN MM.
SOLID LINE IS UNDER THIS PROJECT
DOTTED LINE AND SHADED LINE IS OUT OF SCOPE OR FUTURE OR EXISTING
THE OVERHEAD GROUND WIRE(OHGW) TYPICALLY SHOWN ON THIS DRAWING WILL BE FIXED BY LIGHTNING PROTECTION PLAN.
HEIGHT OF FOUNDATION WILL BE FSL+200.
SPACING OF BUNDLE CONDUCTOR : 400KV = 300MM, 230KV = 200MM.
MINIMUM CLEARANCE ARE AS PER SPECIFICATION

CLEARANCE (mm)	400KV	230KV	33KV
MINIMUM CLEARANCE BETWEEN LIVE METAL AND EARTH(PE)	3500	2100	380
MINIMUM CLEARANCE BETWEEN LIVE METAL AND DIFFERENT PHASES(PP)	4000	2400	430
MINIMUM SAFETY CLEARANCE BETWEEN GROUND AND THE NEARAST LIVE UNSCREENED CONDUCTOR		2500	
SAFETY CLEARANCE VERTICAL (SV)	6400	4600	2800

8. SYSTEM PARAMETER ARE AS PER SPECIFICATION

DESCRIPTION	UNIT	REQUIRED		
NOMINAL SYSTEM VOLTAGE BETWEEN PHASES	kV	400kV	230kV	33kV
SYSTEM FREQUENCY	Hz	50		
RATED VOLTAGE BETWEEN PHASES	kV	420	245	36
RATED LIGHTNING IMPULSE WITHSTAND VOLTAGE	kV	1425	1050	170
RATED SWITCHING IMPULSE WITHSTAND VOLTAGE	kV	1050	–	–
RATED POWER FREQUENCY WITHSTAND VOLTAGE	kV, 1min	–	460	70
RATED SYMMETRICAL SHORT-CIRCUIT CURRENT	kV, 1sec	63	50(new) 40(existing)	25

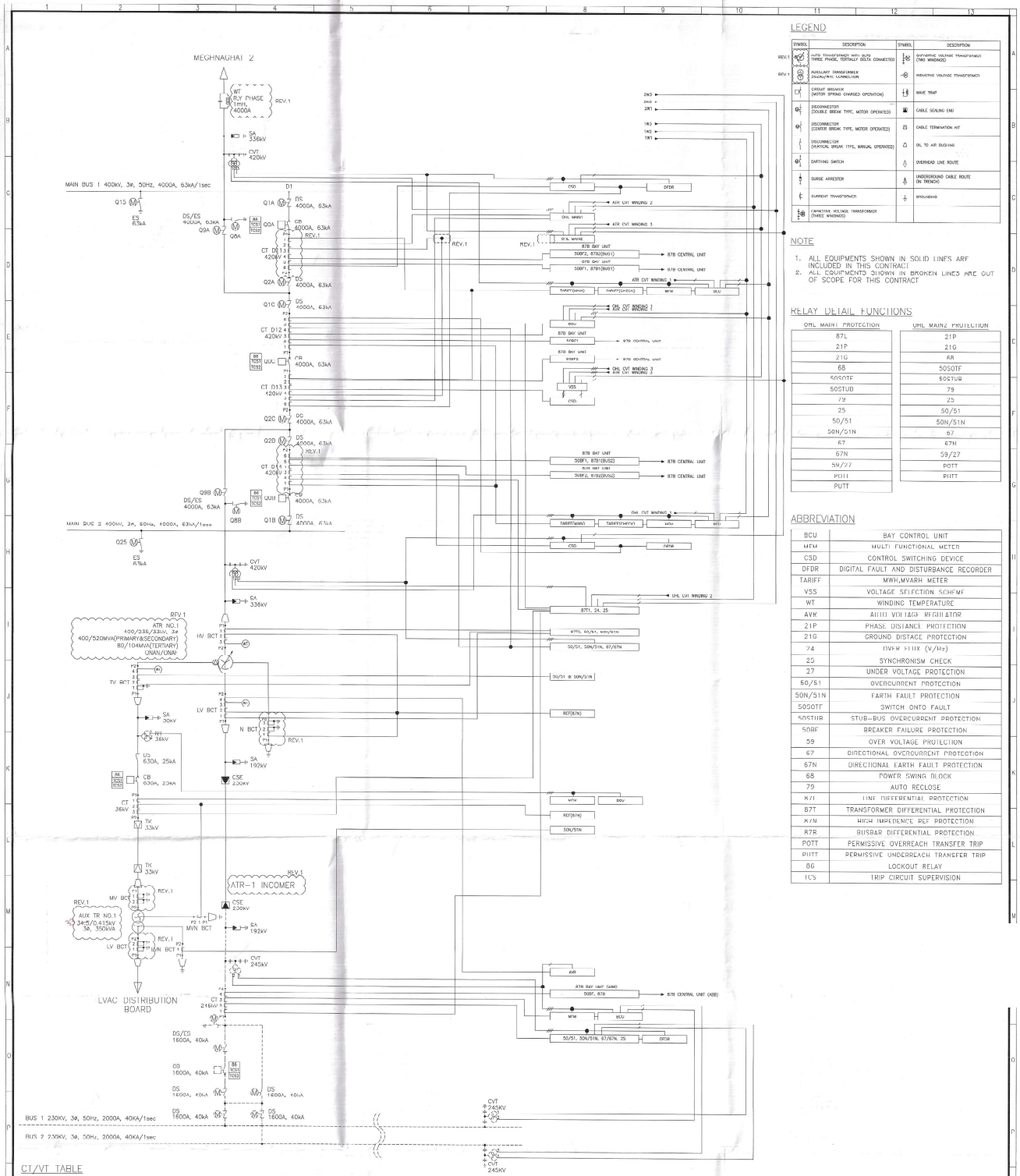
9. CONNECTION TYPE

420KV SWITCHYARD			230KV SWITCHYARD		
	LEVEL	CONDUCTOR TYPE		LEVEL	CONDUCTOR TYPE
JACK BUS	FSL+19500	TWIN ACSR	JACK BUS	FSL+16200	TWIN ACSR
MAIN BUS	FSL+11900	AL. TUBE	MAIN BUS	FSL+11700	TWIN ACSR
EQUIPMENT TO EQUIPMENT	FSL+7400	AL. TUBE/TWIN ACSR	EQUIPMENT TO EQUIPMENT	FSL+5600	TWIN ACSR

10. QUANTITY OF DISC INSULATOR FOR STRING SET OF TENSION AND SUSPENSION AS BELOW

	SINGLE TENSION	SINGLE SUSPENSION
230kV	18	18
	DOUBLE TENSION	SINGLE SUSPENSION
400kV	25	25

11. EXISTING TOWERS AND BOUNDARY WALLS WILL BE DEMOLISHED BY END USER, BEFORE THIS PROJECT WORK STARTS.
12. DISTINGUISHED SCOPE :
- SCOPE OF WORK : SOLID LINE IN BLACK COLOR
- OUT OF SCOPE(EXISTING) : DOTTED LINE IN RED COLOR
- OUT OF SCOPE(FUTURE) : DOTTED LINE IN BLUE COLOR



CT/VT TABLE

1.CT – 420kV BAY

CORE NO.	RATIO (A)	BURDEN (VA) *	CLASS
1	4000:1	15	0.2 FS10
2	4000:1	30	5P20
3	4000:1	30	5P20
4	4000:1	30	5P20
5	4000:1	30	5P20
6	4000:1	30	5P20

2.CVT – 420kV BAY

WINDING NO.	RATIO (kV)	BURDEN (VA) *	CLASS
1	400/√3:0.11/√3	25	0.2
2	400/√3:0.11/√3	75	1/3P
3	400/√3:0.11/√3	75	1/3P

3.CT – 245kV ATR-1, 2, 3 INCOMER BAY (EXISTING)

CORE NO.	RATIO (A)	BURDEN (VA)	CLASS
1	1600/800:1	30	5P20
2	1600/800:1	30	5P20
3	1600/800:1	30	0.2
4	1600/800:1	30	5P20

4.CVT – 245kV ATR-1, 2, 3 INCOMER BAY (EXISTING)

WINDING NO.	RATIO (KV)	BURDEN (VA)	CLASS
1	220/√3:0.11/√3	150	3P
2	220/√3:0.11/√3	150	0.5

5.CVT – 245kV BUS 1, 2 (EXISTING)

WINDING NO.	RATIO (KV)	BURDEN (VA)	CLASS
1	220/√3:0.11/√3	150	3P
2	220/√3:0.11/√3	150	0.5

6.HV BCT – 400/235/33kV AUTO-TRANSFORMER

CORE NO.	RATIO (A)	BURDEN (VA) *	CLASS
1	2000/1000:1	30	5P20
2	2000/1000:1	30	45TH
3	AS PER TR VENDOR (WT)		

7.LV BCT – 400/235/33kV AUTO TRANSFORMER

CORE NO.	RATIO (A)	BURDEN (VA) *	CLASS
1	2000/1000:1	30	5P20
2	2000/1000:1	30	5P20
3	AS PER TR VENDOR (WT)		
4	AS PER TR VENDOR (AVR)		

8.TV BCT – 400/235/33kV AUTO-TRANSFORMER

CORE NO.	RATIO (A)	BURDEN (VA) *	CLASS
1	800:1	30	5P20
2	800:1 (REV.1)	30	5P20
3	100:1	10	5P20
4	AS PER TR VENDOR (WT)		

9.NEUTRAL BCT – 400/235/33kV AUTO-TRANSFORMER (REV.1)

CORE NO.	RATIO (A)	BURDEN (VA) *	CLASS
1	2000/1000:1	30	5P20
2	2000/1000:1	30	5P20
3	2000/1000:1	30	5P20

10.CT – 36kV BAY

CORE NO.	RATIO (A)	BURDEN (VA) *	CLASS
1	800:1	15	0.2 FS10
2	800:1	45	45TH
3	800:1	30	5P20

11.VT – 36kV BAY

WINDING NO.	RATIO (KV)	BURDEN (VA) *	CLASS
1	33/√3:0.11/√3	25	0.2
2	33/√3:0.11/√3	75	1/3P

12.MV BCT – 34.5/0.415kV AUXILIARY TRANSFORMER (REV.1)

CORE NO.	RATIO (A)	BURDEN (VA) *	CLASS
1	100:1	10	5P20
2	100:1	10	5P20

13.LV BCT – 34.5/0.415kV AUXILIARY TRANSFORMER

CORE NO.	RATIO (A)	BURDEN (VA) *	CLASS
1	600:1	10	5P20
2	600:1	10	5P20

14.MV NEUTRAL BCT – 34.5/0.415kV AUXILIARY TRANSFORMER

CORE NO.	RATIO (A)	BURDEN (VA) *	CLASS
1	800:1	10	5P20

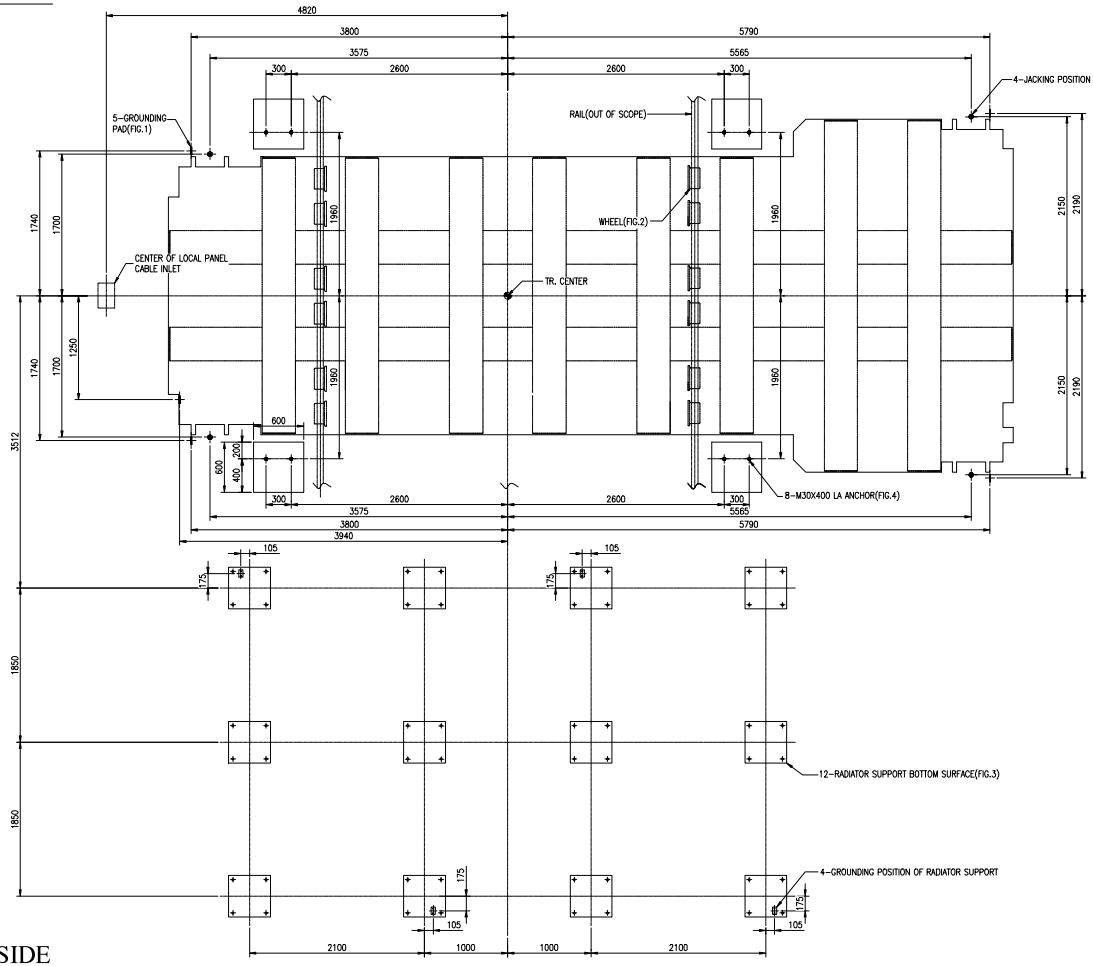
15.LV NEUTRAL BCT – 34.5/0.415kV AUXILIARY TRANSFORMER

CORE NO.	RATIO (A)	BURDEN (VA) *	CLASS
1	600:1	30	5P20

* THE BURDEN (VA) WILL BE UPDATED AFTER CT SIZING CALCULATION

PROTECTION & METERING SINGLE LINE DIAGRAM (DIAMETER-1)

H.V SIDE



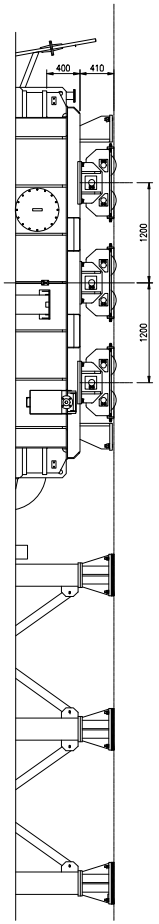
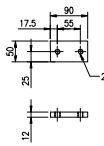
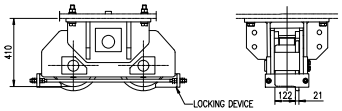


FIG.1



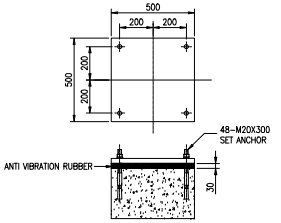
DETAIL OF GROUNDING PAD

FIG.2



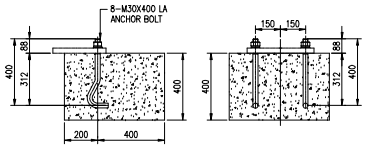
DETAIL OF BI-DIRECTIONAL WHEEL

FIG.3



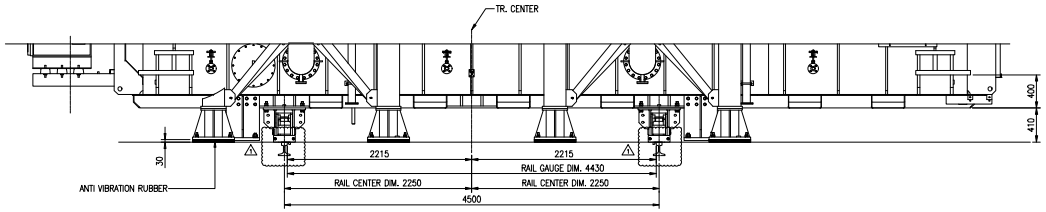
RADIATOR SUPPORT (12 POINT)

FIG.4



LA ANCHOR FOR MAIN TR.

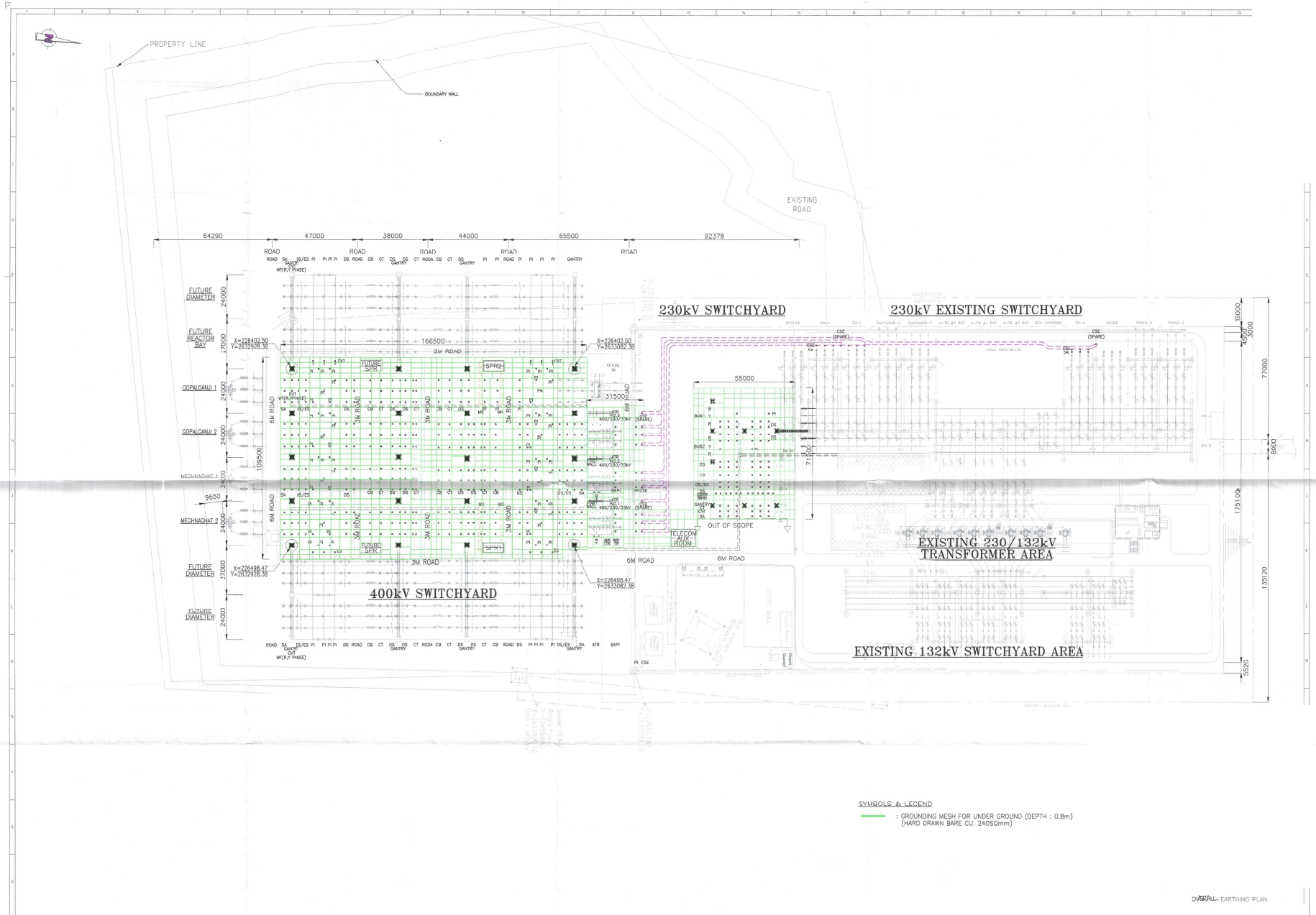
L.V SIDE

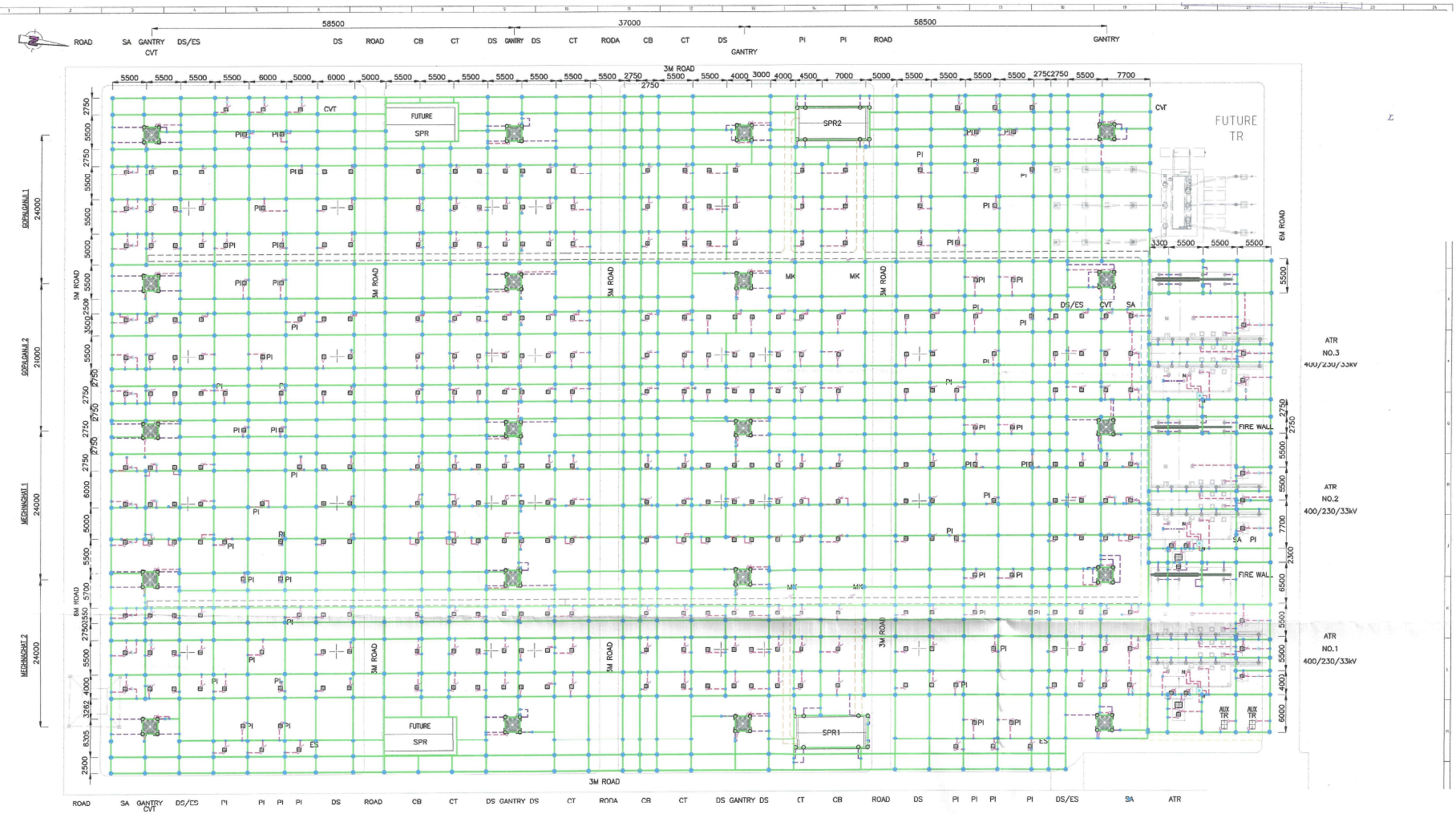


NOTE : 1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSION TOLERANCE : ±5%
3. DIMENSION AND WEIGHT WILL BE CHANGED SLIGHTLY AFTER DETAIL DESIGN.
4. ANGLE OF PROJECTION : 3RD

TITLE :

FOUNDATION DRAWING FOR 400/235/33KV AUTO TR


PROPERTY LINE
BOUNDARY WALL
EXISTING ROAD
64290
47000
38000
44000
65500
92378
ROAD
FUTURE DIAMETER
FUTURE REACTOR BAY
GOPALGANJI 1
GOPALGANJI 2
MEGHNAGHAT 1
MEGHNAGHAT 2
FUTURE DIAMETER
FUTURE DIAMETER
24000
27000
9650
109500
166500
3M ROAD
6M ROAD
X=226402.50
Y=2632928.38
X=226498.47
Y=2632928.38
X=226402.50
Y=2633082.38
X=226498.47
Y=2633082.38
SPR2
SPR1
FUTURE SPR
315000
400/230/33kV
ATR
SAPH
230kV SWITCHYARD
400kV SWITCHYARD
230kV EXISTING SWITCHYARD
55000
OUT OF SCOPE
TELECOM AUX ROOM
EXISTING 230/132kV TRANSFORMER AREA
EXISTING 132kV SWITCHYARD AREA
15000
3000
77000
800
1751.08
1351.20
5520
SYMBOLS & LEGEND
: GROUNDING MESH FOR UNDER GROUND (DEPTH : 0.8m)
(HARD DRAWN BARE CU. 240SQmm)
OVERALL EARTHING PLAN



400kV SWITCHYARD

NOTE

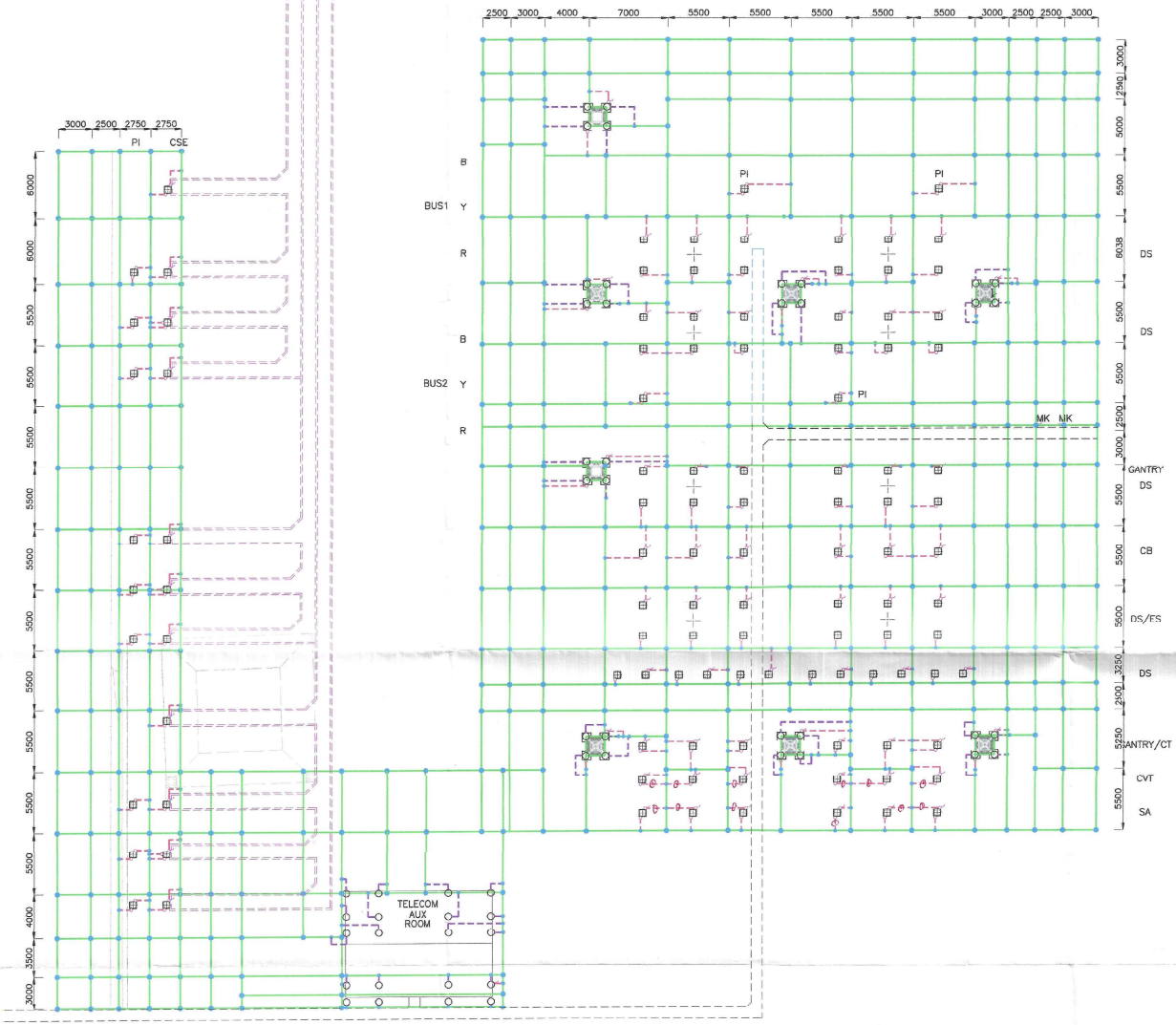
1. ALL DIMENSIONS ARE IN MILLIMETER UNLESS OTHERWISE NOTED.
2. EXACT LOCATION FOR EQUIPMENT EARTHING SHALL BE ADJUSTED AS PER SITE CONDITION.
3. IF REQUIRED, THE COMMON EARTH LINK BAR WILL BE USED TO ANY POSITION AS PER INSTALLATION CONDITION.

Number of pile rod (re-bar) - 192 nos, each 24m long

SYMBOLS & LEGEND

- : GROUNDING MESH FOR UNDER GROUND (DEPTH : 0.6m) (HARD DRAWN BARE CU. 240SQmm)
- : EXOTHERMIC CONNECTION (CROSS & TEE)
- : 240SQmm STRANDED BARE COPPER CABLE
- : 240SQmm GREEN STRANDED CABLE (PVC-INSULATED)
- : 150SQmm STRANDED BARE COPPER CABLE (FOR PILE)
- : EQUIPMENT/STRUCTURE EARTHING POINT
- : CONNECTION POINT
- : STUB UP FOR EQUIPMENT
- : EQUIPMENT GROUNDING
- : GROUND RODS (ø16 x 20m LONG) : 51 PCS
- : T.R NEUTRAL INSPECTION PIT : 3 PCS

OUTDOOR EARTHING PLAN FOR 400kV SWITCHYARD



NOTE

1. ALL DIMENSIONS ARE IN MILLIMETER UNLESS OTHERWISE NOTED.
2. EXACT LOCATION FOR EQUIPMENT EARTHING SHALL BE ADJUSTED AS PER SITE CONDITION.
3. IF REQUIRED, THE COMMON EARTH LINK BAR WILL BE USED TO ANY POSITION AS PER INSTALLATION CONDITION.

SYMBOLS & LEGEND

- : GROUNDING MESH FOR UNDER GROUND (DEPTH : 0.8m) (HARD DRAWN BARE CU. 240SQmm)
- : EXOTHERMIC CONNECTION (CROSS & TEE)
- : 240SQmm STRANDED BARE COPPER CABLE
- : 240SQmm GREEN STRANDED CABLE (PVC-INSULATED)
- : 150SQmm STRANDED BARE COPPER CABLE (FOR PILE)
- : EQUIPMENT/STRUCTURE EARTHING POINT
- : CONNECTION POINT
- : STUB UP FOR EQUIPMENT
- : EQUIPMENT GROUNDING
- : GROUND RODS (Ø16 x 20m LONG) , 12 NOS.
- : T.R NEUTRAL INSPECTION PIT

N

Number of pile rod (re-bar) - 32 nos, each 24m long

230kV SWITCHYARD

OUTDOOR EARTHING PLAN FOR 230kV SWITCHYARD

NOTE : 1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSION TOLERANCE : ±5%
3. DIMENSION AND WEIGHT WILL BE CHANGED SLIGHTLY AFTER DETAIL DESIGN.
4. ANGLE OF PROJECTION : 3RD
5. ⊕ MARK : CENTER OF GRAVITY FOR TOTAL UNIT

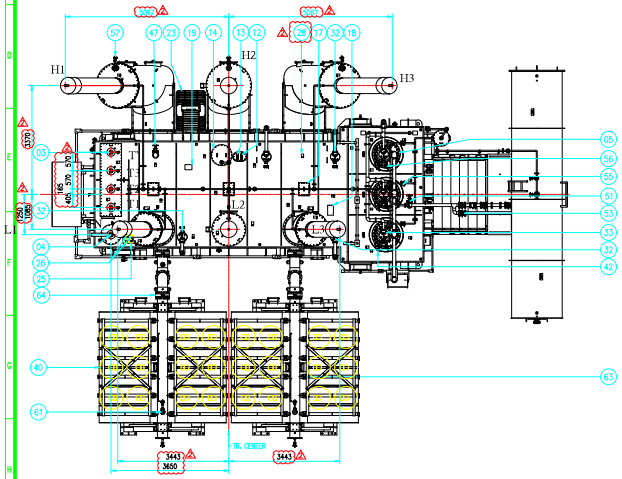
WEIGHTS		
CORE & COIL		178,000 kg
TANK & FITTING	TOTAL	104,000 kg
	MAIN TANK ASS'Y	64,000 kg
	CONSERVATOR	6,000 kg
	RADIATOR	34,000 kg
INSULATING OIL	TOTAL	136,300 kg
	MAIN TANK	125,500 kg
	CONSERVATOR	3,800 kg
	RADIATOR	7,000 kg
TOTAL WEIGHT		418,300 kg

TRANSPORTATION	
DIMENSIONS	12,250(LG)x5,400(WD)x5,500(HT)
WEIGHT (WITHOUT OIL)	233,000 kg

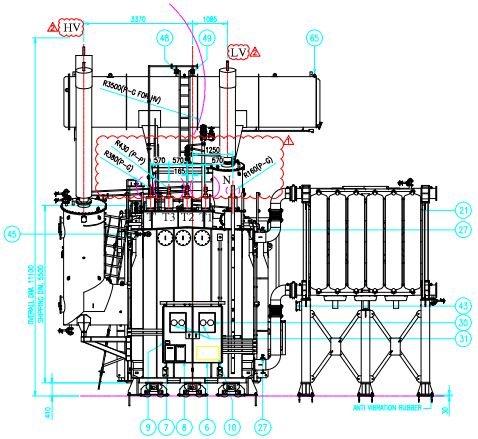
PART LIST

ITEM	DESCRIPTION	SPECIFICATION	Q'TY	MAKER
54	DRAIN VAVLE FOR OLTC CONSERVATOR	1" GATE	1 EA	HYOSUNG (KOREA)
55	CONNECTING VALVE FOR OLTC CONSERVATOR	1" GATE	4 EA	HYOSUNG (KOREA)
56	DRAIN VALVE FOR OLTC	–	3 EA	ABB (SWEDEN)
57	UPPER FILTER VALVE FOR HV BUSHING CHAMBER	2" GATE	3 EA	HYOSUNG (KOREA)
58	DRAIN VALVE FOR HV BUSHING CHAMBER	2" GATE	3 EA	HYOSUNG (KOREA)
59	CONNECTING VALVE FOR FIRE PROTECTION DEVICE	6" BUTTERFLY	1 EA	HYOSUNG (KOREA)
60	VALVE FOR NITROGEN INJECTION	1" GATE	6 EA	HYOSUNG (KOREA)
61	UPPER FILTER VAVLE FOR OILBOX	2" GATE	2 EA	HYOSUNG (KOREA)
62	LOWER FILTER/DRAIN VALVE FOR OILBOX	2" GATE	2 EA	HYOSUNG (KOREA)
63	INLET AND OUTLET VALVE FOR RADIATOR	3" BUTTERFLY	48 EA	HYOSUNG (KOREA)
64	CONNECTING VALVE FOR OILBOX	12" BUTTERFLY	8 EA	HYOSUNG (KOREA)
65	AIR RELEASE PLUG FOR MAIN CONSERVATOR	–	3 EA	HYOSUNG (KOREA)
66	AIR RELEASE PLUG FOR MAIN OILBOX	–	12 EA	HYOSUNG (KOREA)
67	AIR RELEASE PLUG FOR RADIATOR	–	24 EA	HYOSUNG (KOREA)
68	DRAIN PLUG FOR RADIATOR	–	24 EA	HYOSUNG (KOREA)
69	CONNECTING VALVE FOR RAPID PRESSURE RISE RELAY	2" GATE	1 EA	HYOSUNG (KOREA)
70	CONSERVATOR ISOLATION VALVE	3" GATE	2 EA	HYOSUNG (KOREA)

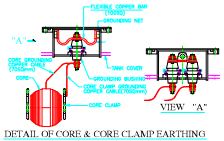
ITEM	DESCRIPTION	SPECIFICATION	Q'TY	MAKER
1	HV BUSHING	GOE 1425–1150–2500–0.6	3 EA	ABB (SWEDEN)
2	LV BUSHING	GOE 1050–750–2500–0.6	3 EA	ABB (SWEDEN)
3	TV BUSHING	36–2000/P3	4 EA	CEDASPE (ITALY)
4	NEUTRAL BUSHING	36–2000/P3	1 EA	CEDASPE (ITALY)
5	ON LOAD TAP CHANGER (OLTC)	VUCGRT–1050–801–1000–III	3 EA	ABB (SWEDEN)
6	LOCAL CONTROL PANEL	OUTDOOR TYPE	1 EA	HYOSUNG (KOREA)
7	RATING NAMEPLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
8	VALVE LOCATION NAMEPLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
9	OIL LEVEL TEMPERATURE CURVE PLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
10	BCT RATING NAMEPLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
11	HYOSUNG MARK	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
12	GROUNDING BUSHING FOR END FRAME ASSEMBLY	1.2KV, 30KV BIL	1 EA	TY–TECH (KOREA)
13	GROUNDING BUSHING FOR CORE	1.2KV, 30KV BIL	1 EA	TY–TECH (KOREA)
14	MANHOLE & HANDHOLE	–	1 LOT	HYOSUNG (KOREA)
15	LIFTING HOOK FOR MAIN TANK		4 EA	HYOSUNG (KOREA)
16	JACKING PAD WITH PULLING EYE	–	4 EA	HYOSUNG (KOREA)
17	FIXING FOR CORE & COIL ASSEMBLY	–	3 EA	HYOSUNG (KOREA)
18	MOUNTING PAD FOR MECHANICAL IMPACT RECORDER	–	1 EA	–
19	MOUNTING PAD FOR ELECTRONICS IMPACT RECORDER	–	1 EA	–
20	GROUNDING PAD	FLAT PAD(STS304)	4 EA	HYOSUNG (KOREA)
21	RADIATOR		24 SET	HYOSUNG (KOREA)
22	CONSERVATOR FOR MAIN TANK WITH RUBBER BAG	RUBBER BAG TYPE	1 SET	HYOSUNG (KOREA)
23	LADDER WITH SAFETY COVER		1 EA	HYOSUNG (KOREA)
24	Wheel	–	6 SET	HYOSUNG (KOREA)
25	THERMOMETER POCKET FOR OIL TEMPERATURE INDICATOR	–	1 EA	HYOSUNG (KOREA)
26	THERMOMETER POCKET FOR WINDING TEMPERATURE INDICATOR	–	3 EA	HYOSUNG (KOREA)
27	THERMOMETER POCKET	–	2 EA	HYOSUNG (KOREA)
28	MOUNTING BRACKETS FOR FIRE DETECTOR	–	25 EA	HYOSUNG (KOREA)
29	MOUNTING BRACKETS FOR SIGNAL BOX	–	1 EA	HYOSUNG (KOREA)
30	OIL TEMPERATURE INDICATOR	MT–ST160SK/TT	1 EA	MESSKO(GERMANY)
31	WINDING TEMPERATURE INDICATOR	MT–ST160WR/TT	3 EA	MESSKO(GERMANY)
32	PRESSURE RELIEF DEVICE FOR MAIN TANK	MPREC	4 EA	MESSKO (CERMANY)
33	PRESSURE RELIEF DEVICE FOR OLTC	MPREC	3 EA	MESSKO (CERMANY)
34	OIL LEVEL GAUGE FOR MAIN CONSERVATOR	DIAL TYPE	1 EA	TAIJIN (KOREA)
35	OIL LEVEL GAUGE FOR OLTC CONSERVATOR	DIAL TYPE	1 EA	TAIJIN (KOREA)
36	BREATHER FOR MAIN CONSERVATOR	SILICA–GEL	2 EA	TAIJIN (KOREA)
37	BREATHER FOR OLTC CONSERVATOR	SILICA–GEL	1 EA	TAIJIN (KOREA)
38	BUCHHOLZ RELAY	EE3–MA	1 EA	CEDASPE (ITALY)
39	GAS SAMPLING VALVE FOR BUCHHOLZ RELAY	RG3	1 EA	CEDASPE (ITALY)
40	COOLING FAN	TJD–2143	24 EA	TAIJIN (KOREA)
41	MOTOR DRIVE UNIT FOR OLTC	–	1 EA	ABB (SWEDEN)
42	OIL SURGE RELAY FOR OLTC(ABB)		3 EA	ABB (SWEDEN)
43	JUNCTION BOX FOR COOLING FANS	–	4 EA	HYOSUNG (KOREA)
44	RAPID PRESSURE RISE RELAY	–	1 EA	QUALITROL(USA)
45	UPPER FILTER VALVE FOR MAIN TANK	2" GATE	1 EA	HYOSUNG (KOREA)
46	LOWER FILTER/DRAIN VALVE FOR MAIN TANK	2" GATE	1 EA	HYOSUNG (KOREA)
47	VACUUM VALVE FOR MAIN TANK	3" GATE	1 EA	HYOSUNG (KOREA)
48	VACUUM VALVE FOR MAIN CONSERVATOR	1" GATE	1 EA	HYOSUNG (KOREA)
49	EQUALIZING VALVE FOR MAIN CONSERVATOR	1" GATE	1 EA	HYOSUNG (KOREA)
50	DRAIN VAVLE FOR MAIN CONSERVATOR	1" GATE	1 EA	HYOSUNG (KOREA)
51	CONNECTING VALVE FOR MAIN CONSERVATOR NEXT TO COVER	3" GATE	1 EA	HYOSUNG (KOREA)
52	CONNECTING VLAVLE FOR MAIN CONSERVATOR NEXT TO CONSERVATOR	3" GATE	1 EA	HYOSUNG (KOREA)
53	BUCHHOLZ BY–PASS VALVE	3" GATE	1 EA	HYOSUNG (KOREA)



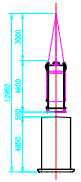
TOP VIEW



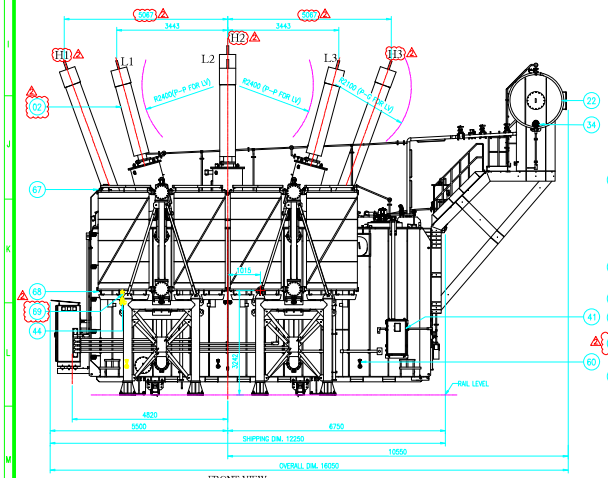
LEFT VIEW



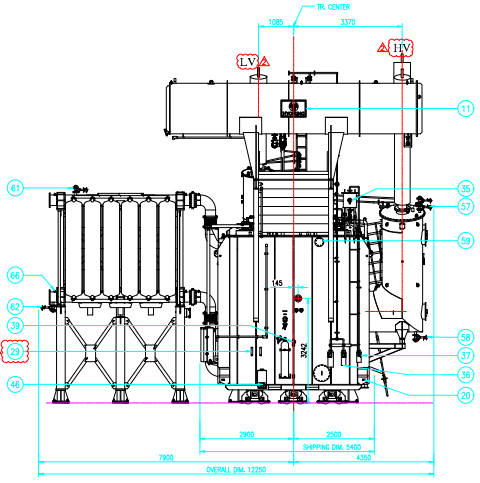
DETAIL OF CORE & CORE CLAMP EARTHING



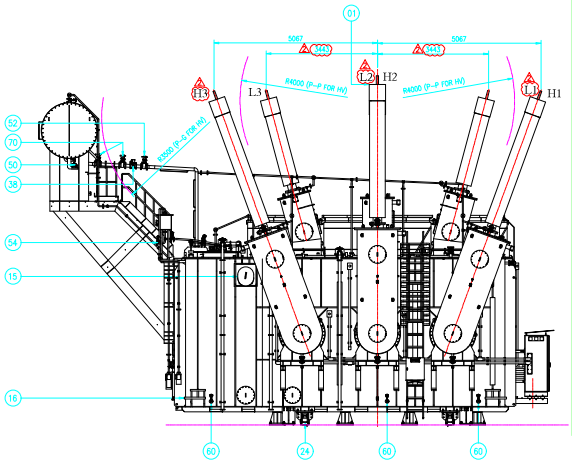
UN-TANKING HEIGHT OF CORE & COIL



FRONT VIEW



RIGHT VIEW



BACK VIEW

OUTLINE DRAWING
FOR 400/235/33KV AUTO TR

NOTE : 1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSION TOLERANCE : ±5%
3. DIMENSION AND WEIGHT WILL BE CHANGED SLIGHTLY AFTER DETAIL DESIGN.
4. ANGLE OF PROJECTION : 3RD
5. ⊕ MARK : CENTER OF GRAVITY FOR TOTAL UNIT

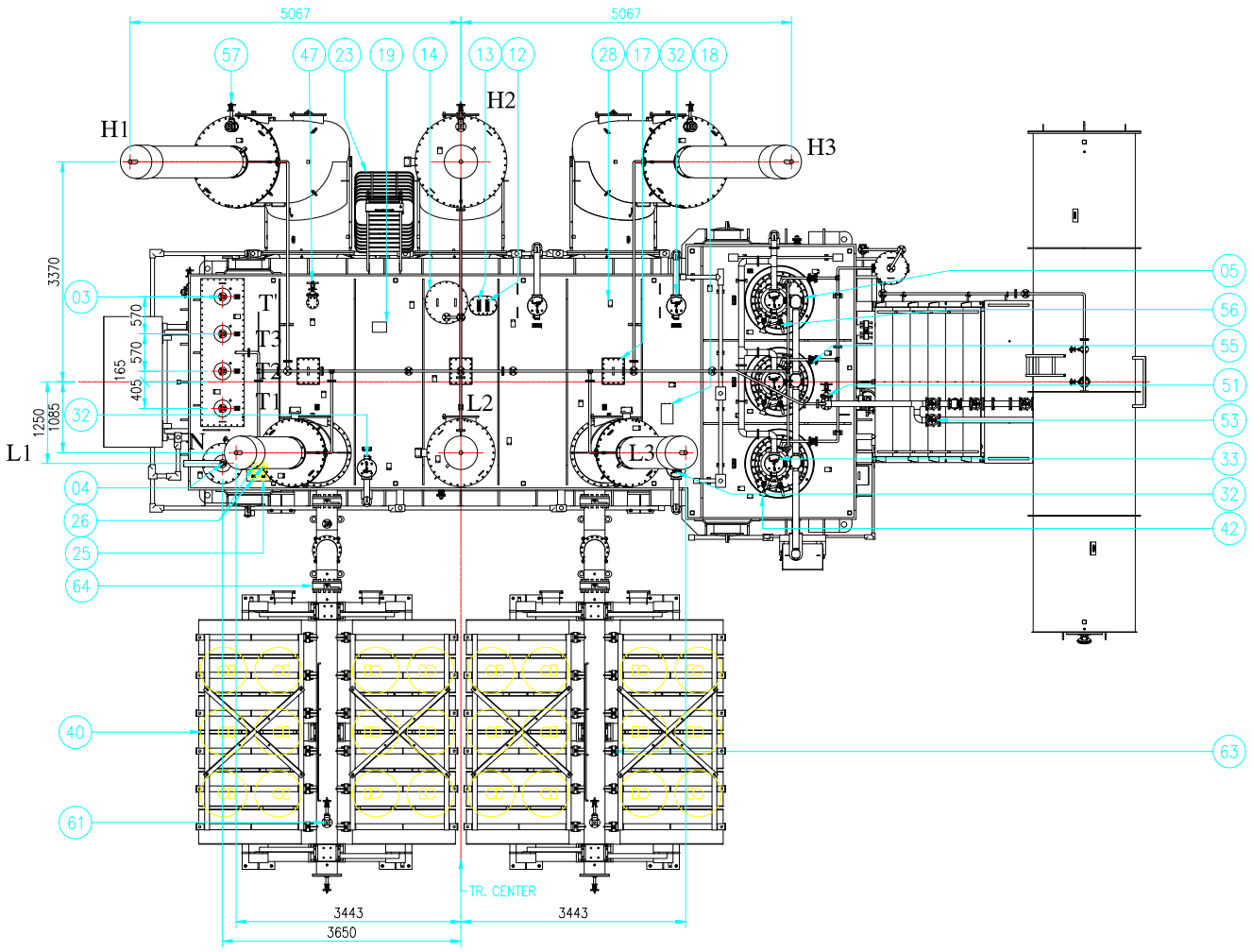
WEIGHTS		
CORE & COIL		172,200 kg
TANK & FITTING	TOTAL	106,600 kg
	MAIN TANK ASS'Y	66,600 kg
	CONSERVATOR	6,000 kg
	RADIATOR	34,000 kg
INSULATING OIL	TOTAL	134,300 kg
	MAIN TANK	125,500 kg
	CONSERVATOR	3,800 kg
	RADIATOR	7,000 kg
TOTAL WEIGHT		415,100 kg

TRANSPORTATION	
DIMENSIONS	12,250(LG)x5,400(WD)x5,500(HT)
WEIGHT (WITHOUT OIL)	233,000 kg

PART LIST

ITEM	DESCRIPTION	SPECIFICATION	Q'TY	MAKER
54	DRAIN VAVLE FOR OLTC CONSERVATOR	1" GATE	1 EA	HYOSUNG (KOREA)
55	CONNECTING VALVE FOR OLTC CONSERVATOR	1" GATE	4 EA	HYOSUNG (KOREA)
56	DRAIN VALVE FOR OLTC	–	3 EA	ABB (SWEDEN)
57	UPPER FILTER VALVE FOR HV BUSHING CHAMBER	2" GATE	3 EA	HYOSUNG (KOREA)
58	DRAIN VALVE FOR HV BUSHING CHAMBER	2" GATE	3 EA	HYOSUNG (KOREA)
59	CONNECTING VALVE FOR FIRE PROTECTION DEVICE	6" BUTTERFLY	1 EA	HYOSUNG (KOREA)
60	VALVE FOR NITROGEN INJECTION	1" GATE	6 EA	HYOSUNG (KOREA)
61	UPPER FILTER VAVLE FOR OILBOX	2" GATE	2 EA	HYOSUNG (KOREA)
62	LOWER FILTER/DRAIN VALVE FOR OILBOX	2" GATE	2 EA	HYOSUNG (KOREA)
63	INLET AND OUTLET VALVE FOR RADIATOR	3" BUTTERFLY	48 EA	HYOSUNG (KOREA)
64	CONNECTING VALVE FOR OILBOX	12" BUTTERFLY	8 EA	HYOSUNG (KOREA)
65	AIR RELEASE PLUG FOR MAIN CONSERVATOR	–	3 EA	HYOSUNG (KOREA)
66	AIR RELEASE PLUG FOR MAIN OILBOX	–	12 EA	HYOSUNG (KOREA)
67	AIR RELEASE PLUG FOR RADIATOR	–	24 EA	HYOSUNG (KOREA)
68	DRAIN PLUG FOR RADIATOR	–	24 EA	HYOSUNG (KOREA)
69	CONNECTING VALVE FOR RAPID PRESSURE RISE RELAY	2" GATE	1 EA	HYOSUNG (KOREA)
70	CONSERVATOR ISOLATION VALVE	3" GATE	2 EA	HYOSUNG (KOREA)

ITEM	DESCRIPTION	SPECIFICATION	Q'TY	MAKER
1	HV BUSHING	GOE 1425-1150-2500-0.6		ABB (SWEDEN)
2	LV BUSHING	GOE 1050-750-2500-0.6	3 EA	ABB (SWEDEN)
3	TV BUSHING	36-2000/P3	4 EA	CEDASPE (ITALY)
4	NEUTRAL BUSHING	36-2000/P3	1 EA	CEDASPE (ITALY)
5	ON LOAD TAP CHANGER (OLTC)	VUCGRT-1050-801-1000-III	3 EA	ABB (SWEDEN)
6	LOCAL CONTROL PANEL	OUTDOOR TYPE	1 EA	HYOSUNG (KOREA)
7	RATING NAMEPLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
8	VALVE LOCATION NAMEPLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
9	OIL LEVEL TEMPERATURE CURVE PLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
10	BCT RATING NAMEPLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
11	HYOSUNG MARK	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
12	GROUNDING BUSHING FOR END FRAME ASSEMBLY	1.2KV, 30KV BIL	1 EA	TY-TECH (KOREA)
13	GROUNDING BUSHING FOR CORE	1.2KV, 30KV BIL	1 EA	TY-TECH (KOREA)
14	MANHOLE & HANDHOLE	–	1 LOT	HYOSUNG (KOREA)
15	LIFTING HOOK FOR MAIN TANK	–	4 EA	HYOSUNG (KOREA)
16	JACKING PAD WITH PULLING EYE	–	4 EA	HYOSUNG (KOREA)
17	FIXING FOR CORE & COIL ASSEMBLY	–	3 EA	HYOSUNG (KOREA)
18	MOUNTING PAD FOR MECHANICAL IMPACT RECORDER	–	1 EA	–
19	MOUNTING PAD FOR ELECTRONICS IMPACT RECORDER	–	1 EA	–
20	GROUNDING PAD	FLAT PAD(STS304)	4 EA	HYOSUNG (KOREA)
21	RADIATOR		24 SET	HYOSUNG (KOREA)
22	CONSERVATOR FOR MAIN TANK WITH RUBBER BAG	RUBBER BAG TYPE	1 SET	HYOSUNG (KOREA)
23	LADDER WITH SAFETY COVER		1 EA	HYOSUNG (KOREA)
24	Wheel	–	6 SET	HYOSUNG (KOREA)
25	THERMOMETER POCKET FOR OIL TEMPERATURE INDICATOR	–	1 EA	HYOSUNG (KOREA)
26	THERMOMETER POCKET FOR WINDING TEMPERATURE INDICATOR	–	3 EA	HYOSUNG (KOREA)
27	THERMOMETER POCKET	–	2 EA	HYOSUNG (KOREA)
28	MOUNTING BRACKETS FOR FIRE DETECTOR	–	25 EA	HYOSUNG (KOREA)
29	MOUNTING BRACKETS FOR SIGNAL BOX	–	1 EA	HYOSUNG (KOREA)
30	OIL TEMPERATURE INDICATOR	MT-ST160SK/TT	1 EA	MESSKO(GERMANY)
31	WINDING TEMPERATURE INDICATOR	MT-ST160WR/TT	3 EA	MESSKO(GERMANY)
32	PRESSURE RELIEF DEVICE FOR MAIN TANK	MPREC	4 EA	MESSKO (CERMANY)
33	PRESSURE RELIEF DEVICE FOR OLTC	MPREC	3 EA	MESSKO (CERMANY)
34	OIL LEVEL GAUGE FOR MAIN CONSERVATOR	DIAL TYPE	1 EA	TAUIN (KOREA)
35	OIL LEVEL GAUGE FOR OLTC CONSERVATOR	DIAL TYPE	1 EA	TAUIN (KOREA)
36	BREATHER FOR MAIN CONSERVATOR	SILICA-GEL	2 EA	TAUIN (KOREA)
37	BREATHER FOR OLTC CONSERVATOR	SILICA-GEL	1 EA	TAUIN (KOREA)
38	BUCHHOLZ RELAY	EE3-MA	1 EA	CEDASPE (ITALY)
39	GAS SAMPLING VALVE FOR BUCHHOLZ RELAY	RG3	1 EA	CEDASPE (ITALY)
40	COOLING FAN	TJD-2143	24 EA	TAUIN (KOREA)
41	MOTOR DRIVE UNIT FOR OLTC	–	1 EA	ABB (SWEDEN)
42	OIL SURGE RELAY FOR OLTC(ABB)	–	3 EA	ABB (SWEDEN)
43	JUNCTION BOX FOR COOLING FANS	–	4 EA	HYOSUNG (KOREA)
44	RAPID PRESSURE RISE RELAY	–	1 EA	QUALITROL(USA)
45	UPPER FILTER VALVE FOR MAIN TANK	2" GATE	1 EA	HYOSUNG (KOREA)
46	LOWER FILTER/DRAIN VALVE FOR MAIN TANK	2" GATE	1 EA	HYOSUNG (KOREA)
47	VACUUM VALVE FOR MAIN TANK	3" GATE	1 EA	HYOSUNG (KOREA)
48	VACUUM VALVE FOR MAIN CONSERVATOR	1" GATE	1 EA	HYOSUNG (KOREA)
49	EQUALIZING VALVE FOR MAIN CONSERVATOR	1" GATE	1 EA	HYOSUNG (KOREA)
50	DRAIN VAVLE FOR MAIN CONSERVATOR	1" GATE	1 EA	HYOSUNG (KOREA)
51	CONNECTING VALVE FOR MAIN CONSERVATOR NEXT TO COVER	3" GATE	1 EA	HYOSUNG (KOREA)
52	CONNECTING VLAVLE FOR MAIN CONSERVATOR NEXT TO CONSERVATOR	3" GATE	1 EA	HYOSUNG (KOREA)
53	BUCHHOLZ BY-PASS VALVE	3" GATE	1 EA	HYOSUNG (KOREA)



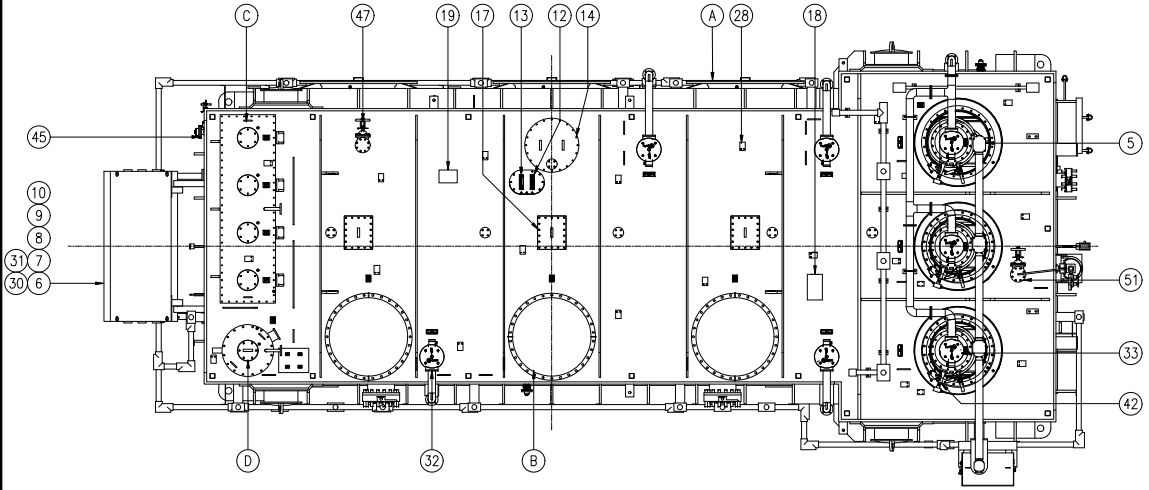
TOP VIEW

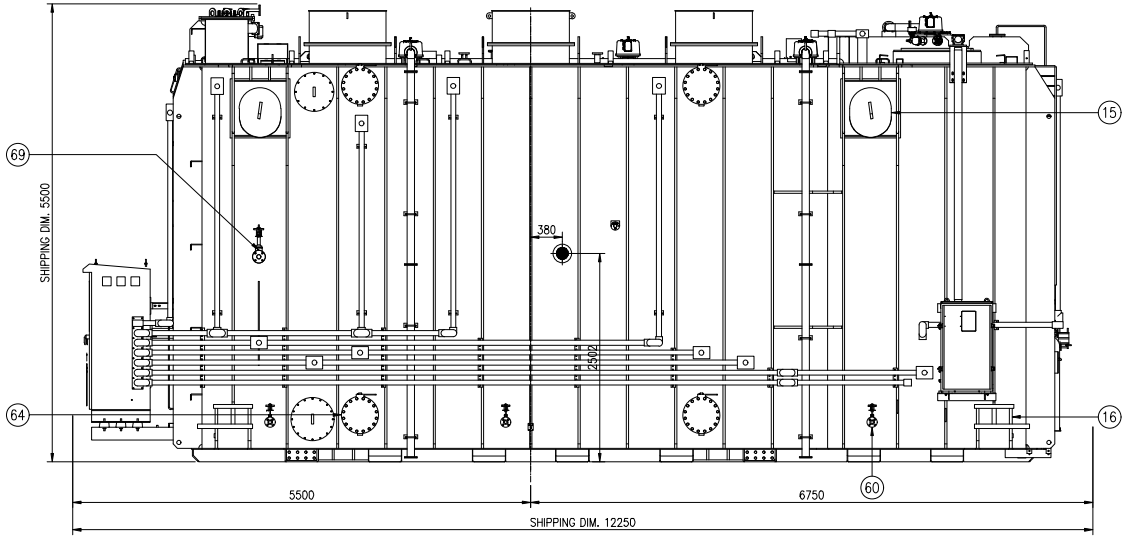
OUTLINE DRAWING
FOR 400/235/33KV AUTO TR

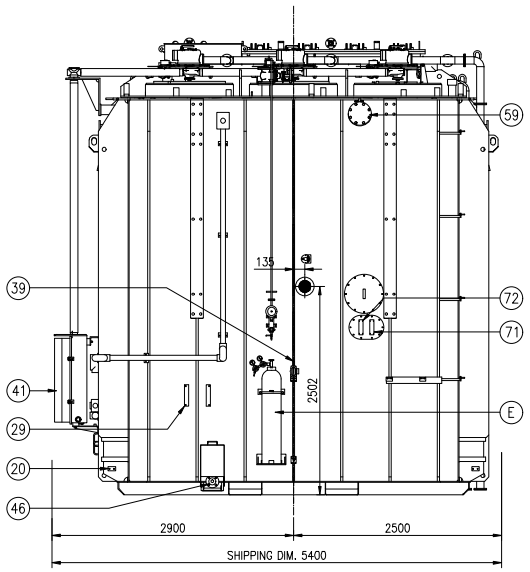
NOTE : 1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSION TOLERANCE : ±5%
3. DIMENSION AND WEIGHT WILL BE CHANGED SLIGHTLY AFTER DETAIL DESIGN.
4. ANGLE OF PROJECTION : 3RD
5. ⊕ MARK : CENTER OF GRAVITY FOR SHIPPING (WITHOUT OIL)

TRANSPORTATION	
DIMENSIONS	12,250 (LG) X 5,400 (WD) X 5,500 (HT)
WEIGHT (WITHOUT OIL)	233,000 kg

ITEM	DESCRIPTION	SPECIFICATION	Q'TY	MAKER
5	ON LOAD TAP CHANGER (OLTC)	VUCGRT-1050-801-1000-III	3 EA	ABB (SWEDEN)
6	LOCAL CONTROL PANEL	OUTDOOR TYPE	1 EA	HYOSUNG (KOREA)
7	RATING NAMEPLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
8	VALVE LOCATION NAMEPLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
9	OIL LEVEL TEMPERATURE CURVE PLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
10	BCT RATING NAMEPLATE	STAINLESS STEEL	1 EA	HYOSUNG (KOREA)
12	GROUNDING BUSHING FOR END FRAME ASSEMBLY	1.2KV, 30KV BIL	1 EA	TY-TECH (KOREA)
13	GROUNDING BUSHING FOR CORE	1.2KV, 30KV BIL	1 EA	TY-TECH (KOREA)
14	MANHOLE & HANDHOLE	–	1 LOT	HYOSUNG (KOREA)
15	LIFTING HOOK FOR MAIN TANK		4 EA	HYOSUNG (KOREA)
16	JACKING PAD WITH PULLING EYE	–	4 EA	HYOSUNG (KOREA)
17	FIXING FOR CORE & COIL ASSEMBLY	–	3 EA	HYOSUNG (KOREA)
18	MOUNTING PAD FOR MECHANICAL IMPACT RECORDER	–	1 EA	–
19	MOUNTING PAD FOR ELECTRONICS IMPACT RECORDER	–	1 EA	–
20	GROUNDING PAD	FLAT PAD(STS304)	4 EA	HYOSUNG (KOREA)
25	THERMOMETER POCKET FOR OIL TEMPERATURE INDICATOR	–	1 EA	HYOSUNG (KOREA)
26	THERMOMETER POCKET FOR WINDING TEMPERATURE INDICATOR	–	3 EA	HYOSUNG (KOREA)
28	MOUNTING BRACKETS FOR FIRE DETECTOR	–	25 EA	HYOSUNG (KOREA)
29	MOUNTING BRACKETS FOR SIGNAL BOX	–	1 EA	HYOSUNG (KOREA)
30	OIL TEMPERATURE INDICATOR	MT-ST160SK/TT	1 EA	MESSKO(GERMANY)
31	WINDING TEMPERATURE INDICATOR	MT-ST160WR/TT	3 EA	MESSKO(GERMANY)
32	PRESSURE RELIEF DEVICE FOR MAIN TANK	MPREC	4 EA	MESSKO (GERMANY)
33	PRESSURE RELIEF DEVICE FOR OLTC	MPREC	3 EA	MESSKO (GERMANY)
39	GAS SAMPLING VALVE FOR BUCHHOLZ RELAY	RG3	1 EA	CEDASPE (ITALY)
41	MOTOR DRIVE UNIT FOR OLTC	–	1 EA	ABB (SWEDEN)
42	OIL SURGE RELAY FOR OLTC(ABB)		3 EA	ABB (SWEDEN)
45	UPPER FILTER VALVE FOR MAIN TANK	2" GATE	1 EA	HYOSUNG (KOREA)
46	LOWER FILTER/DRAIN VALVE FOR MAIN TANK	2" GATE	1 EA	HYOSUNG (KOREA)
47	VACUUM VALVE FOR MAIN TANK	3" GATE	1 EA	HYOSUNG (KOREA)
51	CONNECTING VALVE FOR MAIN CONSERVATOR NEXT TO COVER	3" GATE	1 EA	HYOSUNG (KOREA)
59	CONNECTING VALVE FOR FIRE PROTECTION DEVICE	6" BUTTERFLY	1 EA	HYOSUNG (KOREA)
60	VALVE FOR NITROGEN INJECTION	1" GATE	6 EA	HYOSUNG (KOREA)
64	CONNECTING VALVE FOR OILBOX	12" BUTTERFLY	4 EA	HYOSUNG (KOREA)
69	CONNECTING VALVE FOR RAPID PRESSURE RISE RELAY	2" GATE	1 EA	HYOSUNG (KOREA)
71	GROUNDING BUSHING FOR REACTOR END FRAME ASSEMBLY	1.2KV, 30KV BIL	1 EA	TY-TECH (KOREA)
72	GROUNDING BUSHING FOR REACTOR CORE	1.2KV, 30KV BIL	1 EA	TY-TECH (KOREA)
A	HV BUSHING BOSS	–	3 EA	HYOSUNG (KOREA)
B	XV BUSHING BOSS	–	3 EA	HYOSUNG (KOREA)
C	TV BUSHING DUCT	–	3 EA	HYOSUNG (KOREA)
D	NEUTRAL BUSHING BOSS	–	1 EA	HYOSUNG (KOREA)
E	SHIPPING AIR EQUIPMENT	–	1 SET	HYOSUNG (KOREA)







TITLE :

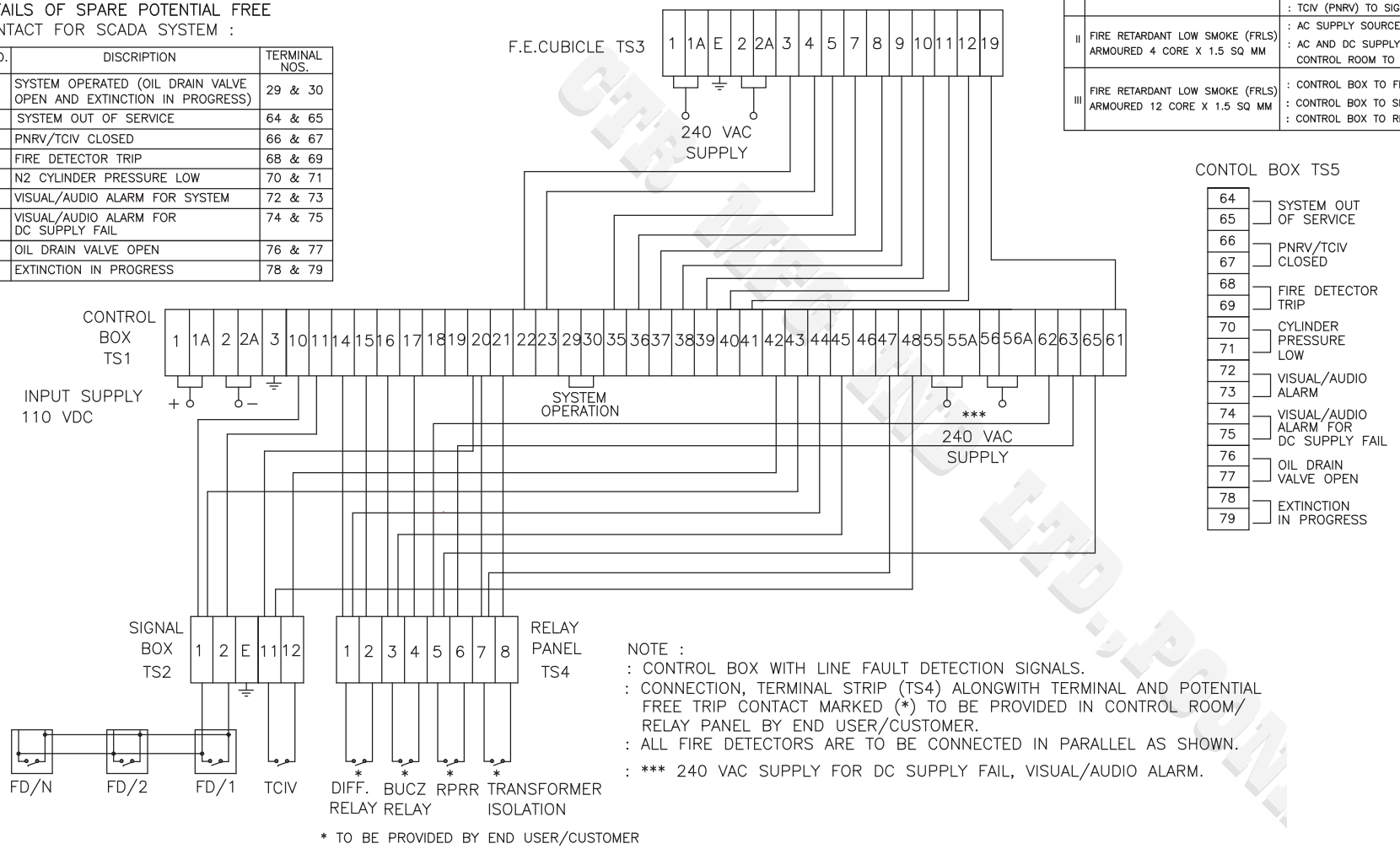
SHIPPING OUTLINE DRAWING FOR 400/235/33KV AUTO TR

DETAILS OF SPARE POTENTIAL FREE
CONTACT FOR SCADA SYSTEM :

SR.NO.	DISCRIPTION	TERMINAL NOS.
1.	SYSTEM OPERATED (OIL DRAIN VALVE OPEN AND EXTINCTION IN PROGRESS)	29 & 30
2.	SYSTEM OUT OF SERVICE	64 & 65
3.	PNRV/TCIV CLOSED	66 & 67
4.	FIRE DETECTOR TRIP	68 & 69
5.	N2 CYLINDER PRESSURE LOW	70 & 71
6.	VISUAL/AUDIO ALARM FOR SYSTEM	72 & 73
7.	VISUAL/AUDIO ALARM FOR DC SUPPLY FAIL	74 & 75
8.	OIL DRAIN VALVE OPEN	76 & 77
9.	EXTINCTION IN PROGRESS	78 & 79

DETAILS OF CABLES :

NR.	TYPE & SIZE	CONNECTION BETWEEN EQUIPMENTS
I	FIRE SURVIVAL, 750 DEG. C FOR 3 HOURS, UNARMOURED 4 CORE X 1.5 SQ MM	: BETWEEN FIRE DETECTORS : FIRE DETECTORS TO SIGNAL BOX : TCIV (PNRV) TO SIGNAL BOX
II	FIRE RETARDANT LOW SMOKE (FRLS) ARMOURED 4 CORE X 1.5 SQ MM	: AC SUPPLY SOURCE NEAR TRS TO FEC : AC AND DC SUPPLY SOURCE IN CONTROL ROOM TO CONTROL BOX
III	FIRE RETARDANT LOW SMOKE (FRLS) ARMOURED 12 CORE X 1.5 SQ MM	: CONTROL BOX TO FEC. : CONTROL BOX TO SIGNAL BOX : CONTROL BOX TO RELAY PANEL.



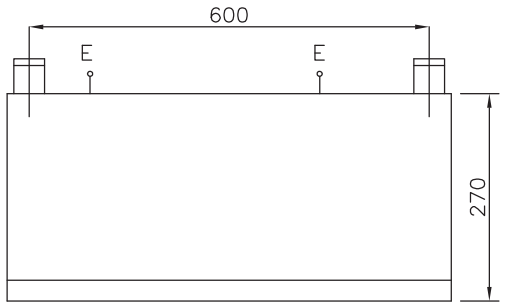
CONTOL BOX TS5

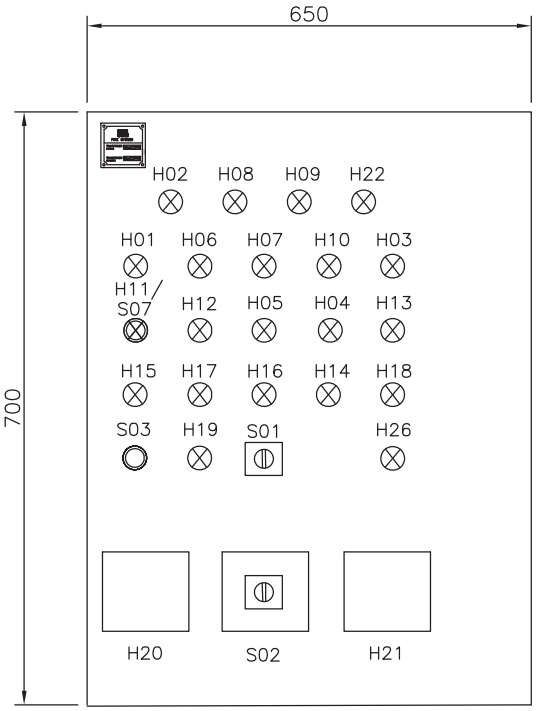
64, 65	SYSTEM OUT OF SERVICE
66, 67	PNRV/TCIV CLOSED
68, 69	FIRE DETECTOR TRIP
70, 71	CYLINDER PRESSURE LOW
72, 73	VISUAL/AUDIO ALARM
74, 75	VISUAL/AUDIO ALARM FOR DC SUPPLY FAIL
76, 77	OIL DRAIN VALVE OPEN
78, 79	EXTINCTION IN PROGRESS

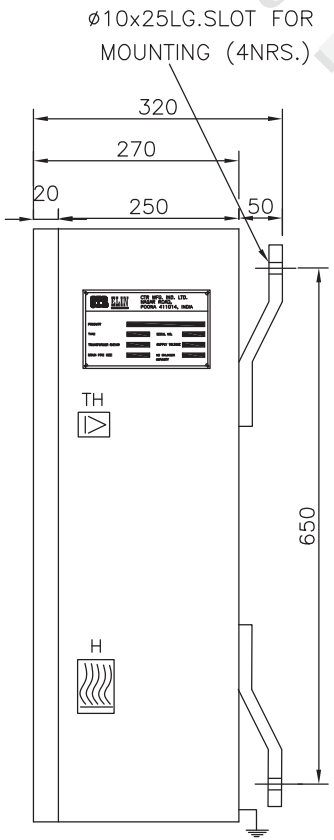
NOTE :
: CONTROL BOX WITH LINE FAULT DETECTION SIGNALS.
: CONNECTION, TERMINAL STRIP (TS4) ALONGWITH TERMINAL AND POTENTIAL FREE TRIP CONTACT MARKED (*) TO BE PROVIDED IN CONTROL ROOM/ RELAY PANEL BY END USER/CUSTOMER.
: ALL FIRE DETECTORS ARE TO BE CONNECTED IN PARALLEL AS SHOWN.
: *** 240 VAC SUPPLY FOR DC SUPPLY FAIL, VISUAL/AUDIO ALARM.

TITLE :
DETAILS OF
INTERCONNECTION DIAGRAM OF PNT
FIRE SYSTEM 110 VDC

CTR WORKS LTD., PUNE







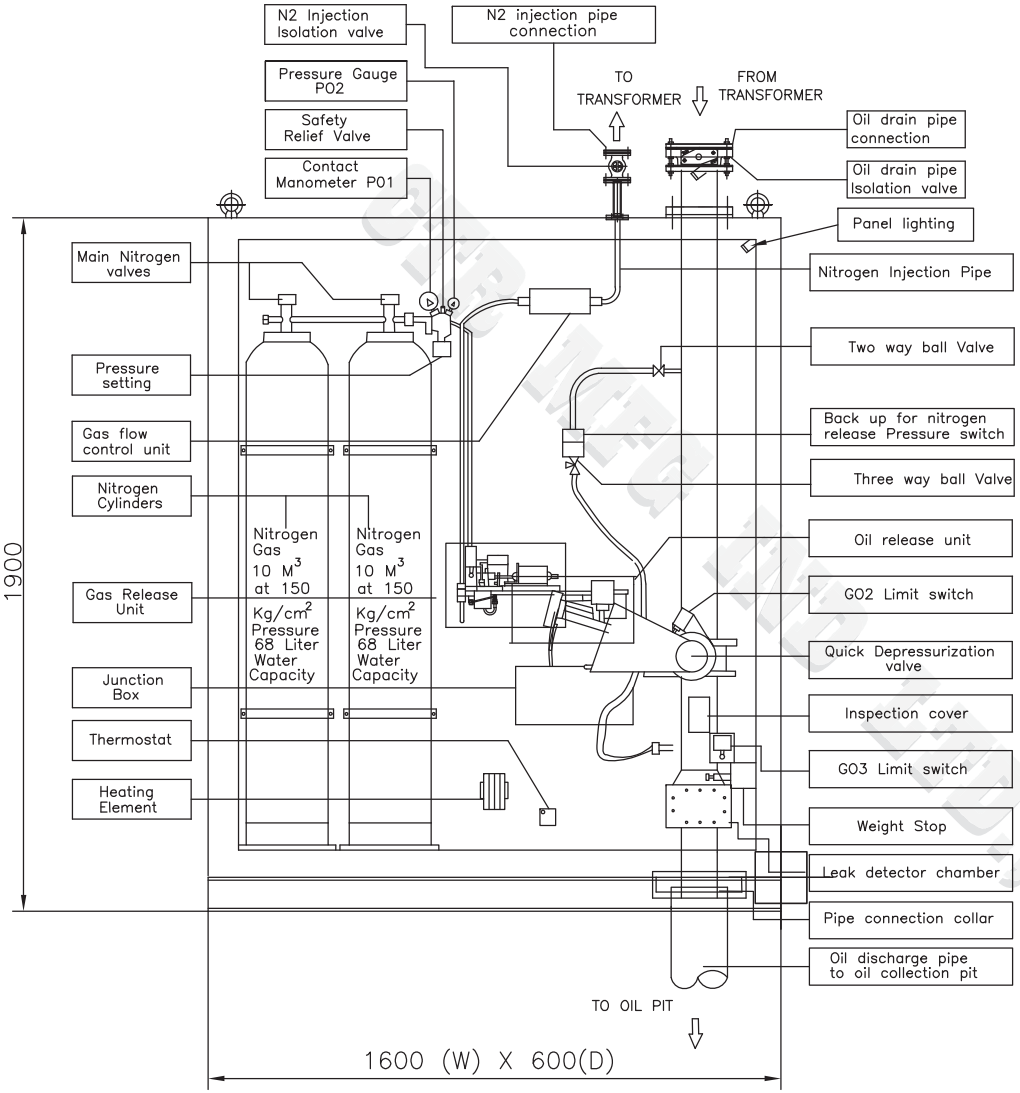
LEGENDS OF CONTROL BOX

SR. NR.	ID.NO.	COLOUR	DESCRIPTION
1	H01	RED	OUT OF SERVICE
2	H02	GREEN	SYSTEM ON
3	H03	RED	TCIV CLOSED
4	H04	RED	FIRE DETECTOR TRIP
5	H05	RED	BUCHHOLZ RELAY TRIP
6	H06	RED	OIL DRAIN VALVE OPEN
7	H07	RED	EXTINCTION IN PROGRESS
8	H08	GREEN	OIL DRAIN VALVE CLOSED
9	H09	GREEN	GAS INLET VALVE CLOSED
10	H10	RED	CYLINDER PRESSURE LOW
11	H11/SO7	RED	DIFFERENTIAL RELAY TRIP
12	H12	RED	RPRR TRIP
13	H13	RED	TRANSFORMER TRIP
14	H14	RED	LINE FAULT FIRE DETECTOR
15	H15	RED	LINE FAULT DIFFERENTIAL RELAY
16	H16	RED	LINE FAULT BUCHHOLZ RELAY
17	H17	RED	LINE FAULT RPRR
18	H18	RED	LINE FAULT TRANSFORMER TRIP
19	H19	RED	LINE FAULT TCIV
20	SO1	–	AUTO/MANUAL/OFF
21	SO2	–	EXTINCTION RELEASE ON/OFF
22	SO3	WHITE	LAMP TEST
23	H20	–	VISUAL/AUDIO ALARM
24	H21	–	VISUAL/AUDIO ALARM FOR DC SUPPLY FAIL
25	H22	GREEN	TCIV OPEN
26	H26	RED	LEAKAGE FROM DRAIN PIPE
27	H	–	HEATER
28	TH	–	THERMOSTAT

CFR MAKE PVT. LTD.

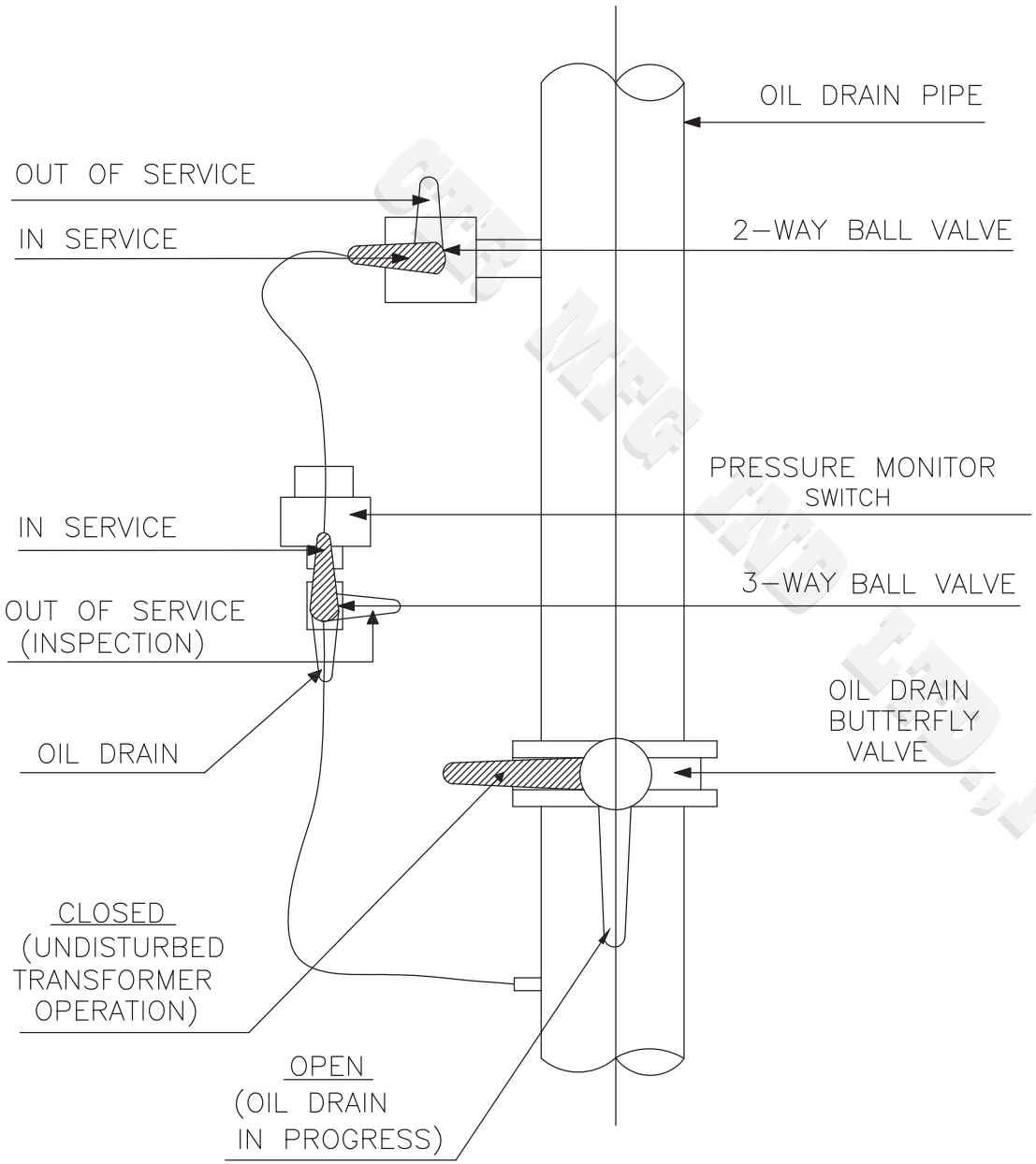
TITLE :

DETAILS OF
CONTROL BOX OF PNT FIRE SYSTEM
WITH TCIV INDICATION



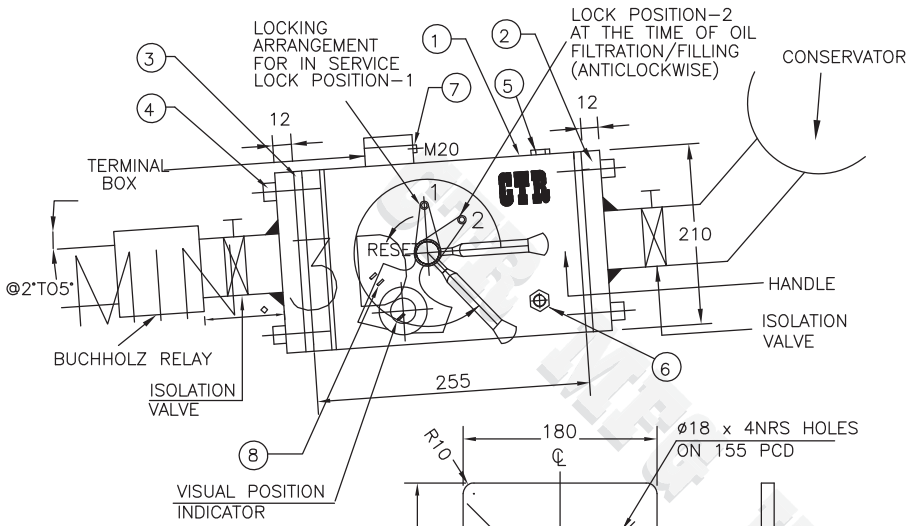
TOTAL WEIGHT : 560 KG MAXIMUM
PAINT : P.O. RED SHADE 538 OF IS 5
INSIDE & OUTSIDE
DOORS : HINGED, SPLIT TYPE WITH
TAMPER PROOF LOCK
PANEL LIGHTING : CFL

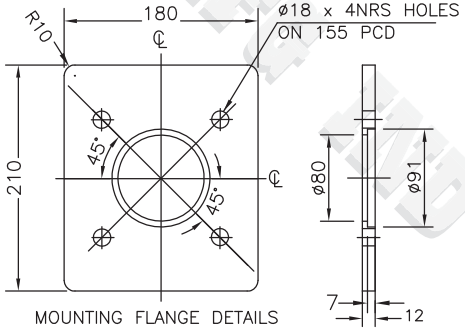
TITLE :
DETAILS OF
FIRE-EXTINGUISHING CUBICLE
OF PNTMXXXC20 FIRE SYSTEM



CEB MFG ENGG...POONA

TITLE :
DETAILS OF
VALVE POSITION WITH PRESSURE
SWITCH IN F.E.C. OF PNT FIRE SYSTEM





MOUNTING FLANGE DETAILS

IMPORTANT NOTE:

1. TRANSFORMER MANUFACTURER TO SUPPLY SPACER CONNECTED BETWEEN FLANGES WHILE DESPATCHING TRANSFORMER. THIS WILL BE REPLACED WITH TCIV (PNRV) DURING SYSTEM INSTALLATION AT SITE.
2. ISOLATION VALVE SHOULD BE PROVIDED BETWEEN CONSERVATOR TANK AND TCIV (PNRV).
3. CONSERVATOR PIPE ANGLE : IN CASE OF ANGLE OTHER THAN 2° TO 5° CONSULT CTR FOR CALIBRATION

SR.NR.	DESCRIPTION	QTY.	MATL	SIZE	REMARKS
8	PROXIMITY SWITCH	1	–	–	REMOTE ALARM INDICATION
7	CABLE GLAND	1	BRASS	M20	–
6	OIL DRAIN PLUG	1	SS	M6 X 10	–
5	AIR RELEASE PLUG	1	SS	M6 X 10	–
4	HEX BOLT	8	SS	M16 X 30L	–
3	GASKET	2	CORK SHEET	210X180X8	FS 2325 A4 00
2	MOUNTING FLANGE	2	MS	210X180X12	TRANSFORMER MANUFATURER'S SCOPE
1	TRANSFORMER CONSERVATOR ISOLATION VALVE (PRE–STRESSED NON RETURN VALVE)	1	–	–	–

TITLE :

DETAILS OF

TCIV (PNRV) AND MOUNTING FLANGES

FOR TCIV (PNRV) OF PNT FIRE SYSTEM

CTR MFG PVT LTD., POONA

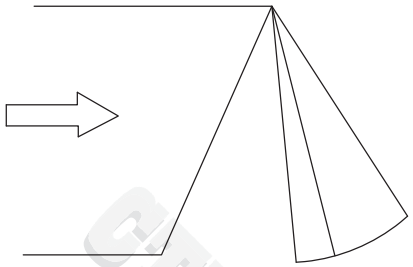


FIG1: OIL FLOW FROM TRANSFORMER TANK

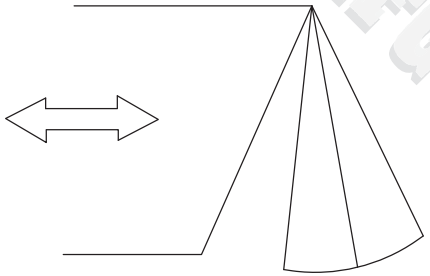


FIG2: OIL FLOW FROM TRANSFORMER TANK
OR FROM CONSERVATOR TANK
WITH FLOW RATE BELOW PRE–SET LIMIT

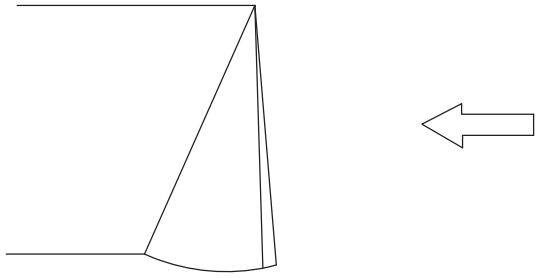


FIG3: OIL FLOW FROM CONSERVATOR
WITH FLOW RATE ABOVE
PRE–SET LIMIT (60–100L.P.M.)

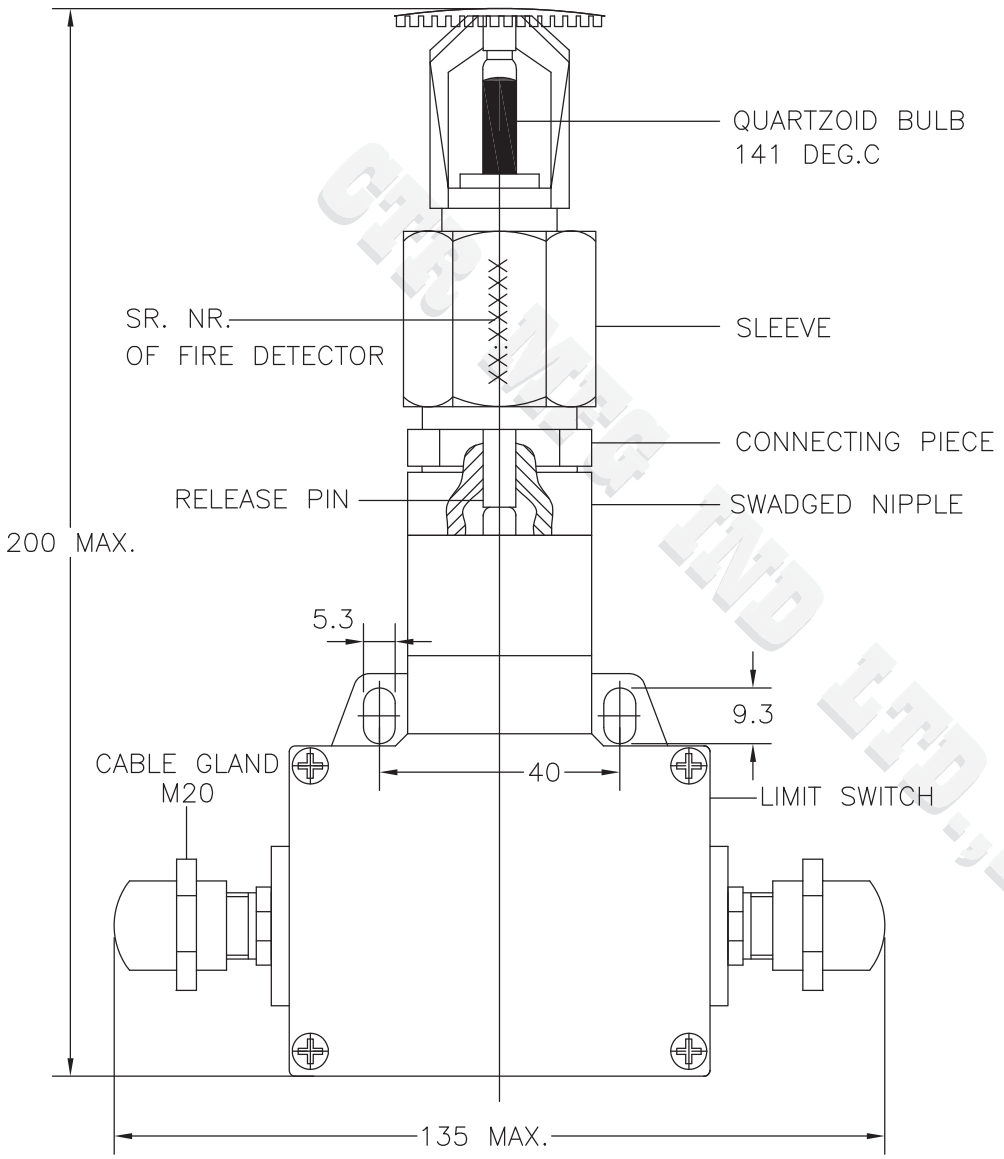
CFP MFG IND LTD.,POON

TITLE :

DETAILS OF

WORKING OF PRE–STRESSED NON

RETURN VALVE OF PNT FIRE SYSTEM



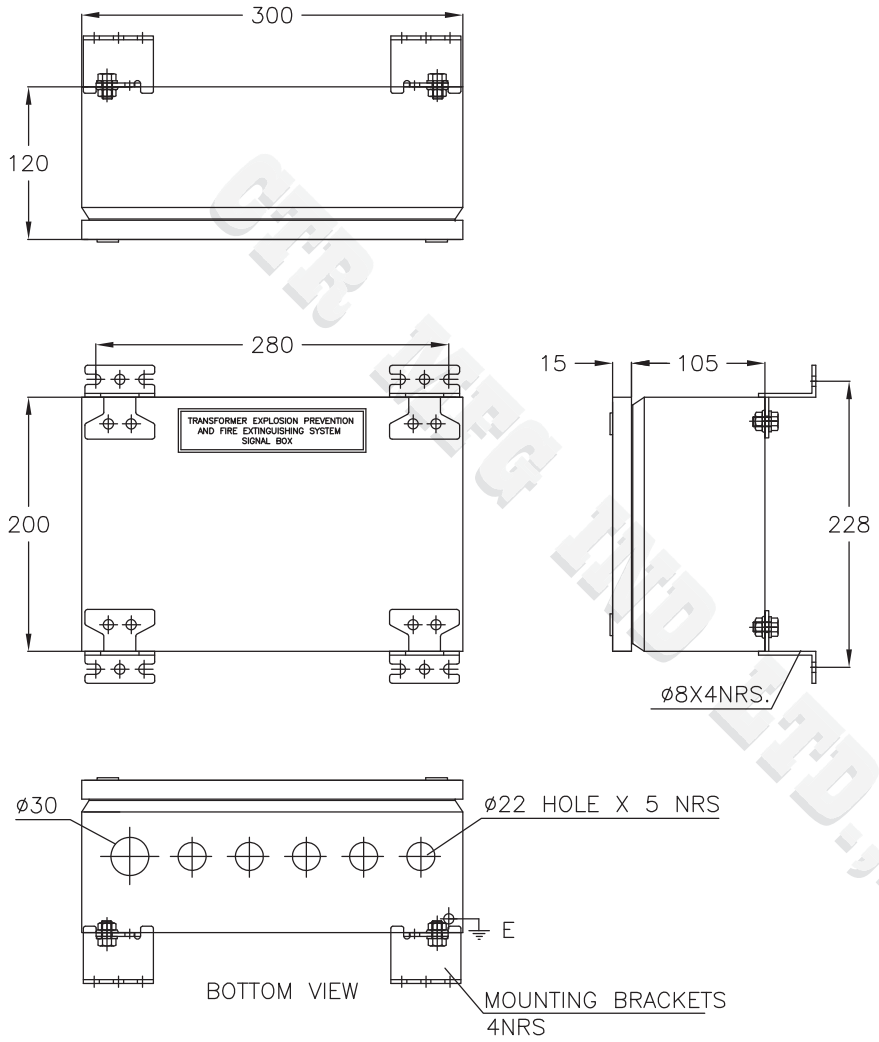
NOTE :

1. EFFECTIVE HEAT SENSING AREA FOR FIRE DETECTOR IS 800MM RADIUS CIRCLE
2. DEPTH OF FIRE DETECTOR : 50 MAX.

TITLE :

DETAILS OF
'T' TYPE FIRE DETECTOR OF PNT
FIRE SYSTEM

CFP MFG IND LTD.,POON



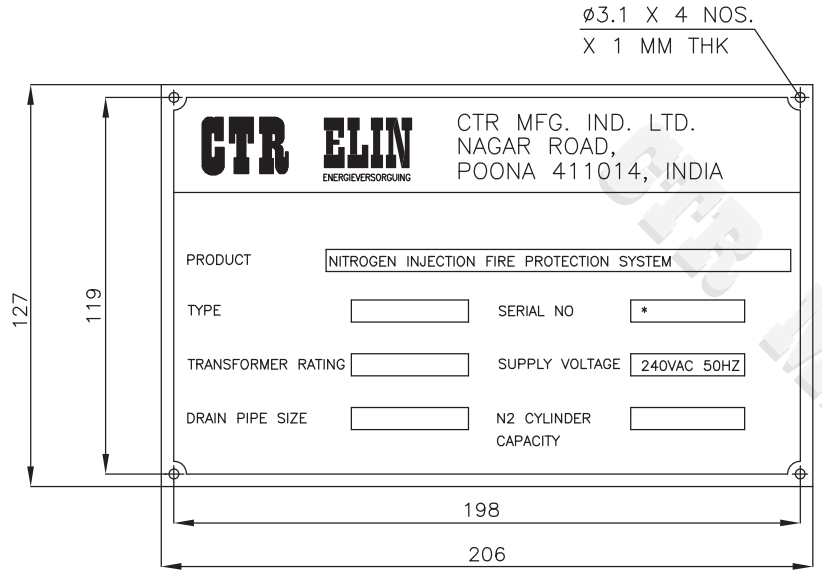
E	1	1	2	2	3	3	4	4	5	6	11	11	12	E

TERMINAL STRIP (TS2)

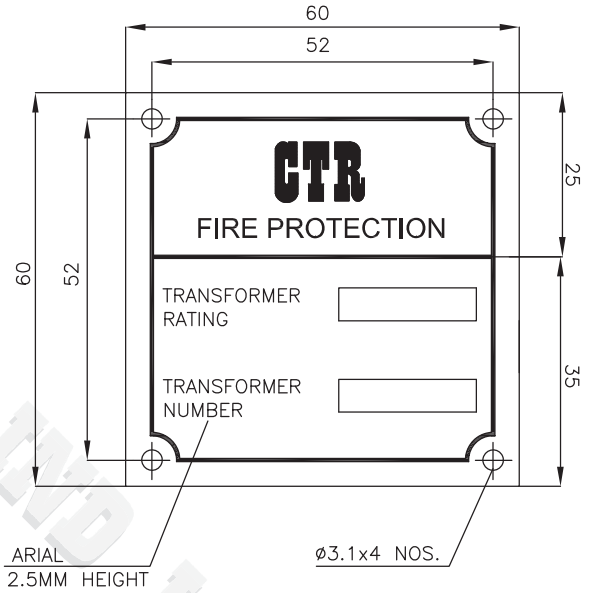
NOTE :
DEGREE OF PROTECTION : MINIMUM IP 55
CABLE TERMINATION : BOTTOM
PAINT SHADE : POST OFFICE RED
SHADE 538 OF IS 5

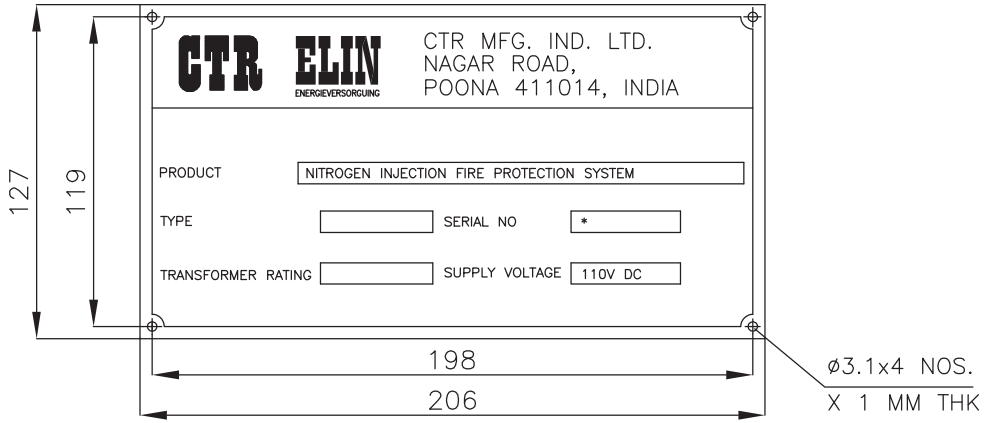
TITLE :
DETAILS OF
SIGNAL BOX OF PNT FIRE SYSTEM

CER ENG IND LTD.,POON



* DIFFERENT NUMBER FOR EACH TRANSFORMER SYSTEM
(FOR FEC)





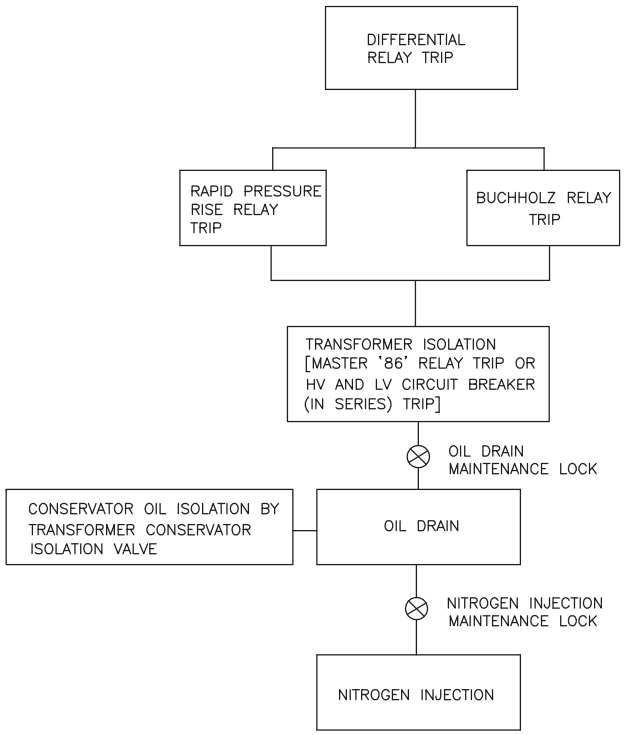
* DIFFERENT NUMBER FOR EACH CONTROL BOX

TITLE :
DETAILS OF
RATING PLATES FOR PNT
FIRE SYSTEM

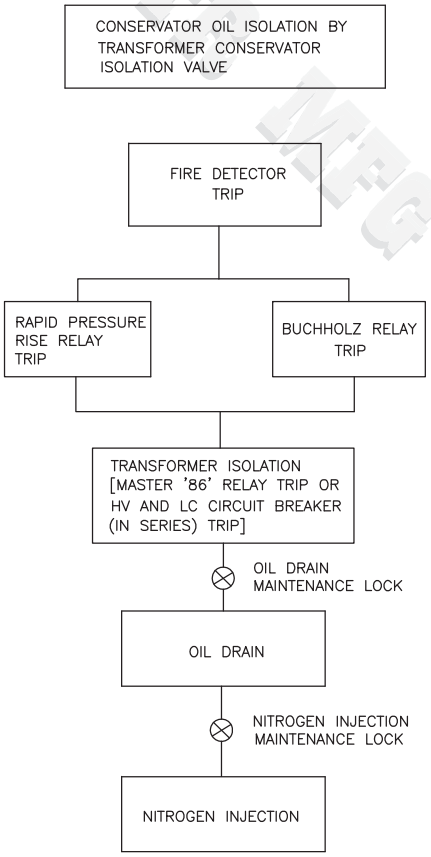
CTR MFG IND LTD.,POONA

AUTO–MODE

PREVENTION

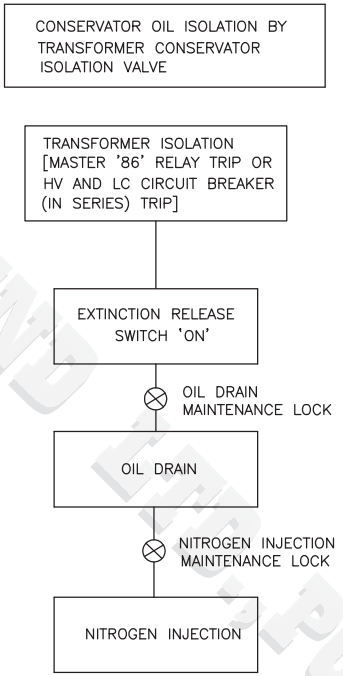


EXTINCTION



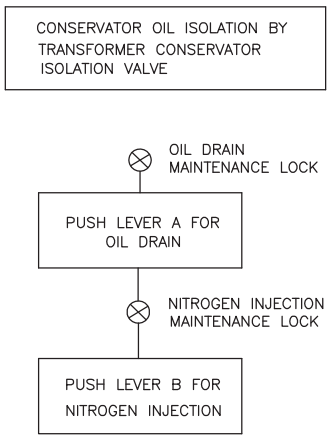
REMOTE ELECTRICAL

EXTINCTION



LOCAL MECHANICAL MANUAL

EXTINCTION

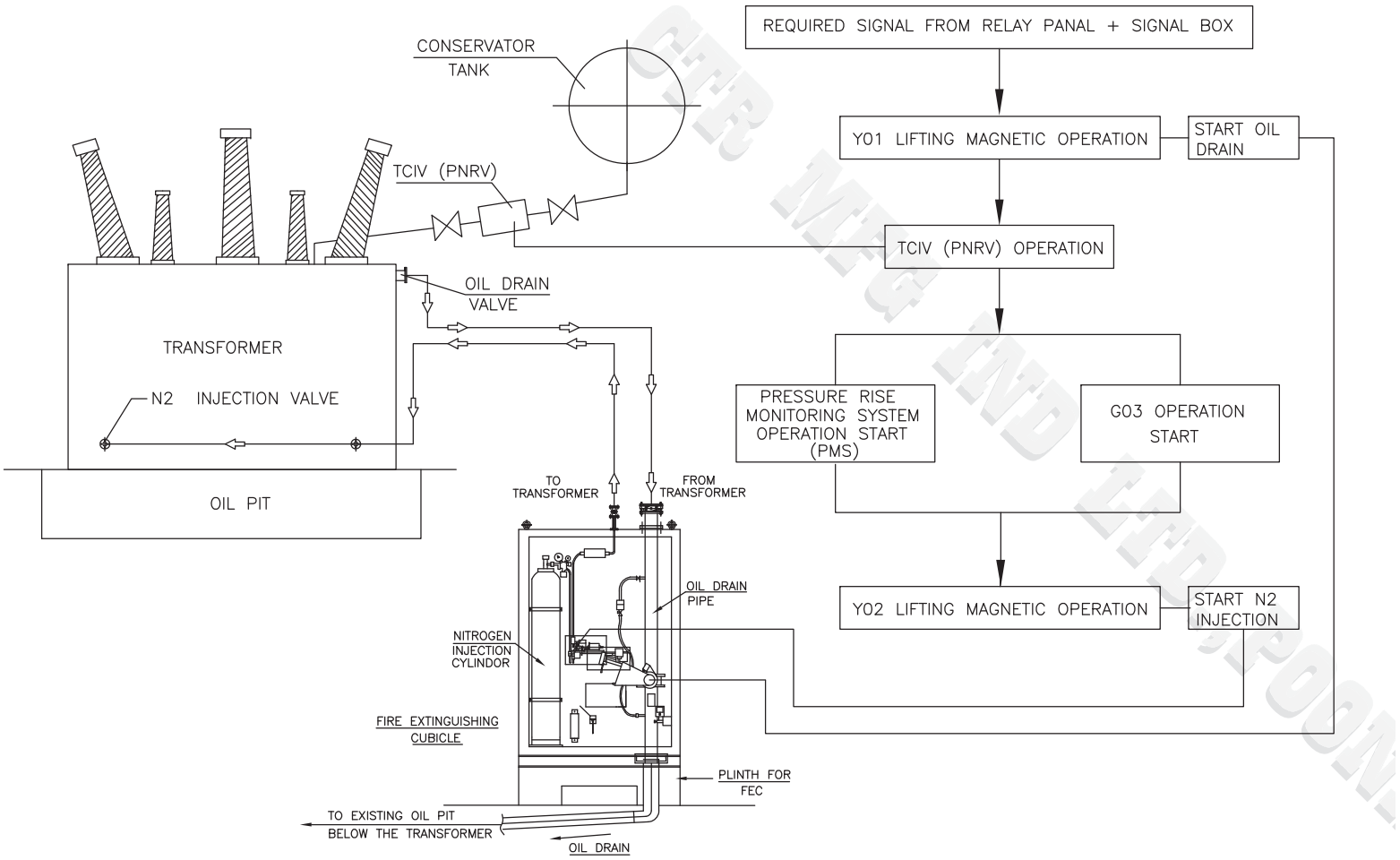


TITLE :

DETAILS OF

LOGIC DIAGRAM FOR OPERATION OF

PNT FIRE SYSTEM



NOTE:

1. TCIV (PNRV) : TRANSFORMER CONSERVATOR ISOLATION VALVE (PRE STRESSED NON RETURN VALVE).
2. G03 : LIMIT SWITCH FOR INDICATION OF OIL DRAIN VALVE OPEN AND SIGNAL FOR OPERATION OF Y02 LIFTING MAGNET
3. Y01 : LIFTING MAGNET FOR OIL DRAIN
4. Y02 : LIFTING MAGNET FOR NITROGEN GAS RELEASE (INJECTION)

TITLE :

DETAILS OF

P & I DIAGRAM

OF PNT FIRE SYSTEM

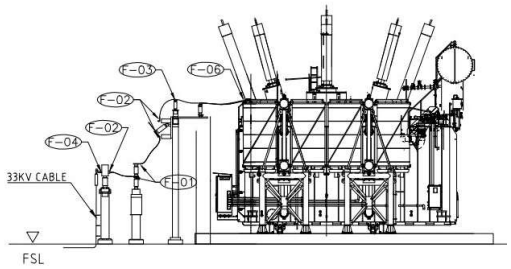
CFR MFG IND LTD.,PUNE

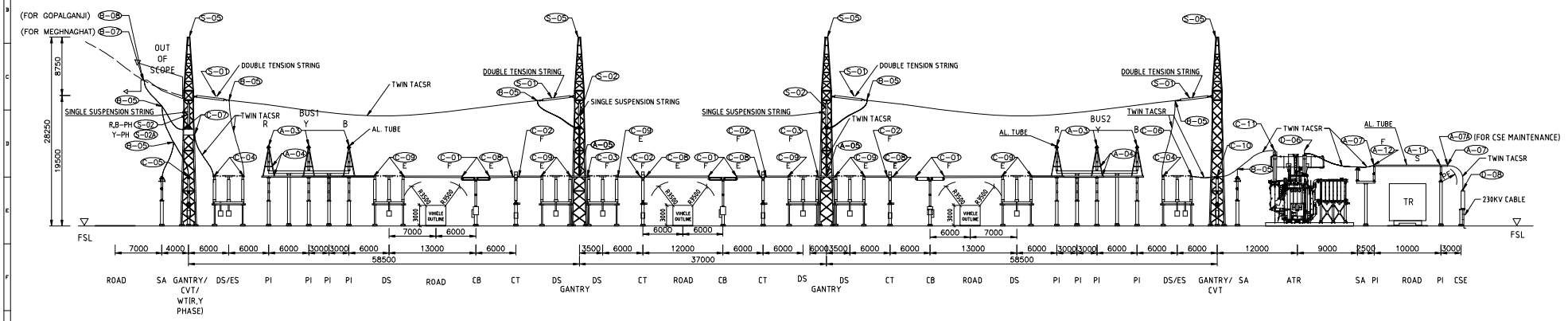
NOTE :
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. MATERIAL : STAINLESS STEEL.
3. THICKNESS : 2mm
4. LETTER COLOR : BLACK
5. ANGLE OF PROJECTION: 3RD.

VALVE LOCATION

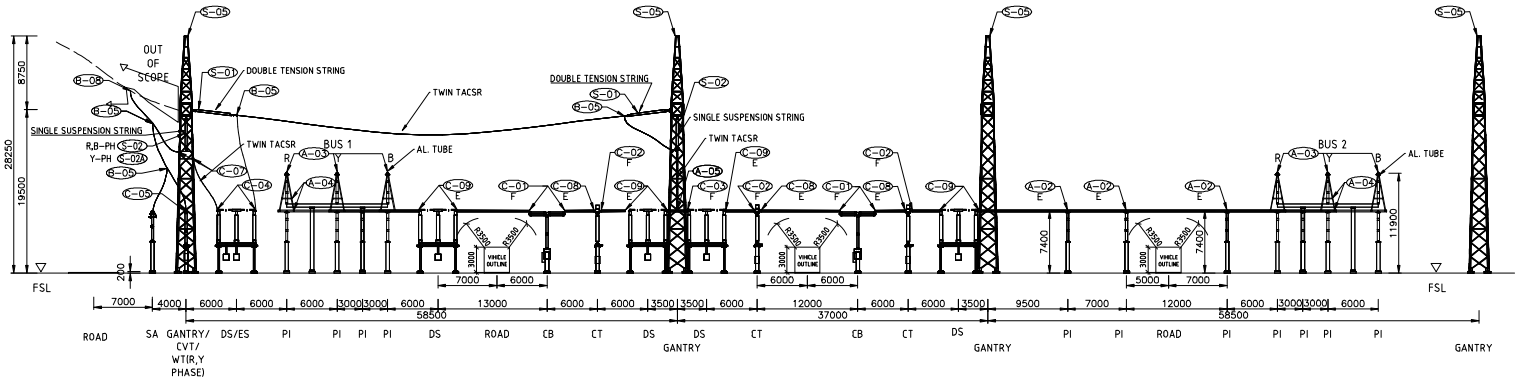
POS. NO.	NO. IN OUTLINE	DESCRIPTION	VALVE TYPE	TOTAL Q'TY	NORMAL CONDITION
1	45	UPPER FILTER VALVE FOR MAIN TANK	2" GATE	1	CLOSED
2	46	LOWER FILTER/DRAIN VALVE FOR MAIN TANK	2" GATE	1	CLOSED
3	47	VACUUM VALVE FOR MAIN TANK	3" GATE	1	CLOSED
4	48	VACUUM VALVE FOR MAIN CONSERVATOR	1" GATE	1	CLOSED
5	49	EQUALIZING VALVE FOR MAIN CONSERVATOR	1" GATE	1	OPEN
6	50	DRAIN VALVE FOR MAIN CONSERVATOR	1" GATE	1	CLOSED
7	51	CONNECTING VALVE FOR MAIN CONSERVATOR NEXT TO COVER	3" GATE	1	OPEN
8	52	CONNECTING VALVE FOR MAIN CONSERVATOR NEXT TO CONSERVATOR	3" GATE	1	OPEN
9	53	BUCHHOLZ RELAY BY-PASS VALVE	3" GATE	1	OPEN
10	54	DRAIN VALVE FOR OLTC CONSERVATOR	1" GATE	1	CLOSED
11	55	CONNECTING VALVE FOR OLTC CONSERVATOR	1" GATE	4	OPEN
12	56	DRAIN VALVE FOR OLTC	–	3	CLOSED
13	57	UPPER FILTER VALVE FOR HV BUSHING CHAMBER	2" GATE	3	CLOSED
14	58	DRAIN VALVE FOR HV BUSHING CHAMBER	2" GATE	3	CLOSED
15	59	CONNECTING VALVE FOR FIRE PROTECTION DEVICE	6" BUTTERFLY	1	OPEN
16	60	VALVE FOR NITROGEN INJECTION	1" GATE	6	CLOSED
17	61	UPPER FILTER VALVE FOR OILBOX	2" GATE	2	CLOSED
18	62	LOWER FILTER / DRAIN VALVE FOR OILBOX	2" GATE	2	CLOSED
19	63	INLET AND OUTLET VALVE FOR RADIATOR	3" BUTTERFLY	48	OPEN
20	64	CONNECTING VALVE FOR OILBOX	12" BUTTERFLY	8	OPEN
21	65	AIR RELEASE PLUG FOR MAIN CONSERVATOR	–	3	CLOSED
22	66	AIR RELEASE PLUG FOR OILBOX	–	12	CLOSED
23	67	AIR RELEASE PLUG FOR RADIATOR	–	24	CLOSED
24	68	DRAIN PLUG FOR RADIATOR	–	24	CLOSED
25	69	CONNECTING VALVE FOR RAPID PRESSURE RISE RELAY	2" GATE	1	OPEN
26	70	CONSERVATOR ISOLATION VALVE	3" GATE	2	OPEN
27	39	GAS SAMPLING VALVE FOR BUCHHOLZ RELAY	–	1	CLOSED

CAUTION : OPERATORS HAVE TO REFER TO THE MAINTENANCE INSTRUCTION MANUAL BEFORE APPLYING ANY VACUUM TREATMENT.


F-03
F-06
F-02
F-02
F-04
33KV CABLE
F-01
FSL
TK/CT CB
DS/IVT/SA
ATR
NO.1



SECTION A-A'
400KV FULL DIAMETER



SECTION B-B'
400KV HALF DIAMETER

REV	DATE	DESCRIPTION	DRN	DES	CHK	APP
0	21.AUG.2019	FOR APPROVAL	J.H.KIM	J.H.KIM	W.B.LEE	D.H.KIM

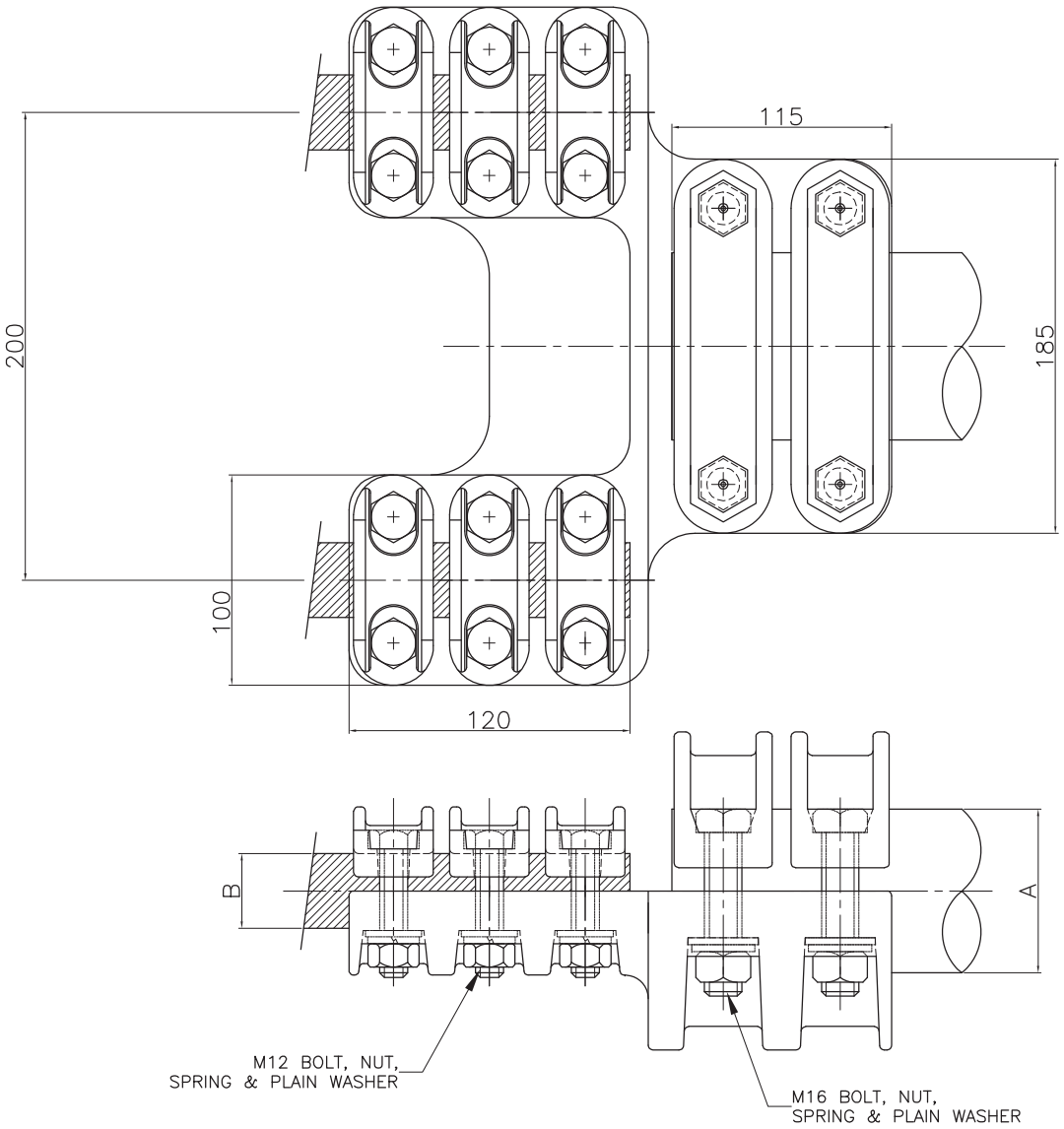
CLIENT : POWER GRID COMPANY OF BANGLADESH LIMITED (PGCB)

CONSULTANT : intec

CONTRACTOR : HYOSUNG CORPORATION

PROJECT NAME
DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING OF AMINBAZAR 400/230KV SUBSTATION ON TURNKEY BASIS

SIZE : A3	TITLE
SCALE : 1:600	HARDWARE INSTALLATION
DRAWN : J.H.KIM	400KV SWITCHYARD SECTION A-A', B-B'
DESIGN : J.H.KIM	
CHECKED : W.B.LEE	
APPROVED : D.H.KIM	
DATE : 21.AUG.2019	DWG NO.: PGCB-AMN-C-39-L001 SH NO. 1/3 REV 0



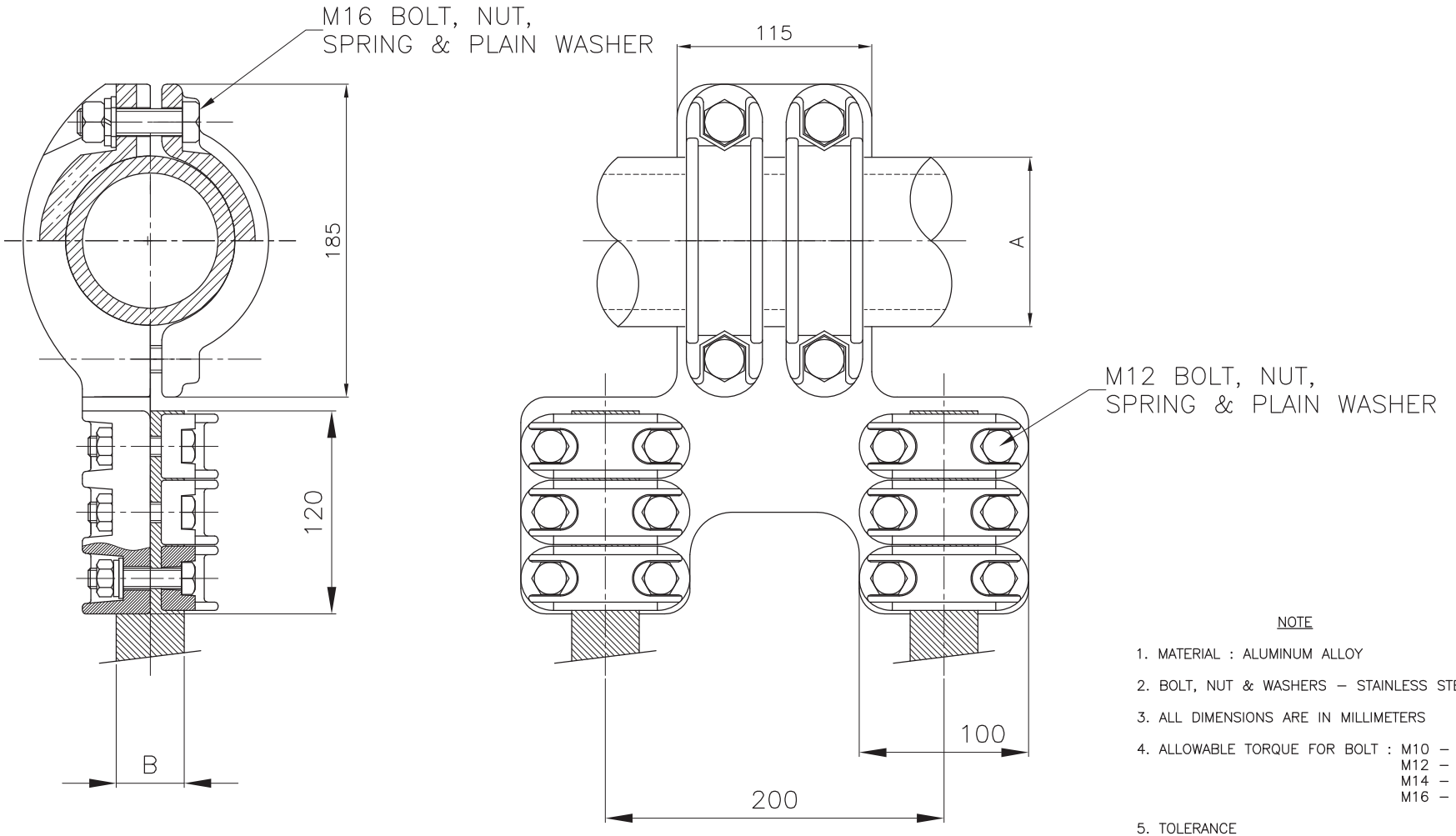
NOTE

1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
5. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm

TITLE:

A–07

230kV
SINGLE / DUPLEX STRAIGHT CONNECTOR
A: AL. TUBE ø100/80
B: TACSR 810SQmm (ø38.4)
(FOR 230kV AL-TUBE END CONNECTOR)



NOTE

1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
5. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm

TITLE:

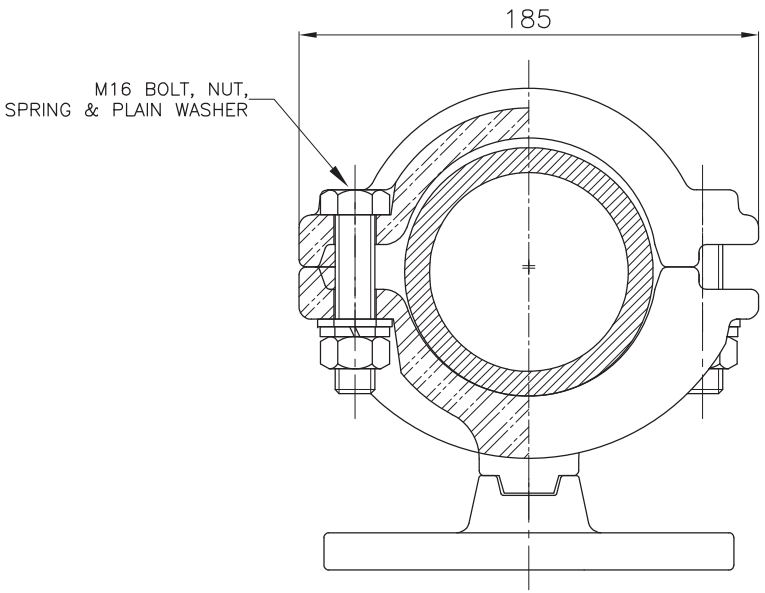
A–07A

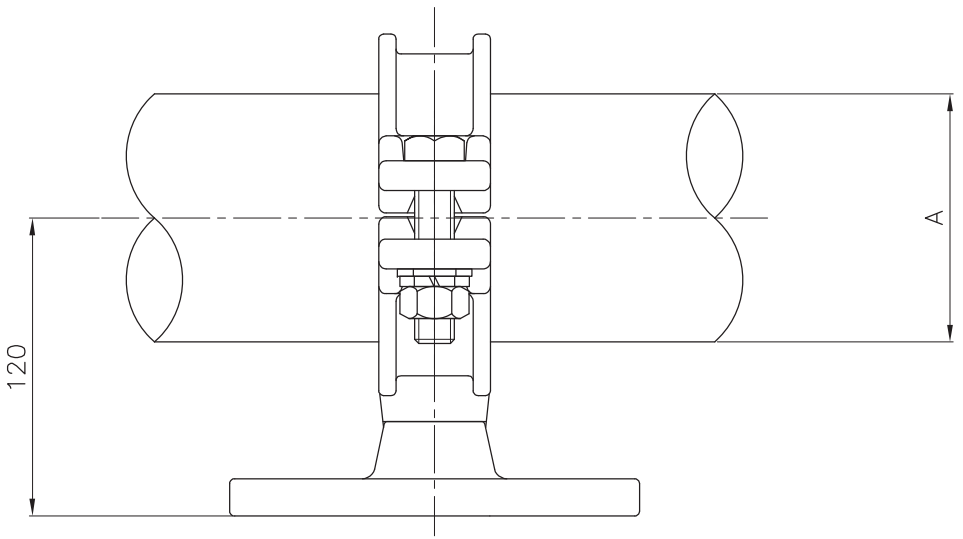
SINGLE / DUPLEX T–CONNECTOR

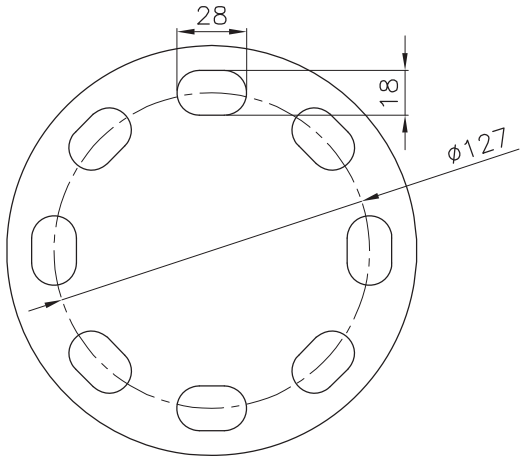
A : AL. TUBE ø100/80

B : TACSR 810SQmm

(FOR 230kV C.S.E MAINTENANCE)

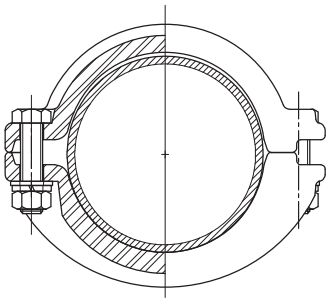




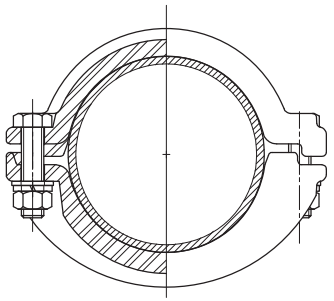


DETAIL " 5" BCD PI "

COVER 180° ROTATE



SLIDING TYPE



FIXED TYPE

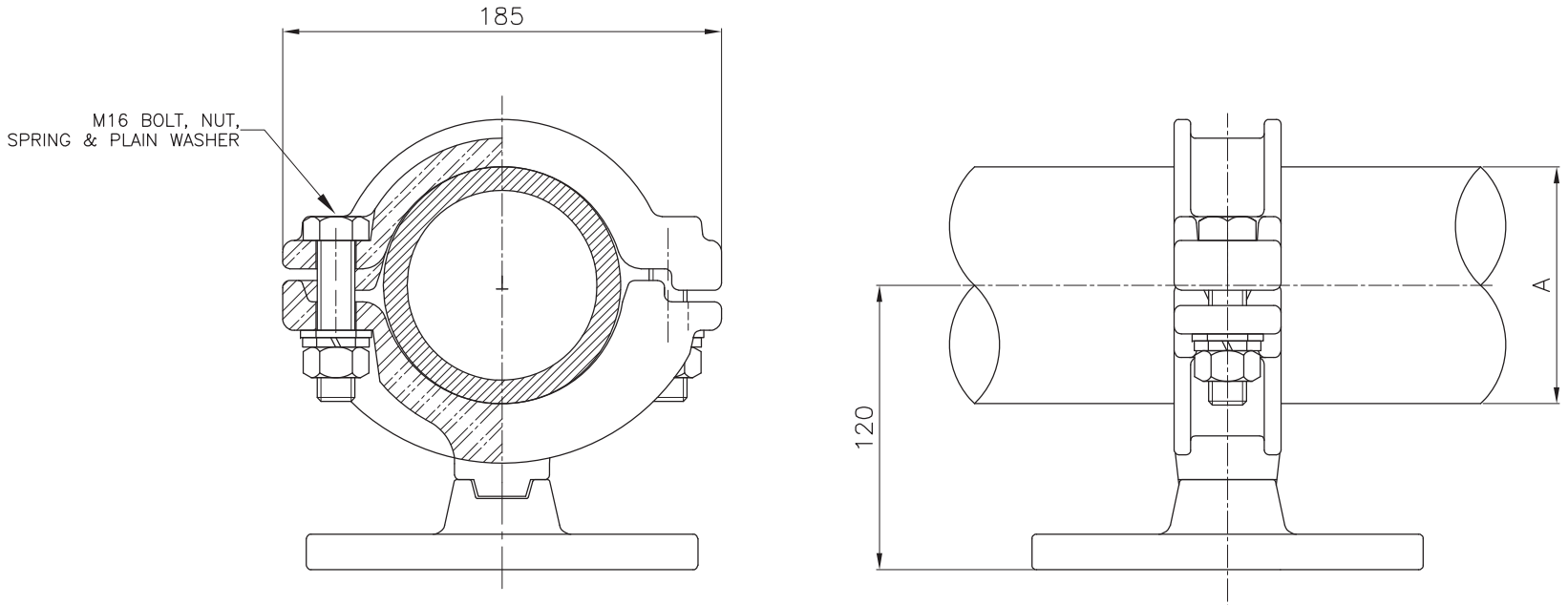
NOTE

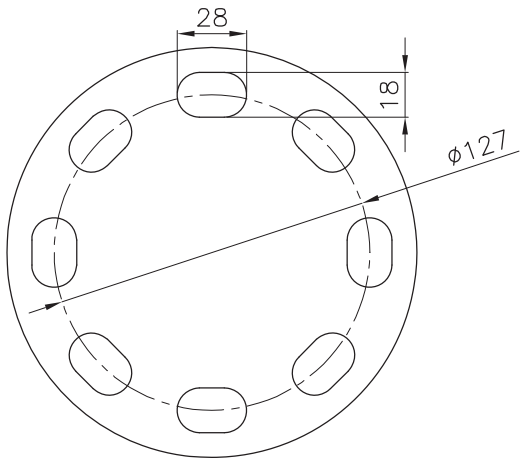
1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
3. MOUNTING HARDWARES – H.D.G. STEEL
   FOR 5" BCD PI : 4–M16x40L BOLTS, WASHERS
4. ALL DIMENSIONS ARE IN MILLIMETERS
5. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
6. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm

TITLE:

A–11

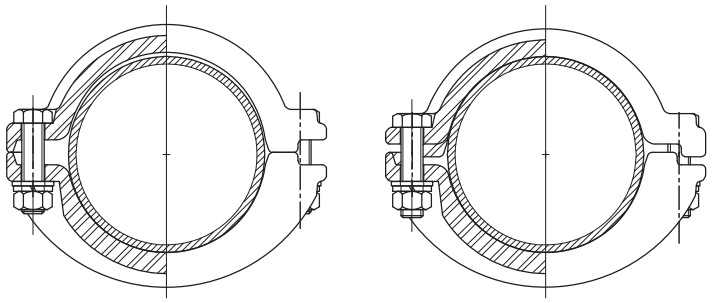
BUS SUPPORT CLAMP FOR 5" BCD
A: AL. TUBE ø100/80
(FOR 230kV PI _ SLIDING TYPE)





DETAIL " 5" BCD PI "

COVER 180° ROTATE



SLIDING TYPE

FIXED TYPE

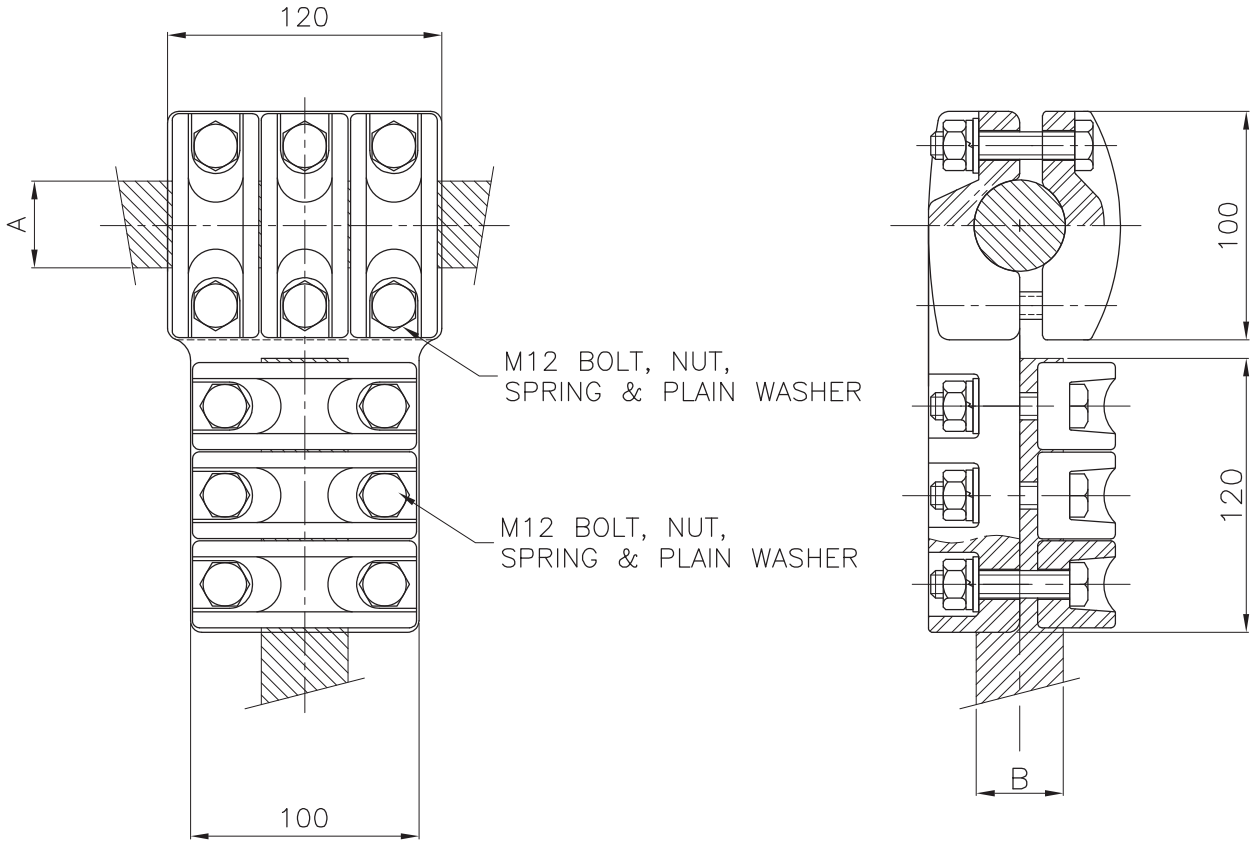
NOTE

1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
3. MOUNTING HARDWARES – H.D.G. STEEL
   FOR 5" BCD PI : 4–M16x40L BOLTS, WASHERS
4. ALL DIMENSIONS ARE IN MILLIMETERS
5. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
6. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm

TITLE:

A–12

BUS SUPPORT CLAMP FOR 5" BCD
A: AL. TUBE ø100/80
(FOR 230kV PI _ FIXED TYPE)



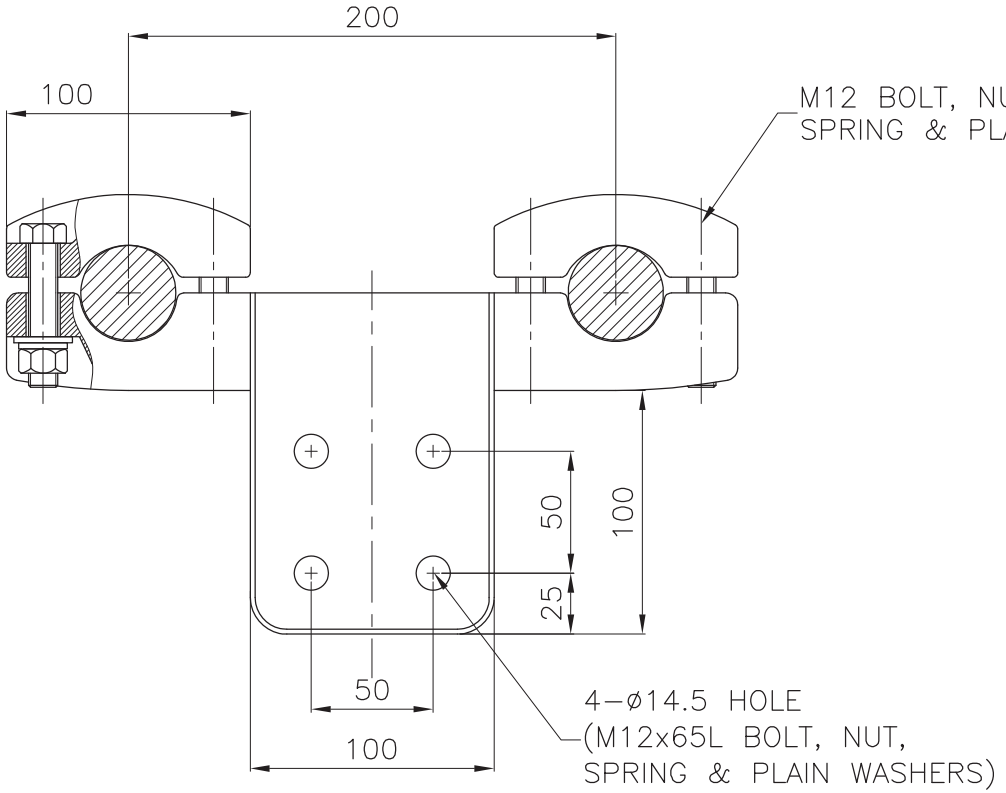
NOTE

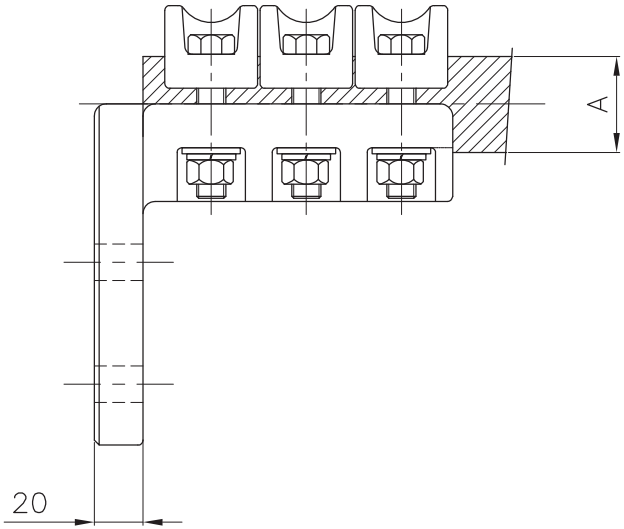
1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
5. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm

TITLE:

B–05

400kV T–CONNECTOR
A : TACSR 810SQmm (ø38.4)
B : TACSR 810SQmm (ø38.4)
(FOR 400kV TR PRIMARY CONNECTION)





NOTE

1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
4. ALL DIMENSIONS ARE IN MILLIMETERS
5. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
6. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm

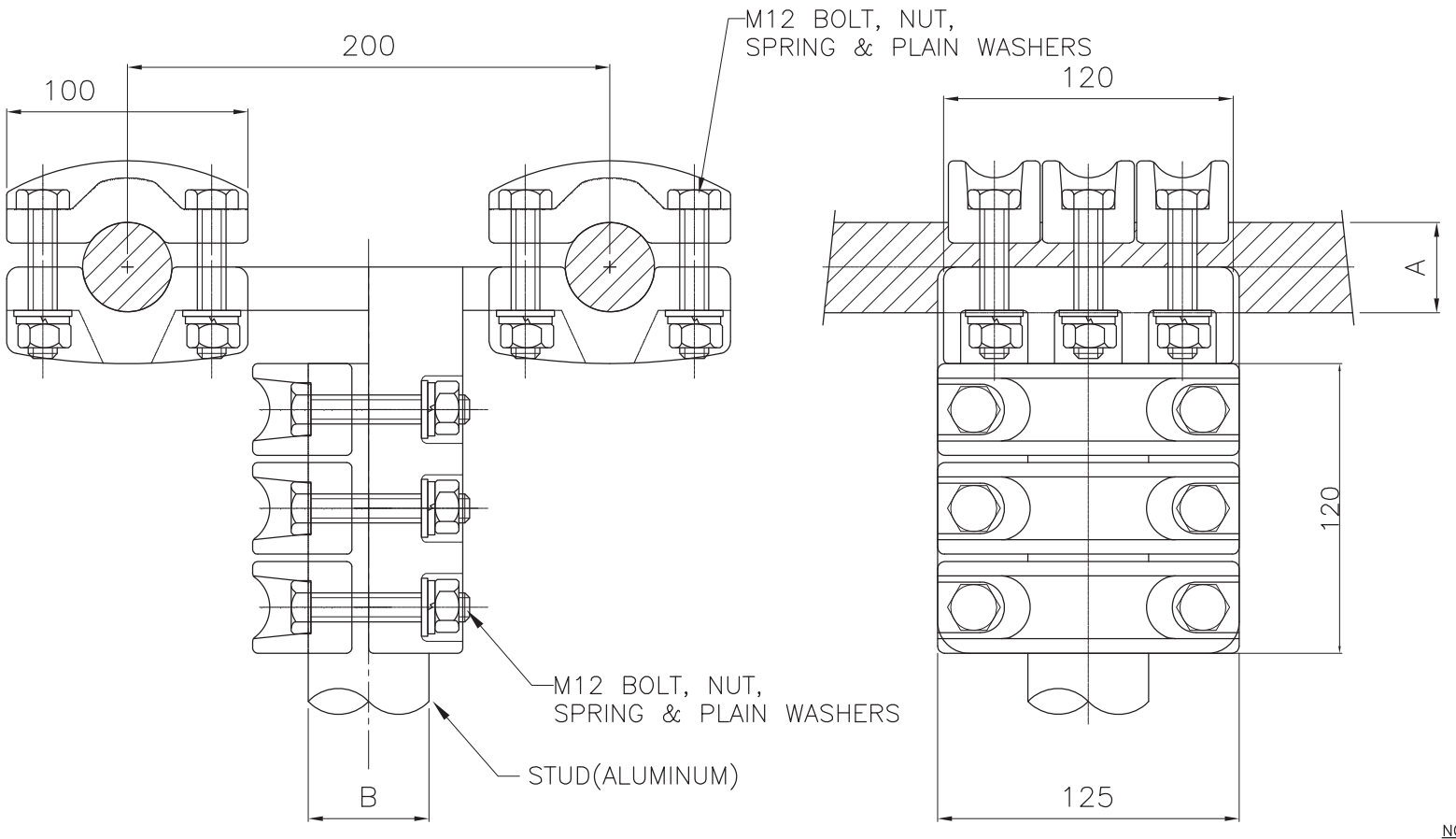
TITLE:

C–10

400kV DUPLEX 90° TERMINAL CONNECTOR

A : TACSR 810SQmm (ø38.4)

(FOR 400kV CVT)



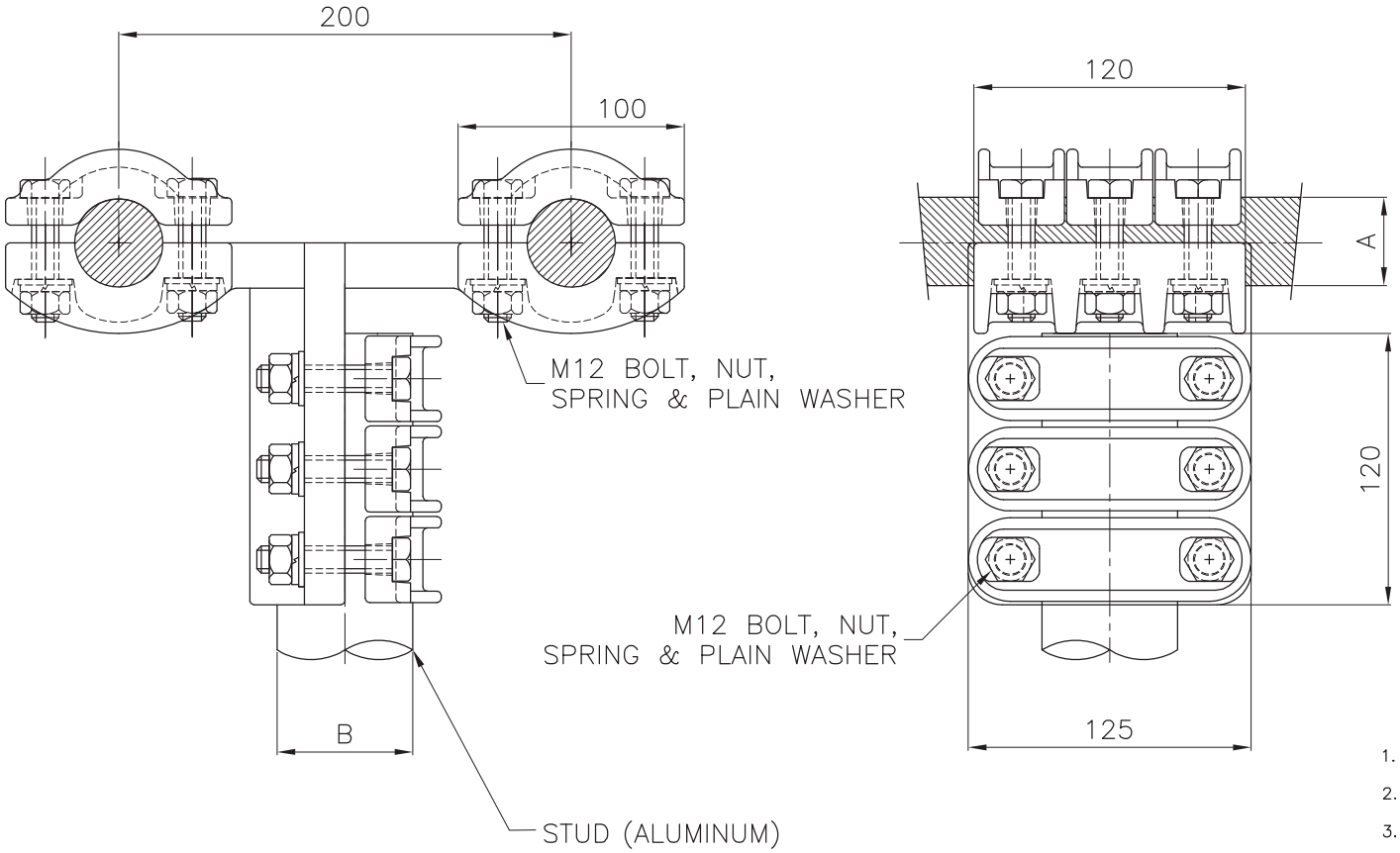
NOTE

1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
5. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm

TITLE:

C–11

400kV T–TERMINAL CONNECTOR
A : TACSR 810SQmm (ø38.4)
B : STUD ø60
(FOR POWER TR_ PRIMARY)



NOTE

1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
5. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm

TITLE:

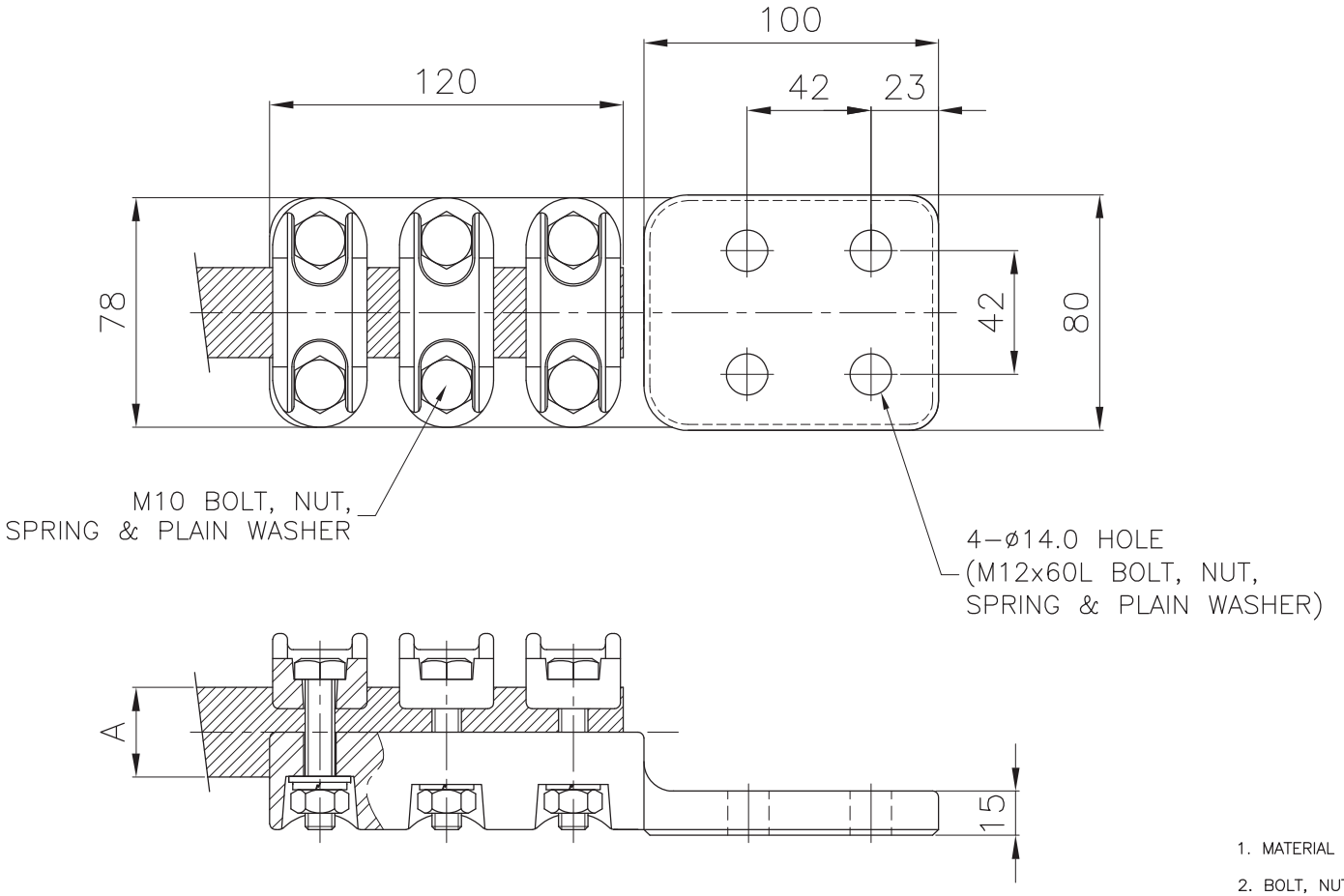
D–06

DUPLEX/SINGLE T–TERMINAL CONNECTOR

A : TACSR 810SQmm (ø38.4)

B : STUD ø60

(FOR POWER TR _ SECONDARY)



NOTE

1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
5. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm

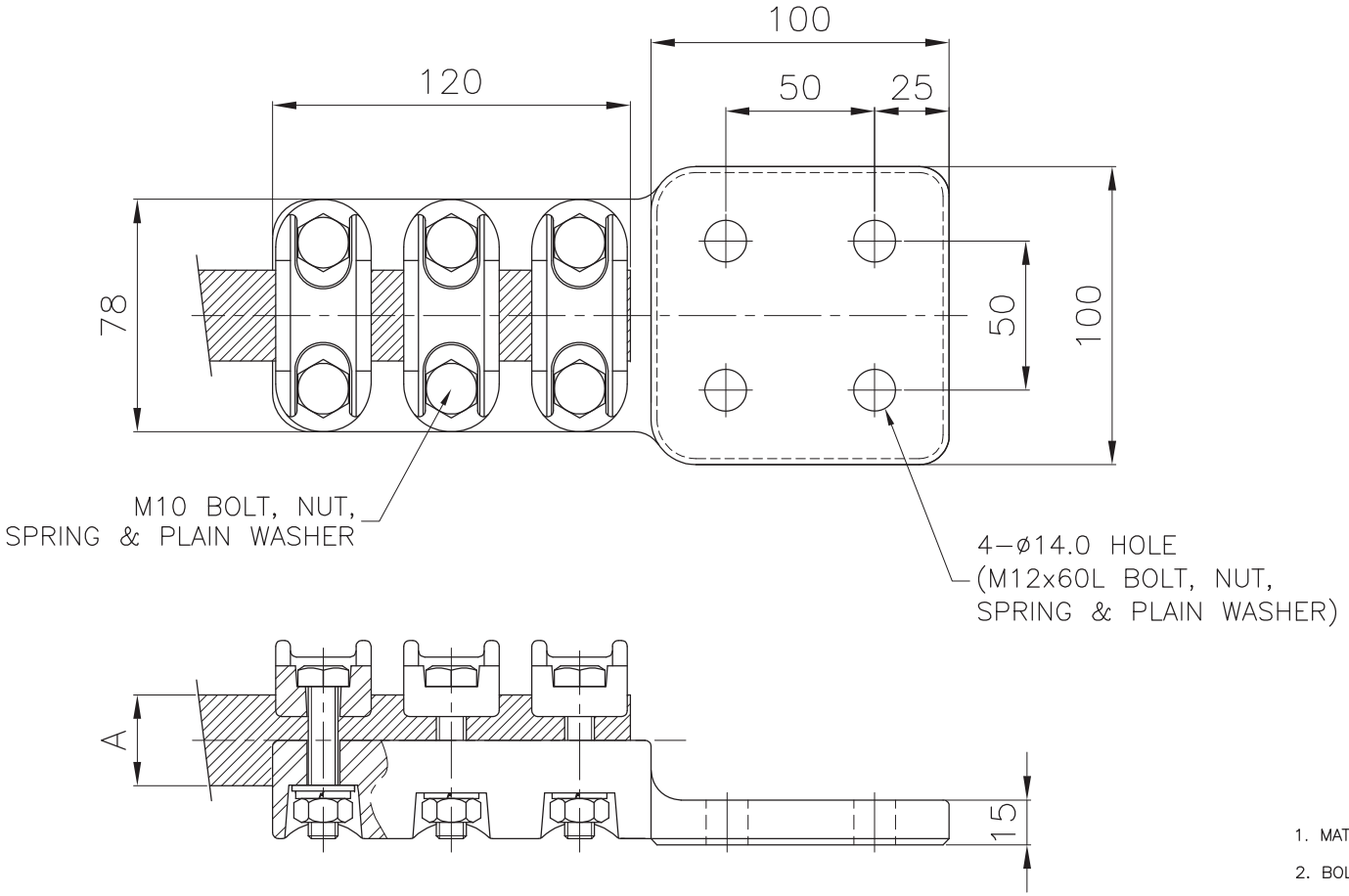
TITLE:

F–01

STRAIGHT TERMINAL CONNECTOR

A : TACSR 410SQmm (ø28.5)

(FOR 33kV CB)



NOTE

1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
5. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm

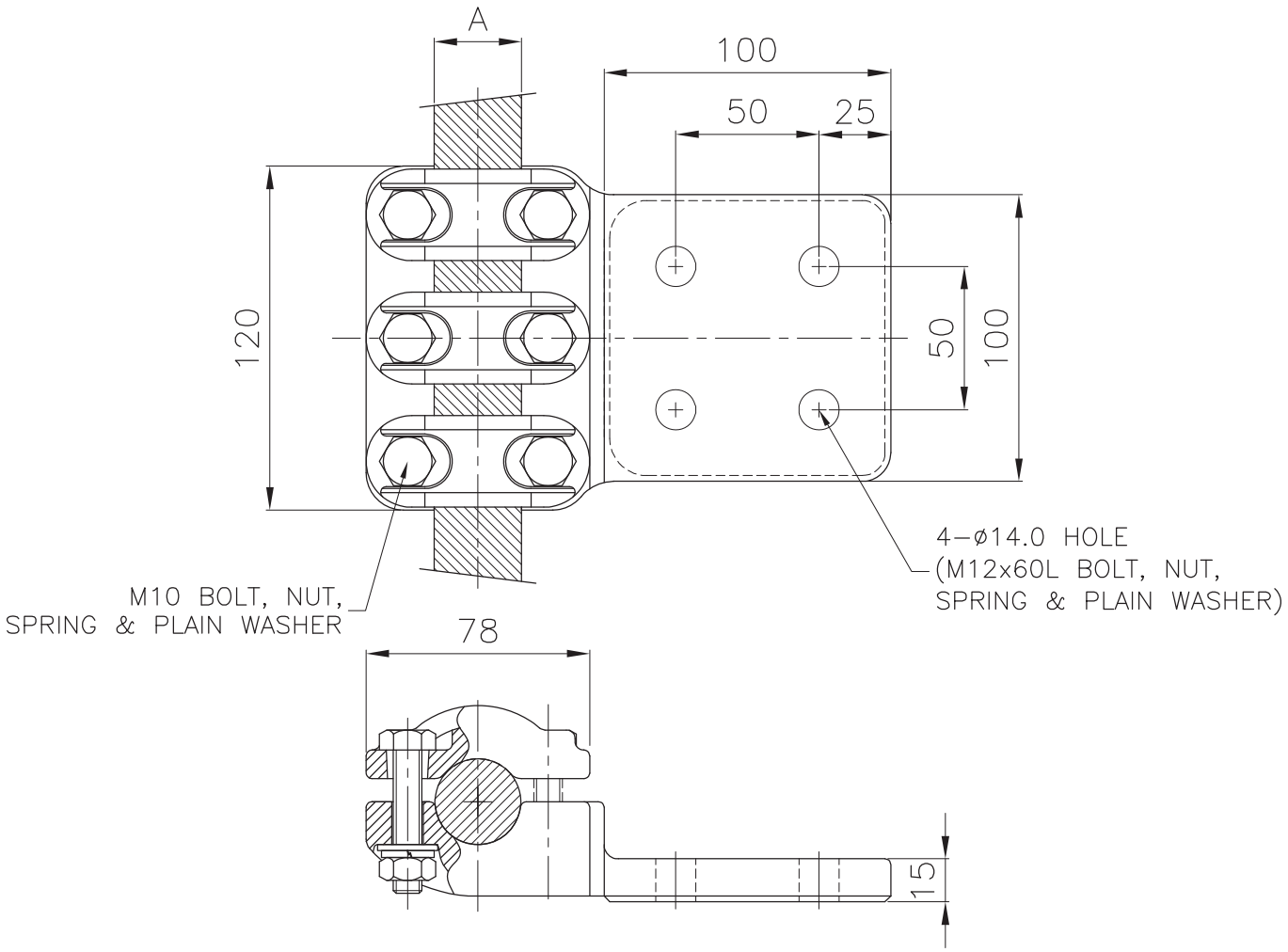
TITLE:

F–02

STRAIGHT TERMINAL CONNECTOR

A : TACSR 410SQmm (ø28.5)

(FOR 33kV CT & DS)



NOTE

1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
5. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm

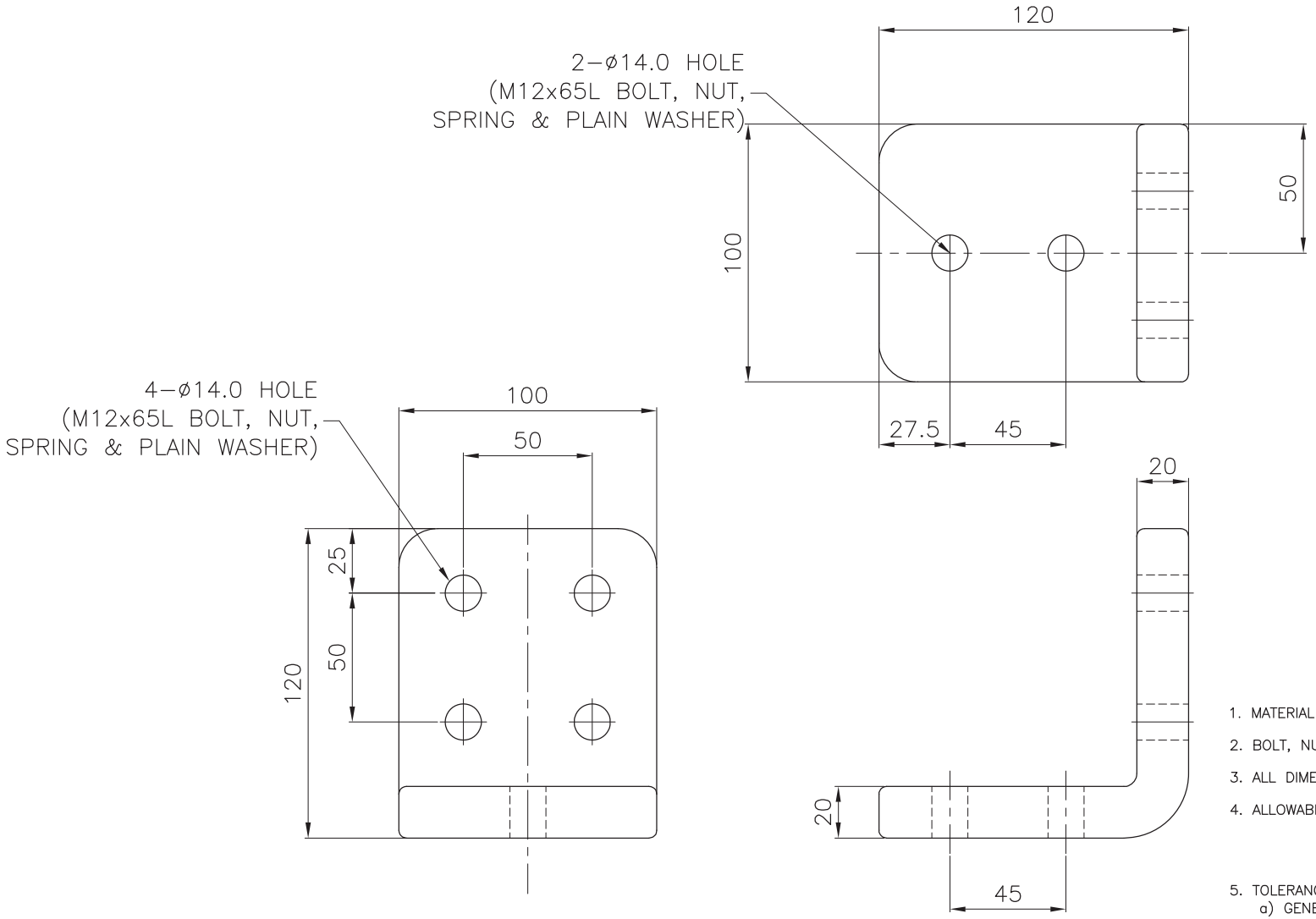
TITLE:

F–03

T–TERMINAL CONNECTOR

A : TACSR 410SQmm (ø28.5)

(FOR 33kV IVT)



NOTE

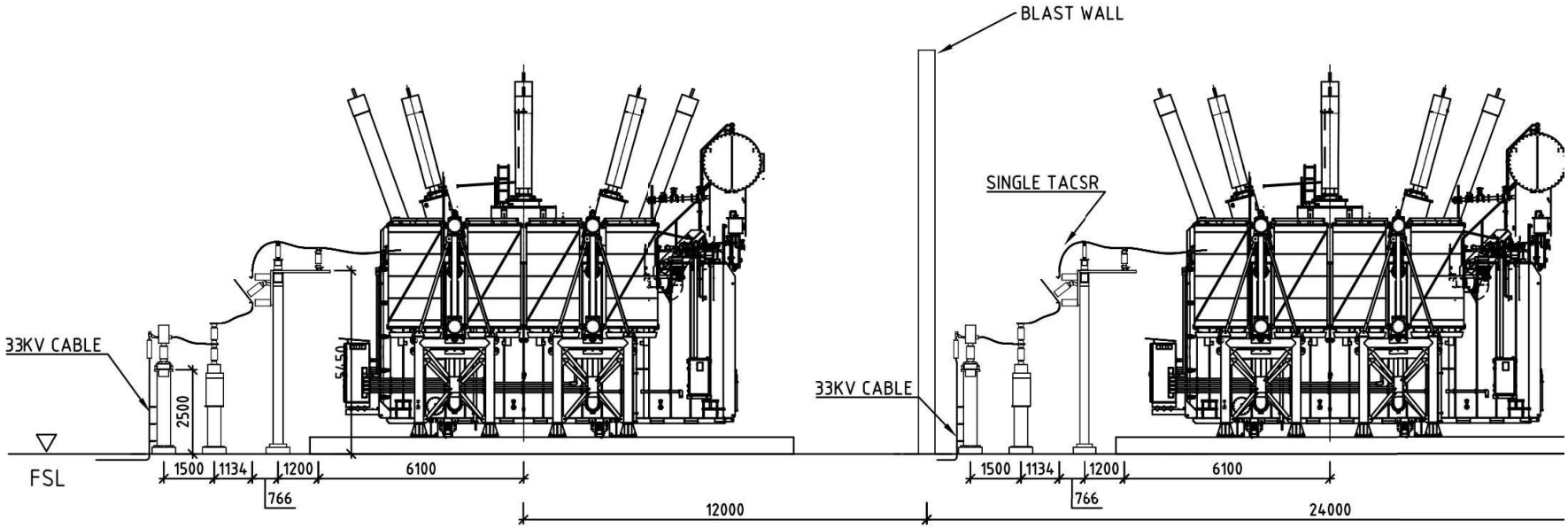
1. MATERIAL : ALUMINUM ALLOY
2. BOLT, NUT & WASHERS – STAINLESS STEEL
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. ALLOWABLE TORQUE FOR BOLT : M10 – 276 KG.CM
   M12 – 553 KG.CM
   M14 – 762 KG.CM
   M16 – 762 KG.CM
5. TOLERANCE
   a) GENERAL TOLERANCE : ± 5%
   b) HOLE : ± 0.5mm
6. FINISH : TIN PLATING

TITLE:

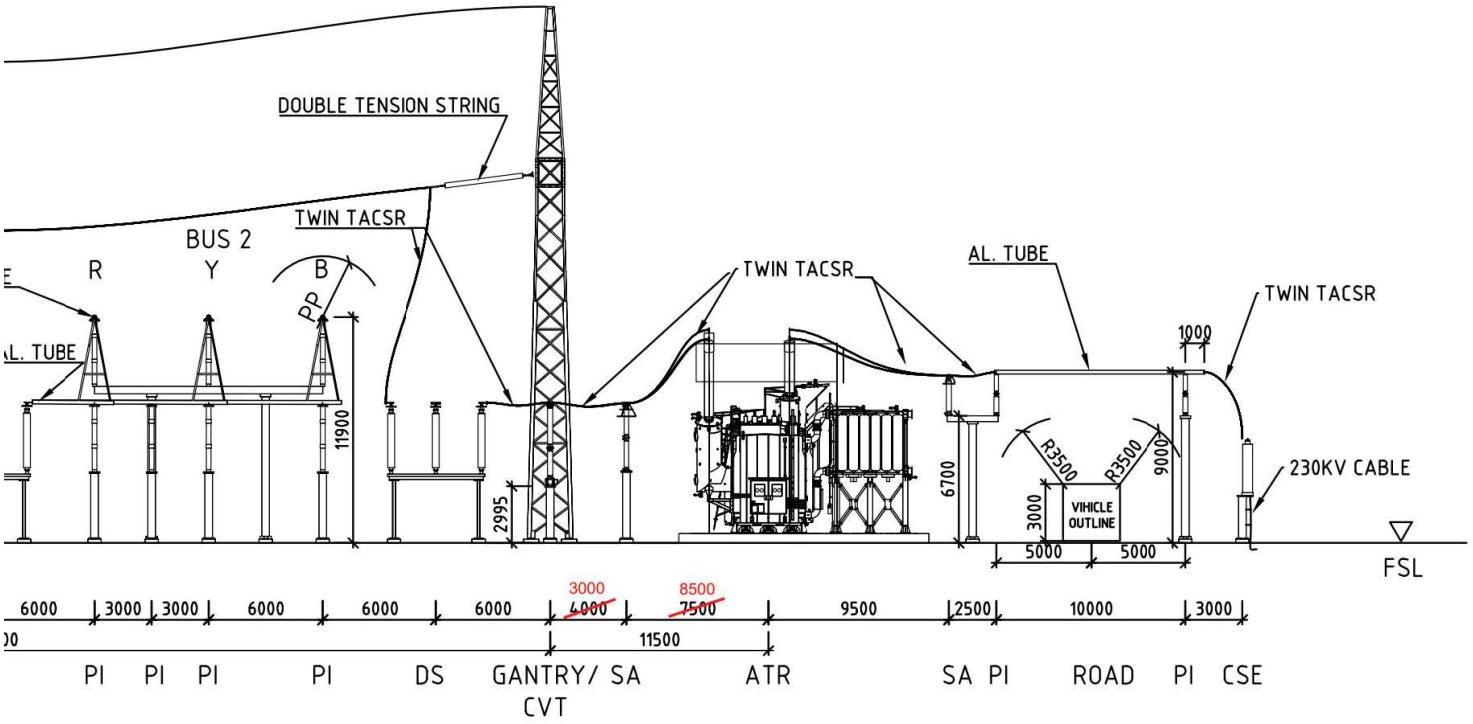
F–04

ADAPTER ALGLE PLATE

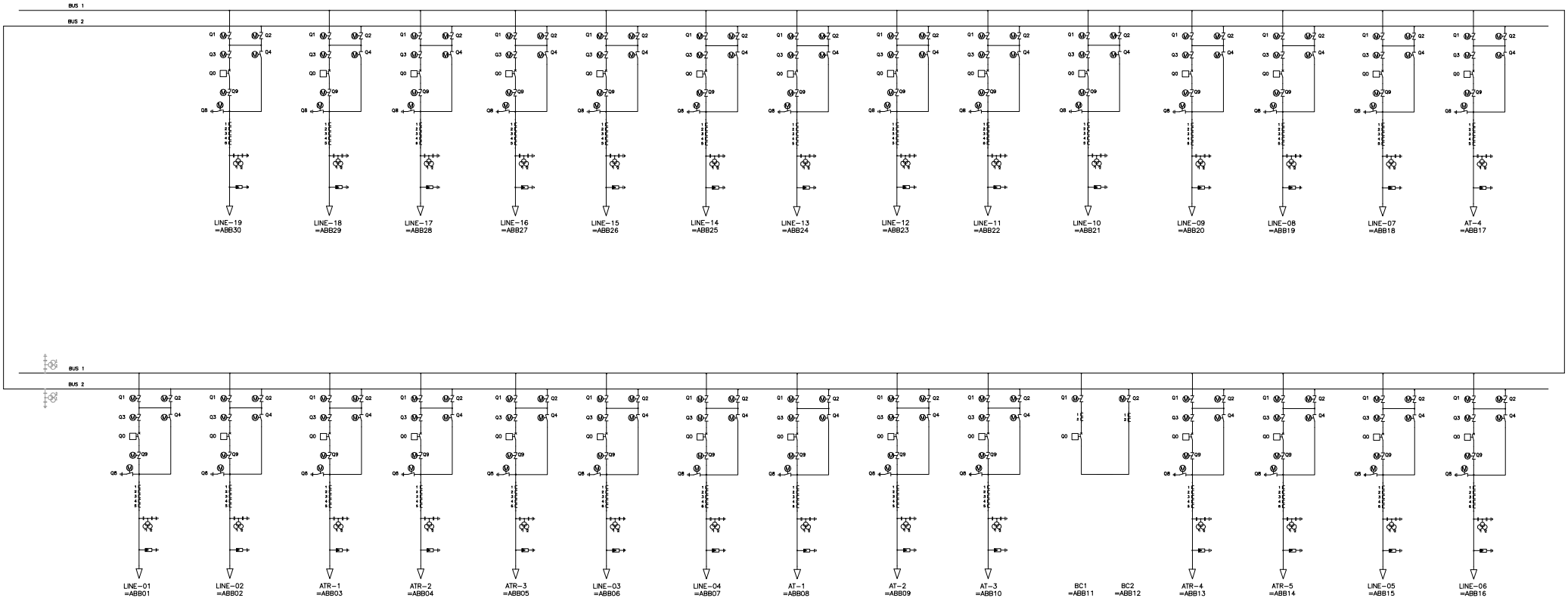
(FOR 33kV CT)


BLAST WALL
SINGLE TACSR
33KV CABLE
33KV CABLE
2500
5450
FSL
1500
1134
1200
6100
766
12000
1500
1134
1200
6100
766
24000
TK/CT CB
DS/IVT/SA
ATR NO.1
TK/CT CB DS
DS/IVT/SA
ATR NO.2

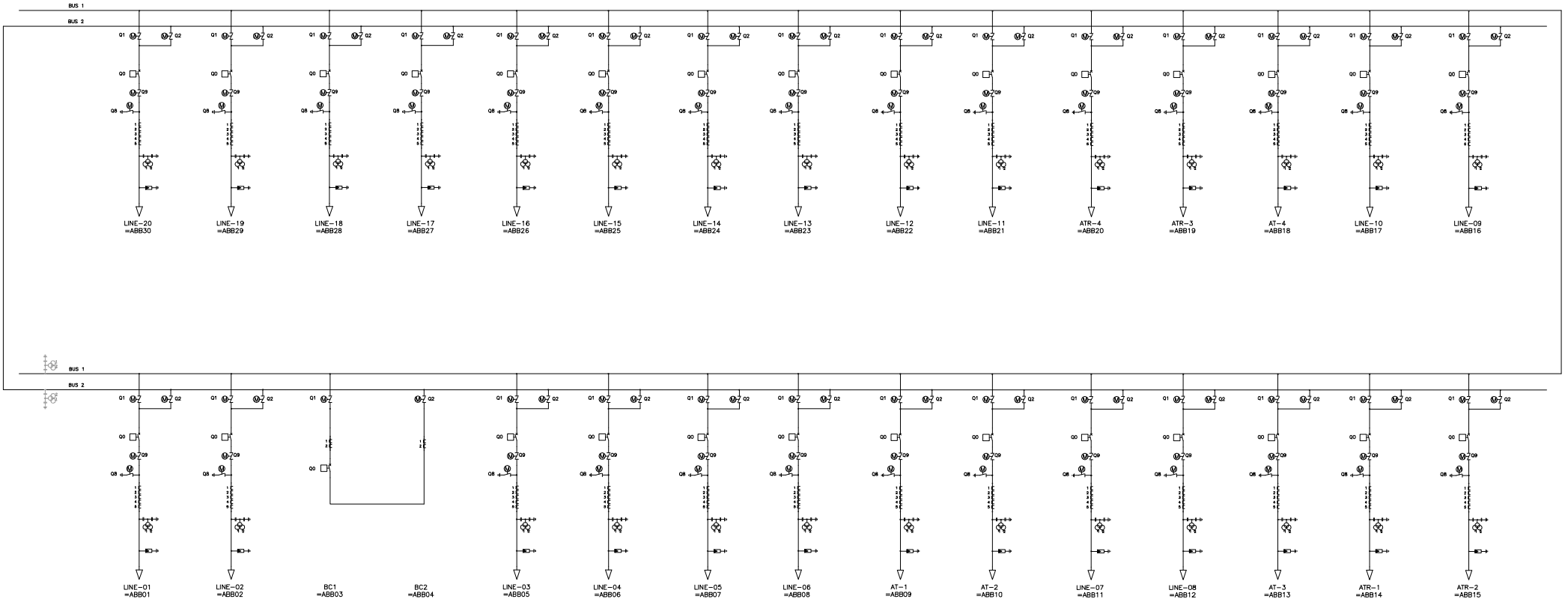
SECTION


DOUBLE TENSION STRING
TWIN TACSR
BUS 2
R
Y
B
PP
L. TUBE
11900
2995
TWIN TACSR
AL. TUBE
TWIN TACSR
1000
6700
R3500
R3500
9000
3000
VIHICLE OUTLINE
5000
5000
230KV CABLE
FSL
6000
3000
3000
6000
6000
6000
3000
4000
8500
7500
9500
2500
10000
3000
00
11500
PI
PI
PI
PI
DS
GANTRY/ SA
CVT
ATR
SA
PI
ROAD
PI
CSE

SLD A1


BUS 1
BUS 2
LINE-19 =ABB30
LINE-18 =ABB29
LINE-17 =ABB28
LINE-16 =ABB27
LINE-15 =ABB26
LINE-14 =ABB25
LINE-13 =ABB24
LINE-12 =ABB23
LINE-11 =ABB22
LINE-10 =ABB21
LINE-09 =ABB20
LINE-08 =ABB19
LINE-07 =ABB18
AT-4 =ABB17
BUS 1
BUS 2
LINE-01 =ABB01
LINE-02 =ABB02
ATR-1 =ABB03
ATR-2 =ABB04
ATR-3 =ABB05
LINE-03 =ABB06
LINE-04 =ABB07
AT-1 =ABB08
AT-2 =ABB09
AT-3 =ABB10
BC1 =ABB11
BC2 =ABB12
ATR-4 =ABB13
ATR-5 =ABB14
LINE-05 =ABB15
LINE-06 =ABB16

SLD A2


BUS 1
BUS 2
LINE-20 =ABB30
LINE-19 =ABB29
LINE-18 =ABB28
LINE-17 =ABB27
LINE-16 =ABB26
LINE-15 =ABB25
LINE-14 =ABB24
LINE-13 =ABB23
LINE-12 =ABB22
LINE-11 =ABB21
ATR-4 =ABB20
ATR-3 =ABB19
AT-4 =ABB18
LINE-10 =ABB17
LINE-09 =ABB16
BUS 1
BUS 2
LINE-01 =ABB01
LINE-02 =ABB02
BC1 =ABB03
BC2 =ABB04
LINE-03 =ABB05
LINE-04 =ABB06
LINE-05 =ABB07
LINE-06 =ABB08
AT-1 =ABB09
AT-2 =ABB10
LINE-07 =ABB11
LINE-08 =ABB12
AT-3 =ABB13
ATR-1 =ABB14
ATR-2 =ABB15