site conditions as specified in the data sheet. If not specifically mentioned therein, design ambient temperature of 40°C and altitude not exceeding 1000 m above MSL shall be considered for all equipment.

5.0 TECHNICAL REQUIREMENTS

5.1 Input Power Supply

5.1.1 The Battery Chargers shall be suitable for input power supply as defined in the data sheet. If not specified therein, they shall be suitable for the following input power supply:

Voltage : 415V ± 10%
Frequency : 50 Hz ± 3%

In addition to the above variations, the input voltage may be subject to transient variations comprising of voltage dips up to 20% of normal voltage during motor start-up, voltage interruptions during short circuits as well as frequency variations due to large motor start-up. The Battery Chargers shall operate satisfactorily with a total harmonic distortion of up to 5% in the input power supply.

The Battery Chargers shall also be designed to operate satisfactorily while drawing input power from an emergency diesel generator set.

5.1.2 The incoming power supply to the Battery Charger system shall be provided by 2 independent feeders. One feeder shall supply power to each rectifier.

5.2 Battery Charger

5.2.1 **Design Basis**

5.2.1.1 The Battery Charger system shall have two chargers (Charger-1 & Charger-2). Both chargers shall be of identical design and rating. The battery to be connected to the chargers shall be of Nickel Cadmium/ flooded electrolyte Lead Acid/ VRLA type as indicated in the data sheet. Battery Chargers for flooded Lead Acid and Nickel Cadmium batteries shall be sized to provide quick charging of the battery within a duration of 10 hours. Battery Chargers for VRLA battery shall be sized to provide quick charging of the battery up to 90% of rated Amperehours within a duration of 24 hours and to 100% within 4 days. Each charger shall be sized for the most stringent of the following duty conditions, whichever is higher:

a. Offline quick charging of the battery assembly. The charger shall be sized as under:

Charger rating in Amps. = 0.14 Ah(C_{10}) of battery (for Lead Acid battery)
= 0.2 Ah(C_{10}) of battery (for VRLA battery)
= 0.2 Ah(C_5) of battery (for Nickel Cadmium battery).

b. Online float charging of the battery assembly while feeding the complete DC load. The charger shall be sized as under:

Charger rating in Amps. = 1.15 x Average DC load + float charging current
(Average DC load = Area under the battery duty cycle/ battery duty cycle duration).

5.2.1.2 Each charger shall have a 3 phase full wave, controlled rectifier bridge with protective devices.

5.2.1.3 Independent current limits shall be provided for charger load current and battery charging current. Subsequent to a discharge cycle and completion of quick charging, when battery is connected to charger under float mode, the battery current shall be monitored, controlled and limited to set value automatically irrespective of the value of load current. Fast acting semi-conductor fuses shall be provided for protection against internal short circuits. In case of external short circuits, the chargers shall be protected by rapid shutdown of the semi-conducting power devices. The high speed semi-conductor fuses used for rectifier protection shall be complete with trip indication.

5.2.1.4 Filter circuits consisting of smoothing choke and condenser, complete with protection to limit the ripple content at the output, shall be provided.

5.2.1.5 Silicon blocking diodes shall be provided in the charger output circuit to prevent back-feed from battery into the charger and filters.

5.2.1.6 Protection against reverse battery connection and DC earth fault relay for earth leakage detection shall be provided.

5.2.1.7 Silicon blocking diodes (min. 4 nos.) connected to 80% tap of the battery bank shall be provided to maintain continuity in the DC supply to the load.

5.2.1.8 Internal cooling of the charger unit shall preferably be by natural ventilation. If forced air cooling is necessary, a redundant air cooling fan shall be provided. The charger components shall be capable of delivering their rated output with one forced air cooling fan out of service. Under this condition, maximum continuous temperature of components shall not exceed the permissible limits. In case of chargers with forced cooling, loss of ventilation alarm/ trip with override facilities shall be provided.

5.2.1.9 Selection, sizing and suitability of all components used for various applications shall be vendor's responsibility and the rating of components shall be increased, if required, to suit associated components during execution of the order without any claim for extra price or time.

5.2.1.10 The DC system shall be unearthed. However, a high impedance earth fault relay shall be provided for the protection of the battery.

5.2.1.11 Each charger shall be galvanically isolated from the input power supply by providing a double wound transformer at its input. The transformer shall be natural air cooled, dry type suitable for location inside a panel.

5.2.1.12 An RFI filter shall be provided to suppress the radio frequency interference to permissible limits. The production of radio frequency interference voltages shall not exceed the value of suppression grade N' as defined in VDE-0875.

5.2.1.13 Transient/ surge protection devices shall be provided in the input circuit of chargers to protect them against surges & voltage spikes.

5.2.1.14 The Chargers shall be designed to draw power from mains supply at a minimum power factor of 0.85 lag while sharing the rated load in normal operating configuration.

5.2.1.15 The chargers shall be designed to ensure that the harmonic component in the input currents are limited so as not to cause undue harmful effects on other sensitive equipment operating on the same supply bus. Suitable filters/ harmonic traps shall be provided, as required, for this purpose.

5.2.1.16 All breakers shall be adequately rated for the required continuous rating and breaking capacity as applicable. Paralleling of breaker/ switch/ contactor poles to achieve the required current rating is not acceptable. All output isolating devices shall be double pole type. The DC contactors shall be operated with a DC control supply using ON/ OFF selector switches and not push buttons.

5.2.1.17 All the thyristors, diodes and other power electronic devices shall be protected with high speed semiconductor fuses. I²t co-ordination between fuse and semi-conducting power devices shall be ensured.

5.2.1.18 The Battery Chargers shall be specifically designed to limit float and quick charging voltages to the battery to limits recommended by the battery manufacturer. Output voltage shall be limited to maximum +10% of nominal system voltage when the battery is float charged while feeding the load. Vendor shall specifically ensure that the charger output voltage does not exceed the recommended limits of operation under any conditions of internal/ external fault or operation, including:

- Filter capacitor fuse failure of either charger

- DC output switch OFF of either charger
- DC output fuse blown of either charger.

Other specific current/ voltage limits during normal charging/ operation of the chargers shall also be incorporated in the design of the chargers.

5.2.2 **Operation and Performance**

5.2.2.1 **Operation (Option – I)**

The DC system shall comprise of 2 Nos. Float cum quick Chargers (each rated for 100% capacity) with 1 set of battery (Refer typical scheme block diagram option – I).

a. Normal operation requires that the battery assembly shall be float charged simultaneously by both Chargers-1 & 2 while feeding the DC load, the chargers thus operating in parallel and equally sharing the total load.

b. However in case of failure of either of the chargers, the other charger shall float charge the battery while feeding the complete DC load. Faulty charger shall automatically get disconnected from the healthy system.

c. In case of AC mains failure, the battery shall continue to supply the load.

d. The process of changeover from float to quick charging and reverting from quick to float charging shall be selectable in Automatic or Manual mode by means of an Auto/ Manual selector switch. In Automatic mode, the changeover from float to quick charging shall be initiated through a current sensor, set at a preset value. Similarly, the changeover from quick to float charging shall also be automatic based on current sensing. In Manual mode, both change over from float to quick charging and from quick to float charging shall be performed manually using push buttons. When quick charging mode is selected, the battery charger shall initially charge the battery under constant current mode followed by constant voltage (finishing charging) mode or as per the battery manufacturer's recommendation. Changeover from constant current to constant voltage (finishing charging) mode shall be fully automatic. A backup synchronous or digital timer shall also be provided for initiating the changeover to float mode by default after a preset time period. The timer range shall be 0 to 24 hours or the nearest available as per manufacturer's standard range.

e. In the event of failure of the charger feeding the load, when battery is being quick charged by the other charger, continuity in DC supply shall be maintained from the battery to the load through 80% tap of the battery bank followed by full battery supplying the load through contactor C-2 (refer block diagram Option – I).

f. Interlock shall be provided to ensure that when either of the chargers is selected in quick charging mode, it will be disconnected from both the DC load and the other charger operating under float charging mode.

g. The chargers shall have facility for manual mode of operation in the event of failure of controller under closed loop control. The selection shall be done through Auto/ Manual selector switch.

h. Energisation of contactor for DC critical lighting shall be initiated by means of an AC mains failure relay complete with Auto/ Manual selector switch, On/ Off push buttons etc.

5.2.2.2 **Operation (Option – II)**

a) The DC system shall comprise of 2 nos. Float cum quick Chargers (each rated for 100% capacity) and 2 sets of Batteries (each of the battery sets rated for 50% AH capacity). (For typical scheme, refer block diagram Option - II).

b) Normal operation requires that Battery–1 shall be float charged by Charger-1 while Battery-2 shall be float charged by Charger-2. In this case both the chargers 1 and 2 shall feed the DC load by operating in parallel and equally sharing the total load.

c) Selection of Float / quick mode shall be Automatic or Manual based on the position of selector switch for Auto / Manual selection.

d) In case of failure of either of chargers, the other charger shall float charge both the batteries while feeding the complete DC load. Faulty charger shall automatically get disconnected from the healthy system.

e) In case of AC mains failure, both the batteries shall continue to supply the load.

f) After restoration of power supply, one of the Charger (say Charger-1) shall float charge Battery-1 and also feed the complete DC load while the other Charger-2 shall quick charge Battery-2. Upon completion of quick charge of Battery-2, Charger-2 shall switchover to float mode and shall float charge Battery-2 and also feed the complete DC load while the other Charger-1 shall switchover to quick mode and shall quick charge Battery-1.

g) The process of changeover from float to quick charging and reverting from quick to float charging mode shall be selectable in Automatic or Manual mode by means of Auto / Manual selector switch.

h) In automatic mode, the changeover from float to quick charging shall be initiated through a current sensor set at a preset value. Similarly, the changeover from quick to float charging shall also be automatic based upon current sensing and through timer.

i) In manual mode, both the changeovers i.e. from float to quick charging and from quick to float charging shall be performed manually using push buttons. When quick charging mode is selected, one of the battery charger (say Charger-1) shall initially charge the battery under constant current mode followed by constant voltage (finishing charging) mode or as per the battery manufacturer's recommendation. Changeover from constant current to constant voltage (finishing charging) mode shall be fully automatic. A back-up synchronous or digital timer shall also be provided for initiating the changeover to float mode by default after a preset time period. The timer range shall be 0 to 24 hours or the nearest available as per manufacturer's standard range.

j) In the event of failure of charger feeding the load (say Charger-1), when Battery-2 is being quick charged by the other Charger-2, Charger-2 shall changeover to float mode and continuity of 100% DC supply to the load shall be maintained from the Charger-2 while float charging both Battery-1 as well as Battery-2 after providing suitable time delay.

k) In an event of AC mains failure, when one of the Charger (say Charger-1) is float charging the Battery-1 and supplying the 100% DC load while the other Charger-2 was quick charging Battery-2, continuity of 100% DC supply to the load shall be maintained from Battery-1 (through 100% tap). Further, Battery-2 (which was being quick charged) shall also be made available, after providing suitable time delay, to feed the DC load by operating in parallel with Battery-1 and sharing the total load.

l) Interlock shall be provided to ensure that when either of the chargers (say Charger-1) is selected in quick charging mode, it will be disconnected from both the DC load as well as the other Charger-2 operating under float charging mode.

m) The chargers shall have facility for manual mode of operation in the event of failure of controller under closed loop control. The selection shall be done through Auto/Manual selector switch.

n) Energisation of contactor for DC critical lighting shall be initiated by means of an AC mains failure relay complete with Auto/Manual selector switch, On/Off push buttons etc.

5.2.2.3 **Performance**

a. Both chargers shall be of solid state design, constant voltage and current limit type. The output voltage shall be stabilised to within ±1% of set value in float charging mode for mains steady state voltage and frequency variation of ±10% and ±3% respectively, and load variation of 10 to 100% at any temperature up to the design ambient temperature specified in the data sheet. However, the variation in output voltage can be up to ±2% for chargers with rated output voltage up to 24V.

b. Under constant current quick charging condition, the DC output current shall be maintained within ±2% of set value.

The output voltage dynamic response of the charger unit with battery disconnected shall not vary more than ±10% of nominal output voltage in the event of step load of up to 50% of the rated output. The output voltage shall be restored to a value within the steady state limits within 250 msec.

c. The maximum allowable RMS ripple voltage, with battery disconnected, shall be equal to or less than 2% of the nominal output voltage.

d. The maximum noise level from the chargers measured at 1 metre distance in any position, at any load between 0- 100% with all normal cooling fans running shall not exceed 75 dB(A).

5.2.2.4 **Controls**

The minimum controls shall include but not be limited to those shown in the block diagrams (OPTION-I or OPTION-II as applicable):

5.2.2.5 **Panel Metering and Indication**

These shall include but are not limited to those shown in the block diagrams (OPTION-I or OPTION-II as applicable):

LEDs provided for indication shall be cluster type with adequate brightness and minimum 2 Nos. LEDs chips per light. LEDs shall be connected in parallel and each LED chip having diameter not less than 3mm.

5.2.2.6 **Annunciation**

Static type audio-visual annunciator with annunciation windows, acknowledge, test and reset push buttons and hooter shall be provided on each charger for the following annunciations. Any additional relays/ components, including DC undervoltage relay and current sensors, required for this purpose shall be provided in the chargers. Facility for bypassing the audio alarm on each charger shall also be provided.

- DC under voltage
- DC overvoltage
- DC earth leakage
- AC incoming power supply failure
- AC input fuse blown-off
- Thyristor/ diode failure
- DC output fuse blown-off
- DC battery fuse blown-off
- Filter Capacitor fuse blown-off
- Load on Battery (using current direction sensing with time delay)
- Battery undervoltage/ Disconnected during discharge (using zero current sensing)
- Cubicle fan failure/ cubicle temperature high (for chargers with forced cooling).

One summary alarm potential-free contact each for Battery, Charger-1 and Charger-2 shall be wired to terminal block for remote annunciation.

5.2.2.7 **Printed Circuit Boards (PCBs)**

PCBs used in the chargers shall be made of glass epoxy material. The PCBs shall be firmly clamped in position so that vibration or continued usage do not result in loose contacts. All PCBs shall be fitted in a manner to avoid replacement of a PCB by a wrong spare card. The PCBs shall be provided with visual light emitting diode (LED) status indications, monitoring points/ test connections and setting potentiometers in a readily accessible location which is visible without removing the PCBs.

5.2.2.8 Vendor shall provide adequate protection to the system.

5.3 Construction of Chargers/ Distribution Board

5.3.1 Each Battery Charger and DC distribution board shall be housed in a separate free standing cubicle with minimum IP-31 degree of protection. All panels shall be of the same height so as to form a panel line up which shall have good aesthetic appearance. Chargers-1 & 2 shall be installed side by side whereas DCDB may be located separately and interconnected to the charger through cables. The DCDB shall accommodate outgoing feeders as desired. Each panel shall be provided with an 11W CFL light with a door operated switch and a thermostatically controlled MCB protected space heater.

The DCDB shall be compartmentalised with each outgoing feeder housed in a separate compartment. Cable alley of minimum 200mm width with suitable supports shall be provided for the termination of cables for each vertical arrangement of outgoing feeders in DCDB.

5.3.2 The Chargers, DCDB and Cell Booster enclosures shall be fabricated from structural/ CRCA sheet steel. The frames shall be fabricated by using minimum 2 mm thick CRCA sheet steel while the doors and covers shall be made from minimum 1.6 mm thick CRCA sheet steel. Wherever required, suitable stiffeners shall be provided. The panels shall be provided with suitable louvers for ventilation backed by wire mesh. They must be suitable for use in a tropical climate. Hinged doors shall be provided at the front and back as required. Inter panel sheet steel barriers shall be provided.

5.3.3 Bus bars shall be colour coded and live parts shall be shrouded to ensure complete safety to personnel intending routine inspection by opening the panel doors. All the equipment inside the panel and on the doors shall have suitable nameplates and device tag numbers as per the schematic diagram. All wires shall be ferruled and terminals shall be numbered.

5.3.4 The DCDB incomer and main bus bars shall be rated based on the maximum load current considering an additional 10% design margin for contingencies. The rating shall be selected from standard available ratings and shall be adequate for the expected short circuit current. The bus bar voltage shall be higher than the recommended quick charging voltage for the system. The insulation for all equipment where provided shall be heat resistant, moisture proof and tropicalised.

5.3.5 All power and control switches shall be rotary/ cam operated type. All power switches shall be air insulated load break type. Vendor shall ensure that all equipment/ components such as incomer switches, outgoing DC switches, MCCBs, push buttons, indicating lamps, charger mode selector switches, voltage control switches, annunciator windows etc. are suitably located on the charger and distribution board door such that they can be operated without opening the front door. Power switches shall be provided with a door interlock. In case of difficulty in installation on the charger front panel door, the AC incoming power switches, DC outgoing switches and MCCBs may be installed within the panel provided that they are operable after opening the front panel door. However, all other selector/ control switches, push buttons, indicating lamps, annunciators, meters etc. shall necessarily be installed on the front panel door as specified above.

5.3.6 All instruments shall be switchboard type, back connected and 72 x 72 mm square size. Accuracy class of all meters shall be 1%. Digital meters capable of displaying different parameters can be considered subject to Owner's/ EIL's approval. Analogue instrument scales shall have a red mark indicating maximum permissible operating rating.

5.3.7 All fuses shall be link type and shall be located inside the panel. Diazed fuses shall not be accepted.

5.3.8 All power and control wiring connections within the panels shall be carried out with 660V grade, PVC insulated, BIS marked wires having stranded copper conductors. However, copper strip connections shall preferably be used for currents exceeding 100A. Control wiring for electronic circuits/ components shall be through flat ribbon cable or copper wire of minimum 0.5mm diameter. Ferruling of wires shall be as per relevant IS.

5.3.9 For all cabling external to panels, power cables shall be with aluminium/ copper conductors and control cables shall be with copper conductors. All cable connections shall be from the bottom of the panel. Removable bolted undrilled gland plates shall be provided along with single compression type nickel plated brass cable glands for all external cable connections. Separate test terminals shall be provided for measuring and testing the equipment to check performance. All panels shall be supplied complete with tinned copper cable termination lugs.

5.3.10 A suitably sized earth bus shall be provided at the bottom of the panels running through the panel line up with provision for earth connections at both ends to owner's main earth grid. All potential free metallic parts of equipment shall be suitably earthed to ensure safety.

5.3.11 The maximum height of the operating handles/ switches shall not exceed 1800 mm and the minimum height shall not be below 300 mm.

5.3.12 All components/ devices/ feeders shall be provided with screwed nameplates and lettering shall be of minimum 6 mm height.

5.3.13 Panels shall undergo manufacturer's standard cleaning and painting cycle. After preparation of the under surface, the panel shall be painted with two coats of epoxy based final paint. Colour shade of final paint shall be 631 of IS 5/ RAL 7032. All unpainted steel parts shall be suitably treated to prevent rust formation. If these parts are moving elements, then they shall be greased.

5.4 Cell Booster

Cell booster shall be suitable for charging one to six cells within the time duration specified at Cl.5.2.1.1. It shall be suitable for charging not only new cells before being introduced to the battery bank but also for any treatment to be given to individual weak cells. Cell booster shall be suitable for 240 V $\pm$ 10%, 50 Hz $\pm$ 3% SPN input power supply. Cell booster output voltage shall be in the range of 0-18V and 0-12V for Lead Acid and Nickel Cadmium batteries respectively. Cell booster shall be sized as under:

For Lead Acid battery	=	0.14 x Ah(C_{10}) of cell
For VRLA battery	=	0.2 x Ah(C_{10}) of cell
For NiCd battery	=	0.2 x Ah(C_5) of cell.

Cell booster shall have a heavy duty switch fuse or MCCB on both AC incomer and DC output sides, along with AC voltmeter, DC ammeter, DC voltmeter and indicating lamps for AC/ DC power ON. The output voltage and current of cell booster shall be manually controlled using a suitably rated variac or a full wave controlled rectifier bridge. Suitable interlock shall be provided so as to ensure that the variac/ controlled rectifier is at its minimum position while switching on the cell booster. Cell booster shall be portable type with wheels. Each cell booster shall be supplied with 5 m long flexible copper conductor, PVC insulated braided cables for both AC incoming power supply and DC output connection to the battery. An industrial type 3 pin 15A plug shall be provided on AC incoming cable end and lugs shall be provided on DC outgoing cable end.

5.5 Reliability

All necessary care shall be taken in selection, design, manufacture, testing and commissioning of the equipment for ensuring high system reliability. The following design considerations shall be taken into account to ensure maximum availability of the system:

5.5.1 There shall be no common device between the two units, the failure of which could cause shutdown of more than one charger.

5.5.2 It shall be possible to attend to any individual power circuit for maintenance without affecting the total DC supply.

5.5.3 Series-parallel combination of smaller devices to achieve specified rating shall not be acceptable.

6.0 INSPECTION, TESTING AND ACCEPTANCE

6.1 During fabrication, the equipment shall be subjected to inspection by EIL / Owner or by an agency authorised by the Owner. Manufacturer shall furnish all necessary information concerning the supply to EIL's/ Owner's inspector. Tests shall be carried out at manufacturer's works under his care and expense.

6.2 Each Battery Charger/ DCDB/ Cell Booster shall be tested in accordance with applicable standards. The following acceptance tests shall be performed on each Battery Charger and DCDB as a minimum. Detailed test schedule and procedures shall be formulated by the vendor and submitted for EIL's/ Owner's approval. Vendor shall indicate the maximum allowable tolerance against each test parameter in line with applicable standards. All tests shall be witnessed by owner or his authorised representative and 4 weeks prior notice shall be given before the date of commencement of tests. In case the equipment fails to meet any requirements of the specifications, necessary modifications/ corrections shall be made by the vendor to ensure compliance to the specifications, and the equipment shall be retested before acceptance. Test certificates indicating the test results shall be submitted to owner.

6.2.1 Insulation Tests

Insulation tests shall be performed as per IEC 60146-1-1.

The insulation tests shall be carried out using an AC power frequency voltage or a DC voltage at the choice of the manufacturer. In the case of AC power frequency voltage test, the test voltage at the frequency available in the test facility or at the rated frequency, but not exceeding 100 Hz, shall be increased to the full value shown in the following table in not less than 10 seconds continuously or in maximum steps of 0.05 p.u. of the full value starting at a maximum of 0.5 p.u. The unit on test shall withstand the specified voltage for 1 minute.

In case DC voltage is used for the test, the value of DC voltage shall be equal to the crest value of the test voltage specified in the table.

V_p / /2 (V_p is the highest crest voltage to be expected between any pair of terminals)	Test Voltage (AC RMS value)
# 60 V	500 V
# 125 V	1000 V
# 250 V	1500 V
# 500 V	2000 V

6.2.2 Printed Circuit Boards

PCBs and other electronic circuits shall undergo a burn-in test for 96 hours at 50°C at a voltage varied between the maximum and minimum supply voltage. In case of failure of any component during testing, the tests shall be repeated after replacement of the faulty component. Supplier's test certificates are also acceptable for the test.

6.2.3 Heat Run Test

Prior to execution of functional tests, each of the two chargers of each Battery Charger set shall be subjected to a Heat Run test performed at rated load and voltage for a period not less than 8 hours. The other charger of the set shall be energized under zero load current condition throughout the test period. The temperature of electronic power devices shall be measured and the device junction temperature shall be calculated. The calculated value shall

be at least 10-20°C lesser than the maximum rated junction temperature of the device with proper ambient temperature correction applied.

6.2.4 **Functional Tests**

Functional tests shall be performed on each charger. If during execution of functional tests, an electronic component of the charger is required to be replaced, e.g. due to charger malfunction or failure of the unit to fulfil the performance requirements of the specification, then the heat run test shall be repeated at rated current following which functional tests shall be carried out.

6.2.4.1 **Charger Testing at Constant Output Voltage**

Measurements shall be carried out in the float charging mode and in the quick charging mode. In each mode, measurements shall be carried out at nominal AC input voltage and at zero, 50% and 100% of rated output current. Measurements at 100% rated load current shall be repeated at 90% and 110% of nominal AC supply voltage. Measurements shall include input AC phase voltage, frequency, current and power and DC output voltage, current and output voltage ripple.

6.2.4.2 **Charger Testing at Constant Output Current Limit**

Measurements shall be carried out both in the float charging and quick charging mode. In each mode, measurements shall be carried out when the charger is operating under DC current limiting conditions with DC output voltage between zero and set value corresponding to constant voltage operation. Measurements shall include DC output voltage and current.

6.2.4.3 **Auxiliary Equipment and Control Circuit Tests**

The correct functioning of all measuring instruments, alarms, indications, protections and controls mentioned in the specification shall be verified.

6.2.4.4 **Parallel Operation**

Parallel operation of both chargers, sharing of the load and automatic isolation of faulty charger shall be checked.

6.2.4.5 **Charger Efficiency**

This shall be determined by measurement of the active power input and output at 50%, 75% and 100% load.

6.2.4.6 **Audible Noise Test**

Audible noise shall be measured around each charger at 1 meter distance in at least 4 to 5 positions.

6.3 **Site Acceptance Test**

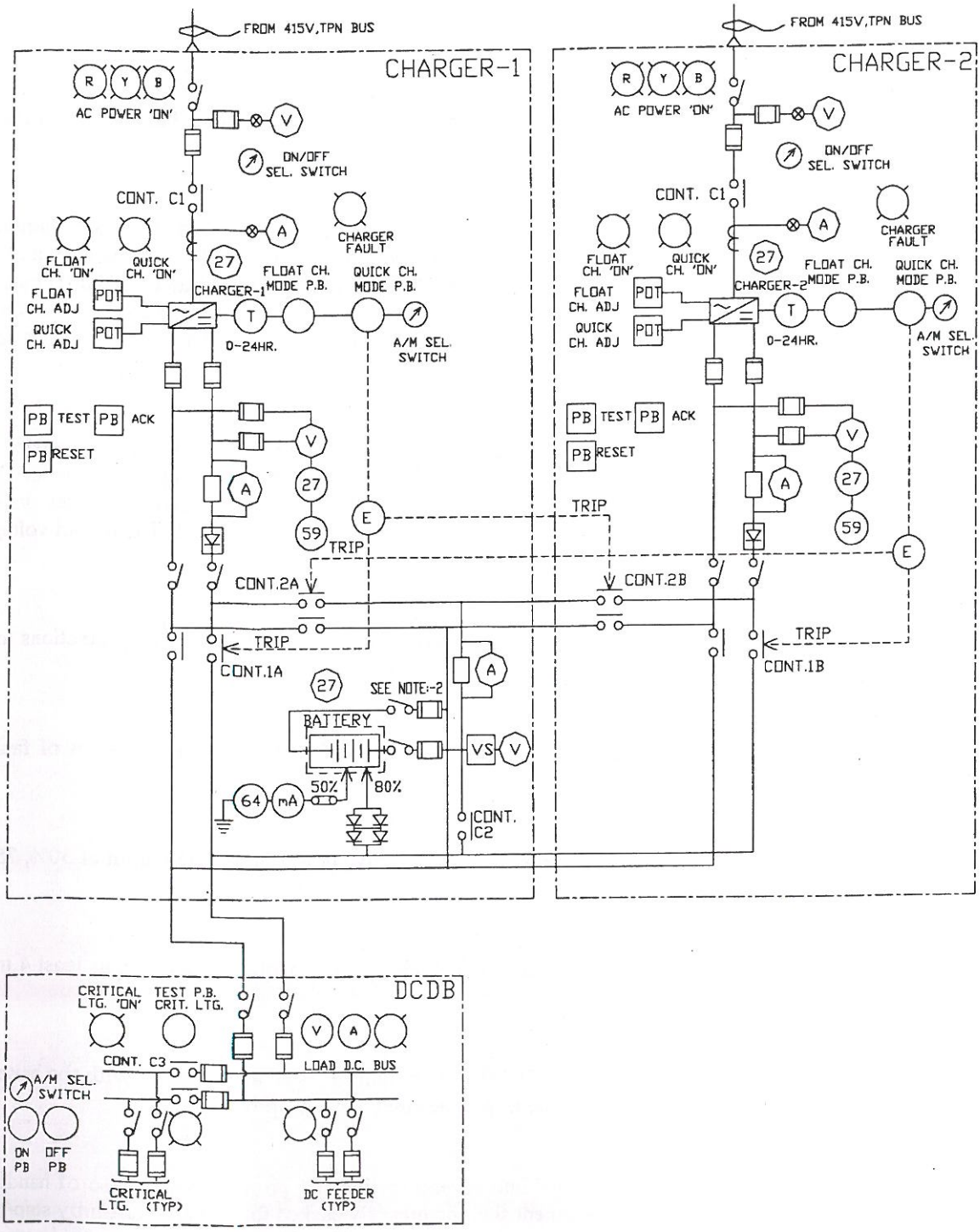
The Battery Chargers, DCDB and Cell Boosters shall be tested at site along with the battery. Vendor shall perform all tests at site as per the approved SAT procedure.

7.0 **PACKING & DESPATCH**

All the equipment shall be divided into several sections for protection and ease of handling during transportation. The equipment shall be properly packed for transportation by ship/ rail or trailer. It shall be wrapped in polythene sheets before being placed in crates/ cases to prevent damage to finish. The rates/ cases shall have skid bottoms for handling. Special notations such as 'Fragile', 'This side up', 'Center of gravity', 'Weight', 'Owner's particulars', 'PO Nos.' Etc., shall be clearly and indelibly marked on the packages together with other details as per purchase order.

The equipment may be stored outdoors for long periods before installation. The packing shall be completely suitable for outdoor storage in areas with heavy rains and high ambient temperature.

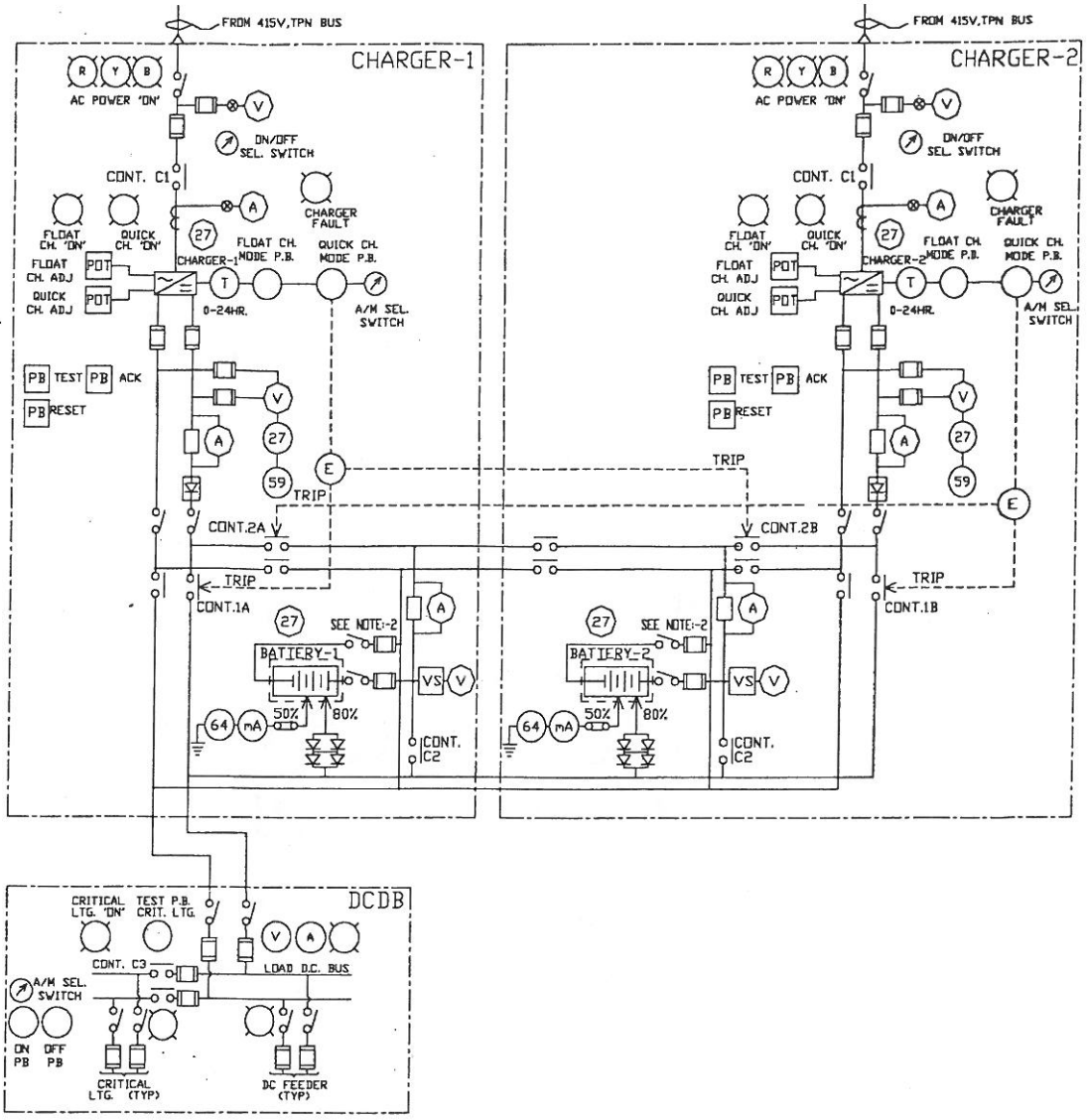
OPTION–I



NOTES: –

1. a) THE DC CONTACTORS SHALL HAVE A TESTED/ PUBLISHED DC RATING EQUAL TO OR EXCEEDING THE MOST STRINGENT CURRENT CARRYING AND BREAKING REQUIREMENTS CONSIDERING ADEQUATE DESIGN MARGINS.
   b) PUSH BUTTONS ARE NOT ACCEPTABLE IN PLACE OF SELECTOR SWITCHES FOR THE ON/OFF SWITCHING OPERATIONS OF THE CONTACTORS.
   c) THE DC CONTACTORS SHALL BE OPERATED WITH A DC CONTROL SUPPLY.
2. SUITABLY RATED DC MCCB CAN BE ACCEPTED IN PLACE OF SWITCH FUSE UNIT AT BATTERY OUTPUT.

OPTION–II



1. a) THE DC CONTACTORS SHALL HAVE A TESTED/ PUBLISHED DC RATING EQUAL TO OR EXCEEDING THE MOST STRINGENT CURRENT CARRYING AND BREAKING REQUIREMENTS CONSIDERING ADEQUATE DESIGN MARGINS.
   b) PUSH BUTTONS ARE NOT ACCEPTABLE IN PLACE OF SELECTOR SWITCHES FOR THE ON/OFF SWITCHING OPERATIONS OF THE CONTACTORS.
   c) THE DC CONTACTORS SHALL BE OPERATED WITH A DC CONTROL SUPPLY.
2. SUITABLY RATED DC MCCB CAN BE ACCEPTED IN PLACE OF SWITCH FUSE UNIT AT BATTERY OUTPUT.

1.0 SCOPE

This specification covers the design, manufacture, testing and supply requirements of stationary flooded Lead Acid cell/batteries for DC power system /AC UPS system application.

2.0 CODES AND STANDARDS

2.1 The equipment shall comply with the requirements of the latest revision of the following standards issued by BIS.

IS-1651 : Stationary Cells and Batteries, Lead Acid type (with tubular positive plates).

IS-1652 : Stationary Cells and Batteries, Lead Acid type (with plante positive plates).

IS-6304 : Stationary Batteries, Lead Acid type with Pasted Positive Plates.

IS-8320 : General Requirement and method of test for Lead Acid Storage Batteries.

2.2 In case of imported equipment, standards of the country of origin shall be applicable if these standards are equivalent or more stringent than the applicable Indian standards.

2.3 The equipment shall also conform to the provisions of CEA regulations with latest amendments and other statutory regulations currently in force in the country.

2.4 In case Indian standards are not available for any equipment, standards issued by IEC/BS/ VDE/IEEE/NEMA or equivalent agency shall be applicable.

2.5 In case of any conflict between various referred standards/ specifications/ datasheets and statutory regulations, the most stringent requirement shall prevail and Owner's/ EIL's decision in this regard shall be final and binding.

3.0 GENERAL REQUIREMENTS

3.1 The offered equipment shall be brand new with state of the art technology and proven field track record. No prototype equipment shall be offered.

3.2 Vendor shall ensure availability of spare parts and maintenance support services for the offered equipment for at least 10 years from the date of supply.

3.3 Vendor shall give a notice of at least one year to the end user of equipment and EIL before phasing out the product/ spares to enable the end user to place order for spares and services.

4.0 SITE CONDITIONS

Stationary Lead Acid cell/battery shall be suitable for operating satisfactorily in humid and corrosive atmosphere found in refineries, petrochemical and gas processing plants, metallurgical plants and other industrial plants. Service conditions shall be as specified in the data sheets/job specification. If not specifically mentioned therein, a design ambient temperature of 40°C and an altitude not exceeding 1000m above MSL shall be considered, with a minimum temperature of 10°C for battery sizing.

5.0 TECHNICAL REQUIREMENTS

5.1 Stationary Lead Acid cell/battery shall be suitable for float duty operation with a constant voltage permanently applied to its terminals which is sufficient to maintain it in a state close to full charge and shall be designed to supply load in the event of normal power supply failure. Type of plate construction for batteries shall be as per the data sheet.

5.2 The standard rated ampere hour capacity of the cell/ battery shall be at a reference temperature of 27°C, constant current discharge at 10 hours rate (C10) and an end cell voltage of 1.85 V/cell.

5.3 Ampere hour of the battery shall be selected based on the following criteria:

a. Minimum site ambient temperature of 10°C
b. Discharge duty cycle
c. End cell voltage
d. Ageing factor of 0.8
e. Capacity rating factor

5.4 Number of cells and end cell voltage shall be decided by the vendor on the basis of maximum permissible voltage to the load when batteries are float charged while feeding the load and minimum DC system voltage. However, the minimum number of cells and end cell voltage shall be as per the data sheet.

5.5 The battery shall be suitable for being quick charged to fully charged condition from fully discharged condition within 10 hours.

5.6 Battery assembly shall be supplied empty, dry and uncharged. Packed unused liquid electrolyte with 10% extra shall be delivered with the battery in suitable non returnable sealed containers.

5.7 Each cell/battery shall have a separate container of 2.0V (nominal voltage). The cell container shall be of restricted breathing type and shall be made from acid resistant material and designed to withstand mechanical stresses, shocks and vibrations. Transparent containers shall have minimum and maximum levels markings on the container wall whereas cell/battery with non transparent containers shall be provided with mechanical indicator for electrolyte level.

5.8 The terminal posts shall be casted of lead alloy and shall be suitable for short circuit current and maximum discharge current without damage to the cell as a result of terminal heating.

5.9 Stationary Lead Acid cells/battery shall be designed to withstand the mechanical stresses encountered during normal transportation and handling.

5.10 Flame arrestor shall be mounted on the cell so that all the vented gases diffuse through the arrestor to the outside environment. The construction of the arrestor shall be such that hydrogen burning on the external surface of the arrestor shall not propagate back into the cell to cause explosion.

5.11 The following information shall be permanently marked on the cell.

- Nominal voltage
- Name of manufacturer/model reference
- Rated capacity in ampere hours (Ah) with End Cell Voltage
- Voltage for float operation at 27°C with tolerance of ±1%
- Month and year of manufacture
- Polarity marking

5.12 Each set of battery shall be supplied with all the necessary accessories, including, but not limited to the following:

a. Battery stand in formation as per data sheet. Mild steel stand pretreated and epoxy painted / epoxy powder coated / PVC coated.

b. Inter cell, inter row and inter bank connectors and end take offs. These shall be of lead plated copper/flexible insulated copper cable/completely insulated solid copper connectors.

c. Cell insulator as applicable.

d. Stand insulator.

e. Cell number plates/permanent stickers, Lugs for cable termination, as required.

f. Other accessories and their quantity as per data sheet.

6.0 PERFORMANCE

Lead Acid batteries shall have been type tested to meet the performance requirements for each design and Ah rating of cells as per the relevant Indian standard referred in clause 2.1 above.

7.0 INSPECTION, TESTING AND ACCEPTANCE

Batteries shall be subject to inspection by EIL/owner or by an agency authorized by the owner, to assess the progress of work. The manufacturer shall furnish all the necessary information concerning the supply to EIL/owner's representative. EIL/owner's representative shall be given free access in the works from time to time for stage wise inspection and progress reporting. Four weeks advance notice shall be given to witness the final routine test and other tests as agreed upon.

The routine, acceptance & type testing shall be carried out as per Inspection & test plan for stationary lead acid battery (Standard no. 6-81-1046). Routine tests shall be conducted on each cell/battery. Acceptance tests & Type tests shall be conducted on few cells/battery as per relevant Indian standard.

Battery load test shall also be performed at site after installation as part of commissioning.

8.0 PACKING AND DESPATCH

All the equipment shall be divided into several sections for protection and ease of handling during transportation. The equipment shall be properly packed for transportation by ship/ rail or trailer. The equipment shall be wrapped in polythene sheets before being placed in crates/cases to prevent damage to finish. Crates/cases shall have skid bottom for handling. Special notations such as 'Fragile', 'This side up', 'Centre of gravity', 'Weight', 'Owner's particulars', 'PO nos.' etc., shall be clearly marked on the package together with other details as per purchase order.

The equipment may be stored outdoors for long periods before installation. The packing shall be completely suitable for outdoor storage in areas with heavy rains/high ambient temperature. A set of instruction manuals for installation, testing and commissioning, a set of operation & maintenance manuals and a set of final drawing shall be enclosed in a waterproof cover along with the shipment.

1.0 SCOPE

This specification along with data sheets covers requirements for design, manufacture, testing at works and supply of Fire survival Medium voltage cables and Flame Retardant Low Smoke Medium & High Voltage cables and cable jointing / terminating accessories for medium and high voltage systems.

2.0 CODES AND STANDARDS

2.1 The cables and cables jointing & terminating accessories shall comply with the latest edition of the following standards as applicable:

IS: 209	:	Specification for zinc.
IS: 1554	:	PVC insulated (heavy duty) electric cables.
IS: 3961(Pt-2)	:	Recommended current ratings for cables: Part - 2 PVC Insulated and PVC sheathed heavy-duty cables.
IS: 3975	:	Mild steel wires, strips and tapes for armouring of cables.
IS: 5831	:	PVC insulation and sheath of electric cables.
IS: 6380	:	Specification for elastomeric insulation and sheath of electric cables.
IS: 7098	:	Cross-linked polyethylene insulated PVC sheathed cables.
IS: 8130	:	Conductors for insulated electric cables and flexible cords.
IS: 10418	:	Drums for electric cables.
IS: 10462 (Pt-1):		Fictitious calculation method for determination of dimensions of protective coverings of cables: Part - I Electrometric and thermo-plastic insulated cables.
IS: 10810	:	Methods of test for cables: - Part 41: Mass of zinc coating on steel armour - Part 58: Oxygen index test - Part-61: Flame retardant test - Part-62:Fire resistance test for bunched cables. - Part-63: Measurement of Smoke density of Electric cables under fire conditions
IS: 13573	:	Joints and terminations for polymeric cables for working voltages from 6.6kV up to and including 33kV.
IEC: 60331-21:		Tests for electric cables under fire conditions circuit integrity – Procedures and requirements – Cables of rated voltage up and including 0.6/1.0kV.
IEC: 60332-1	:	Test of the fire behaviour on single core or single cable (flame retardancy)
IEC: 60332-3	:	Tests of the fire behaviour on bunched cables (reduced flame propagation)
IEC: 61034	:	Measurement of smoke density of cables burning under defined condition
NEMA-WC70	:	Standard for non shielded power cables rated 2000V or less for the distribution of electrical energy.
NEMA-WC53	:	Standard test methods for extruded dielectric power, control, instrumentation and portable cables for test.
ASTM-G-154	:	Standard practice for operating fluorescent light apparatus for UV exposure of non-metallic materials.
ASTM-D-2863	:	Measurement of minimum oxygen concentration to support candle like combustion of plastics
BS: 7846	:	Electric cables- 600/1000V armoured fire resistant cables having thermosetting insulation and low emission of smoke and corrosive gases when affected by fire.

2.2 The cables and accessories shall also conform to the provisions of CEA Regulations and other statutory regulations, as applicable.

2.3 In case of any conflict between requirements specified in various applicable documents for the project, the most stringent one shall prevail. However, Owner's decision in this regard will be final and binding.

3.0 GENERAL CONSTRUCTION

3.1 The cables shall be suitable for laying in trays, trenches, ducts, and conduits and for underground-buried installation with uncontrolled backfill and possibility of flooding by water and chemicals.

3.2 Outer sheath of all cables shall be black in colour and the minimum value of oxygen index shall be 29% at 27 ± 2 ° C. In addition suitable chemicals shall be added into the PVC compound of the outer sheath to protect the cable against rodent and termite attack. However, for earthing cables; colour of outer sheath shall be green.

3.3 All cables covered in this specification shall be Flame Retardant Low Smoke (FRLS) or Fire Survival (FS). The outer sheath of FRLS cables shall possess flame propagation properties meeting requirements as per IS-10810 (Part-62) category AF. FRLS cable shall be identified by indenting, embossing or printing the appropriate legend i.e. 'FRLS, Category – C2' throughout the cable length. FRLS properties shall be as per IS:10810 Part 61 & 62, IEC-60332 Part 1 & Part 3, IEEE-383, IEC-61034, IEC-60754 Part 1, ASTM-D-2863.

3.4 Sequential marking of the length of the cable in metres shall be provided on the outer sheath at every one metre. The embossing/engraving shall be legible and indelible.

3.5 The overall diameter of the cables shall be strictly as per the values declared by the manufacturer in the technical information subject to a maximum tolerance of ±2 mm up to overall diameter of 60mm and ±3mm for beyond 60mm.

3.6 PVC/ Rubber end caps shall be supplied free of cost for each drum with a minimum of eight per thousand metre length. In addition, ends of the cables shall be properly sealed with caps to avoid ingress of water during transportation and storage.

3.7 The joints in armour wire/strips shall be made by brazing or welding and any surface irregularities shall be removed. A joint in any wire/strip shall be at least 300mm. from the nearest joint in any wire/strip in the complete cable.

3.8 The cables meant to be used in mining area under the jurisdiction of DGMS shall satisfy the following

(a) "DGMS CERTIFIED" to be embossed at outer sheath at regular interval.

(b) Cables to be used in Mines shall have copper conductor only.

(c) The resistance of armour shall not exceed that of the conductor as specified in IS-8130 by more than 33%. To satisfy this, substitution of galvanised steel wire/strip in armouring by the required number of tinned copper wires/strips is permissible.

(d) For mining cables, the size and type of armour shall be such that the combined conductance of armour shall be equivalent to 75 percent of the conductance of the largest conductor of the cable.

3.9 Medium Voltage Cables

3.9.1 All power/control cables for use on medium voltage systems shall be heavy-duty type, 650/1100V grade with aluminium/ copper conductor, PVC/XLPE (as mentioned in datasheet / Material requisition) insulated, inner-sheathed, armoured/ unarmoured and overall PVC sheathed. XLPE insulated cables shall meet the requirement specified in IS-7098 (Part-1).

3.9.2 The conductors shall be solid for conductor of nominal area up to and including 6mm² and stranded beyond 6mm². Conductors of nominal area less than 16 mm² shall be circular only. Conductors of nominal area 16 mm² and above may be circular or shaped as per IS 8130. Cables with reduced neutral conductor shall have sizes as per Table 1 of IS 1554 (Part-1).

3.9.3 The core insulation shall be with PVC/XLPE compound applied over the conductor by extrusion. PVC compound shall conform to the requirements of type 'C' compound as per IS: 5831. The thickness of insulation and the tolerance on thickness of insulation shall be as per Table 2 of IS: 1554 (Part-1). Control cables having 6 cores and above shall be identified with prominent and indelible Arabic numerals on the outer surface of the insulation. Colour of the numbers shall contrast with the colour of insulation with a spacing of maximum 50 mm between two consecutive numbers. Colour coding for cables up to 5 cores shall be as per Indian standard.

3.9.4 The inner sheath shall be applied over the laid-up cores by extrusion and shall be of PVC conforming to the requirements of Type ST-2 PVC compound as per IS: 5831. The minimum thickness of inner sheath shall be as per Table-4 of IS: 1554 (Part-1). Single core cables shall have no inner sheath.

3.9.5 All cables shall be provided with armour except those specifically specified as unarmoured. For single core cables intended for use on AC system, the armouring shall be of non-magnetic material. For multicore cables, the armour shall be by single round galvanised steel wires where the calculated diameter below armouring does not exceed 13 mm and by galvanised steel strips where this dimension is greater than 13 mm. Requirement and methods of tests for armour material and uniformity of galvanisation shall be considered as per IS - 3975 and IS - 10810 (Part 41). The dimensions of armour shall be considered as per method (b) of IS - 1554 (Part -1).

3.9.6 The outer sheath for the cables shall be applied by extrusion and shall be formulated for lower smoke and shall be of PVC compound conforming to the requirements of type ST-2 compound as per IS: 5831. The minimum and average thickness of outer sheath for unarmoured cables and minimum thickness of outer sheath for armoured cables shall be as per Table-7 of IS: 1554 (Part -1).

3.9.7 If heat resisting PVC cables are specified in the data sheet,, it shall be possible to continuously operate the cable at a maximum conductor temperature of 85°C under full load condition and 160°C under short-circuit condition.

3.9.8 For XLPE insulated cables, it shall be possible to continuously operate the cable at a maximum conductor temperature of 90°C under full load condition and 250°C under short-circuit condition.

3.9.9 The fire survival cables shall meet the following additional requirements :

i) The insulation shall be of EPR or equivalent material with glass mica tape below or above insulation.

ii) The cables shall meet requirement of circuit integrity test for a minimum period of 3 hours at maximum temperature of 950° C.

iii) Vendor shall have the test certificate for circuit integrity test as per IEC: 60331-21.

3.10 High Voltage Cables

3.10.1 Power cables from 3.3kV and up to and including 33kV systems shall be Aluminium/ Copper conductor, XLPE insulated, sheathed, armoured/ unarmoured and overall PVC sheathed.

3.10.2 The conductors shall be stranded and compacted circular for all cables.

3.10.3 All cables rated 3.8/ 6.6kV and above shall be provided with both conductor screening and insulation screening. The conductors shall be provided with non-metallic extruded semi conducting screen.

3.10.4 The core insulation shall be with cross linked polyethylene insulating compound dry cured, applied by extrusion. It shall be free from voids and shall withstand all mechanical and thermal stresses under steady state and transient operating conditions. It shall conform to the properties given in Table-1 of IS: 7098 (Part -2).

3.10.5 The insulation screen shall consist of non-metallic extruded semi-conducting compound in combination with a non-magnetic metallic copper screen. The copper screen for all the three cores together shall be capable of carrying the single line to ground fault current value and the duration specified in the data sheet. For single core cable, non-magentic armour shall constitute the copper screen which shall be capable of carrying the single line to ground fault current value and the duration specified in the data sheet.

3.10.6 The conductor screen, XLPE insulation and insulation screen shall all be extruded in one operation by 'Triple Extrusion' process to ensure perfect bonding between the layers. The core identification shall be by coloured strips or by printed numerals.

3.10.7 The inner sheath shall be applied over the laid up cores by extrusion and shall conform to the requirements of type ST 2 compound of IS: 5831. The extruded inner sheath shall be of uniform thickness. In case of single core cables, there shall be extruded inner sheath between insulation metallic screen and armouring.

3.10.8 All cables shall be provided with armour except those specifically specified as unarmoured. For single core cables intended for use on AC system, the armouring shall be of non-magnetic material. For multicore cables, the armour shall be by galvanised steel strips. Requirement and methods of tests for armour material and uniformity of galvanisation shall be as per IS - 3975 and IS -10810 (Part 41). The dimensions of armour shall be as per method (b) of IS - 7098 (Part -2).

3.10.9 The outer sheath of the cables shall be applied by extrusion over the armouring and shall be of PVC compound conforming to the requirements of Type ST 2 compound of IS: 5831. The minimum and average thickness of outer sheath for unarmoured cables and minimum thickness of outer sheath for armoured cables shall be as per IS: 7098 (Part-2).

3.10.10 The thickness of the insulation, inner sheath shall be governed by values given in Table-4 and Table-5 of IS: 7098 (Part -2).

4.0 CABLE ACCESSORIES

4.1 The termination and straight through jointing kits for use on the systems shall be suitable for the type of cables offered as per this specification and shall meet requirements of IS 13573.

4.2 The accessories shall be supplied in kit form. Each component of the kit shall carry the manufacturer's mark of origin.

4.3 The kit shall include all stress grading, insulating and sealing materials apart from conductor fittings and consumable items. An installation instruction sheet shall also be included in each kit.

4.4 The contents of the accessories kit including all consumable shall be suitable for storage without deterioration at a temperature of 45° C, with shelf life extending to more than 5 years.

4.5 Terminating Kits

The terminating kits shall be suitable for termination of the cables to an indoor switchgear or to a weatherproof cable box of an outdoor mounted transformer/ motor. For outdoor terminations, weather shields/ sealing ends and any other accessories required shall also form part of the kit. The terminating kits shall be from one of the makes/ types mentioned in the data sheet.

4.6 Jointing Kits

The straight through jointing kits shall be suitable for installation on overhead trays, concrete lined trenches, and ducts and for underground burial with uncontrolled backfill and possibility of flooding by water and chemicals. These shall have protection against any mechanical damage and suitably designed to be protected against rodent and termite attack. The inner sheath similar to that provided for cables shall be provided as part of straight through joint. The jointing kits shall be from one of the makes/ types mentioned in the data sheet.

5.0 INSPECTION, TESTING AND ACCEPTANCE

The cables shall be tested and inspected at the manufacturer's works. Manufacturer shall furnish all necessary information concerning the raw material supply to EIL/ Owner's inspectors. The inspector shall have free access to the manufacturer's works for the purpose of inspecting the process of manufacture in all its stages and will have the power to reject any material, which appears to be of unsuitable description or of unsatisfactory quality. For HV cables, the vendor shall give at least 2 weeks advance notice to the purchaser, regarding the date of testing to enable purchaser's representative to witness the tests.

5.1 Cables

5.1.1 After completion of manufacture of cables and prior to despatch, the cables shall be subjected to type, routine, acceptance and special tests as detailed below. The test reports for all cables shall be got approved from the Engineer before despatch of the cables.

5.1.2 All routine tests, acceptance tests, type tests and additional type tests for improved fire performance shall be carried out as listed in IS: 1554 (Part-1) and IS: 7098 (Part-2) on PVC and XLPE insulated cables respectively.

5.1.3 The test requirements for PVC insulation and sheath of cables shall be as per latest revision of IS: 5831.

5.1.4 Test for Resistance to Ultra Violet Radiation: This test shall be carried out as per ASTM-G-53 or ASTM-G-154 on outer sheath. The retention value of tensile strength and ultimate elongation after the test shall be minimum 60 % of tensile strength and ultimate elongation before the test. Test certificates with respect to this test (not older than one year) from recognised testing laboratory to be furnished for review by EIL before despatch clearance of cables. In case test certificates are not available, test is to be conducted by vendor at his own cost in any recognised test laboratory or in house testing laboratory, before despatch clearance

of cables. Sampling for this test is to be done randomly once for each order, provided outer sheath remains same.

5.1.5 Acceptance tests as per IS-1554 (Part-1) and IS-7098 (Part-2) and the following special tests to be performed on the cables as per sampling plan for all cables. However these tests are required to be witnessed by EIL/ Owner for HV cables.

a. Accelerated water absorption test for insulation as per NEMA-WC-70. (For PVC insulated cables) and as per NEMA-WC-53 (for XLPE/ EPR insulated cables). Test certificates with respect to this test (not older than one year) from recognised testing laboratory to be furnished for review by EIL before despatch clearance of cables. In case test certificates are not available, test is to be conducted by vendor at his own cost in any recognized test laboratory or in house testing laboratory, before despatch clearance of cables. Sampling for this test is to be done randomly once for each order, provided type of insulation remains same.

b. Dielectric Retention Test: The dielectric strength of the cable insulation tested in accordance with NEMA-WC-70 at 75 ± 1° C shall not be less than 50 % of the original dielectric strength. (For PVC insulated cables). Test certificates with respect to this test (not older than one year) from recognised testing laboratory to be furnished for review by EIL before despatch clearance of cables. In case test certificates are not available, test is to be conducted by vendor at his own cost in any recognized test laboratory or in house testing laboratory, before despatch clearance of cables. Sampling for this test is to be done randomly and once for each order.

c. Oxygen Index Test: The test shall be carried out as per IS-10810 (Part 58). Sampling to be done for every offered lot/size as per sampling plan.

d. Flammability Test: The test shall be carried out on finished cable as per IS-10810 (Part 61 & 62). Sampling for these tests is to be done randomly once for each order, provided outer sheath remains same. The acceptance criteria for tests conducted shall be as under:

Part-61-The cable meets the requirement if there is no visible damage on the test specimen within 300 mm from its upper end

Part-62-The maximum extent of the charred portion measured on the test sample should not have reached a height exceeding 2.5 m above the bottom edge of the burner at the front of the ladder.

e. Test for rodent and termite repulsion property shall be done by analysing the property by chemical method.

5.1.6 Following tests shall be carried out to prove FRLS property of the cable.

a. Critical oxygen index as per ASTM-D-2863 i.e. Determination of % of oxygen required for combustion at room temperature of FRLS sheath which shall remain as 29%(min.)

b. Temperature index as per ASTM-D-2863 i.e. To determine at what temperature normal oxygen content of 29% in air will support combustion of FRLS sheath which shall remain as 250°C.

c. Halogen acid gas emission as per IEC-60754 Part 1 i.e. To determine the % of release of hydrochloric acid gas from the FRLS sheath under fire which shall be 20% (max.)

600

d. Smoke Density Test shall be as per ASTM D - 2843 and Smoke Density Rating of FRLS Sheath shall be 60% (max.).

5.1.7 The test for circuit integrity for fire survival cables shall be carried out as per IEC-60331 (Part-21).

5.2 Cable Accessories

Type tests should have been carried out to prove the general qualities and design of a given type of termination/ jointing system as per IS-13573. The type test certificates from independent testing laboratory shall be submitted before despatch.

6.0 PACKING AND DESPATCH

6.1 Cables shall be despatched in non-returnable steel drums of suitable barrel diameter, securely packed, with the take-off end fully protected against mechanical damage. Ferrous parts used shall be treated with a suitable rust preventive finish or coating to avoid rusting during transit or storage.

6.2 On the flange of the drum, necessary information such as project title, manufacturer's name, type, size, voltage grade of cable, length of cable in metres, drum no., cable code, BIS certification mark, gross weight etc. shall be printed. An arrow shall be printed on the drum with suitable instructions to show the direction of rotation of the drum.

6.3 Cables shall be supplied in drum lengths as follows:

6.3.1 **MV Cables**

-	Multicore Power cables upto 6 mm^2	:	1000 m
-	Multicore Power cables from 10 mm^2 up to 500 mm^2	:	500 m
-	Single Core Power cables upto 630 mm^2	:	1000 m
-	Control cables upto 61 cores	:	1000 m

6.3.2 **HV Power Cables Upto 11kV Grade**

-	Three Core cables upto 400 mm^2	:	500 m
-	Single Core cables upto 400 mm^2	:	1000 m
-	Single Core cables above 400 mm^2 and upto 1000 mm^2	:	750 m

6.3.3 **HV Power Cables Above 11kV Grade and upto 33kV Grade**

-	Three Core cables upto 300 mm^2 grade	:	350 m
-	Single Core cables upto 400 mm^2	:	1000 m
-	Single Core cables above 400 mm^2 and upto 1000 mm^2	:	500 m

However exact drum lengths shall be finalised during order execution. A tolerance of ± 3 % shall be permissible for each drum. However overall tolerance on each size of cable shall be limited to ±2%.

1.0 SCOPE

The intent of this specification is to define the requirements for design, manufacture and supply of Flame Retardant Low Smoke type and Fire Survival type PVC sheathed cables for use in plant communication and fire alarm systems and jelly filled telecommunication cables.

2.0 CODES AND STANDARDS

The equipment shall comply with the requirements of the latest revision of the following standards:

2.1 BIS and other Standards

ASTM D-883	:	Standard terminology relating to plastics.
ASTM-D-2863	:	Measurement of minimum oxygen concentration to support candle like combustion of plastics
ASTM-G-154	:	Standard practice for operating fluorescent light apparatus for UV exposure of non-metallic materials.
IEC: 60331-21	:	Tests for electric cables under fire conditions circuit integrity – Procedures and requirements – Cables of rated voltage up and including 0.6/1.0kV.
ASTM D-924	:	Standard test method for dissipation factor (or power factor) and relative permittivity (dielectric constant) of electric insulating liquids.
BS-6234	:	Specification for polythene insulation and sheath of electric cables.
IS-694	:	PVC insulated cables for working voltages upto and including 1100V.
IS-1554 (Part 1)	:	PVC insulated (heavy duty) electric cables (Part-1 for working voltages up to and including 1100V).
IS-5831	:	PVC insulation and sheath of electric cable.
IS-8130	:	Conductors for insulated cables and flexible cords.
IS-9938	:	Recommended colour for PVC insulation for LF wires and cables.
IS-10418	:	Drums for electric cables.
IS-10462 (Part 1)	:	Fictitious calculation method for determination of dimensions of protective coverings of cables (Part-1: Elastomeric and thermoplastic insulated cables).
IS-10810 (Part 58)	:	Methods of test for cables (Part 58: Oxygen index test).
IS-10810 (Part 61)	:	Methods of test for cables (Part 61: Flame retardant test)
IS-10810 (Part 62)	:	Methods of test for cables (Part 62: Fire resistance test for bunched cables).
IS-12444	:	Continuously cast and rolled electrolytic copper wire rods for electrical conductors.

2.2 DOT Standards

GR/WIR-06/03	:	Specification for cable - switchboard (Screened and Unscreened) - Generic requirements.
GR/CUG-01/03	:	Specification for solid polythene insulated fully filled, polythene sheathed underground telecom cables.

2.3 In case of imported cables, standards of the country of origin shall be applicable, if these standards are equivalent to or stringent than the applicable Indian standards.

2.4 The cables shall also conform to the provisions of the CEA Regulations and other statutory regulations currently in force in the country.

2.5 In case Indian standards are not available for any material, standards issued by IEC/ BS/ VDE/ IEEE/ NEMA or equivalent agency shall be applicable.

2.6 In case of any conflict between requirements specified in various applicable documents for the project, the most stringent one shall prevail. However, Owner's decision in this regard will be final and binding.

3.0 SITE CONDITIONS

Cables shall be suitable for installation in following conditions:

i. Above ground in open-air locations (trays/ ducts) in tropical, humid and corrosive atmosphere prevalent in refineries/ petrochemical plants with severe weathering and exposure to solar radiation.

ii. Directly buried in underground trenches, conduits with uncontrolled back-fill and possibility of flooding by water and chemicals.

iii. Design ambient air temperature of 40°C/ ground temperature of 30°C.

4.0 TECHNICAL REQUIREMENTS FOR NON JELLY FILLED CABLES

4.1 Non jelly filled communication and fire alarm cables shall in general conform to the requirements of DOT specification GR/WIR-06/03.

4.2 Conductors

4.2.1 The size of conductor shall be as per job requirement.

4.2.2 The conductors shall consist of annealed, high conductivity solid copper wire, smoothly drawn, circular in cross-section, uniform in quality, free from defects and uniformly coated with pure tin and shall conform to Cl. 3.0 of DOT specification GR/WIR-06/03.

4.3 Insulation

4.3.1 The core insulation shall be with PVC compound applied over the conductor by extrusion.

4.3.2 PVC insulation shall meet the following requirements:

Conductor Diameter (Area)	Type of Insulation	Thickness of Insulation (Minimum)
Up to 0.5mm (0.2mm^2)	Type-A or B as per IS-5831	0.18 mm
Above 0.5mm (0.2mm^2) & up to 0.71mm (0.4mm^2)		0.26 mm
Above 0.71mm (0.4mm^2) & up to 0.9mm (0.63mm^2)		0.31 mm
Above 0.9mm (0.63mm^2) & up to 1.12mm (1mm^2)		0.39 mm
Above 1.12mm (1mm^2) & up to 1.38mm (1.5mm^2)		0.58 mm
1.78mm (2.5mm^2)		0.71 mm
2.26mm (4mm^2)		0.80 mm

4.3.3 The colours used for insulation shall conform as nearly as practicable to the standard colours as per IS-9938. The wire insulation shall have colours in accordance with Table-2 of DOT specification GR/WIR-06/03. The applied colour shall neither have deleterious effect on the electrical, mechanical or ageing properties of basic insulation nor shall get damaged by any friction etc.

4.3.4 For single pair cables, the colour shall be incorporated in the insulation.

4.3.5 For multi pair cables, cores shall have uniform pattern of continuous spiral (Pitch not exceeding 25mm) to facilitate easy identification. This may be done by the application of one or more coloured strips on a base colour or by direct extrusion.

4.3.6 Alternately, colouring may consist of concentric coloured rings or dots or dashes on the base colour. The coloured rings, dots or dashes shall have a width of not less than 1.0mm and shall be repeated along the length of the insulation at an interval not less than 15mm and not more than 25mm.

4.3.7 The dots or dashes shall be applied on diametrically opposite sides of the insulation, so that all colours are visible when the insulation is viewed from any side.

4.4 Twisting

The two insulated conductors of a pair shall be uniformly twisted with a suitable right hand lay, which shall not exceed 80mm.

4.5 Core Formation

The core formation shall conform to Cl. 6.0 of DOT specification no. GR/WIR-06/03.

4.6 Screen

4.6.1 The cables shall be provided with overall screen. The screen shall be of aluminium tape with minimum thickness of 0.04mm. The overlap shall be minimum 3mm for cables up to 50 pair & minimum 6mm for cables above 50 Pair. The screen shall be backed by an outer protective layer of 0.13mm PVC tape or other non-hygroscopic material lapped applied longitudinally or helically with overlap.

4.6.2 The cables shall be provided with a drain wire. Drain wire shall have a minimum cross-section of 0.5mm^2, shall be composed of multistrand bare tinned annealed copper conductor. The drain wire shall be in continuous contact with the aluminium side of the overall screen. The drain wire resistance including screen shall not exceed 30 ohm/km.

4.7 Ripcord

A non-metallic ripcord of suitable quality shall be laid longitudinally under the inner sheath & screen. The ripcord when pulled shall cut through the sheath and strip the core.

4.8 Inner Sheath

4.8.1 An extruded inner sheath of type ST2 PVC, as per IS-5831, with minimum thickness as per Table-4 of IS-1554 (Part-1) shall be applied over the laid up core, by extrusion to fit closely on it.

4.8.2 The inner sheath shall be as circular as possible. It shall be possible to remove the inner sheath without damage to the insulation.

4.8.3 When one or more layers of non-hygroscopic tape is helically applied over the laid up cores, as a binder, the thickness of such tape(s) shall not be construed as a part of the inner sheath.

4.9 Armour

4.9.1 The cables shall be provided with armouring, made of hot dip galvanised steel wire /strip over the inner sheath.

4.9.2 The armour shall be by means of 1.4mm thick round wires for cables with under armour diameter upto 13mm. For cables with an under armour diameter above 13mm, the armour shall either be of steel strip or round wire with thickness as per IS-1554 (Part-1).

4.10 Outer Sheath

4.10.1 The cables shall be provided with an extruded PVC sheath for external protection. The PVC shall be type ST2 PVC, as per IS-5831.

4.10.2 All cables covered in this specification shall be flame retardant low smoke (FRLS). The other sheath shall be with oxygen index 29% at 27±2°C and possess flame retardant low smoke properties meeting the requirements of IS 10810 Part-62 category - AF. In addition, suitable chemicals shall be added to the PVC compound of the outer sheath to protect the cable against rodent and termite attack.

4.10.3 The thickness of outer sheath shall be as per IS-1554 (Part 1).

4.10.4 The outer sheath shall fit tightly on the armour and shall be applied in such a manner that no undue residual strain is left in the material.

4.10.5 The outer sheath shall be red in colour for cables to be used for fire alarm system, grey in colour for cables to be used for telephone & communication system and black in colour for all other functions.

4.10.6 Sequential marking of the length of the cable, in meters, shall be provided on the outer sheath at every one meter. The marking shall be legible and indelible by suitable method.

4.10.7 The overall diameter of the cables shall be strictly as per the values declared in the data sheet, subject to a maximum tolerance of ±2mm.

4.11 The fire survival cables (if specified in data sheet) shall meet the following additional requirements:

i) The insulation shall be of EPR or equivalent material with glass mica tape below or above insulation.

ii) The cables shall meet requirement of circuit integrity test for a minimum period of 3 hours at maximum temperature of 950° C.

iii) Vendor shall have the test certificate for circuit integrity test as per IEC: 60331-21.

4.12 Cable Capacitance

4.12.1 The core to core capacitance of the cables shall not exceed 100nF/km at 1kHz.

4.12.2 The core to screen capacitance for the screened cables shall not exceed 250nF/km at 1kHz.

5.0 TECHNICAL REQUIREMENTS FOR JELLY FILLED CABLES

5.1 Jelly filled telecom cables shall in general conform to the requirements of DOT specification GR/CUG-01/03.

5.2 Conductors

5.2.1 The conductors shall consist of annealed, high conductivity solid copper wire, smoothly drawn, circular in cross-section, uniform in quality, free from defects and uniformly coated with pure tin and shall conform to Cl. 3.0 of DOT specification GR/CUG-01/03.

5.3 Insulation

5.3.1 Each conductor shall be insulated with insulating grade PE conforming to Cl. 4.0 of DOT specification GR/CUG-01/03.

5.4 Twisting

The two insulated conductors of a pair shall be uniformly twisted with a suitable right hand lay, which shall not exceed 150mm.

5.5 Core Formation

The core formation shall conform to Cl. 6.0 of DOT specification GR/CUG-01/03.

5.6 Filling Compound

5.6.1 The cable core shall be filled with a suitable stable water resistant compound, which shall be compatible with the insulation, binders and tapes used in the cable.

5.6.2 It shall be homogeneous and uniformly mixed material containing an anti-oxidant.

5.6.3 The compound shall not obscure the identification of the colour of the insulation of the conductors.

5.6.4 It shall not contain dirt, metallic particles or other foreign matter.

5.6.5 The compound shall be readily removable from the insulated conductors by wiping.

5.6.6 It shall be free from any unpleasant odour and shall have no toxic or dermatic hazards.

5.6.7 The flash point of the compound shall not be less than 200°C.

5.6.8 The volume resistivity measured at 100°C shall not be less than 10^{10} ohm-cm.

5.6.9 The permittivity at 1 MHz tested as per ASTM D-924 shall not be greater than 2.3 at 20°C.

5.7 Core Wrapping

At least one closed helical or longitudinal application of a nonhygroscopic and nonwicking polyester tape or tape of any other suitable material shall be provided over the cable core.

5.8 Screen

5.8.1 The cables used for telephone system shall be provided with overall screen. The screen shall be of aluminium tape with minimum thickness of 0.2mm. The overlap shall be minimum 3mm for cables having maximum diameter over inner sheath < 30mm & minimum 6mm for cables having maximum diameter over inner sheath ≥ 30mm. The screen shall be coated with 0.05 mm nominal thickness polythene/copolymer on both sides. The thickness of the composite tape shall be 0.3mm ± 15%.

5.8.2 The aluminium tape shall be electrically continuous through out the length of the cable.

5.9 Inner Sheath

5.9.1 The inner sheath shall be as circular as possible and free from pinholes and other defects. It shall be possible to remove the inner sheath without damage to the insulation.

5.9.2 The inner sheath shall be of polythene conforming to type 03C or H03C of BS 6234 and shall contain a suitable antioxidant system. The material shall be virgin as per ASTM D-883 and meet the requirements of Cl. 10.1 of DOT specification no. GR/CUG-01/03.

5.9.3 The thickness of inner sheath shall conform to Table-6 of DOT specification no. GR/CUG-01/03.

5.9.4 The maximum diameter over inner sheath shall conform to Table-7 of DOT specification no. GR/CUG-01/03.

5.10 Armour

5.10.1 The cables shall be provided with bedding and armour over the inner sheath.

5.10.2 The bedding shall consist of two close helical lappings of polythene or polypropylene tape. Each tape shall be applied with a minimum of 5% overlap.

5.10.3 The armour shall be made of hot dip galvanised steel tape of thickness as per Table-8 of DOT specification GR/CUG-01/03.

5.11 Outer Sheath

5.11.1 The external protection shall consist of a polythene sheath conforming to the material specification defined in Clause 5.9 above.

5.11.2 The thickness of outer sheath shall conform to Table-9 of DOT specification GR/CUG-01/03.

5.11.3 The outer sheath shall be as circular as possible and free from pinholes and other defects.

5.11.4 Colour of outer sheath shall be grey.

5.11.5 The maximum diameter over outer sheath shall conform to Table-7 of DOT specification GR/CUG-01/03.

5.12 Cable Capacitance

The average mutual capacitance of the pairs measured at 800 to 1000Hz shall be 52 ± 3 nF/km. However, the mutual capacitance of individual pairs shall be within the limits of 52 ± 4.5 nF/km.

6.0 INSPECTION, TESTING AND ACCEPTANCE

6.1 The cables shall be tested and examined at the manufacturer's works. All the materials employed in the manufacture of the cable shall be subjected to examination, testing and approval by EIL/ Owner. Manufacturer shall furnish all necessary information concerning the supply to EIL/ Owner's inspectors. The inspector shall have free access to the manufacturer's works for the purpose of inspecting the process of manufacture in all its stages and will have the power to reject any material, which appears to be of unsuitable description or of unsatisfactory quality.

6.2 The following acceptance tests shall be conducted on the completed jelly filled cables as per the test procedures given in DOT specification GR/CUG-01/03 and this specification:

i. Measurement of diameter of conductor, over inner sheath & over outer sheath.
ii. Measurement of thickness of insulation, inner sheath, screen, armour & outer sheath.
iii. Measurement of resistance of conductor.
iv. Measurement of resistance unbalance.
v. Continuity check & measurement of resistance of Poly-al tape.
vi. Colour coding.
vii. Conductor continuity test.
viii. Mutual capacitance test.
ix. Capacitance unbalance test.
x. Cross talk test.
xi. Attenuation test.
xii. Insulation resistance test.
xiii. Dielectric strength test.
xiv. Drip test.
xv. Armour galvanisation test.
xvi. Conductor annealing test.
xvii. Measurement of drum length.

6.3 Following tests shall be carried out to prove FRLS property of the cable.

a. Critical oxygen index as per ASTM-D-2863 i.e. Determination of % of oxygen required for combustion at room temperature of FRLS sheath which shall remain as 29% (min.)

b. Temperature index as per ASTM-D-2863 i.e. To determine at what temperature normal oxygen content of 29% in air will support combustion of FRLS sheath which shall remain as 250°C.

c. Halogen acid gas emission as per IEC-60754 Part 1 i.e. To determine the % of release of hydrochloric acid gas from the FRLS sheath under fire which shall be 20% (max.)

d. Smoke Density Test shall be as per ASTM D - 2843 and Smoke Density Rating of FRLS Sheath shall be 60% (max.).

6.4 The test for circuit integrity for fire survival cables shall be carried out as per IEC-60331 (Part-21).

6.5 The following tests shall be conducted on the completed non jelly filled cables as per the test procedures given in DOT specification GR/WIR-06/03 and this specification:

607

6.5.1 **Acceptance tests**

i. Measurement of diameter of conductor, over inner sheath & over outer sheath.
ii. Measurement of thickness of insulation, inner sheath, screen, armour & outer sheath.
iii. Measurement of resistance of conductor.
iv. Colour coding.
v. Conductor continuity test.
vi. Mutual capacitance test.
vii. Capacitance unbalance test.
viii. Insulation resistance test.
ix. High voltage test.
x. Armour galvanisation test.
xi. Conductor annealing test.
xii. Measurement of drum length.

6.5.2 **Special Tests**

The non jelly filled cables shall also be subjected to following special tests.

i. Oxygen index test as per IS-10810 (Part 58).
ii. Flammability test on finished cable as per IS-10810 (Part 61 & 62).

The special test shall be conducted on one sample from each lot. The sample will be selected by the inspector.

7.0 PACKING AND DESPATCH

7.1 Cables shall be dispatched in non-returnable steel drums of suitable barrel diameter, securely packed, with the take-off end fully protected against mechanical damage.

7.2 On the flange of the drum, necessary information such as project title, manufacturer's name, type, size, length of cable in meters, drum no., cable code, BIS certification mark, gross weight, 'Owner's particulars', 'P.O. numbers' etc., shall be printed. An arrow shall be printed on the drum with suitable instructions to show the direction of rotation of the drum.

7.3 The drum lengths for cables shall be as below:

- Upto 50 pairs	:	1000 meters
- Above 50 pairs & upto 100 pairs	:	500 meters
- Above 100 pairs	:	As per job requirement (subject to max. length of 500 meters)

7.4 A tolerance of ± 5% shall be permissible for each drum. However overall tolerance on each size of cable shall be limited to ± 2%.

7.5 For non jelly filled cable, PVC/ rubber end caps shall be supplied free of cost for each drum with a minimum of eight per thousand meter length. In addition, ends of the cables shall be properly sealed, with caps, to avoid ingress of moisture/ water during transit and storage.

7.6 For jelly filled telephone cables, the ends of the cable shall be sealed by thermo shrinkable end caps of adequate wall thickness. Alternately ends may be sealed by enclosing them in rubber or PVC caps of wall thickness not less than 1.8mm. The caps shall be secured to the outer sheath with hose clips or ties or black adhesive tape or heat shrinkable sleeves.

7.7 The cables may be stored outdoors for long periods before installation. The packing shall be completely suitable for outdoor storage, in areas with heavy rains and high ambient temperature.

1.0 SCOPE

This specification covers the requirements for design, manufacture, testing at manufacturer's works, packing and supply of Medium Voltage & High Voltage air insulated and Medium Voltage sandwich bus duct.

2.0 CODES AND STANDARDS

2.1 The equipment shall comply with the requirements of the latest revision of the following standards issued by BIS (Bureau of Indian standards) unless otherwise specified.

IS: 5	:	Colours for ready mixed paints and enamels.
IS: 737	:	Wrought aluminium and aluminium alloy sheet and strip for general engineering purposes.
IS: 4171	:	Copper Rods and Bars for general engineering purpose.
IS: 5082	:	Wrought aluminum and aluminum alloy bars, rods, tubes and sections for electrical purposes.
IS: 8084	:	Interconnecting bus bars for AC voltage above 1 kV upto and including 36 kV.
IS: 8623(Part-2)	:	Low voltage switchgear and control gear assemblies. Particular requirement for bus bar trunking system.
IS: 12729	:	Common High voltage switchgear and controlgear standards.
IS/ IEC 60529	:	Degree of protection provided by enclosures (IP Code).
IS/ IEC 60947	:	Low Voltage switchgear and control gear.

2.2 In case of imported equipment, standard of the country of origin shall be applicable if these standards are equivalent or stringent than the applicable Indian standards.

2.3 The equipment shall also conform to the provisions of CEA Regulations with latest amendments and other statutory regulations currently in force in the country.

2.4 In case Indian standards are not available for any equipment, standards issued by IEC/ BS/ VDE/ IEEE/ NEMA or equivalent agency shall be applicable.

2.5 In case of any conflict between various referred standards/specifications/data sheets and statutory regulations, the most stringent requirement shall govern and decision of owner/EIL in this regard shall be final & binding.

3.0 SITE CONDITIONS

Bus duct shall be suitable for installation and satisfactory operation in a tropical, humid and corrosive atmosphere found in refineries, petrochemicals and fertilizer plants or as specified in the material requisition. The equipment shall be suitable for continuous operation under the site conditions as specified in the material requisition/data sheet. If not specifically mentioned therein the bus duct shall at least be designed for an ambient temperature of 40°C, relative humidity of 90% and altitude not exceeding 1000 m.

4.0 GENERAL REQUIREMENTS

The offered equipment shall be brand new and having proven field track record. No prototype equipment shall be offered.

5.0 TECHNICAL REQUIREMENTS FOR BUSDUCT (COMMON FOR BOTH AIR INSULATED AND SANDWICH TYPE BUSDUCT)

5.1 Busbars of busduct shall be made of high conductivity electrolytic aluminium or copper flats/ channels.

5.2 The enclosure of busduct shall be designed to withstand the maximum applicable mechanical and electro-dynamic forces. The enclosure of air insulated bus duct shall be of box frame

construction having 3 mm thick cold rolled sheet steel, galvanised steel or aluminium alloy suitably braced. The enclosure of the sandwich busduct system shall be of galvanised steel or aluminium alloy painted to provide high protection and mechanical resistance for the phase conductors along the entire length. The aluminium alloy sheet shall be grade 31000 H2 or better as per IS: 737.

5.3 The hotspot temperature of bus bars including joints at design ambient temperature shall not exceed 95° C for normal operating conditions. However, for silver plated joints, the allowable maximum temperature shall be 115° C.

5.4 The continuous current rating of the neutral bus bars shall be at least half that of the phase bus bars.

5.5 The busbars, busduct construction and supports shall be adequately sized and braced such that entire length shall be able to withstand dynamic and thermal stresses expected due to the specified short time rating

5.6 The busbar installation shall be suitably designed to accommodate expansion and contraction during all modes of operation.

5.7 Bus duct shall be manufactured in standard lengths. However maximum length of single straight section generally shall not exceed 3000mm considering transportation and handling.

5.8 The construction of bus duct shall be such that all nuts/bolts shall be easily accessible at site during installation and maintenance.

5.9 Necessary flanged opening shall be provided at the terminating ends of bus duct. These flanges shall match with corresponding flanges in the equipment to which they are connected.

5.10 GI earth bus of minimum size 75 x 10 mm² shall run throughout the length of bus duct and all metallic non-current carrying parts shall be connected to it. Sandwich busducts with aluminium enclosure acting as earth conductor (integral earth) is acceptable, however the aluminium enclosure shall be suitable to withstand rated short circuit current for specified time and type test certificates for same shall be available with vendor. The earth bus shall have provision to connect it either to the system earth bus or to the earth bus of the equipment on which the bus duct is terminating, as the case may be. The earth bus shall run outside the bus duct enclosure. Suitable provision shall be made to cross bus duct flanges/joints etc.

5.11 Proper alignment and co-ordination regarding phase sequence etc. between bus duct, transformer installed outside the switchgear room, switchgear termination etc. shall be ensured by the bus duct supplier.

5.12 Phase crossover chamber, if required, shall be provided.

5.13 Separate adapter chambers shall be provided at the transformer and switchgear ends, matching with the transformer flange and switchgear flange respectively.

5.14 The termination of bus bars at the equipment end (e.g. transformer switchgear and generator end) shall be done through copper flexible.

5.15 Copper flexible shall be thermally fused together at ends and the fused portion of the flexible shall be tinned. Alternatively, tinned copper strips, riveted at ends, can also be used.

5.16 The bus duct shall be supplied with all the necessary hardware's required for the site assembly of shipping sections, including that for bus bar joints/coupling/termination etc. Only zinc passivated high tensile strength steel bolts, nuts and washers shall be used for all bus bar joints and supports.

5.17 Bus duct shall be suitably supported inside the switchgear room and for outdoor installation. Suitable supporting arrangement shall be designed and supplied by the manufacturer with busduct.

610

5.18 Each bus duct shipping section shall have details such as switchboard number, bus duct tag number, section number, painted arrows on the shipping section for connection and easy matching of adjacent bus duct sections, etc.

5.19 Bus duct drawings shall indicate shipping section markings and the same shall be marked on crates and the bus duct to ease assembly.

5.20 Suitable wall frame assembly shall be provided at all the wall crossings.

6.0 SPECIFIC TECHNICAL REQUIREMENTS FOR AIR INSULATED BUSDUCT

6.1 High Voltage bus duct shall be phase-segregated type with metallic/ insulating material.

6.2 The busbars of air insulated busduct shall be insulated by using heat shrinkable PVC sleeves for flats and insulation coating in case of channels. The sleeves/ insulation coating shall be rated to withstand the system line-to-line voltage for 1 minute.

6.3 All bus bar phases shall be identified with red, yellow, blue, black colour sleeves. Alternatively colour bands may be used for bus bars identification at all cover openings and at regular intervals not exceeding 600mm.

6.4 The bus duct shall meet the requirement of water tightness test and air tightness test as per IS/IEC: 60529 or degree of protection IP-55. Additional canopy shall be provided for outdoor horizontal portion of the bus duct.

6.5 All bus bar joints shall be provided with removable FRP shrouds.

6.6 Bus bars shall be supported at regular intervals on insulators made of high dielectric strength, non-hygroscopic, non-inflammable material with tracking index equal to or more than that defined in standards.

6.7 All joints and covers shall be provided with Neoprene/HDPE/EPDM or equivalent gaskets.

6.8 The covers shall be in suitable lengths for ease of removal and shall be arranged to give complete accessibility to the bus bars, joints, bends, supports etc.

6.9 Suitable drain holes with drain pipes and plugs shall be provided for natural draining of any water collecting within enclosure due to moisture condensation. Necessary slope shall be provided for water drainage so that water does not fall on the switchgear /transformer.

6.10 One flexible, as a minimum, shall be provided for each 3000 mm long straight length of bus duct. Copper flexible shall be used for expansion joints.

6.11 Bus bar chamber shall be provided with adequate number of space heaters rated at 240V and shall be complete with MCB and thermostat having variable setting. Suitable connectivity between different sections of the bus duct shall be provided for the space heaters power supply

6.12 Space heater junction box for termination of incoming cable for bus bar space heaters shall be provided near switchgear end termination. All wiring/cabling beyond this junction box shall be in the scope of bus duct supplier. The minimum degree of enclosure protection for junction box shall be IP-31.

6.13 Bus duct shall be provided with easily accessible inspection covers at suitable intervals not exceeding 3 meters. Inspection covers shall be provided at bends and bus bars joints. Inspection covers having weight more than 5 kg shall have lifting hooks. Warning and caution boards shall be fixed to these covers. Inspection cover shall be suitable for opening from the bottom or top or sides as per the final bus duct layout.

6.14 Seal off bushings shall be provided inside the enclosure at wall/floor crossings to prevent propagation of fire. The seal off bushings shall be type tested for the specified short time rating.

7.0 SPECIFIC TECHNICAL REQUIREMENTS FOR MV SANDWICH TYPE BUSDUCT

7.1 The sandwich busduct shall have arrangement such that the busbars are sandwiched together to provide compactness & low impedance.

7.2 The each busbar of sandwich type busduct shall be insulated with non-hygroscopic and high thermal conductivity providing minimum Class-F insulation. The rated insulation voltage shall be minimum 1000V.

7.3 All bus bar phases shall be identified with red, yellow, blue, black colour.

7.4 The bus duct shall meet the requirement of water tightness test and air tightness test as per IS/IEC 60529 for degree of protection IP-54 for indoor section and minimum IP-55 for outdoor section. Additional canopy shall be provided for outdoor horizontal portion of the bus duct.

7.5 The joint covers shall be in suitable lengths for ease of removal and shall be arranged to give complete accessibility to the bus bars joints etc.

7.6 The sandwich busduct shall be Resistant to flame propagation in accordance with the applicable IS/IEC standards.

8.0 PAINTING

After preparation of the under surface, the busduct shall be spray painted with two coats of epoxy based final paint or shall be powder coated. The colour shade of the final paint shall be 631 of IS-5 / RAL-7032 and 632 of IS-5 / RAL-7031 for indoor and outdoor part of the bus duct respectively, unless specified otherwise. busduct finish shall be free from imperfections like pinholes, orange peels, runoff paint, etc.

All unpainted steel parts shall be zinc passivated, cadmium plated or suitably treated to prevent rust and corrosion.

9.0 INSPECTION, TESTING AND ACCEPTANCE

9.1 During fabrication, the BUSDUCT shall be subject to inspection by EIL / Owner, or by an agency authorised by the Owner, to assess the progress of work, as well as to ascertain that only quality raw material is used. The manufacturer shall furnish all necessary information concerning the supply to EIL / Owner's inspectors.

9.2 For testing requirements refer Inspection & Test Plan No. 6-81-1054. Prior notice of minimum 4 weeks shall be given to EIL/owner for witnessing the final testing of the complete assembly to ensure satisfactory operation of all components. Tests shall be carried out at manufacturer's works under his care and expense.

10.0 PACKING AND DESPATCH

All the equipment shall be divided into several sections for protection and ease of handling during transportation. The equipment shall be properly packed for the selected mode of transportation, i.e. by ship/ rail or trailer, and shall be wrapped in polythene sheets before being placed in crates/ cases to prevent damage to finish. The crates/ cases shall have skid bottom for handling. Special notations such as 'Fragile', 'This side up', 'Center of gravity', 'Weight', 'Owner's particulars', 'PO no.' etc., shall be clearly marked on the packages together with other details as per purchase order.

The equipment may be stored outdoors for long periods before installation. The packing should be suitable for outdoor storage in areas with heavy rains and high ambient temperature unless otherwise agreed. A set of instruction manuals for installation, testing and commissioning, a set of operation & maintenance manuals and a set of final drawing shall be enclosed in a waterproof cover along with the shipment.

Abbreviations:

AC	:	Alternating Current
BS	:	British Standard
BTD	:	Bearing Temperature Detector
CBCT	:	Core Balance Current Transformer
CPU	:	Central Processing Unit
CT	:	Current Transformer
DC	:	Direct Current
DCS	:	Distributed Control System
ECS	:	Electrical Control Station
EMI	:	Electromagnetic Interference
FIFO	:	First in first out
FO	:	Fibre Optic
GPS	:	Global Positioning System
HV	:	High Voltage
I/O	:	Input/output
ICT	:	Intermediate Current Transformer
IDMTL	:	Inverse Definite Minimum Time Lag
IEC	:	International Electrotechnical Commission
IEEE	:	Institute of Electrical and Electronics Engineers
IP	:	Ingress Protection
IRIG- B	:	Inter-Range Instrumentation Group Subcarrier Channel-B
KEMA	:	Keuring Electrotechnisch Materieel Arnhem
LAN	:	Local Area Network
LCD	:	Liquid Crystal Display
LED	:	Light Emitting Diode
HMI	:	Human Machine Interface
TCP-IP	:	Transmission Control Protocol-Internet Protocol
MOG	:	Magnetic Oil Gauge
NEMA	:	National Electrical Manufacturers Association
NO	:	Normally Open
OTI	:	Oil Temperature Indicator
PC	:	Personal Computer
PCB	:	Printed Circuit Boards
PLC	:	Programmable Logic Controller
PT	:	Potential Transformer
PVC	:	Poly Vinyl Chloride
REF	:	Restricted Earth Fault
RSTP	:	Rapid Spanning Tree Protocol
RTD	:	Resistance Temperature Detector
RTU	:	Remote Terminal Unit
SNTP	:	Simple Network Time Protocol
SOE	:	Sequence of event
VDE	:	Verband Deutscher Elecktrotechniker
WTI	:	Winding Temperature Indicator

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1.0 SCOPE

The intent of this specification is to define the minimum requirement of design, manufacture, testing, packing and dispatch of numerical relays. The specification also defines the requirement of communication and integration for Substation Automation System.

2.0 CODES AND STANDARDS

2.1 The equipment shall comply with the requirements of latest revision of following IEC standards / equivalent Indian Standards, unless otherwise specified:

IEC 60068	:	Environmental Testing
IEC 60073	:	Basic safety principles for man machine interface, marking & identification – Coding principles for indicators and actuators
IS/IEC 60529	:	Degree of protection provided by enclosure (IP Code)
IEC 60255	:	Electrical relays
IEC 61000	:	Electromagnetic compatibility (EMC)
IEC 61850	:	Communication networks & systems in substations

2.2 In case of imported equipment, standards of the country of origin shall be applicable, if these standards are equivalent or more stringent than the applicable IEC / Indian standards.

2.3 The equipment shall also conform to the provisions of CEA regulations and other statutory regulations currently in force in the country.

2.4 In case Indian standards are not available for any equipment, standards issued by IEC / BS / VDE / IEEE / NEMA or equivalent agency shall be applicable.

2.5 In case of any contradiction between various referred standard/ specification/ data sheet and statutory regulation, most stringent requirements shall prevail. However, Owner's decision in this regard will be final and binding.

3.0 SITE CONDITIONS

3.1 The relay shall be tropicalised, for satisfactory operation when installed in a panel located in a pressurised substation with restricted natural air ventilation, in tropical humid and corrosive atmosphere. Relay shall be designed to perform all its functions and operate under site conditions specified in numerical relay data sheet. If not specifically mentioned there in, a design ambient temperature of 40°C and an altitude not exceeding 1000M above the mean sea level shall be considered.

4.0 GENERAL REQUIREMENTS

4.1 The equipment offered shall be brand new with state of the art technology with proven field track record of similar type and model or model in same series with additional features. No prototype equipment shall be offered.

4.2 Vendor shall ensure availability of spare parts and maintenance support services for the offered equipment at least for 15 years from the date of supply.

4.3 Vendor shall give a notice of at least one year to the end user of equipment and EIL before phasing out the product/spares to enable the end user for placement of order for spares and services.

4.4 In case of relays manufactured outside India, the relay manufacturer through his Indian establishment or associate in India shall provide application, testing, commissioning, after sales service and other necessary support for minimum of 15 years to customer. Their Indian establishment or associate company in India shall also maintain adequate inventory of each type of relay or spares to meet the requirement arising during project execution and plant operation. Relay manufacturer shall possess a signed Memorandum of Understanding with their Indian associate for providing customer support

5.0 TECHNICAL REQUIREMENTS

5.1 Auxiliary Power Supply

Unless otherwise specified, numerical relays, data concentrator, Ethernet switches, gateway & HMI shall be suitable to accept both AC/DC supplies with range 110V to 240V with tolerance of ± 15%. The auxiliary power supply shall preferably be site-selectable requiring no additional hardware.

5.2 Basic Requirement and Construction Details

5.2.1 Relay shall be suitable for flush mounting. The relay enclosure front shall be dust tight having degree of protection minimum as IP5X.

5.2.2 Relay terminals shall be suitable for termination of 1.5/2.5/4 sq mm wires, for all hardwired connections.

5.2.3 Relay shall be modular with plug in type PCB for easy replacement. The relay terminals shall be easily accessible for testing and commissioning.

5.2.4 Current operated relay shall have provision for minimum 3 number phase CT inputs and 1 number CBCT input. Voltage operated relay shall have provision of minimum 3 numbers PT inputs. The exact number of CT and PT inputs shall be based on the schematic requirements, relays shall be selected accordingly.

5.2.5 CT shorting link shall be provided at terminal block as required.

5.2.6 All numerical relays shall have key pad/ keys to allow relay setting from relay front. All hand-reset relays shall also have reset button on relay front. Self reset or hand reset feature of the relay shall be software selectable and password protected.

5.2.7 Relay shall be suitable for 1 A or 5A CT secondary. CT secondary 1A or 5A shall either be software selectable or by providing suitable link. Selection between 1A or 5A should be possible at site.

5.2.8 Relays shall have self-diagnostic feature with indication of relay failure on relay front. Relay faults (Self- diagnostic) shall be communicated and annunciated to substation automation system.

5.2.9 Relays shall, as a minimum, have protection functions as per feeder equipment data sheets. Other functions such as metering and control shall be provided, if specified in data sheets/job specifications.

5.3 Software Security

The relays shall be provided with suitable security (pass word protection) against unauthorized WRITE ACCESS for change in relay setting. However it should be possible to view metering, protection settings, status and event data as READ ONLY without password protection.

5.4 Display and Indication

5.4.1 All relays shall have LCD display along with LED indications for display of settings, status, faults and events. Relays for generator protection, switchyard and GIS shall be provided with medium size LCD display having facility for graphical display of mimic with upto 15 objects on each page.

5.4.2 LCD display shall be backlit and temperature compensated up to 55°C for contrast and legibility.

5.4.3 Relays shall have 3 fixed LEDs for Relay ON/Control supply ON, fault trip & relay unhealthy apart from freely configured LEDs.

5.5 Protection Functions

5.5.1 **Over Current/Earth Fault Protection**

i) This section describes over current & earth fault protection function, which mainly include different setting stages such as low set, high set and high set instantaneous (51, 50, 51N,

50N). Over current protection function provided should have IDMTL characteristic for low set and high set stages and definite time delay for high set instantaneous stage.

ii) Over current relay shall be three phase type with 4 elements; 3 elements for inverse and definite time delay over current and one element for inverse and definite time delay earth fault current. Selection of inverse or definite time feature shall be user selectable.

iii) The IDMTL characteristic (for 51 and 51N) shall be as per IEC. The inverse characteristics shall include normal inverse, very inverse, extremely inverse, long inverse and shall be soft ware selectable. Inverse element shall have two or more stages (low and high set) for selection of required inverse characteristic to achieve close protection as required.

Definite time characteristic shall have minimum 2 stages with adjustable current and time setting.

iv) Relay shall also have separate current input from CBCT for measured earth fault current element. It shall be possible to connect earth fault element either through CBCT or to be connected residually. Minimum setting current for sensitive earth fault element shall be 1%.

v) Directional overcurrent & earth fault element shall be provided, wherever required.

vi) Voltage biased overcurrent / earth fault element shall be provided wherever required.

5.5.2 **Motor Protection**

i) Motor protection relay shall have all protection function such as over current, thermal (over load), locked rotor current, zero sequence, negative sequence, maximum number of start, motor overload pre-alarm, motor re-acceleration, lock out, inhibit of over current protection during motor starting through contactor feeders, hour run count, inhibit start after elapse of maximum number of starts etc.

ii) The relay shall be provided with 6 Nos. RTD and 2 Nos. BTD analog inputs, if specified in the data sheet / job specification. Alternatively, external RTD/BTD module having interface with numerical relay can be provided. The numerical relay with RTD / BTD inputs shall be suitable for shielded triad cable of conductor size 1.5sqmm copper, unless otherwise specified.

iii) Separate motor differential protection shall be provided, wherever specified.

5.5.3 **Transformer Protection**

i) In addition to overcurrent & earth fault function, wherever required, the main numerical relay shall also include standby earth fault protection function (51G) for the transformer. The standby earth fault shall operate from a separate neutral CT input and shall have definite time / IDMTL characteristics as per IEC.

ii) Wherever the transformer requires restricted earth fault protection (64R), separate numerical relay shall be provided. 64R function can be included as a part of main differential protection relay (87T), unless otherwise specified. For details of transformer differential protection relay refer Cl. 5.5.6.

iii) Transformer auxiliary protection (OTI/WTI/Buchholz/MOG etc) shall be included as a part of numerical relay.

iv) Transformer differential protection shall be provided, wherever specified.

5.5.4 **Generator Protection**

i) Medium Voltage Generators (415V) shall have all protection functions such as voltage restrained overcurrent (51V), standby earth fault (51G), negative sequence (46), Reverse power (32), under voltage (27), overvoltage (59), thermal overload (49), PT fuse failure monitoring function (60), generator differential (87G) as a minimum.

ii) In addition to the above, HV generators (turbine / diesel engine driven) shall have additional protection functions such as rotor back up earth fault (64R)-1st and 2nd stage, low forward

power flow (37), loss of excitation (40), under frequency (81U), rate of change of frequency (df/dt) unless otherwise specified.

iii) If specified in the datasheet, additional protection functions such as field overcurrent, over frequency (81O), back up impedance (21), over fluxing (99), out of step shall be provided as a part of generator protection numerical relay.

iv) The generator protection functions can be included as a part of one numerical relay or a separate numerical relays can be provided.

5.5.5 **Voltage Operated Protection Functions**

i) These functions include under voltage (27), over voltage (59), ON delay and OFF delay timers, phase sequence voltage, neutral displacement and Synchro-check functions etc.

ii) The under voltage and overvoltage protective function shall have different stages with IDMTL and definite time characteristics.

iii) If specified in datasheet, the relay shall have under and over frequency function along with frequency supervised Rate of change or average rate of change of frequency function.

5.5.6 **Differential Protection**

Suitable differential protection shall be provided as required as per data sheet / job specification for the specific application such as for generator, transformer, overall generator & transformer, motor, feeder, bus section etc. The following requirements, as applicable, shall be complied:

i) Differential protection shall be either high impedance or low impedance type. In case of high impedance type, suitable non linear resistor shall be provided to limit the peak overvoltage.

ii) Transformer differential protection shall have suitable harmonic restraint feature to avoid maltripping during switching.

iii) For transformer differential protection, necessary correction for ratio error and for transformer primary and secondary vector grouping shall be taken care in the relay itself without additional ICTs. The required relay setting for this shall be programmable.

iv) Bus differential relay shall have feature for CT supervision and check differential.

v) In case separate hard-wired relay is used for check differential, the status/ event of same shall be communicated through the numerical relay provided for main differential application.

vi) Unless otherwise specified, the differential relays such as generator differential, transformer differential, overall generator transformer differential, motor differential, feeder differential etc. shall be suitable for cable connection between CTs and relay using 2.5 sq.mm., Cu conductor, PVC insulated, armoured cable. However for differential protections provided for feeders having long lengths, armoured FO cable may be considered. In cases where FO cable is not suitable, shielded twisted pair cable of conductor size 1.5sqmm copper shall be specifically mentioned by the bidder in the offer for EIL/Owner's acceptance on case to case basis.

5.6 Metering Functions

The metering function shall be provided as required and same shall be built inside the numerical relays.

5.7 Control Functions

5.7.1 The control function shall be built inside the numerical relays. For this purpose relays shall have all graphical PLC/Boolean logic functions such that complete control logic of the feeder along with all necessary interlocks as required can be developed inside the relay.

5.7.2 Relays for motor feeder shall be equipped with all control functions and interlocks related to motor feeder. If reacceleration is a part of motor feeder, the control function shall also cover reacceleration logic.

5.7.3 Relays shall have sufficient integral I/Os to take care of complete feeder logic. External I/O module for implementation of logics is not acceptable.

5.8 Lock Out (86), Trip Circuit Supervision (95), Auxiliary Relays and Timer Functions

5.8.1 Unless otherwise specified the numerical relays shall have built in lock out function. For motor feeders additional built-in lockout element shall be provided to receive process trip signals. Lock out elements shall be self reset or hand reset and shall be software selectable.

5.8.2 The numerical relays shall have built in trip circuit supervision function, unless otherwise specified.

5.8.3 Auxiliary relays/ Timers function etc as required for control schematics shall be programmable as a part of numerical relay. The number of such elements as required for schematic shall be considered.

5.8.4 Timer function shall be programmable for both ON/OFF delays.

5.9 Disturbance/ Event Recording and Data Storage

5.9.1 Breaker trip/ close status, relay faults, trip values, event data and disturbance record data shall be stored in the relay in non-erasable memory or memory backed up by lithium battery. Under no circumstances such as withdrawal of power to the relays shall the status, data and events in the memory get erased. Unless otherwise specified, it should be possible to store total 10 seconds of disturbance recording and 200 sequence of event records. Subsequent events shall be overwritten following principle of FIFO.

5.9.2 All disturbances/ events shall be time stamped within the relay.

5.10 Input/ Output Interface, Filters and Galvanic Isolation

5.10.1 Voltage (through PT) input to relay, shall be 110V +/- 10%, unless otherwise specified.

5.10.2 Out put relays shall have 4 numbers spare NO contacts; each shall separately be programmable for either hand reset or self- reset.

5.10.3 Contacts of pushbuttons from field, interlocks from DCS/ other switchboards shall be wired to the relay as binary input using 1.5/2.5sqmm, multi core, copper conductor cables. The distance between push buttons/ interlock to switchboard may be considered as 1000m, unless otherwise specified. The pick-up voltage for BIs/BOs shall be site selectable. The additional components as required to overcome the cable capacitance effect shall be considered as a part of supply of relay. The binary input to relay from field contacts and interlocks shall be momentary type. Logic to latch the momentary contact, as required shall be built as a part of protection relay.

5.10.4 All I/Os shall have galvanic isolation. Analog inputs shall be protected against switching surges, harmonics etc.

5.11 Relay Communication

5.11.1 All numerical relay shall have RS232/RJ45/USB port on the front for hooking laptop.

5.11.2 At the rear numerical relays shall have suitable communication port for communication with data concentrator/ HMI/ Station bus. The type of port shall be selected based on method of communication (Serial or Ethernet) and type of physical transmission medium (twisted pair copper or fiber optic). For serial communication, the relay port shall be RS485 or FO (fiber optic) and for Ethernet (IEC 61850 based) communication same shall be RJ45or FO.

5.11.3 The communication protocol shall be selected to transfer all information including time stamp data from relay to data concentrator/ substation HMI. The relays shall communicate on industry open protocol such as IEC 60870-5-103/IEC 61850/ Modbus-RTU / Modbus TCP-IP or any other open protocol.

5.11.4 For IEC 61850 based communication, each relay shall be suitable for communicating with minimum three numbers client devices.

6.0 SUBSTATION AUTOMATION SYSTEM

Substation automation system broadly comprises of numerical relays, data concentrator panels (as required), HMI, laptop, printers and their associated software for monitoring of the electrical system.

6.1 Communication

Communication is the backbone of any substation automation system. It is through this medium, the monitoring of various parameters takes place effectively.

6.1.1 Serial Communication

i) Data concentrator shall have two serial ports (1 no. in each CPU module) for simultaneous remote communication on relay LAN. The relays shall be multi-dropped on RS485 through single drop from LAN to each relay. In the event of either failure of any relay or break in LAN cable or failure of port at data concentrator, the redundant hardware shall ensure healthy communication between relay and data concentrator (refer Figure-1).

ii) Alternatively, relays shall communicate in star topology using star coupler. Communication from relays to star coupler shall be through single communication port. Communication from star coupler to data concentrator shall be through redundant communication link (each link part of separate star coupler unit). RS485 to FO converters wherever required shall be part of offered relay/ other hardware. Star coupler shall be provided with dual power supply module

iii) The maximum number of relays in one loop shall be decided so as to achieve maximum scan time as 500 ms for status input and maximum 6 sec for analog and historical data considering total number of serial loop and star coupler as a total integration. The above scan time does not include screen refresh rate at HMI.

iv) For sequence of event recording, time discrimination between two events shall be maintained to 1 m sec or better.

6.1.2 IEC-61850 based Communication

i) Ethernet switches shall provide error free communication in harsh substation environment and shall be immune to EMI. The Ethernet switches shall comply to IEC 61850-3 and shall be KEMA approved or equivalent.

ii) For real time deterministic performance, managed Ethernet switch shall be considered in the Ethernet network. The switch shall support following features:

- Full duplex operation
- Priority Queuing
- Virtual LAN (VLAN)
- Rapid Spanning tree
- Multicast filtering

iii) Dedicated Ethernet switches shall be provided for each switchboard. 20% spare ports shall be provided in each Ethernet switch.

iv) Ethernet switch shall have dual DC power supply facility.

v) Communication between relay and HMI shall be provided as follows:

Redundant Ethernet communication architecture shall have RSTP topology. Numerical relays shall be hooked up to Ethernet switch in star topology and the switches (within the switchboard) shall be further connected in ring (refer Figure 2).

Alternatively, from each switch (within the switchboard) redundant communication link shall be extended to two number backbone switches to be located within the switchboard (refer Figure 3).

For hooking up to HMI/gateway for upper level connectivity, redundant communication link either from any two switches within the ring or from back bone switches shall be further extended and hooked up to two numbers master Ethernet switches dedicated for hooking HMI/gateway/printers/GPS etc. From HMI redundant communication link shall be extended to the master Ethernet switches.

6.2 Data Concentrator

6.2.1 Data concentrator shall be supplied to facilitate communication with relays on open protocol.

6.2.2 As a minimum data concentrator shall have separate power supply module, CPU module and I/O module. To achieve redundant architecture, either separate data concentrator shall be considered or data concentrator shall have redundant power supply module and redundant CPU module. The CPU module shall have sufficient communication ports depending on relay LAN requirement.

6.2.3 Data concentrator shall provide gateway to upper level control system on Ethernet/ IEC61850 protocol/Modbus-RTU protocol or protocol as specified in the data sheet. The communication to upper level control system shall be redundant as per data sheet/ system architecture.

6.2.4 Data concentrator shall have binary and analog (4 to 20mA) I/O cards suitable for interface requirement specified in data sheet. Unless otherwise specified, 20% I/Os shall be considered as spare. Alternatively, a separate Data Acquisition Unit may be supplied for binary and analog interface.

6.2.5 Data concentrator shall have required number of ports for relay LAN/ star couplers. Number of relay LAN/ star couplers shall be as per project requirement. 20% or minimum 2 Nos. spare ports whichever is maximum shall be provided for future extensions.

6.2.6 Data concentrator shall have required number of RS232/ RS422/RJ45 ports for connection to Laptop PC and substation HMI having operator's work station and engineering station PC.

6.2.7 Data concentrator shall have redundant RS485/ FO/ Ethernet port for communication to substation HMI and upper level ECS-RTU. Hook up to upper level system shall be carried out by extending serial connectivity from each communication ports in two CPU modules.

6.3 Gateway

6.3.1 Gateway for upper level connectivity if separately provided shall have redundancy in power supply module, CPU module. Alternatively, redundant gateways can be provided.

6.3.2 In case of IEC-61850 based communication, if gateway is envisaged, gateway shall have binary and analog (4 to 20mA) I/O cards suitable for interface requirement specified in datasheet. Unless otherwise specified, 20% I/Os shall be considered as spare. Alternatively, a separate Data Acquisition Unit may be supplied for binary and analog interface with communicates to ethernet switch on IEC-61850 protocol.

6.4 Human Machine Interface (HMI)

6.4.1 Following functions as a minimum shall be a part of HMI:

- Display of Single Line Diagram
- Feeder status monitoring
- Data logging
- Relay parameterization
- Event recording
- Historical data & trending
- Annunciation