

**EMPLOYERS REQUIREMENT FOR
MECHANICAL & ELECTRICAL WORKS**

**CHAPTER 05
MATERIALS & WORKMANSHIP
ELECTRICAL WORKS**

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ELECTRICAL WORKS

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CHAPTER 05

MATERIALS & WORKMANSHIP

ELECTRICAL

5.1 Introduction

This Chapter of the Specification sets out the minimum standards of materials, workmanship and design to be used by the Contractor for electrical plant. Reference to any specific material or equipment does not necessarily imply that such material or equipment is included in the Work. These requirements are in addition to those given in the Materials and Workmanship - General Chapter No.1. In case of any conflict between this Chapter and the General Chapter No.1, the requirements of this Chapter shall take precedence.

All component parts of the Work shall, unless otherwise specified, comply with the provisions of this Chapter unless overridden by the Particular Requirements or be subject to the approval of the Employer.

5.2 General Requirements

The electrical installations shall comply with and be tested in accordance with the latest edition of BS7671 "Requirements for Electrical Installations" hereinafter referred to as "IEE Wiring Regulations".

All works shall be carried out by licensed workmen authorized to undertake such works under the provision of Electricity Act, 1910 and the Electricity Rules 1937 as adopted and modified by Government of Pakistan.

The installation in general shall be carried out in conformity with the BS, the Electricity Rules 1937 as amended and the latest Edition of the Regulations for the Electrical Equipment for Buildings by the Institute of Electrical Engineers, London (IEE). However, in case of any conflict between these specifications and the IEE Regulations, the former shall prevail.

Any special requirement of the local electric supply authority particularly Karachi Electric Supply Company (K - Electric) shall be complied with.

The Contractor shall be responsible for submitting the test certificates and getting the installations passed by the Electric Inspector, Government of Sindh.

The Contractor shall take all necessary steps for obtaining the power connection from Karachi Electric Supply Company (K - Electric) including obtaining and submitting the prescribed forms to the relevant authorities and shall maintain liaison with K - Electric till power connection is made and energized. However, all cost as per estimates for the power connection obtained by the Contractor from the concerned authorities shall be paid directly by the Employer.

The Contractor shall arrange for the electric supply authority to undertake any testing and inspection necessary for the electricity supplies to be connected when required. On completion of the tests and inspections the Contractor shall supply to the Employer copies of the Electrical Installation Completion Certificate and of the electric supply authority's test certificates etc.

The Contractor shall be responsible for determining the requirements of the concerned authorities for:

- a. Applications for power supply,
- b. Approval procedures,
- c. Inspection and testing procedures,
- d. Any other documentation.

The Contractor shall be responsible for implementing the same and obtaining all approvals for connection of a new supply.

5.3 Environmental conditions

All electrical equipment shall be designed and manufactured for operation under maximum duty loads under the specified climatic and environmental conditions at site.

Where electrical equipment is installed in a controlled environment, it shall be capable of continuous full load operation under the condition of failure of the air conditioning or ventilation systems. The normal working conditions for controlled environments are:

a. Air conditioned areas:

- Ambient air temperature - maximum +45 °C - minimum -5 °C
- Relative humidity - 96%

b. Ventilated areas

- Relative humidity - 100%
- Minimum ambient temperature - 5 °C
- Maximum ambient temperature - 45 °C or any higher temperature
determined to be applicable

The Contractor shall determine the maximum ambient temperature in ventilated plain areas. This shall comprise the peak internal ambient temperature based on the maximum specified external temperature together with internal building heat gain due to energy losses from the full load operation of all installed duty plant and direct solar heat gain through the building fabric.

All electrical equipment which is not sealed against free movement of air shall be protected from condensation with anti-condensation heaters. In general these heaters shall be thermostatically controlled and switched off when heat is generated by the operation of the Plant.

Iron and steel are to be painted or galvanized in accordance with the Specification. 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 are to be treated in an approved manner to prevent rusting, Cores etc which are built up of laminations or cannot be antirust

treated for any other reason be antirust treated are to have all exposed parts cleaned and heavily enameled or lacquered.

When it is necessary to use dissimilar metals in contact these should be so selected so that the electrochemical potential difference is not greater than 250 milli-volts and if practicable the two metals are to be insulated from each other by an approved insulating material or by a coating of approved varnished compound.

The use of iron and steel is to be avoided in instruments and electrical relays wherever possible. Steel screws when used are to be zinc, cadmium or chromium plated or when plating is not possible owing to tolerance limitations, are to be of corrosion resisting steel.

The use of wood within electrical equipment is to be avoided as far as possible and, if used shall be of a type resistant to termite attack and fungal decay.

The use of hygroscopic insulating materials is not permitted except immersed in oil or otherwise suitably sealed to prevent ingress of moisture.

5.4 Equipment Protection

As a minimum and where not specified otherwise, the IP ratings for electrical equipment shall be:

- for outdoor installation IP65
- for indoor installation adjacent to water carrying plant IP54

Notwithstanding the location in which it is installed, electrical equipment and materials provided for external installation shall incorporate additional design/protection features to provide resistance against windblown sand and dust, and salt laden atmosphere. All externally mounted electrical equipment and materials shall be directly protected or shaded against heat gain or damage by solar radiation. Sunshades shall be of a non-metallic material for protection from embitterment due to prolonged exposure to high intensity u/v radiation.

All fixings used for the anchorage, support or connection of all materials and equipment associated with the electrical works shall be of stainless steel grade 316L. Where a fixing is in contact with a dissimilar material such that galvanic action can occur, a spacer of inert material shall separate the materials.

5.5 Abbreviations of electrical terms

For the purpose of this Specification the following abbreviations of electrical terms have been used.

R	- red phase
Y	- yellow phase
B	- blue phase
N	- neutral
ac	- alternating current
dc	- direct current

A	- Ampere
mA	- milli-Amp
V	- Volt
kW	- kiloWatt
kWh	- kiloWatt hour
kvAr	- kiloVolt Ampere reactive
kVA	- kiloVolt Ampere
Hz	- Hertz (cycles per second)
CT	- current transformer
PT	- potential transformer
SP	- single pole
SPN	- single pole and neutral
DP	- double pole
TP	- triple pole
TPN	- triple pole and neutral
SPSwN	- single pole and switched neutral
TPSwN	- triple pole and switched neutral
MCB	- miniature circuit breaker
MCCB	- moulded case circuit breaker
RCD	- residual current device
MCC	- motor control centre

5.6 Polarity

All cables shall be so connected between main switchboards, distribution boards, plant and accessories so that the correct sequence of phase rotation is preserved throughout the system.

All non-flexible cable cores shall be identified with phase colors for three and four wire circuits. Single-phase circuits shall be red and black.

Where more than one phase is incorporated on a common system in one room, the live cores shall be red, yellow, or blue as appropriate. The neutral shall always be black. All fittings and switch accessories shall be permanently labeled and segregated.

Harmonized systems of phase layouts on plant and equipment of cable and plant phase identification, and of cable core insulation coloring shall be used throughout the work.

The polarity of all apparatus used in the Work shall be arranged as follows, when viewed from the front:

- a. For two pole apparatus, the phase or live poles at the top (or left hand side) and the neutral or earthed pole at the bottom (or right hand side).
- b. For three or four pole apparatus, the phases in order, red, yellow, blue and neutral reading from top to bottom or left to right in the case of vertical or horizontal layouts respectively.

5.7 Fault withstand ratings

The fault withstands ratings for the electrical equipment will be calculated by the

Contractor based on the network data.

The network data given in the Tender Documents is indicative only.

5.8 Electric motors

5.8.1. Rating and duty

Motors shall comply with the general requirements for construction, rating and performance as stipulated in BS 4999, BS 5000 and BS EN 60034-1 and VDE 0530/DIN 57530 except where amended. Unless otherwise specified, motors shall be suitable for continuous operation duty type S1 at rated output at any voltage between 94 and 106 percent and any frequency between 98 and 102 percent of rated values.

Cage induction motors shall be full voltage direct-on-line started and wound rotor induction motors shall be rotor resistance started.

The starting performance of cage induction motor shall comply with BS EN 60034-15 design "N", "NY" or "D" as appropriate for DOL starting. The minimum voltage at the motor terminals shall be assumed to be a constant value of 90% of rated voltage during the acceleration period and the starting current shall not exceed 6 times the full load current.

Medium voltage motors and other motors for main plant drives shall be capable of the following minimum starting cycle duties.

- a. Two consecutive starts from "cold" state per hour;
- b. Four restarts from "hot" condition at rated maximum operating temperature per hour.

Motors shall be capable of operating under conditions of three phase supply imbalance where the negative and zero phase sequence components of the voltage do not individually exceed 2% of the positive phase sequence components.

5.8.2. Windings and Insulation

Winding insulation shall be Class F or better to BS 2757 and the maximum temperature shall not exceed that permitted for class B.

Windings shall be supported, braced, wedged and blocked to provide adequate rigidity and strength to withstand all thermal, mechanical and vibration stresses under all operating conditions for the full service life of the motor. Special attention shall be given to the windings of direct-on-line started motors and the support of windings of vertical motors to prevent any permanent displacement during the service life.

Electrical joints and connection shall withstand the mechanical and thermal stresses under normal and abnormal operating conditions. Stator end windings shall be blocked and braced to provide high rigidity.

Completed windings including connections shall be subjected to a minimum of two cycles of vacuum impregnation with solvent-free resin varnish followed by curing to effectively fill gaps between individual conductors, to enhance mechanical

strength and to provide a high resistance to moisture, oil and chemical contamination.

The insulation of flexible cables connecting starter windings to terminal boxes shall be of the chlorosulphonated polyethylene (CPS) or ethylene propylene (EPR) rubber. Natural rubber insulated cables shall not be used. Cables shall be securely fixed to the stator frame.

On 11 kV motors both ends of the stator windings shall be brought out to an accessible link assembly mounted within the stator main cable box or in a segregated link chamber with bolted cover plate.

The winding insulation materials and cable insulation shall be resistant to flame propagation.

5.8.3. Degree of protection for motor enclosures

The degree of protection for motor enclosures shall be in accordance with BS 4999; Part 105 and IEC 34, 72 and 79. Unless otherwise specified the following minimum degrees of protection shall apply.

- a. Motors located indoor : IP54
- b. Motors located outdoor: IP65

Fans and blades external to the enclosure shall be protected against contact by means of guards.

Totally enclosed motors shall be provided with suitable means for breathing and for drainage to prevent the accumulation of water.

5.8.4. Cooling

Cooling arrangements shall be in accordance with BS EN 60034-6. Unless otherwise specified, the cooling classification shall be as follows:

- a. Motors located indoors in a dry and clean environment IC01 or IC611
- b. Motors located indoors in damp or wet areas IC41
- c. Motors located outdoors IC41

5.8.5. General constructional features

Motor dimensions shall be in accordance with BS 4999 Part 141 and IEC 60034, 60072 and 60079.

Motor frame shall be cast iron, fabricated from steel plate or aluminium as appropriate. Frames shall incorporate substantial ribbing to provide high structural strength.

End covers, end shields, external fan cowls and other external components shall be of adequate strength and robustness and shall be constructed of metal unless otherwise approved by the Employer.

Plastic components shall be designed to take into account the environmental conditions and the long term effects of operating temperature, ageing and thermal stability of the material. Where used for external components, the material shall be resistant to flame propagation. Where plastic covers enclose live parts, the

design shall eliminate the risk of electrical shock to personnel during operation of the motor.

5.8.6. Bearing

a. General:

Bearings shall be capable of accepting:

- (1) Mechanical and electrical forces imposed on them by the rotor.
- (2) Forces imposed by the motor mounting.
- (3) External forces due to the drive method.

Bearings shall be of the rolling type as determined by consideration of rotor rating and speed, shaft system, duty, method of drive and the type of bearing of the driven equipment.

Unless otherwise specified or approved, motor speed above and including 400 kW will not exceed 1000 rpm. Higher speed may be adopted for motors of lower ratings.

“Sealed for life” maintenance free bearings shall be provided on motors rated up to 10 kW.

Bearing insulation to the main frame to suppress shaft circulating currents shall be of the double insulation system on each bearing and shall be connected to earth at one point via link. The link shall be removable to permit testing of the bearing insulation. The insulation shall not be short circuited by the application of electrically conducting paint.

Rolling type bearings shall comply with the relevant British and the International Standards and the assembly shall be designed to exclude the ingress of dirt and water. The bearings shall be grease lubricated and shall be sealed to prevent leakage of the lubricant along the shaft and designed to permit easy removal of bearings.

Rolling type bearings shall be selected to meet the following requirements:

- (1) Minimum life of 40000 hours when the forces on the bearings are from the motor only and 32000 hours when the forces include those from motor and driven unit.
- (2) Re-lubricant interval preferably of 8000 hours but not less than 4000 hours.
- (3) Maximum outer case temperature of 80 degree centigrade.

Rolling bearings of the “sealed for life” type shall operate for a minimum of 18,000 running hours or for a period of 5 years if the later occurs sooner.

Grease lubricated bearings shall be packed with lithium based grease at the time of assembly.

A separate grease nipple shall be provided for each lubricating point, grease nipples shall be manufactured from steel and shall comply with BS 1486: Part I. Bearings shall be provided with faculties to eject surplus grease

Where there is a danger of vibration from other plant being transmitted to a stationary motor, provisions shall be made to prevent fretting damage to bearings.

It shall be possible for lubrication to be carried out with the motor stationary or running and without the need to remove guards.

5.8.7. Balancing

Rotors shall be dynamically balanced with full key. The rotors of motors fitted with an external fan shall be initially balanced without the fan and then with the previously statically balanced fan. Any additional weights required shall be fitted to the fan balance rings in accordance with IEC 60034.14.

5.8.8. Noise levels

Unless otherwise specified, the mean sound power level shall not exceed those given in BS EN 60034-9 Class "Normal"

5.8.9. Vibration levels

Unless otherwise specified, the maximum limits of vibration severity for horizontally mounted motors shall be quality grade "N" (normal) as given in BS 4999 Part 142. For vertical motors the same limits shall apply to lower bearings and 1.5 times these limits for top bearings unless otherwise agreed or as per IEC 60034.14.and NEMA MG1.

5.9 Lifting facilities

All heavy parts of motors shall be provided with facilities for lifting.

5.10 Temperature monitoring devices

Monitoring devices for motor winding temperature indication and thermal protection shall be of the RTD resistance type. For thermal protection application only, positive temperature coefficient (PTC) type thermistors shall be used unless otherwise specified.

Resistance monitoring devices shall be distributed evenly around the stator periphery and installed at the hottest points. The devices shall not be directly exposed to the cooling air. Each phase shall have a minimum of two RTDs, one of which shall be spare.

Thermistor shall be installed in the stator end windings and shall be distributed evenly over the winding periphery. The thermistor reference temperatures for alarm and tripping shall be in accordance with BS 4999: Part –III

For medium voltage motors RTDs shall have surge suppressers.

Monitoring devices shall be wired to an insulated terminal strip within a dedicated terminal box fitted with an identification label.

Devices for bearing and cooling air temperatures monitoring shall be of the RTD or PTC type.

5.11 Anti-condensation heaters

Anti-condensation heaters shall be fitted to all high voltage motors.

Anti-condensation heaters shall be fitted to low voltage motors of rated output 10 KW and above and to all low voltage motors, if required.

The rating per unit length of the heaters shall be such that the surface temperature of the heater does not exceed 200° C in an ambient temperature of 45 °C. The heater voltage shall be 220 V unless otherwise specified.

Heater shall be connected to an insulated terminal strip within a dedicated terminal box by means of flexible butyl rubber insulated leads. The terminal box cover shall be fitted with a warning label advising the need to isolate the supply before removing.

5.12 Switchboard anti-condensation heaters

Each cubicle or panel section within a switchboard shall be fitted with an anti-condensation heater and rotary action isolating switch. A common singly-phase supply controlled by suitably placed calibrated adjustable thermostat shall energize all the heaters.

An individually mounted cubicle shall have a thermostatically controlled heater, isolating switch and circuit breaker.

5.13 Motor anti-condensation heaters

Where specified provision shall be made to supply a motor anti-condensation heater from its motor starter. The heater shall be energized from the cubicle isolator and controlled by a normally closed auxiliary contact on the main contactor. The heater circuit shall be protected by an internal circuit breaker and thermo-statically controlled.

5.14 Terminal boxes

Terminal boxes shall be cast iron or fabricated from sheet steel as appropriate to motor frame construction and shall have matching cover. A neoprene bonded gasket shall be fixed between the box and motor frame and between the box and cover.

Cable boxes on medium voltage motors shall have an enclosure specification not less than IP55 NEMA 4 protection and IEC Regulation.

Terminal boxes shall be dimensioned to permit external cables to be satisfactorily connected.

The termination arrangement for low voltage motors shall be of the air insulated stud type. The termination arrangement for high voltage motors shall be of the phase insulated, phase separated or phase segregated stud type.

Terminations, associated leads and terminal boxes shall be able to withstand the effect of a short –circuit at motor terminal without damage. For low voltage motors, unless otherwise specified, it may be assumed that the supply protective device will be of the current limiting type. For medium voltage motors, the short-circuit withstand requirements shall be specified.

Winding terminations and terminal markings shall comply with BS 4999 Parts 145 and 108 respectively.

5.15 Power Transformers

5.15.1. Reference codes and standards

The equipment and material selection design, manufacturing testing and inspection shall conform to the latest editions of the IEC Regulations.

In addition to IEC Regulations, National Standards and Karachi Electric Supply Company (K - Electric) requirements shall also be complied.

In the event of conflict between the standards, most stringent shall prevail.

5.15.2. Service conditions

The transformers shall be suitable for continuous operation under the prevailing ambient conditions with a minimum of supervision and maintenance. Minimum degree of protection of the enclosures shall be IP 55 in accordance with IEC 60529.

5.16 Main electrical Characteristics

Auxiliary MV /LV transformers shall be fed from the 11 kV system to step down the voltage supply to 400 / 230 V.

Characteristics of main power supply system shall be as follows:

Voltage	11 kV \pm 6%
Phase	3
Frequency	50 Hz \pm 2%
Neutral System	solidly earthed.

Transformers shall be designed and build for continuous service at full load with occasional overload capacity, in accordance with IEC 60076. Under combined variation of both voltage and frequency as stated above, without exceeding the permitted temperature.

The temperature rise limit for top oil and for average temperature rise (by resistance measurement) shall not exceed the values given by IEC 60076-2.

Impedance voltage shall be less than 4% and when computed from the impedance volts and watts, shall not exceed the guaranteed values at unity and 0.8 lagging power factor by more than 10%

The transformers shall be designed and constructed to withstand the dynamic and thermal effects of short circuit currents in accordance with IEC 60076.

The maximum permissible average winding temperature specified in the standards shall not exceed the fault duration as specified above.

5.17 Design requirements

a. Construction

Transformers shall be of welded steel construction, three phase, step down, mineral oil immersed self cooled (ONAN), core type, double wound, wheel mounted, with conservator, dehydrating breather and Buchholz relay, and suitable for outdoor installation.

The transformer tanks and tank covers shall be constructed of electrically welded mild steel sheets of sufficient strength to withstand full vacuum without developing any deformation and a pressure at least 25% greater than the maximum operating pressure caused by the expansion of oil/ gas under service conditions.

The transformer tanks shall be mechanically strong, leak proof and suitable for proper heat dissipation. They shall be shot blasted and tested under pressure for detecting any leakage before assembly.

The tank's covers shall be of sufficient strength to prevent distortion when lifted and shall be directly bolted to the top rim of transformer tanks using gasket for oil seal. They shall essentially be constructed in a manner that they can be separated from the transformer tanks without core and windings when required. These shall be designed to ensure the elimination of all air pockets during oil filling operation and shall be provided with pockets for oil temperature indicators.

The conservators shall be fabricated from welded steel sheets, complete with drain valves, filling plugs and having a suitable percentage of oil in the radiators and the main transformer tanks, they shall be vacuum tested under pressure for detecting any leakage.

The connections between the cover and conservator shall be placed so as to ensure positive operations of the Buchholz relay upon the formation of gas or sudden movement of oil. Water shall not accumulate on the outside surfaces.

The joints between tank and cover and the handhole/manhole joints shall be provided with suitable flanges, bolts and gaskets. Gaskets between metal surfaces shall be set in grooves or held in position by retainers so arranged that all parts are bolted metal to metal. The gaskets shall be made of resilient material which will not deteriorate under the action of hot oil.

The cooling system for ONAN shall consist of fixed radiators welded on the tank sides and shall be designed to withstand the same vacuum and pressure conditions as the transformer tank. These radiators shall be designed to sufficiently cool down the heat generated by the transformers due to losses.

Transformers shall be supplied filled with insulating oil which shall be mineral oil for use as insulating and cooling medium.

b. Tap changer

Transformers shall have means for manual tap changing. This shall be by means of externally operated, side mounted hand wheel or crank designed for operation when transformer is isolated from the supply. Interlock shall be provided to prevent energisation of the transformer when the handle is engaged. The tap changing equipment shall provide:

- Primary winding variations of 0, $\pm 2.5\%$, $\pm 5\%$ - 7% in addition to principle tapping, with mechanically operated stops to prevent over-travel beyond the maximum raise and lower positions. These tapings shall be of full kVA rated output.
- Clearly marked corrosion resistant local position indicator located where it can be read while operating the tap changer.

c. Cores

The cores shall be made of high grade, non-aging, and cold-rolled electrical silicon steel. Laminations shall have low losses and high permeability. After the laminations have been cut and sharp projections removed, they shall be annealed to relieve shearing stresses. All laminations shall be machine coated to ensure a thin uniform coating. The coating material shall be heat resistant, inert to hot oil and shall be baked on. The core shall be rigidly clamped with insulated clamping bolts or by other approved method into one piece steel structure which will retain its shape under the most severe stresses encountered during shipment and handling and under short-circuit conditions. Insulated packets of the core shall be connected so that potential difference does not exist between them. Flux distortion will be minimized to reduce noise level.

The design of the magnetic circuit shall avoid static discharges, development of short circuit paths and production of flux components at right angles to the plane of the laminations which may cause local heating.

d. Windings

Transformer windings shall be made of high conductivity electrolytic copper without impurities, burr and cracking, insulated thoroughly with insulating varnish or equivalent compound, as necessary, to withstand not only available short circuit forces but also impulse voltages and to minimize deterioration. All materials used shall be insoluble and chemically inactive in the hot oil or shall not soften or become brittle under operating conditions.

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

The coils shall be wound and assembled so that the voltage between turns is kept as low as is consistent with good design and co-coordinated with voltage gradient distribution during voltage surge.

The windings and leads of all transformers shall be braced to withstand the shocks which may occur through rough handling and vibration during transport, switching and other transient service condition.

The windings shall be arranged concentrically around the core limbs providing vertical and horizontal cooling ducts to ensure that cooling oil is in intimate contact with every portion of the core and windings.

The star point of secondary windings shall be brought out to a neutral terminal. The windings shall be Dyn11 unless otherwise specified.

e. Terminal boxes

The design shall provide for mechanically well protected and insulated enclosed terminals and bushings with adequate space for cable termination. Exposed bushings are not acceptable.

All incoming cables shall enter from below.

Entries for cables shall be provided with removable cable gland plate of non-magnetic material suitable for the reception of either multiple or single core shielded cables compatible with the type, size etc. of cables.

All terminal bushings shall be wet process porcelain, homogenous, free from laminations, cavities or other physical flaws and shall be glazed, brown coloured, rigidly clamped with effective creeping distances. Fittings made of steel shall be galvanized.

Bushings shall be removable without the need of untanking of the transformer or removing/dismantling the tank cover.

Cable boxes shall be finished with corrosion resistant paint and shall be fitted with externally removable drain plugs.

Earthing studs shall be provide within the terminals compartment to facilitate direct earthing of cable screens and outside for earthing cables.

f. Auxiliary terminal box

Auxiliary circuits for measurement, control and protection requiring external connection shall be wired up to an auxiliary terminal box mounted on the transformer, when specified.

Auxiliary circuit's box shall in general be fitted with terminal blocks with 20% spare terminals on each block and with the manufacturer's standard wire numbers at both ends.

Cable glands shall be provided at the bottom of the terminal box.

The cabling between the terminal box and the auxiliary devices shall be made using PVC insulated wires in metal conduits. The minimum conductor size shall be 1.5 sq.mm.

g. Accessories

Each transformer shall be fitted with the following accesories as a minimum.

- (1) A pressure relief device for rapid release of any dangerous pressure within the transformer. The device shall operate at a pressure less than the test pressure of the tank and the outlet shall be arranged to face away from the bushings.
- (2) Oil level indicator fitted on one end of the conservator provided with alarm contacts for low oil level.
- (3) Dial type temperature indicator of mercury type stem-mounted in a closed

well. Adequate mechanical protection shall be provided for the capillary tube.

5.18 Medium voltage switchgear and motor control assemblies

5.18.1. General

a. Construction

Switchgear and motor control assemblies shall comply with BS 5227 and IEC 60694 and shall be metal clad.

Assemblies shall be constructed of sheet steel of not less than 2 mm thick braced to form a rigid structure. The degree of protection against approach to live parts and contact with moving parts shall be IP3X as defined by BS 5490. Those covers or doors that are required to be opened for normal operation shall not reduce this level of protection.

The floor surface on which the assembly is installed shall be considered a part of the assembly and shall not reduce the level of protection.

Assemblies shall be constructed to maintain the same level of protection during normal operation of the assembly and during and after removal of any parts designed to be removed during normal operations, test or for isolation purposes. Facilities shall be provided to padlock removable parts in 'service', 'test' or 'isolated' positions and shutters in the closed position.

Bus-bar shutters shall be coloured red and labelled "BUSBARS". Circuit shutters shall be colored yellow. Shutters in bus section units shall be coloured red and shall be labelled with large white arrows pointing in the direction of bus-bar section to which the contacts are connected.

Cable chambers shall be suitable for three core or single core cables and designed for dry type joints.

b. Interlocks

Interlocks shall be provided between different components of the assemblies to ensure safety and convenience for operation

These interlocks shall ensure that:

- (1) Withdrawal or engagement of circuit breaker, switch or contactor shall be impossible unless it is in the service, disconnected, removed, test or earthing position;
- (2) Operation of a circuit breaker, switch or contactor shall be impossible unless it is in the service, disconnected, removed, test or earthing position;
- (3) It shall be impossible to close the circuit breaker, switch or contractor in the service position unless it is connected to the auxiliary circuit and unless it is designed to open automatically without the use of an auxiliary circuit;
- (4) Earthing switches having a short circuit capacity less than the rated peak withstands of the circuit shall be mechanically interlocked with the associated disconnections.

- (5) Integral bus-bar and circuit earthing arrangements shall be provided within the assembly.

The position of removable parts, earth switches, switch disconnections and the like shall be clearly and unambiguously indicated.

c. Auxiliary power supply

Assemblies incorporating short circuit protection other than that provided by fuses shall be provided with an independent external dc power source for the supply of protection relays, shunt trip coils and the like.

d. Testing facilities

Assemblies shall be provided with facilities for high voltage cable testing, for checking of phase rotation and for primary injection testing.

e. Voltage transformers

Voltage transformers designed for use with the assemblies shall be of the cast resin type incorporating an earthed metal screen between the high and low voltage windings. Voltage transformers shall be withdrawable.

5.19 Medium voltage circuit breakers

Medium voltage circuit breakers shall comply with IEC 62271-100. The rated operating sequence shall be for 3 min-co-3 min co.

Circuit breakers for internal use shall be withdrawable with the circuit breaker assembly truck mounted. Isolation shall be by either horizontal or vertical withdrawal. They shall be motor charged / manually spring charged with manual release.

Two auxiliary contacts shall be provided of each type in addition to that required for control, indication and interlocking of the circuit breakers.

For circuit breakers to be used for starting motors of 11 kV, surge suppressors shall be fitted.

Circuit breakers for external use shall be of the open terminal type and shall have their operating mechanism, control, instrumentation and protective equipment located within a lockable, sturdy ground-mounted, weatherproof housing. Current transformers shall be accommodated in weatherproof enclosure on the bushings.

The circuit breaker shall be of a simple and rugged construction and designed for minimum maintenance.

5.20 Medium voltage motor starters

Medium voltage motor starters shall comply with BS 5227 and IEC 60694 and shall be fully compartmentalized to avoid the possibility of fault propagation (metal clad).

Each starter shall comprise of:

- a. Bus-bars;
- b. On-load circuit earthing switch;
- c. Vacuum circuit breaker;
- e. Control transformer;
- f. Ammeter and phase selector switch;
- g. Hour counter;
- h. Controls as specified

The vacuum circuit breaker shall be withdrawable with positions for 'service', 'test' and 'disconnected'. Removal from the 'service' position shall automatically apply to the earth circuit.

Facilities shall be provided for operation of the breaker in the 'test' position.

Control transformer shall be double wound, single phase. The windings shall be encapsulated with an earthed metal screen between the windings.

The major protection relay shall be solid state and provide protection for:

- a. Thermal overload with adjustable inverse current/time curves;
- b. High set over current;
- c. Locked rotor and stall;
- d. Motor protection relay;
- d. Earth fault;
- e. Phase imbalance, breaking and reversal;
- f. Insulation fault between turns;
- g. Stator frame;
- h. Under and over voltage;
- i. Incomplete starters

The relay shall be of the self-supervisory type with continuous monitoring of hardware and software.

The relay shall be hand resettable and give clear indication of the reason for resettable operation.

Starters shall be provided with power factor correction capacitors. Unless otherwise specified the capacitors shall raise the power factor to 0.95 lagging when operating at the duty point. If VFD provides power factor above 0.95 power factor compensation is not required.

Capacitors shall comply with BS 1650 and IEC 60871. They shall be low loss (approximately 0.20 W/kVAr) and of large number of high quality, self-heating round makeup elements wired to each other.

Capacitors shall be provided with HRC fuses and inrush current inductors if required.

Each capacitor shall be fitted with discharge resistors and shall bear a label clear warning of the need to allow a discharge time after isolation prior to working on the capacitor.

The starter cable box shall provide provision for the connection of a capacitor supply cable such that the capacitor current does not pass through the motor protection relay.

Where specified provision shall be made to supply a motor anti condensation heater from its motor starter. The heater shall be energized from the cubicle isolator and controlled by a normally closed auxiliary contact on the main contractor. The heater circuit shall be protected by an internal circuit breaker.

5.21 Variable frequency drive

The variable drive should have the ability to bypass any one cell during operation while maintaining the full output voltage. It should provide 18 pulse or better input harmonz cancellation with a power factor above 0.95 under any operating conditions. Output voltage should be close to perfect sine wave shape.

Overheating and increased torsional vibration should not occur. Instead of tripping the drive and automatically shutting down the system due to a malfunction it should provide system of warnings. Following is the technical requirement:

Voltage	: 11 kV
Power	: 1050 kW
Cooling	: Air cooled
Maximum output frequency	: 330 Hz
Open/close loop control	: sensor less vector control

Communication with all current BUS systems
Automatic motor identification
Automatic startup
Standards : ANSI; NEMA; UL; CSA; CE

5.22 Switchgear and motor control assemblies (less than 1000 V)

5.22.1. Construction

Cubicles and enclosures for electrical equipment shall be constructed of sheet steel not less than 2 mm thick or other approved material suitably traced to form a rigid structure. Adjacent frames dividers and covers shall be securely bolted or welded to ensure earth continuity throughout.

The exterior corners and edges shall be rounded to give a smooth overall appearance with projections kept to a minimum.

Lifting lugs shall be provided for installation purposes and shall be replaced with corrosion resistant bolts after installation.

5.22.2. Enclosures

Multi-enclosure assemblies shall be constructed to BS 5486 and IEC 60947-2 with internal separation of compartments to Form 4. Where more than one outgoing circuit occupies a common distribution section all cable terminations, cable lugs and such like shall be fully insulated or screened to allow work to be carried out on any one circuit with other circuits remaining live.

Unless otherwise specified assemblies shall be floor standing with lockable hinged front doors, and bolted removable rear panels where access to live equipment such as bus-bars and terminals is possible. The panel height shall not exceed 2300 mm.

Instrumentation shall not be positioned above 2000 mm and devices for isolation and switching shall be accessible within the zone 800 mm to 1600 mm above floor level. Suitable warning labels and instructions for earthing and isolating shall be fitted where necessary.

Unless otherwise specified, cable entry shall be from the base and shall enter an accessible cabling compartment via suitable cable glands and gland plate. Access to cable terminations shall be via bolted panels either from the rear or front as specified.

Cubicles and enclosures for outdoor locations shall be fitted with lockable doors and housing so designed that all controls, instruments are fully enclosed, with the whole assembly being weather and vandal proof. The doors shall be fitted with stays arranged to prevent overstraining of the hinge fixings and allow fixing of the doors in the open position.

The internal cubicles shall also be weatherproof to allow operation of the controls when the outside doors are open during inclement weather.

Enclosures shall give a degree of protection as follows:

Indoor Installation:

- | | |
|-------------------------------------|--------|
| a. Substation or switch room | - IP4X |
| b. Plant room | - IP43 |
| c. Outdoor Installation: Undercover | - IP65 |
| d. Exposed | - IP65 |

5.23 Electrical Safety

The Contractor shall be responsible for the electrical safety of all equipment supplied and installed. Whilst any equipment is being installed or tested, the Contractor shall ensure that all necessary precautions are taken to safeguard personnel working on Site. If necessary this shall include fencing off areas that are considered to pose a risk, and erecting warning notices.

The Contractor shall be responsible for ensuring that competent and authorized personnel carry out the electrical installations and that the work is carried out in accordance with standard procedures and regulations. Before any piece of apparatus is energized it shall be thoroughly examined to ensure that it is free of dirt, water, vermin or other foreign matter.

Electrical equipment shall be designed and constructed to provide a maximum standard of safety for operating and maintenance.

Access to any enclosure shall be possible only when the circuit isolator is open and connections within the enclosure are isolated or fully shrouded against accidental contact or when connections within the enclosure are not at a voltage

exceeding 50 V.

Where a test facility exists for use with the enclosure door open all live contacts shall be shrouded to prevent accidental contact.

5.23.1. Withdrawable components

Where removable or withdrawable components are specified they shall, where appropriate, be provided with distinct locations for test and removed position. Provisions shall be made to padlock the withdrawable part in each position. Withdrawable parts shall not be withdrawn or re-inserted unless the main circuit has been interrupted.

The degree of protection applying to the connected position shall be maintained in the test and disconnected position and during transfer from one position to another.

Withdrawable parts shall be fitted with positive guides to ensure correct alignment of the isolating contacts in which ever circuit or earthing position is selected.

5.23.2. Safety shutters

A set of safety shutters shall be provided to cover each of the three phase groups of stationary isolating contacts. The shutters shall be opened automatically by a positive drive from the circuit breaker moving portion and when closed shall prevent access to the stationary isolating contacts. When the circuit breaker is withdrawn each set shall be capable of being individually operated and of being padlocked in the closed position.

To facilitate inspection and testing, a device shall be provided for propping (not locking) the shutters in the open position and for releasing them into the closed position. The device shall be arranged to be cancelled by the moving portion to ensure the restoration of the automatic feature of shutters.

Busbar shutters shall be coloured red and labeled BUSBARS in large white letters. Circuit shutters shall be labeled with a large white arrow pointing in the direction of the section of busbars to which the contacts are connected.

5.23.3. Short circuit

Unless otherwise specified the short circuit rating of assemblies shall be 50 KA for 1 second. Where possible short circuit protective devices shall be coordinated to ensure that a fault in any outgoing branch does not operate the assembly incoming protection device.

5.24 Labels

The assembly as a whole and each compartment shall be clearly and unambiguously identified.

The labels shall be engraved letters and numbers filled black on a white background. They shall be affixed with non-corrodible rivets or screws.

Warning labels shall be engraved and filled red on a white background.

Internal labels shall be used to identify all components and terminal strips. They shall be non-degradable paper fabric or plastic in construction and shall be affixed adjacent to the component to which they appertain.

5.25 Switchboard ancillary equipment

The following ancillary articles shall be supplied with each switchboard

- a. Operating handles, tools
- b. 1 set of maintenance warning labels
- c. 1 set of padlocks
- d. 1 set of earthing leads, if required.
- e. Other tools, gloves, notices etc. required to comply with the statutory legislation.
- f. Black colored rubber safety mat running the length of the switchboard

Items a., b., c. & d. shall be contained within a lockable wall mounted steel cabinet.

5.26 Switchboard assembly component

Switchgear control components shall be as such that those components mounted on the external surfaces of assemblies shall not reduce the degree of protection from that specified.

5.27 Indicating instruments and meters

All instruments and meters shall be flush mounted and digital multimedia with electrical analyzer with more than 100 parameters with size 96 x 96 mm. Digital output for remote manufacturing.

Ammeters in motor starter circuits shall be capable of withstanding the starting current.

Kilowatt-hour meters shall be electronic meters with built in communication interface.

5.28 Indicator lights

Indicator lights shall not be less than 20 mm diameter and shall be panel mounted types with metal bodies adequately fastened so that the lamps shall be capable of replacement from the front of the apparatus without disturbance to the lamp holder or panel wiring. Lamp holders shall be keyed into panels to prevent rotation. Lens colours shall comply with IEC 60073 as follows:

Power on	: White*
Running	: Green
Tripped / alarm	: Red
Status (open, closed, etc)	: Blue
Warning (no imminent danger)	: Amber

*Note: white may be used where doubt exists as to which other color to use.

The lights shall be long life LEDs.

5.29 Push buttons

Colours of pushbuttons shall generally comply with BS 4099 (IEC 60073) and in particular shall be as follows:

Stop, Emergency Stop	- Red
Start	- Green
Jogging / inching	- Black
Reset (when not also acting as st	- Blue
Lamp test	- Blue
Override accept	- Yellow

5.31 Contactors

Terminals within cubicles and enclosures shall not be obscured and shall be easily accessed for installation and testing purposes, without removal of equipment.

5.30 Terminal blocks

Terminal blocks shall be of the screw clamp, rail mounted type to VDE 0611; Part 1 for connection of copper conductors upto 1000 V.

The terminals used shall be suitable for the type of wire to be terminated and current carrying capacity.

No more than one cable shall be terminated per clamp. Cross connections shall be used to link adjacent terminals when multiple wire connections are required. Each terminal rail and each individual terminal shall be indelibly marked with a unique number corresponding to the schematic diagram terminal numbering system.

Each terminal shall be coloured green /yellow and shall clamp to the fixing rail in order to provide earth continuity.

Terminals of different sizes and voltage terminations shall be partitioned.

Where un-isolated external voltages may be present terminals shall be screened and a warning label fitted.

Terminals used in conjunction with current transformers shall have facilities for shorting-out of the output to enable removal of instrumentation.

In any terminal arrangement adequate space shall be provided for the neat and logical termination of the incoming wiring. Terminal rails shall have provision for the installation of at least 10% additional terminals.

Contactors shall comply with BS 5424. They shall be maintenance free and where possible allow replacement of the coil, without disturbance to the wiring. The mechanical life shall be in the region of 10 million operations and 3 million operations for contactors rated in excess of 400 kW AC3 utilization category.

Contactors shall be provided for AC3 utilization category.

5.32 Relays

Relays shall comply with BS 4794. They shall be suitable for mounting to rail to BS 5584. Positive locating being assured by a built-in screw clamp or clip.

Terminals shall be numbered in accordance with BS 5472

Relays shall be designed to accept top adder auxiliary contact blocks, latch and timer attachments.

5.33 Switchboard assembly small wiring

Switchboard wiring shall be carried out in 600/1000 V PVC cable to BS 6231 and the conductors shall not be less than 1 mm² and shall be stranded.

Current transformer secondary circuits shall have a minimum cross-sectional area of 2.5 mm². Earth wires of meters, doors, etc shall have a minimum cross-sectional area of 2.5 mm².

Wiring within the switchboard shall be marked with ferrules at each end for identification. The letters and numbers used shall correspond with the switchboard wiring diagram.

The wiring colour code shall be as follows:

Phases	- Red, yellow, blue
Neutral	- Black
Control	- Grey
Earth	- Green/ yellow

The wiring shall be neatly laced and cleated to the switchboard structure or contained within purpose designed plastic trunking and arranged so that access to equipment is not impeded. Cables installed in trunking shall have a space factor not exceeding 50%. Where wiring passes through metalwork the access hole shall be fitted with a suitable grommet.

Cable ferrules shall be applied to all cable ends to ensure sound termination to terminal blocks and all circuit components. The type of ferrule used shall be suitable for the application in each instance.

Wiring between cubicles or panel sections shall be terminated in terminal blocks at each end. Such arrangements shall only be permitted between sections which have to be split for transportation purposes.

No tees or joints between termination points shall be permitted.

5.34 Local control stations

These shall be of heavy duty construction and with the smaller sizes designed for

mounting on or near the plant to be controlled.

The bottom face shall be arranged to accept, with adequate space for the use of spanners, gland terminations for the number of cables required.

Terminals shall be provided for interconnections and shall be easily accessible and marked with identification numbers/letters corresponding with the associated diagrams.

Indicator lamps shall not be less than 20 mm diameter and shall have projecting lenses with a wide angle of vision.

Pushbuttons and selector switches shall be of heavy duty, oil tight type of matching design. Legend plates shall be provided to identify plant to be controlled and the purpose of each operating or indicating device.

Pendant type control for cranes, hoists, etc. shall be of the moulded neoprene or equivalent heavy, flexible, high impact strength materials, with a long moulded-in cable strengthening sleeve, to minimize the possibility of cable fracture at the bending point. The enclosure shall be coloured in safety yellow.

5.35 Current transformers

Current transformers shall comply with BS 3938 IEC 60044-1 and shall be of the wound-primary or bar-primary type according to ratio required. All current transformers shall have a short-time current ratio of not less than that of the switch panel in which they are incorporated. For bar-primary current transformers this rating shall be for a period of 3 seconds. For wound-primary patterns the rating shall preferably be for a period of 3 seconds but may be reduced to not less than 0.5 second subject to the Employer's approval.

Where multi-ratio current transformers are specified, a label shall be provided, clearly indicating the connections required for the alternative ratios. All ratio terminals shall be connected to the multi-core terminal box and be clearly marked. These connections shall also be shown on panel wiring diagrams.

Identification labels shall be fitted giving type, ratio, rating, output and serial numbers and duplicate rating labels are to be fitted on the exterior of the mounting chambers suitably located to enable reading without the removal of any cover or metal sheeting forming part of the structure of the switchboards.

Current transformers for balanced earth fault protection shall be designed for a stability of not less than six times the rated primary current.

Current transformers for unit protection schemes shall be designed for a stability of not less than the maximum through fault of the units.

Where attracted armature relays are employed the spill current with maximum stability conditions shall not exceed one quarter of the operating current of the relay.

Magnetization characteristics, calculated performance and protection settings shall be provided.

Current transformers shall be of Class 1 accuracy for use with measuring

instruments and Class 10P for use with protective relays. Class 5P shall be used for combined overcurrent and earth fault protection of the inverse time overcurrent type. The Contractor shall ensure that the class and capacity of the current transformers is corrected for the meter or relay being supplied. Separate current transformers shall be used for instrumentation circuits unless otherwise approved.

Each group of current transformers shall be earthed at one point via a removable test link.

The accuracy limit factor selected for protection of current transformers shall take due account of the prospective short circuit current and the connected burden.

5.36 Voltage transformers

Voltage transformers for use with measuring and protective equipment shall comply with BS 3941 and IEC 60044-2.

Single phase voltage transformers shall have a secondary voltage of 110 V. Three phase voltage transformers shall have a secondary line to neutral voltage of 63.5 V.

Voltage transformers shall have a rated burden at the stated accuracy, in accordance with the requirements of all connected instruments, meters and relays and of any instruments or meters to which they may be connected via test blocks. The primary circuits shall be protected by HRC fuses. The connections between the fuses and the switchgear primary conductors shall have a short-circuit rating equal to that of the switchgear.

The secondary circuit shall be protected by fuses or miniature circuit-breakers mounted as close as possible to the secondary terminals. Fuses and miniature circuit-breakers shall be accessible for renewal or resetting without the need to isolate the switchgear.

Where voltage transformers are of the isolatable pattern they shall be arranged for padlocking in the service position. Safety shutters shall be provided to automatically cover the fixed contacts when the transformer is withdrawn. Means shall be provided to enable the shutters to be padlocked in the closed position.

5.37 Air break switches, switch disconnectors and fuse switches

Air break and fuse switches for use in distribution and motor circuits for voltages upto 1000 V ac shall comply with BS 3419.

Switches for distribution circuit's use shall be of utilization category AC 22

Switches for motor circuits shall be of utilization category AC 23

Utilization category shall be as defined in BS 5419.

Provision shall be made for them to be located in the "off" position.

5.38 Low voltage motor starters

Each starter shall comprise of:

- a. Fully door interlocked switch dis-connecter of utilization category AC 23 as defined by BS 5419, lockable in the off position.
- b. HRC fuses or MCCBs for short-circuit protection, when not provided upstream of the starter.
- c. Contactor.
- d. Overload.
- e. Thermostatically controlled anti-condensation heater with protection and isolator.
- f. Start and stop push buttons.
- g. Running, stopped and fault indication
- h. Ammeter and hour runs meter where specified. Ammeter fitted in blue phase (for starters above 10 kW).

The starter shall be housed in its own enclosure or shall be incorporated within a switchgear assembly constructed to BS 5486. Small individual starters may have front panels secured by screws. Above 15 kW front covers shall be hinged and lockable unless otherwise approved by the Employer.

The utilization category of the starter shall be AC 3 and the duty class coordination shall be Type C as defined by BS 4941.

Overload protection unless otherwise specified shall be by hand resettable thermal overload providing differential single phase protection. Where the requirement for stall, earth fault or phase reversal protection is specified, an electronic protection relay shall be provided.

Where specified starters shall be provided with power factor correction to raise the power factor to 0.95 lagging when operating at the duty point, where practical, they shall be incorporated within the starter or in a location approved by the Employer.

The capacitor shall comply with BS 1650. It shall be fitted with discharge resistors and shall bear a label clearly warning of the need to allow a discharge time after isolation prior to working on the capacitor.

The capacitor current shall not pass through the motor protection thermal overload.

5.39 Circuit breakers

5.39.1. Moulded case circuit breakers

Moulded case circuit breakers shall comply with BS 4752, IEC 60947 and shall have a category of duty $I_{cs} = I_{cu}$.

They shall be of the low energy let through type incorporating positive ion quenching in order to ensure rapid arc quenching.

The operating dolly shall have three positive positions 'ON' 'OFF' and 'TRIPPED'

Tripping characteristics shall be ambient temperature compensated and selected according to application, i.e., distribution, generation or motor duty.

5.39.2. Miniature circuit breakers

Miniature circuit breakers shall comply with BS 387 : Part 1 or IEC 60898. They shall be type 3 with a breaking capacity of at least 4.5 kA at 240/415 V unless the fault level at the point of installation dictates otherwise.

5.39.3. Residual current circuit breakers

Residual current circuit breakers shall be current operated and comply with BS 4293. The tripping current shall be selected dependent on location within the supply network and the calculated loop impedances. It shall operate to trip all phases including the neutral.

Unless otherwise specified the following sensitivities shall be applied:

- | | | |
|-----|--|--------|
| (1) | Individual ring mains, ring main groups or socket outlets | 30 mA |
| (2) | Small consumer boards incorporating no other RCCB protection | 30mA |
| (3) | Small consumer boards incorporating RCCB protection on Outgoing ways | 100 mA |
| (4) | Large consumer board incoming RCCB at least | 300 mA |

The residual current circuit breaker shall be capable of withstanding the likely fault current at the point of installation.

5.39.4. Air circuit breakers

Air circuit breakers shall comply with BS 4752 and shall be ASTA certified to 50 kA Cat P2.

Circuit breakers shall be withdrawable.

a. Operating mechanisms

All circuit breakers shall be provided with operating mechanisms as detailed in Specifications, the selection being from the following types:

- a. Independent manual spring
- b. Hand charged spring with manual release
- c. Motor charged spring with electrical release
- d. dc solenoid

All operating mechanisms shall have mechanical 'ON' and 'OFF' indicators and a manual trip device fitted with means for locking. Hand charged and motor charged spring mechanisms shall have mechanical indicators to show 'SPRINGS CHARGED' and 'SPRINGS DISCHARGED'.

Operating mechanisms of the hand charged and motor charged spring types shall be arranged so that release of the springs to close the circuit breaker can only be achieved by a deliberate action. It shall not be possible for vibration or mechanical shocks to release the charged springs. Motor spring mechanisms shall be arranged so that charging is initiated automatically following a discharge, and the necessary limit stops and switches for the automatic control of the charge once initiated, shall form an integral part of the mechanism. It shall be possible to hand charge a motor charged spring mechanism in an emergency.

Spring operated mechanisms shall be provided with volt-free contacts to give indication that the springs are charged.

The closing solenoids of dc solenoid operated mechanisms shall be suitable for operation at a minimum of 80% of the nominal supply voltage and shall not maloperate or cause excessive vibration when energized at a voltage equal to that of the closing battery with the charge set at the maximum rate or equal to that from a full wave rectified source designed for multiple simultaneous operation Unless otherwise agreed, this higher voltage shall be taken as 120% of the nominal supply voltage.

To facilitate maintenance and adjustment of contract, it shall be possible to slow close the circuit breaker but this operation shall only be possible in the fully withdrawn position. Any necessary operating handle, lever or tube shall be supplied.

b. Interlocks and test operation facilities

- (1) The circuit breaker cannot be plugged in or isolated whilst it is closed; attempted isolation shall not trip a closed circuit breaker;
- (2) The circuit breaker cannot be closed until it is fully plugged in or completely isolated;
- (3) The circuit breaker cannot be closed in the service position without completing the auxiliary circuits between the fixed and moving portions;
All circuit breakers shall be provided with interlocks to ensure that:
- (4) The circuit breaker cannot be 'slow-closed' except in the fully withdrawn position;
- (5) With hand charged or motor charged spring mechanisms the springs cannot be discharged until they have been fully charged or until the means for charging has been fully removed and disconnected;
- (6) With the circuit breaker plugged-in to an earthing location tripping can only be effected by the manual device on the operating mechanism.
- (7) Where mechanical key interlocking is employed, tripping of a closed circuit breaker shall not occur if any attempt is made to remove trapped key from the mechanism.

c. Protection

The circuit breaker shall incorporate an integral overcurrent protection relay

offering facilities for site selection of inverse, very inverse and extremely inverse characteristics. The circuit breaker shall incorporate integral protection current transformers.

5.40 Power system protective relays

Protective relays shall be mounted on the front of the switchgear or relay panel in such a position that operation and maintenance can be conveniently carried out. Auxiliary relays may be mounted inside a cubicle provided that they are readily accessible.

Protection relays shall comply with BS 142 and shall where possible be of solid state design.

Flush, jack in type relays are preferred. Each relay shall have an indicator device to show when the relay has operated and, where appropriate, which phase element. Resetting devices shall not require the removing or opening of the relay.

Solid state relays shall be of the module type comprising of a number of plug in elements allowing interchange of functions. Each of the protection elements shall have adjustable controls for current and time settings as required.

A build-in test facility shall be provided for individual testing of the settings of each of the protection elements. The tests shall be carried out by means of test sockets so that elements do not have to be removed from the panel.

- (1) Over current and earth fault relays shall have site selectable inverse characteristics and where specified shall be capable of incorporating definite time, high set, earth fault and restricted earth fault tripping characteristics.
- (2) Overvoltage/ under voltage relays shall operate between 105 to 135% and 70 to 100% of rated voltage in 5% steps. The relay shall incorporate an adjustable time delay to suit the application.

Generally, if relay types are specified other than those mentioned above no further details are required as relays are so standardized these days. It is important for the Contractor to demonstrate that the system is fully coordinated.

5.41 Fuses and links

Fuses used for the protection of power circuits shall be of the high rupturing capacity, HRC type.

(a) Low voltage

Fuses shall comply with BS 88.

Fuse carriers and bases shall be black. Solid link carriers and bases shall be white.

Fuses and links shall be shrouded and positioned to enable easy removal of the fuse and carrier without risk of contact with live parts.

(b) High voltage

Fuses shall comply with BS 2692 for use in oil or air. Fuses shall be equipped with striker pins where appropriate to operate a trip mechanism.

When used for distribution transformer protection they shall be sized in accordance with IEC 60787

High voltage fuses sized to DIN 43625 tested to IEC 60282 are also acceptable.

5.42 Distribution boards

Distribution boards and consumer units shall be metal clad, with cases of good quality folded sheet steel construction and shall have a protection classification of at least IP 31

Distribution boards and consumer units shall conform to BS 5486: Parts 12 and 13 respectively.

The bus-bars shall be mounted on non-hygroscopic insulators and shall be completely shrouded or covered with PVC sleeving which shall be coloured to denote the appropriate phase.

Neutral and earth bars shall be provided with separate terminals for each circuit.

All phases shall be identified and each circuit shall be labelled, typewritten or stenciled and fixed to the inside cover of the board.

Unless otherwise specified spare ways shall be fitted with the maximum size of miniature circuit breaker for the board and other circuits shall be rated as indicated on the circuit diagrams.

Distribution boards for outside use shall be of a corrosion resistant design and fitted with a lockable outer door to give protection of at least IP 41.

Incoming supplies to the distribution board shall enter by means of a lockable isolator, switch fuse, residual current device or moulded case circuit breaker. Outgoing supplies shall be protected by miniature circuit breakers.

5.43 Marshalling panels and boxes

Marshalling panels and boxes shall be constructed of sheet steel with ample space for routing and terminating cables and cores.

Cable entries shall be from the underside of the box. Front and rear enclosure access shall be provided for floor mounting marshalling panels.

Every marshalling panel and box shall be provided with:

- a. Undrilled gland plates
- b. Anti-condensation heater with fuse
- c. Padlocking facility
- d. Earthing bar with terminal holes
- e. Door-controlled internal light with fuse
- f. Front door label, labels for fuses and terminal blocks
- g. Panel wiring diagram secured in internal plastic covers

h. Transparent plastic covers on terminal blocks.

5.44 Earthing

Assemblies shall be provided with earthing facilities as follows:

For single compartment assemblies an earth stud shall be provided.

For multi-compartment assemblies a clearly marked continuous copper earth bar shall run the length of the assembly and shall be provided with terminals for connections to the metal cladding or armoring of all incoming and outgoing cables.

The short-term rating of the earth bus-bar and connections shall not be less than that of the associated equipment, or the maximum through-fault current of the power source. The temperature rise of the bus-bar and connections under fault conditions shall not cause damage to the connections of any equipment to which they may be connected.

No earth terminal bolts or studs shall be less than 8 mm diameter.

An earth bond of minimum size 4 mm shall be made to all enclosure doors.

5.44.1. General arrangement

The electrical installation shall where required be connected to the general mass of the earth and the earthing system shall comply with BS 7671

The installation shall comprise of one or more earth electrodes, high conductivity copper earthing tape network, mesh or a combination of these in order to obtain the required earth electrode resistance and shall comply with the requirements of BS Code of Practice CP 7430 Earthing.

Each earth electrode shall be of copper and will be provided with an approved clamp for the connection of the earthing conductor or tape as required. These connections shall each be housed in individual concrete inspection pits set flush to the finished ground level and shall allow disconnection for testing of individual electrodes.

All materials used for the earth electrode installation shall be purpose made for the application and site conditions shall be approved by the Employer.

All excavation of trenches and c.c. work for the installation of the earth electrodes and the inspection pits shall be carried out by the Contractor. After the earth installation has been completed. The contractor shall demonstrate to the Employer that the resistance of the electrodes to earth and the continuity of the earth network are within the limits specified. Any additional earth electrodes and test instruments required for the tests shall be provided by the Contractor.

Marker posts and plates shall be provided to mark the position of the electrodes and buried conductors. The markers shall be similar to those provided for cable routes.

5.44.2. Network

Where specified a main earth bar shall be installed in an approved location. This shall comprise of a 50 mm x 6 mm minimum copper bar supported on porcelain barrel type insulators and wall mounted. The bar shall be of sufficient length to accommodate bolted earth bonding connections from transformers, major items of plant, building structural steel work, concrete reinforcement and the earth electrode system.

5.44.3. Earth continuity conductors

An earth continuity conductor shall be provided between all electrical plant, mechanical plant, exposed steelwork and the like as required to meet the requirements of BS Code of Practice CP 7430 - Earthing and Pakistan Electricity Rules. This can be as follows:

- (a) Copper tape connections forming part of the earth network.
- (b) Where the distributor is an armoured cable, the metal sheath and armouring of the cable shall be securely bonded at each end to the metalwork of the apparatus or to an earth bar. Particular care shall be taken to ensure continuity across items of apparatus situated within a cable run and should the design of such items of apparatus not give adequate and lasting continuity through its structural body then additional earthing clips and conductors shall be provided to independently bond the cable sheaths together. Similarly additional earthing clips shall be provided to bond the cable sheaths armour to any piece of apparatus fitted with a special earth terminal should the earth connection for the terminal gland prove inadequate. Any additional earthing clips shall be fitted within the apparatus wherever possible.
- (c) Where the distribution system is contained within conduit or trunk, a separate earth conductor shall be provided for each circuit. Steel conduit or trunking must not be used as an earth continuity conductor.
- (d) Earthing of each section of a trunking or cable tray installation shall be ensured by bonding. This requirement will be fulfilled by installation of:
 - (i) A continuous earth continuity conductor bonded to each section, or
 - (ii) bonding straps installed across each joint
- (e) Where the distribution system is mineral insulated copper sheathed cable the sheath can be used.
- (f) Main equipotential bonding conductors and supplementary bonding conductors shall be installed and sized in accordance with IEE Regulations for Electrical Installations.

5.44.4. Lightning protection

For buildings or sections of the plant to be protected against lightning or static charges, an earthing system shall be provided. The installations shall be carried out in accordance with BS 6651

The down connectors shall be of hard drawn high conductivity copper of 25mm x 3mm section. The tape shall be fixed to the outside of the structure by means of standoff saddles. Where required connections shall be made to the concrete

reinforcing. The route of the tapes and the fixings shall be discussed with the Employer before installation.

Where the conductors specified shall be PVC insulated to prevent corrosion and

to blend with the building fabric.

A test link shall be installed in each down conductor adjacent to the earth rod at a height of 1.2m above ground level. The overall resistance of the earth termination system to earth shall not exceed 10 ohms. If this requirement is not met the number of earth electrodes shall be increased or they shall be interconnected until a value of 10 ohms is attained.

5.45 Cables and wires

5.45.1. General

Each drum or coil of cable complying with BS or IEC approved equivalent standard shall be accompanied by a certificate stating the manufacture's name, cable size, number of cores, length, result and date of tests as required in the Specification.

Cables manufactured more than 12 months before delivery will not be accepted.

All cables shall be delivered with cable ends effectively sealed. When a cable is cut from a drum both ends shall be immediately sealed to prevent ingress of moisture.

Cables shall not be transported to site in loose coils but a number of short lengths of cable may be transported on the same drum. The Contractor shall be wholly responsible for the purchase and/or hire costs of all cable drums and for the removal of these drums from site after use.

5.46 Standards

a. low voltage (600/1 000 V grade)

- (1) PVC/SWA/PVC and XLPE/SWA/PVC multicore cable to BS 4346 and BS 5467, IEC 60502-1 respectively. Installed direct in the ground, in ducts, on trays or clipped direct. Aluminium wire amounting shall be used for single core cables
- (2) PCV/PVC multicore cable to BS 6346, IEC 60502-1 Installed in floor ducts, trunking or conduits.
- (3) PVC single core non-sheathed (450/750 V grade) to BS 6004 Installed on tray or clipped direct.
- (4) Mineral insulated, copper clad to BS 6207, Installed on trays or clipped direct
- (5) EPR/CSP multicore cable to BS 6883 or IEC 29-3 Installed as down borehole cabling to submersible equipment or trailing leas.
- (6) PVC single core non-sheathed /600/1 000 V) to BS 6231. Installed as internal wiring within switchgear and control assemblies.
- (7) General purpose-PVC insulated copper conductor white PVC sheathed overall, rated at 300/500 V in accordance with BS 6004

b. Medium voltage 3.3kV to 33kV

- (1) XLPE/SWA/PVC cable to BS 6622 or IEC 60502. Installed direct in the ground, in ducts or clipped direct, Aluminium wire armouring shall be used for single core cables.

c. Telecommunications

(1) External Use

The cable shall be cellular polyethylene insulated armored telephone cable manufactured generally in accordance with British Telecom Specification CW 1128. The conductors shall be 0.9 mm diameter copper. The insulated conductors shall be twisted together in pairs and shall be identified by colour. The cable shall be fully filled with tropical grade petroleum jelly and a polyethylene sheath shall be applied over the laid up pairs. A layer of galvanized steel wires shall be applied over this sheath. The armouring shall comply with British Telecom Specification CW 1198.

A black coloured PVC or Polyethylene sheath shall be applied overall.

The electrical Characteristics shall be within manufacturing tolerances which are as follows:

a.	Conductor loop resistance (at 20°C)	60 ohm/km
b.	Insulation resistance (at 20°C)	1500 mega-ohms/km
c.	Mutual capacitance (at 1 kHz)	60 µf/km
d.	Maximum capacitance unbalance between pairs at (1 kHz)	275 µf/km
e.	Characteristics impedance (at 1 kHz)	390 ohms
f.	Attenuation (at 1 kHz)	0.85 dB/km

Installed in ducts, pipe ducts and direct in the ground.

(2) Internal Use

The cable shall have tinned copper conductors of 0.5 mm diameter with PVC insulation and PVC oversheath. It shall comply generally with British Telecom Specification CW 1293 and shall meet following:

- (i) The colour of the sheath shall be cream
- (ii) For use indoors for internal distribution and connection to extension instruments.
- (iii) Installed in conduct, trunking or clipped direct.

5.47 Rating

The Contractor shall ensure that cables and wires associated with the distribution and control systems, plant wiring and all over installations throughout the Work are adequately rated for their use.

In assessing the rating of any cable or wire, the following factors shall be taken into account:

a.	Supply voltage and frequency
b.	Maximum voltage drop permissible
c.	Type and magnitude of load.

d. Fault level and duration related to circuit protection relays and fuses.
e. Circuit overcurrent protection.
f. Route length and disposition of cables.
g. Ambient temperature.
h. Method of installation.

5.48 Colours

All cable cores shall be colour coded throughout their length and shall be so connected between switchboard, distribution board, plant and accessories, that the correct sequence or phase colours are preserved throughout the system.

The colour coding should be as follows:

- a. 3 phase red, yellow and blue
- b. Single phase or dc red and black
- c. Earth green/yellow
- d. Control grey

5.49 Conductors

Copper conductors shall be used throughout. Cores of cross-sectional area greater than 1.5 mm² Small power cables shall be of a minimum cross-section of 2.5 mm². Control cables shall be stranded.

Internal wiring of control panels shall be of a minimum cross-section 1.0 mm² flexible and stranded.

5.49.1. General

Cables shall be installed in such a way that the minimum bending radii are not reduced when installed or during installation. Cables shall not be installed in ambient temperatures below that recommended by the cable manufacturer.

Cables grouped together shall have insulation capable of withstanding the highest voltage present in the group.

Cables shall be segregated into the following categories:

- a. Power (greater than 1000 V)
- b. Power (less than 1000 V)
- c. Instrumentation/ telemetry
- d. Control
- e. Telecommunications

Cables shall be laid in a manner such that any electrical interference between cables shall not have a detrimental effect on the life and operation of equipment installed within the Work. As a general rule the following minimum clearances shall be adhered to wherever practical.

There shall be a minimum separation of 600 mm between HV power and all other cables and 300 mm between all other categories.

These separations are minimum and special circumstances such as the presence of high current flows or harmonic content may necessitate larger separation distances

All cables shall be permanently identified at each end and at entry and exit points of ducts. Identification shall be by means of approved cable markers with semi rigid black PVC carrier strip which shall be fixed axially by means of two PVC straps or other marker type.

On rotating plant and transformers where the required direction of rotation or phasing is to be achieved, if it is not possible to connect the phase cores to the appropriate terminals additional core ferrules shall be fitted to identify each core with the terminal to which it is connected.

Control cables shall have individual cores identified by means of suitable permanent ferrules bearing the same number at both ends. Core identification shall occur at every point of termination using an approved system of ferrule markers. The size of the ferrule markers shall be such that it matches the overall diameter of conductor plus insulation. Numbering shall read away from the termination on all cores.

5.49.2. Direct in ground

Buried cable up to 1000 V shall have a minimum cover of 500 mm measured to the top of the highest cable. On crossing roadways the cable shall be run through a PVC-U duct of minimum diameter 100 mm with a minimum of 1000 mm cover and encased on all sides by 150 mm of concrete.

High voltage cables shall be buried with a minimum cover of 1000 mm.

The bottom of the cable trench shall be free from sharp stones and the like and 75 mm of sieved sand laid below the cable. After cable laying 75 mm of sieved sand shall be laid above. Interlocking cable protective covers, minimum 1000 mm long x 300 mm wide marked 'Danger – Electric Cable' in English and in vernacular shall be laid on top of the sieved sand. Covers shall extend the whole length of the cable trench and shall overlap cables by a minimum of 50 mm.

Warning tape shall be laid a minimum of 200 mm above the protective covers.

Cables are to be installed without tees or though joints unless otherwise approved by the Employer. Single core cables are to be run in trefoil formation.

The thermal resistivity of soil shall be determined at proximity of the cable, after laying of the cable and after compaction of the soil but before complete backfilling. The value of the thermal resistivity of soil as determined above at random points shall be less than $120^{\circ}\text{C} - \text{cm/W}$

5.49.3. In Underground ducts

Underground ducts shall be constructed of impact resistant uPVC glazed earthenware or concrete tiles laid at a minimum depth of 500 mm. Ducts shall be surrounded by at least 75 mm of sieved sand except at road crossings where it shall be 1000 mm deep and encased on all sides by 150 mm of concrete.

The Contractor shall ensure that sufficient draw-in-points have been provided and that adequate room has been allowed for installation of cables. Drawstrings shall be provided in all ducts to enable additional cables to be installed when required.

Where cables pass in or out of any duct entries into or within buildings, such entries together with any spare ducts shall be sealed against the ingress of moisture by means of duct stoppers and bituminous compounds or by any other method approved by the Employer. The stopper shall have a fire resistance of at least 30 minutes. Single core cables in trefoil formation shall pass through the same duct and shall not be separated.

5.49.4. In conduit

Conduits shall be galvanized heavy gauge solid drawn or welded screwed steel type and be in accordance with BS 4568. Accessories shall either be malleable cast iron screwed type or pressed steel and galvanized and shall comply with BS 4568, 4607 and 6099 as appropriate.

A space factor of 40% shall not be exceeded, but in any case conduit of less than 20 mm diameter shall not be permitted. The tubing shall be perfectly smooth inside and out and free from flaws and imperfections of any kind. Both ends of every length of tubing shall be properly reamed with all sharp edges removed before erection.

Where a number of conduits converge, malleable cast iron or heavy gauge sheet steel adaptable plates shall be employed in order to avoid crossings. Conduits shall be connected by means of male brass bushes and couplings.

Where conduits are greater than 24mm, straight through joint boxes shall be of the through type where conduit and/or fittings are attached to equipment casings, the material or case of the casing shall be tapped for a depth of not less than 10 mm or male bushes and flanged couplings shall be used.

Heavy hexagonal lock nuts shall be used at all positions where running joints are required and great care shall be taken to ensure that they seat firmly and evenly on the mating faces of coupling or other adjacent accessories. All junction boxes draw-in boxes, and inspection fittings, shall be so placed that the cables can be inspected and, if necessary, withdrawn and re-wired throughout the life of the installation.

Generally not more than two bends or offsets or one coupling will be permitted without a suitable inspection accessory. Fish wires shall not be left in conduits after erection. The Whole of the installation shall be arranged for a loop-in type of system with joints being carried out at switches, isolators, etc. Intermediate joints in the cable will only be allowed by arrangement with the Employer. Where terminal blocks are necessary, they shall be of the porcelain type with brass pinching screws or other approved type.

Ends of conduits which are liable to be left open for any length of time during building operations shall be plugged to prevent the ingress of dirt, cement etc and covers, either temporary or permanent, shall be fitted on all boxes.

Generally, conduits shall not cross expansion joints of buildings, but where they cannot be installed in any other manner then a flexible conduit shall be used

across the expansion joint. A total 150 mm movement shall be allowed.

a. Surface installation

Surface conduits shall be secured and fixed by means of distance spacing saddles or approved purpose made clips which allow the conduits to be taken directly into accessories without sets or bends. Conduits shall be run in a square and symmetrical manner. An efficient means shall be adopted to provide for the drainage of condensation and the runs shall be properly ventilated. All surface conduit runs shall be marked out for approval by the Employer before the installation is carried out. Where large multiple parallel conduit runs would occur, use may be made of galvanized cable trunking. Conduits installed on structural steel work shall be secured at spacing not exceeding those for surface conduit by girder clips, otherwise fixing shall be as for surface conduits on walls, drilled and tapped to the metalwork. Power driven fixings shall only be used with the express permission of the Employer. Any drilling or access which is required through any structural member of the building shall be agreed with the Employer before carrying out the work.

Exposed threads and places where galvanizing has been damaged shall be cleaned and then painted with two coats of an approved metallic zinc based paint. This treatment shall be applied as the work proceeds.

b. Concealed installation

Concealed conduits shall be securely fixed to prevent movement before laying of screeds, floating of plaster, casting of columns or other building operations necessary after the conduit installation. Cram pets or similar fixings shall be used for attaching the conduit to blockwork, etc. Building nails will not be accepted.

At least 15 mm cover shall be allowed for finishes over the conduit. Where this cover cannot be maintained then expanded metal shall be fitted with the conduit. Conduit cast into reinforced concrete floors shall be fixed to the steel reinforcing with binding wire and the conduit boxes filled with expanded polystyrene or enclosed in a plastic bag to prevent the ingress of concrete when poured. Where possible, the conduit boxes shall be fixed to shuttering to give a flush finish.

Conduits installed in voids, false ceilings, and other concealed routes shall be installed as specified for the surface conduits. Wiring shall be carried out after the false ceiling or permanent ducts have been completed conduits installed in floors shall be sealed against ingress of moisture.

The conduit installation shall be inspected by the Employer before the building operation conceals the work.

c. Flexible conduits

Flexible conduits shall be of the waterproof galvanized type or PVC wire-wound type with cadmium plated mild steel couplings. Lengths of flexible conduits shall be sufficient to permit withdrawal, adjustment or movement of the equipment to which it is attached and shall have a minimum length of 300 mm. Flexible conduits

shall not be used as a means of providing earth continuity. A single earth conductor of adequate size shall be installed external to the conduits complete with earth terminations.

Where conversion from rigid conduit to flexible metallic conduit is to be made, the rigid, conduit shall terminate in a through type box and the flexible conduit shall extend from this box to the equipment. The earth continuity cable shall be secured to the box and to the piece of equipment by properly designed earthing screws. The use of lid facing screws, etc. will not be permitted; Adaptors shall incorporate a grub screw or a gland to prevent the flexible conduit becoming loose.

5.49.5. In cable trunking – metal

Cable trunking shall be manufactured from mild steel of not less than 1.25 mm and shall be hot dipped galvanized. The Contractor shall ensure that the size of the trunking is adequate for the number of cables to be installed together with 50% spare capacity and shall in any case be 50 mm x 50 mm minimum size

Segregation of cables shall be carried out if required using continuous sheet steel barriers with the bottom edge welded to the trunking.

Cables shall be retained in the trunking when the cover is removed by means of straps. Internal connecting sleeves shall be fitted across joints in the trunking and earth continuity ensured by bonding each section of trunking to a continuous earth wire.

Non-flammable fire barriers shall be inserted where the trunking passes through walls or floors. Conduit connections to trunking shall be made by flanged couplings and male bushes.

Trunking shall be supported at intervals not greater than 2 m horizontally or 2.5 m vertically.

Crossings over expansion joints shall be made in flexible conduit.

Should it be necessary to cut or drill a section of trunking or a trunking fitting, the bared ends shall immediately be given a zinc rich cold galvanizing paint.

Cable and conduit/trunking runs shall be determined by the Contractor and agreed by the Employer before any work is started. The run shall be at least 150 mm clear of plumbing and mechanical services.

Conduit/ trunking systems erected outside a building shall be weather proof.

5.49.6. On cable trays

Cable trays shall be of perforated sheet steel with formed flanges and of minimum thickness not less than 1 mm for trays up to 100 mm width, not less than 1.25 mm for trays from 100 mm to 150 mm width and not less than 1.5 mm for trays from 150 mm to 300 mm width. All cable trays and supports shall be in accordance with BS 6946.

Cable trays shall be hot dipped galvanized to BS 729 or PVC coated as specified. Cable tray supports shall be of a compatible finish with the associated cable trays, or where manufactured at site, be given a protective finish of a suitable paint/

coating in accordance with DIN 55928.

All cable tray tees, intersection units, bends, turns and sets shall, whenever possible, be purpose made by the manufacturer and shall be of a matching design to the main section of cable tray

Trays shall only be joined by couplers supplied by the manufacturer and the joint shall be secured by 8 (eight) bolts in each instance.

Cable tray supports supplied by a manufacturer or made up on site shall be of ample strength to maintain rigid support to the fully laden cable trays along its entire length and shall ensure that the deflection of any one section does not exceed 10 mm at mid-span.

Where proprietary channel section cable support racks are being used elsewhere on the Contract with cable cleats, then any such channel used for support of cable trays shall be of the same type and make.

Wherever possible, cable trays shall be installed in full lengths without cutting, should it be necessary to cut or drill a length of tray, then for galvanized trays, the bared ends or damaged section of the tray shall immediately be given a coat of zinc rich cold galvanized paint. Similarly for PVC coated trays, the bared ends shall be immediately sprayed using a PVC aerosol. All site manufactured accessories, supports and metal fittings required to ensure correct installation of the cable trays shall be similarly treated.

All Cables shall be firmly secured to the tray using purpose made saddles, as approved by the Employer, together with proprietary nylon fasteners and/or cable cleats. Following installation of cables, the trays shall remain rigidly supported and the deflection of any section shall not exceed 15 mm at mid-span. All brackets and tray work shall be suitable for withstanding a temporary weight of 125 kg.

The sizing of the cable trays shall provide a minimum of 25% spare capacity.

Cable tray runs shall be determined by the Contractor and agreed by the Employer before any work is started. The trays shall be run at least 150 mm clear of plumbing and mechanical services.

5.49.7. On ladder rack system

Ladder racking either light or heavy weight be constructed from heavy galvanized steel and shall be proprietary item and installed in accordance with manufacturer's instructions. Bends in the installation shall take account of the minimum bending radii of cables to be installed.

Cables shall be clipped to the ladder rack using clips designed for the system in use and appropriate to the type and size of cable installed.

The sizing of the cable rack system shall provide a minimum of 25% spare capacity.

Ladder racking runs shall be determined by the Contractor and agreed by the Employer before any work is started. The ladder racking shall be run at least 150 mm clear of plumbing and mechanical services.

5.49.8. Clipped direct

All cable hangers, clips, cleats and saddles shall be of an approved type and appropriate to the type and size of cable installed.

Their spacing shall be such as to ensure a neat appearance and prevent sagging of the cables at all times during their installed life.

5.50 Internal floor trenches

a. Shallow trenches (maximum depth 500 mm)

In shallow trenches used for electrical services only, cables may be laid in a neat and orderly manner on the floor of the trench. One layout only shall be allowed. Additional cables shall be installed on the walls of the trench in an approved manner.

Where the trench is shared by other services, cable shall be installed on the walls of the trench in an approved manner.

b. All other trenches including “walk through service ducts”

Cabling shall be installed to the walls of the trench in an approved manner. Where other services are present the cables shall be segregated from them and wherever possible kept above ‘cold’ services. Cables should not be run, if at all possible, above or in close proximity to ‘hot’ services.

The cabling shall be installed in such a manner as to allow access to the other services for normal maintenance without disturbance of the electrical installation.

Cross covers shall be kept to a minimum.

The cable trench shall be cleaned prior to and after completion of the installation.

5.51 Cable terminations and joints

5.51.1. Terminations

Power cables shall be terminated in suitable boxes arranged for bolting to switchgear, motor starters and motors.

Cores shall have either crimped lugs or sleeves to match either post terminals or bolted clamp terminals.

Each cable entry into a terminating box shall be made through a suitable gland, which shall have provision for securing the armour where applicable. Where single core glands are required these shall be of the non-magnetic type and the associated box bottom plate, where the core passes through, shall not have a continuous magnetic path.

Adequate provisions shall be made to bond the cable armouring to the box and/ or switchgear casing of a suitable size to withstand the prospective short circuit fault current of the system. Glands shall be fitted with earth bonding tags where intimate screwed contact between gland and cable box is not possible.

Where cable glands are exposed to the weather these shall be protected by heat shrink plastic sleeves or purpose moulded sleeves covering the gland continuously from overall sheath to the gland neck.

Where terminations of multicore type have to be made onto items of plant which have to be dismantled for maintenance, these shall be made of through glands into an adaptor box containing terminals and flexible single cores taken into the equipment via flexible waterproof plastic covered conduit, and a separate earth core linking the box to the equipment.

5.51.2. Joints

Through joints shall only be allowed with the approval of the Employer. Where such joints are necessary in thermoplastic and elastomeric cables, the cables shall be jointed with epoxy or acrylic resin cold setting compound, which has been premeasured and pre packed ready for use. The boxes shall preferably be of split moulded plastic type with filling vents for compound. Bonding straps shall be fitted with armour clamps across the joint and inspected by the Employer prior to filling the box with the compound. Wrapped pressure type joints will not be accepted.

Conductor cores shall be jointed number to number or colour to colour.

5.51.3. Cable identification

At each end of each cable in a uniform and visible position, a label shall be fixed on the cable in accordance with the cable schedule. Labels shall be made of PVC and shall be indelibly marked to the approval of the Employer. The label shall be retained using proprietary nylon strips passing through two fixing holes at either end of the label. If the cable gland is not normally visible, then the label shall be fixed inside the panel by means of screws.

5.51.4. Marking locations of underground cables

The location of all underground cables shall be engraved on brass or other non-corrodible plates to be fixed to the exterior surface of all walls of buildings 300 mm above ground level and directly above the point where cables pass through the wall.

In addition concrete marker posts shall be installed at intervals of not more than 50 meters at all junctions and changes of direction along the cable route. Such marker posts shall be not less than 200 mm high and of substantial construction. A drawing or sample of a typical marker post shall be submitted for the approval of the Employer.

The markers shall be marked 'electric cable' in English and in vernacular shall be laid on top of the sieved sand.

5.51.5. Cable glands

Glands shall generally be of the mechanical compression hanger type. Earth continuity of brass glands shall be assured. This may be achieved by the rigid clamping of the armour within the gland and the intimate contact between the threaded components of the gland and the equipment. Each gland shall be installed completely with proprietary earth tag providing a ready means of connecting a flexible strand or strip earth bond to the gland at any position around

the gland in relation to the associated apparatus. Adequate earth continuity shall be assured between the earth tag, the gland and the armour wires of the cable where applicable.

Each gland shall be installed completely with proprietary lock-nut to secure the gland body to the equipment where the entry hole is plain, i.e. not tapped.

5.52 Electrodes

Electrodes shall be stainless steel rods with PVC coating and housed in appropriate enclosures. Means shall be provided for adjusting the length of each electrode by a minimum of 75 mm without cutting. External enclosures shall be totally weatherproof to IP 55 with tapped cable entries.

Holders subjected or liable to flooding shall be gasketed between cap and body and fitted with a sealed external terminal for connection with the electrodes.

Electrodes for alarm or level control shall have robust, water and airtight heads. Suitable arrangements shall be provided for the withdrawal of the electrodes.

In all applications a separate electrode shall be provided for the earth return circuit.

Each alarm or control signal shall be initiated from a separate single electrode unit, Multi electrode units will not be accepted.

The relay control box shall be totally weatherproof to IP 55 and suitable for wall mounting. It shall include a hand-off-auto, switch, inline fuses and neon lamp indicating the relay condition. The alarm and control contacts in the relay box shall be set for "fail safe". In the event of the electrical supply to the relay box failing or the signal cabling being damaged, the alarms and control circuiting will be initiated.

The sensitivity shall be adjustable between 100 and 20000 ohms and the switching differential should be better than 5% of sensitivity setting.

The supply voltage shall be 110 V, 50 Hz. The electrodes circuit shall be 25 V maximum open circuit, 30 mA short circuit. The relay contacts shall be related for 5 A and 220 V, 50 Hz inductive load.

5.53 Electromagnetic flow meters

Flowmeters shall be of the fully submersible electromagnetic type suitable for fitting in a chamber outside the pump station, in accordance with BS 5792 with protection to IP 67.

Flowmeters installed in steel pipelines which are to be cathodically protected shall be provided complete with insulating flanges, continuity bonding, earthing, etc.

Flowmeters shall be flanged and rated to suit the delivery pipework and provided with a detector head and associated equipment to provide a linear 4 to 20 mA dc output, proportional to the rate of flow. Any equipment required to operate in conjunction with the flowmeter shall be fully submersible or mounted in a location not subject to flooding.

The calibrated accuracy shall be better than + 0.596 of actual flow from full scale flow rate to 50% flow rate increasing progressively to + 1% of actual flow rate at

10% flow. Flowmeters shall be installed in accordance with the manufacturer's instructions and with a minimum of five diameters straight pipe upstream and two diameters downstream.

5.54 Ultrasonic flow meters

Weirs and flumes shall comply with BS 3680. An ultrasonic transducer shall measure the height of flow before the flume or weir and, via a microprocessor based system, convert this depth reading to flow. Computation of flow shall be to

BS 3680 but the system shall allow the entry of user defined data. The system accuracy shall be within +1% of the instrument span over 5% to 100% flow.

The flowmeter electronics shall be housed in an environmentally protected enclosure to IP 67, with transparent front section containing displays and operator control. The sensor shall be suitable for mounting in the open and shall be protected to IP 68.

The minimum output requirements are one isolated 4 to 20 mA output proportional to flow and one 24 V pulse output for driving a counter.

5.55 Ultrasonic level sensors

The sensor head shall be protected to IP 68.

Sensing heads shall be mounted on stainless steel 316 brackets and positioned with due regard given to an unhindered beam path and within easy reach of maintenance personnel.

The signal converter shall be supplied in an IP 55 minimum polycarbonate enclosure and shall comprise of a base unit and a programming device. Communication between the programmer and the signal converter shall be in such a manner that the IP rating is not prejudiced.

The unit shall be suitable for either 24 V dc or 240 / 110 V ac operation.

5.56 Float level switches

The equipment shall consist of a mercury switch housed within a plastic casing and a locally mounted control unit. The casing containing the mercury shall be of polypropylene suitable for total immersion in liquid. The control unit shall be weatherproof to a minimum of IP 55 and contain a transformer, relay fuses, terminal board and isolation contacts for two wire control of remote equipment.

5.57 Supervisory Control And Data Acquisition System (SCADA System)

5.57.1. General

PLC shall receive inputs from 11 kV and LV protection and control and will provide outputs to annunciation control for all desired operations and will perform all logical functions.

PLC shall be constructed in modular form having provision for accepting add-on

cards and shall be capable of operating without trouble in a temperature range of 0-55°C, relative humidity of 10% to 95% and should be environmentally protected not less than IP30. All incoming cables shall terminate in the cable marshalling area and not directly on the PLC for which a separate housing shall be provided.

A personal computer (PC) running SCADA software and MIS application shall communicate with the PLC on Industrial Ethernet network and shall provide all required features of control and monitoring such as:

- (1) Real time data of all variables.
- (2) Trends and graphs of all desired parameters.
- (3) Data logging
- (4) Report and statistical analysis.
- (5) Alarm management and event based programming.
- (6) Advanced graphic display for real time mimic display.
- (7) 8 levels of password protection.
- (8) Multi users support, LNA, PSTN dialup, RAS, WAN and internet fully supported.
- (9) Operator Log

Compatible latest HP Laser printer with 6 Nos. black cartridges shall be provided.

A 24 inch high resolution monitor LED/LCD shall be provided on the module for displaying all logical functions.

Twelve DVDs shall be supplied additionally for storage, data and programs.
UPS shall be provided for PC and PLC power supply only for minimum 15 minutes back up time on full load.

Protection relays shall communicate with the PLC on same data network to allow monitoring of all critical parameters such as RTD temperatures, protection and safety. PLC will send signals to annunciation panels in case of any fault.

LV I/Os shall be connected to PLC and SCADA system to monitor and control all pressures, levels, flow rates and overload relays etc.

An application Process shall record all critical parameters.

5.57.2. Power supply unit (PSU)

Power Supply Unit shall be suitable for the specified supply voltage having protection against voltage and frequency fluctuations and harmonics. The unit shall be provided with battery backup for all volatile registers and memory locations to allow retention of data and programs for a period of not less than three months. Indication shall also be provided on the PSU to show that the power supply is on.

The PSU shall be designed so that forced ventilation is not required.

5.57.3. Input/output Units (I/Os)

The Contractor shall determine the number of I/Os to suit operational requirements with an allowance of 25% spare capacity. Incoming cables from the

Plant shall be terminated in the cable marshalling area and not directly onto the PLC. LED indicators shall be provided to show status of I/Os which shall be individually isolated to prevent system transients and radio interference affecting the normal operation or decoupling shall be provided for I/O signals. Digital and analogue output devices shall be capable of switching 5 A on either 30 V dc or 240 V ac circuits. Where output contacts switch ac or dc loads, arc suppression devices shall be fitted. All outputs shall have individual fuses.

5.57.4. Central Processing Unit (CPU)

Central Processing Unit shall operate at a speed of operation suitable for carrying out all specified duties and shall have all necessary built-in timers, relays and mathematical functions etc. The processor shall have non-volatile Erasable Programmable Read Only Memory (EPROM) and a volatile Random Access Memory (RAM). Allowance shall be made for 25% spare volatile and non-volatile memory.

Programming function for the CPU shall be built into the PLC or Personal Computer (PC). Program entry and modifications shall be possible in mnemonic language, ladder diagram or flow charts. Security arrangement shall be provided to prevent unauthorized tampering with the PLC control.

The contractor shall be responsible to provide Operating System and Application Software on separate media, Preferable on DVDs. The contractor shall train Employer's staff for installation, testing, commissioning, customization, O & M and archiving/restoration of system.

5.57.5. Control of process through PLC

a. Pre requisites

- (1) All selector switches in "auto" position.
- (2) All valves in "auto" position.
- (3) All central flow band screens in "auto" position.

b. Main pumps

- (1) H/O/A selector switch in "auto" position for transforming pump controls from push buttons to PLC.
- (2) Selection of duty pumps for activating their ON signals.
- (3) Low level to pass ON command if there is sufficient water level in suction well.
- (4) If low level, pumps will not start an alarm will be triggered.
- (5) Low level setting to be segregated so that all pumps do not stop simultaneously.
- (6) Starting of pumps to be segregated through a timer so that all pumps cannot be started simultaneously.
- (7) Any other requirement of the manufacturers.

c. Control philosophy

(1) General

Raw water after coarse screening shall enter the screening chamber.

(2) Pre-requisite

Selector switch is on 'auto-mode'.

(3) Operation of central flow band screen

Under normal conditions, PLC based adjustable timer will operate the screen three times a day. Level across the screen will be sensed by ultrasonic level sensors having three level settings.

- (1) **High differential level:** The output of differential level relay-1 will be fed to the PLC which in turn will give command to the screen to start at low speed. An indication of high differential level will also be given to SCADA terminal.
- (2) **Very high differential level:** If clogging of screen still persists causing increase in differential level, differential level relay-2 will operate and give input signal to PLC which in turn will switchover motor from low speed to high speed and an indication of very high differential level will be given to SCADA terminal.
- (3) **Very, very high differential level:** At very, very high differential level, relay will operate and give input command to PLC which in turn will initiate klaxon and first duty pump will stop. At the same time, a PLC timer will be initiated which after preset time intervals will stop second and third pumps if clogging continues and indication of very, very high differential level is given to SCADA.

PLC will also give command to flushing valves to actuate simultaneously with the motor. PLC will keep the "ON" command to flushing valves for about five minutes even after stopping of motor to ensure clearing of the screen.

In case of tripping of any motor PLC will give command to klaxon.

d. PLC interface with pumps

Main pumping sets will start through push buttons manually. However following interlocks will be provided by PLC.

- (1) Duty selector switch input command will ensure that not more than pumps can be operated at one time.
- (2) PLC based adjustable timer will interlock the switching "ON" of the pumps so that pumps cannot be started simultaneously.
- (3) Pump bearing lubrication/water sealing system will be over-ridden for 20 secs to allow flow of water to develop. If after this time, flow pressure is not proved, pump will be stopped and an alarm will be initiated.
- (4) RTD inputs from windings and bearings will be fed to PLC which will

continuously monitor the temperatures. In case of exceeding preset limits, an alarm will be initiated. SCADA terminal will continuously monitor and record the data.

- (5) If circuit breaker trolley is in test position, its remote "ON" will be blocked.
- (6) Starting of pumps will be interlocked with discharge valves both during start and stop operations.
- (7) Fully open/close position of limit switches will be indicated by an indication lamp.
- (8) Power fuse blow control or operation of motor protection relay will give tripping command to motor as well as trigger an alarm.
- (9) Stopping of pumps will be staggered.
- (10) Any other requirement of the pump manufacturer.

e. PLC interface with SCADA

All information available to PLC shall be transferred to PC through Industrial Ethernet such that complete monitoring of the plant can be carried out through HMI.

5.57.6. Air Conditioner

1 No- Supply and installation of a split type air conditioner of 1.5 ton capacity in the PLC/SCADA room.

5.58 Programming medium

The programmer for the CPU shall either be built into the PLC, or shall be the hand-held type complete with suitable connections.

Manual program entry and modifications shall be possible in a mnemonic language and either flowchart or ladder diagrams. The programmer should also allow for reading of programs. Security arrangements should be provided to prevent unauthorized tampering with PLC control.

Unless otherwise specified a programming device shall be supplied with each PLC.

5.59 Peripheral equipment

Where specified, and EPROM erasing device shall be provided. This shall have a built-in 0 to 60 minute timer, and a safety interlock that automatically shuts off the UV source as soon as the drawer holding the EPROM is removed. The cabinet shall be fully sealed against UV leakage and electrical screening shall eliminate interference.

A spare programmed EPROM shall also be provided. This shall be suitably

prepared for storage in a container providing protection from static electricity and light. The container should be externally labeled with details of the program version and date.

5.60 Small power, lighting and lighting installations

a. Power Socket outlets

Power socket outlets for small electrical accessories shall be 15 A, 230 V single phase 2 pole and earth 3 pin shuttered pattern and shall be complete with a mounting box and an earthing terminal.

In office rooms, stores, washrooms etc. socket outlets shall be white plastic plate type and shall be provided at every 10 m distance.

In plant areas, socket outlets shall be splash proof, high impact resistant thermoplastic pattern with spring operated cover plates and complying to BS 4343 and shall be fixed as specified or approved by the Employer.

b. Switch Control

All lighting and power circuits complete with cables, conduit and installation material, shall be controlled by MCBs installed on the main LV distribution board as specified in the Particular Requirements Chapter.

Internal lighting switches in offices, stores, washrooms etc. shall comply with BS 3676 and shall be complete with box, cover plate and fixing screws. At multi-switch position, the switches shall be contained in multi-gang boxes.

c. Building Lighting Installations

Building lighting installations shall be designed in accordance with the latest edition of the UK Chartered Institute of Building Service Engineers "Code for Interior Lighting" or equivalent approved standard.

The minimum service illumination levels shall be in accordance with the subsequent clauses.

In no case shall the illumination be below that necessary to perform work or other essential activity in any particular location.

In areas housing rotating machinery, lighting shall be arranged on multiple phase circuits to prevent stroboscopic effects.

Lighting in high bay area's shall be designed to ensure that ease of maintenance to ensure that use of scaffolding to change bulbs is not required.

Lighting shall be provided in all building areas to provide the following average Luminance levels which, unless otherwise specified, shall be at ground level.

Area	Illuminance (VA)	Type of luminaire
Control room/PLC room	500	A
Pump and motor rooms	200	D
Transformer rooms	200	B
Storage rooms	150	B

Table 5-1 Average Luminance Levels

Type A	Fluorescent luminaires with stove enamel metal clad body and M6 metallic louver.
Type B	Florescent luminaires with totally enclosed plastic coated metal or GRP canopy body to protection standard IP54 and totally enclosing high impact clear acrylic diffuser.
Type C	As type B, but fully corrosion resistant construction to enclosure protection IP65, and also compliant with BS 4533 Part 102.
Type D	Metal halide “Highbay” type luminaries.
Type E	Techno-polymer body with integral electronic control gear with white trim opalescent diffuser surface or recessed mounting as required.
Type F	Weather proof flood lighting luminaires with diecast aluminum housings, high impact glass or polycarbonate diffusers and suitable for LED lamp

Lamps shall be of a type and size available locally.

5.61 Building emergency lighting

Building emergency lighting shall comprise of general area emergency lighting and emergency escape lighting.

The Contractor shall design the emergency escape lighting installations to comply with the requirements of BS 5266 Part 1.

General area emergency lighting shall be provided in the pump and motor rooms and other essential areas viz adjacent to the screens.

The emergency lighting installation shall comprise of 24 V dc LED luminaires connected to the dc battery system for automatic switching on/off in case of main ac supply failure and its restoration.

5.62 Wiring

Internal building services installation wiring shall be carried out by single core PVC insulated cable installed in PVC/steel conduit.

In office, control room and similar rooms with high decorative building finish the conduit shall be concealed within the wall plaster finish. Switch and socket outlets shall be flush mounted.

Elsewhere, conduit/trunking and service fittings shall be surface mounted:

The minimum cable sizes shall be

- a. 2.5 mm² for lighting circuits
- b. 4 mm² for socket outlet circuits

5.63 Batteries and chargers

5.63.1. Batteries

Battery units shall comprise of a floor standing or wall-mounted front access type steel cabinet accommodating batteries, battery charger and distribution facilities.

Unless otherwise specified batteries shall be of the high performance nickel cadmium type having cells housed in translucent, high impact plastic containers. The containers shall be fitted with vented filler plugs. High and low electrolyte levels shall be permanently marked on the containers.

Cell terminals shall be of the bullet type. The terminal polarity shall be permanently marked.

Battery cells shall be arranged so that each is accessible for test and inspection. Cells shall be located in the lower section of the cabinet and shall not be less than 300 mm above floor level.

Batteries shall be supplied completely with all necessary connections. The connections between tiers and cells and disconnection links and fuses shall be of the multi-standard plastic insulated type.

The nominal battery voltage shall be 24 V unless technical considerations otherwise dictate. The battery capacity shall be adequate to supply all connected loads for a minimum period of 8 hours.

5.63.2. Battery charger

The battery charger shall be of the load state design incorporating "Float" and "Boost" charging facilities. In the "Float" charge mode, the charger shall automatically maintain the battery in a fully charged condition whilst supplying its rated current. In the "Boost" charger mode the charger shall be capable of fully charging the battery from a fully discharged state in a period not exceeding 7 hours.

The charger shall be equipped with the following:

- a. Incoming supply On/Off switch
- b. Supply on indication
- c. Output voltmeter
- d. Output ammeter
- e. Float/Boost charge selector switch
- f. Charger failed alarm relay
- g. Charger failed indication

5.64 Un-Interruptible power systems (UPS)

The UPS shall consist of rectifier, static inverters, static switches with bypass and sealed alkaline batteries. The system shall be capable of the following modes of operation.

a. Normal mode

During normal operation the UPS shall provide precisely regulated and transient free power to its load. Power to the rectifier shall be supplied from the primary ac source. The rectifier shall supply the inverter with regulated dc power. The inverter shall convert the dc power into regulated ac power for the load.

b. Emergency mode

On failure of the primary ac power, input power to the inverter shall be supplied automatically from a battery. When the ac power is restored input power to the inverter shall be supplied automatically from the rectifier. If the ac power is not restored before the discharge limit of the battery is reached (the discharge limit being designated by the battery manufacturer) the UPS shall automatically shut itself down in an orderly manner.

c. Bypass mode

The static switch shall transfer the load automatically without interruption to a power conditioner energized from the ac supply on a failure of the UPS output. Circuit breakers shall be provided as part of the static switch such that the complete UPS including the static switch may be isolated electrically for maintenance once the load has been transferred to the alternative supply. Each power semiconductor circuit shall be fused to prevent cascaded or sequential semiconductor failure. Indicating devices shall be provided to show blown fuses.

The UPS shall not generate noise in excess of a sound pressure level of 75 dBA measured one meter from its surface under any mode of operation and at any load upto the maximum rating.

The primary ac source shall be single phase for units upto 5 kVA, single phase or 2 phase for units between 5 and 10 kVA, and shall be 3 or 4 wire, three phase supply for units greater than 10 kVA. The output ac neutral shall be electrically isolated from the UPS chassis. The UPS chassis shall be connected to the instrumentation earthing system. The UPS output as neutral shall be connected to the station earth via a disconnecting link.

The UPS shall have built-in protection against under voltage, overcurrent and overvoltage including surges on the primary as source and voltage and current surges on the output including those caused by load transfer between itself and an external synchronized source.

The complete UPS shall be capable of being started up by the operation of a single switch whose action shall initiate an automatic start up sequence.

The rectifier shall be capable of supplying an overload current of not less than 125% of full load current for 10 minutes. Current limiting shall occur above 125% of full load current.

The inverter transient voltage variation shall not exceed 10% under any of the following circumstances.

- a. 50% load application and reduction with zero and 50% initial load respectively.
- b. Transfer of rated load to the alternative source following an inverter fault.

The system output voltage shall return to within 5% of the steady state value within 30 milliseconds and to within 2% of the steady-state value within milliseconds of the occurrence of any change. The inverter voltage shall remain within these steady state bands under the following circumstances.

- a. Inverter “drop” onto the battery whilst supplying the full rated load
- b. Retransfer of rated load from the alternative source to the inverter

The inverter shall have an output circuit breaker.

The inverter section of the UPS shall include an integral static switch with bypass. The control unit shall contain an automatic transfer circuit which shall monitor the status of the inverter logic signals and alarm conditions and, shall ensure an uninterrupted transfer of the load to the alternative source without exceeding the transient limits specified herein, when a malfunction occurs in the UPS.

The static switch shall be a naturally commutated high speed, static transfer device. The bypass static switch shall be connected in parallel with a circuit breaker which is activated at the same time as the static switch and which shall provide positive connection of the load to the alternative source independently of the internal logic and control supply. Circuit breakers shall be provided in the static switch section of the UPS giving complete isolation of the UPS and static switch for maintenance.

Volt-free contacts shall be provided to operate the following remote alarms and indications.

- a. UPS on bypass
- b. UPS on
- c. UPS battery discharging

Low maintenance batteries shall be used only. The battery cells shall be mounted on wood or painted steel blocks and shall be accommodated in a special battery cubicle for installation adjacent to the UPS. The batteries shall only feed the UPS and no other circuits. The battery shall be capable of feeding the required load for 3 hours without the battery and UPS failing on under voltage.