

WATER SUPPLIES DEPARTMENT

STANDARD SPECIFICATION E-11-01

LV SWITCHBOARD AND CONTROL BOARD

Revision Date : 18.09.2009

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1 GENERAL

1.1 Scope

This Specification covers the design, construction, manufacture, inspection and testing of low voltage switchboards and control boards.

1.2 Standards

The equipment supplied shall comply with the latest editions and amendments of the relevant International Electrotechnical Commission (IEC) Standards and British Standards (BS), which shall include, but not be limited to, the following:-

IEC 60044	Instrument transformers
IEC 60051	Direct acting indicating analogue electrical measuring instruments and their accessories
IEC 60255	Electrical relays
IEC 60269	Low-voltage fuses
IEC 60439	Low-voltage switchgear and controlgear assemblies
IEC 60529	Degrees of protection provided by enclosures (IP code)
IEC 60898	Circuit-breakers for overcurrent protection for household and similar installations
IEC 60947	Specification for low-voltage switchgear and controlgear
BS EN 12476	Phosphate conversion coatings of metals. Method of specifying requirements
BS EN 13601	Copper and copper alloys. Copper rod, bar and wire for general electrical purposes
BS 91	Electric cable soldering sockets
BS 1376	Specification for colours of light signals
BS 3900	Methods of test for paints
BS 4800	Schedule of paint colours for building purposes

- BS 6121 Mechanical cable glands
- BS 6231 Electric cables. Single core PVC-insulated flexible cables of rated voltage 600/1000V for switchgear and controlgear wiring

1.3 Type Test Certification of Equipment

Type test certificates complete with arrangement drawings, oscillograms, photographs, test procedures, test results and conclusive statement, shall be submitted with the tender. Type test certificates shall be issued by the Association of Short Circuit Testing Authorities, (ASTA) UK or equivalent. Test certificates issued by other organisations may be accepted only if the tenderer submits satisfactory documentary evidence that the testing authority is of equal status of ASTA.

Panels, switchgears and busbars that have undergone Short Circuit Tests or Internal Arcing Fault Tests shall not be supplied as part of the equipment to Water Supplies Department.

The following type test certificates applicable to equipment supplied under the Contract shall be submitted with the tender for evaluation:-

<u>Equipment</u>	<u>Current Rating</u>	<u>Type Tests</u>
Switchboard, Busbars and Enclosure	All ratings, 160A or above	(i) Short Circuit Withstand Strength Tests to IEC 60439-1 for all phase and neutral busbars and busbar connections. (ii) Temperature-rise Limits Tests to IEC 60439-1
Motor Starter Panel	315A or above	Internal Arcing Fault Test to verify Form 4 enclosure to IEC 60439-1 or equivalent standards.
Fuse-Switches	315A, 630A, 780A	(i) Making and Breaking Capacities Tests to IEC 60947-3 (ii) Conditional Short-circuit Current Test to IEC 60947-3
Air Circuit-breakers	400A, 800A, 1600A, 2500A	(i) Rated Short-circuit Breaking Capacities Tests to IEC 60947-2 (ii) Rated Short-time Withstand Current Tests to IEC 60947-2

<u>Equipment</u>	<u>Current Rating</u>	<u>Type Tests</u>
Contactors	315A, 630A, 780A	(i) Rated Making and Breaking Capacities Tests to IEC 60947-4-1 (ii) Performance under Short-circuit Conditions Test to IEC 60947-4-1 for verification of type "2" co-ordination with associated SCPDs.

1.4 Switchboard Extension

For switchboard specified as an extension to an existing LV switchboard, the Contractor shall be responsible to take site measurements of existing panels and busbars and to ensure that the extension switchboard panels will match the existing switchboard in shape, colour, height and depth.

2 DESIGN AND CONSTRUCTION

2.1 Standard and Rating

2.1.1 Classification

Standard	:	IEC 60439-1 for indoor installation, stationary use, cubicle type and desk - type assemblies.
Degree of Protection	:	Control Board - IP 54. LV Switchboard - IP 32 general application. - IP 54 chemical installations.
Type of Enclosure	:	Form 4 separation to IEC 60439-1.
Method of Mounting	:	Fixed installation except for motor starters below 100A which may be of drawout type.
Environmental Conditions	:	Equipment shall be suitable for an ambient temperature of 35°C 98% relative humidity over any 24-hour and a maximum of 40°C 98% relative humidity over any 4-hour period.

2.1.2 Electrical Characteristics

Rated Operational Voltage	:	380V 3-phase 50Hz
Rated Insulation Voltage	:	660V 3-phase 50Hz
Auxiliary Supply Voltage	:	220V 50 Hz or 110V/24V d.c.

2.2 General Design

2.2.1 Panel Design

The switchboard shall be formed of free-standing panels fitted together to form a flush front board of uniform height and shape when viewed from the front. The Incoming Supply Panels may be of different depth from other panels.

The switchboard shall be extensible at both ends. Equipment shall be symmetrically arranged with projections kept to a minimum.

For transport purposes, a long switchboard shall be split up into convenient transport sections with weight not exceeding 1300 kg each.

2.2.2 Modular Construction

Each panel shall have a single column of cubicles. Two columns panel shall be considered only if a full type test certification is available and it is the standard design of the manufacturer.

2.3 Panel Dimensions

Panels shall be rectangular and provided with 100 mm high mounting skirt. The overall panel height shall not be greater than 2500 mm.

The various types of switchgear panels shall be designed to the dimension of their type-tested assemblies arrangement with the following nominal width:-

Panel Type	Equipment Rating/ Details	Width of Panel (mm)	
		Minimum	Maximum
Star/Delta Motor Starters	160A & 315A	600	750
	630A	800	1000
Auto-transformer Motor Starters	630A & 780A	1200	1700
Station Auxiliaries	Single column cubicles	600	750
	Double column cubicles	800	1000
Incoming Supply and Bus-section	800A F/S & 400A ACB	600	750
	800-1600A ACB	800	1000
	2500A ACB	900	1000
Control Panel	-	750	1000

2.4 Components Layout on Panel Front

Start push-button shall be at right hand side of stop push button. For equipment occupying a complete panel with vertical front plate, push buttons shall be placed about 1500 mm from floor.

Layout of indication lamps shall correspond with the function of the respective push-buttons.

2.5 Panel Construction

2.5.1 Panel Material

Sheet steel plates of minimum 2 mm thick shall be used for the fabrication of panels. The steel work for equipment mounting plate and swing door with instrument mounted shall have a minimum thickness of 2.5 mm. Plates shall be suitably braced to form a rigid structure for swing panels and access doors.

Base plates and plates for mounting components shall be suitably stiffened to form a rigid structure.

Sheet steel plates of 3 mm thickness shall be used for fabrication of control consoles.

2.5.2 Fabrication Method

Panels shall be fabricated by welded construction with no visible seams or marks on external surfaces. Welding performed on panel openings for doors or access covers shall be smoothed.

Panels fabricated by other construction method shall only be considered if documentary proofs are submitted to show that panels fabricated by such methods are better than welded construction in strength and rigidity.

2.5.3 Constructional Details

External corners and edges shall be rounded to give a smooth overall appearance.

Swing panels, access doors and access covers shall be fitted with rubber or neoprene gaskets to minimise vibration and ingress of dust. Gaskets shall be fitted in a suitably designed recess on the interior surface of panels/plates viz. gaskets shall not be fitted on fixed parts of the panel. Gaskets shall be continuous without joints around corners.

For free standing panel other than arc containment cubicle, ventilation louvres located at the rear vertical face of the panel suitably shielded from dust may be fitted on approval.

2.5.4 Swing Panels

Single leaf swing panels shall be hinged at the left with swing limited to 120°. For swing panel mounted with protective relays, alarm annunciators or similar heavy equipment, the panel shall be suitably reinforced with steel channels to form a rigid structure. Hinges shall be of sufficient number and strength to ensure that no wobbling would occur when swinging the panel. Swing panels and access doors shall be fitted each with a handle with integral lock. The lock shall not be used as the sole means of fastening where the height of door exceeds 400 mm.

2.5.5 Access Doors and Covers

Access doors shall be double-leaf if the opening width exceeds 900 mm.

Busbars and external power cable terminations chambers shall have access covers.

Chromium plate captive knurled nuts with heads suitable for screw-driver fixing or captive stainless steel bolts shall be used for fastening hinged panels and detachable access covers. Fixing bolts and knurled nuts shall be spaced as type tested arrangement but in any event shall be not more than 1000 mm apart.

2.5.6 Internal Partitions

Internal partitions for complying with the requirement of Form 4 separation to IEC 60439-1 shall be of steel sheets. Insulation of cables and busbars shall not be treated as a means of separation in this context.

2.5.7 Equipment Mounting Plates

Equipment and component mounting plates shall be fitted on the steel framework of the panel formed by channels or equal extending the complete height of the panel. The mounting plates shall be positioned to allow easy access of components.

2.5.8 Lifting Provisions

Detachable lifting angles shall be provided on panels for lifting and handling. The lifting angles shall run the full length of each shipping section with provisions for the attachment of slings or shackles.

2.6 Steelwork and Paint Finish

The panel steel work shall be fabricated from electrolytic galvanized sheet steel or prime quality cold rolled sheet steel.

For prime quality cold rolled sheet steel, the metal surface shall be treated by zinc phosphate to BS EN 12476. Humidity resistance test for 1000 hours to BS 3900 shall be conducted. Epoxy powder coating shall be applied by electrostatic process to give a fully protective coating.

Type tests on paint finishes shall be conducted in accordance with BS 3900 on Scratch, Impact and Resistance to Continuous Salt Spray on at least two test samples with size of not less than 150 x 100 mm. The duration of Salt Spray Test shall be not less than 600 hours for zinc-sprayed steel work and 1000 hours for zinc phosphate treated steel work. Blistering or loss in gloss in paint finishes shall not occur at completion of Continuous Salt Spray Test. Type test certificates issued by an independent paint test laboratory shall be submitted with the tender.

The final exterior paint finish shall be semi-matt shade 18B21 (light grey) or equivalent. The colour of Station Control and Instrumentation Panel shall be the same as switchgear panel. The panel interior shall be of white anti-condensation paint.

2.7 Components Arrangement

2.7.1 Access to Equipment and Components

Equipment and associated connections shall be arranged to facilitate easy access for maintenance. Where this is not possible with fixed panels, draw-out or hinged panel arrangements shall be provided.

Parts installed at sides of a panel, relays and instruments shall have unimpeded access without obstruction by other equipment.

2.7.2 Mounting of Components in Compartments

Separate mounting plates shall be used for individual groups of components for easy removal of and access to components. Mounting plates shall be arranged such that it shall not be necessary to remove one group of equipment before another group can be removed or fitted.

Modular components such as relays and fuse holders which are mounted in a row shall be spaced for ready installation and removal.

For equipment generating impact force such as air circuit-breakers, fuse-switches or contactors, rigid supports shall be provided to avoid excessive vibration.

2.7.3 Electricity Supply Company's Current Transformer (CT) Chamber

Where specified, a sealable chamber shall be provided in the incoming supply panels for mounting the Electricity Supply Company's current transformers. The chamber shall have minimum height of 400 mm and depth of 250 mm and be provided with identification labels. The CTs shall be mounted between the Incoming Supply load terminals and the main busbars on detachable solid copper links. A set of busbar mounted fuses and neutral link shall be provided for the voltage reference to the energy meter. Space for mounting four ring type CTs, one each on the L1-L2-L3 phases and the neutral shall be allowed for. Clearance and spacing between the CT shall be provided as follows:-

Measuring C T Ratio	Overall w x h x d (mm)	Hole Dia. (mm)	
		External	Internal
200/5	115 x 150 x 55	120	45
500/5	115 x 150 x 55	120	60
1000/5	165 x 215 x 60	165	75
1500/5	170 x 215 x 60	170	90
2500/5	170 x 215 x 60	170	110

2.7.4 Electricity Supply Company's Metering Chamber

Where specified, a lockable metering compartment with front viewing glass, measuring 550 x 400 x 350 mm (w x h x d) minimum shall be provided on the panel adjacent to the Incomer Supply Panel for the installation of Electricity Supply Company's energy meters. This compartment shall be segregated from other equipment and shall be located between 450 mm and 1800 mm above ground level. A metallic conduit shall be provided between this compartment and the Electricity Supply Company's CT chamber for wiring purpose. The length of the conduit shall be less than 3 metres. A meter board of 13 mm minimum thickness complying with Electricity Supply Company's requirements shall be provided.

2.8 Electrical Design

2.8.1 Auxiliary Power Supplies

2.8.1.1 Switchboard Auxiliary Supplies From AC Mains

The Incoming Supply Panel shall be fitted with two sets of high breaking capacity (HBC) busbar mounted fuses and neutral bolted links for instrument and panel auxiliary supplies. The fuse holders shall be readily accessible and shall be minimum 32A for switchboards up to 800A and 63A for switchboards of larger rating.

Bus-wiring shall be used for a.c. supply to panels, with 20A HBC fuse holders in each panel for tap-off.

2.8.1.2 Switchboard DC supplies

110V and/or 24V d.c. supplies shall be fed from the station battery equipment to the Station Control and Instrumentation Panel, then distributed to other panels via bus-wiring with 20A HBC fuse holders in each panel for tap-off.

2.8.1.3 Control Console Power Supplies

Double pole on-load switches shall be provided for 220V 50 Hz., 110V and/or 24V d.c. power supplies at the Station Control and Instrumentation Panel. Supplies to

other panels shall be via bus-wiring, with 20A HBC fuse holders in each panel for tap-off.

2.8.1.4 Control Transformer Supplies

For cubicles where 220/110V 50 Hz centre earthed double wound transformer is used for provision of control and indication, a separate transformer shall be provided for each cubicle. The transformer shall be rated at 150% of the total connected loads.

2.8.2 Bus-wiring

Bus-wiring shall link adjacent panels regardless whether there is a tap-off, using PVC insulated stranded copper cable terminated on terminal blocks. Leads to 16A fuses shall be 4 mm², and leads to 32A fuses shall be 6 mm² minimum.

Where one end of the bus-wiring is disconnected during transport, the Contractor shall provide wiring details for these to be reconnected on site.

2.8.3 Earthing

A silver-plated or tinned copper earth bar shall be fixed near the rear base of the switchboard or control board. It shall extend to the full length of the board. Provision shall also be made for bonding cable gland plates and metallic casing of switchgear to the earth bar. The minimum dimensions of earth conductor shall be 50 x 6 mm for circuit-breaker switchboard, 30 x 6 mm for fuse-switchgear and control board.

For swing panels where relays or instruments are fitted, a flexible copper cable of 6 mm² shall be used to provide an earth link with the panel.

2.8.4 Identification of Protective Conductors

Protective conductors shall be coloured green and yellow (twin-coloured) marked with the protection symbol to IEC 60439-1.

2.8.5 Clearance and Creepage

The following minimum clearance and creepage distance shall apply to live conductive parts:-

- (a) Clearance to earth or between phases - 19 mm
- (b) Creepage distance - 25 mm (between phase & earth)
38 mm (between phases)

2.8.6 Prevention Against Electric Shock

Exposed live terminals of protective relays or similar equipment shall be shielded with caps or insulating clear perspex sheets, separate sheet shall be used for each relay and fixed rigidly on the mounting stud of the relay.

Instruments such as voltmeters and ammeters which have live terminals shall have individual terminals shrouded by detachable red PVC caps. Power and small wiring terminations with cable lugs exposed beyond any moulded terminal blocks shall be shielded with heat shrinkable PVC sleeving.

Label with warning inscription "DANGER - LIVE TERMINALS" shall be provided where appropriate.

2.9 Panel Wiring

2.9.1 Type of Cables

Cables for small wiring shall be single-core, PVC insulated to BS 6231 with circular annealed copper stranded conductors.

Small wiring shall be black for a.c. and grey for d.c.

2.9.2 Wiring Run

Sufficient spacing between adjacent components and rows of terminals shall be allowed to permit cabling and fitting of identification ferrules.

Small wiring shall be installed in plastic wiring channels. Wires branched out to individual equipment shall be bundled neatly using insulated fixtures or adhesive type plastic cleats.

Wiring channel shall have 25% spare capacity for additional wires. Wiring channel shall be installed in horizontal and vertical directions only. It shall be fitted with a clip-on detachable cover.

2.9.3 Termination Blocks

Termination blocks for small wiring shall be located at least 300 mm above the floor and 150 mm from the panel base plate.

Terminal blocks shall be suitably spaced to enable easy access to wires.

All CT connections shall be brought to termination blocks in the relay compartment. The terminal blocks shall be fitted with short links to facilitate testing and selection of CT ratio.

2.9.4 Wiring Terminations

Identification ferrules for cables shall be tightly fitted.

Ferrules for wires should be read in one direction from left to right or bottom to top.

Wiring for external cabling shall be terminated at terminal blocks. Wires shall not be joined or broken between terminal points, nor have intermediate termination within a cubicle or panel.

Except for 0BA or 2BA stud terminals where a maximum of 2 wires may be connected to one terminal, only one wire shall be connected to each terminal.

Different wires of the same wire number shall be terminated at different but adjacent terminals and shorted by links at the terminal block. Access holes, where wiring passes through partitions or panel side sheets, shall be fitted with rubber or plastic grommets.

Warning labels with red inscription of 'DANGER - CT TERMINATION' shall be affixed to terminals for current transformer wiring.

2.9.5 Wiring Ferrules

Numbered interlocking ferrules of white PVC with black characters shall be supplied for cable core identification.

3 COMPONENTS AND AUXILIARIES

3.1 Design Features - General

The equipment shall be designed for simplicity, reliability, minimum maintenance and rapid fault diagnosis and parts replacement.

Ratings of equipment mounted in enclosures shall take into consideration the heat dissipated by the equipment and nearby components inside the enclosure, the switching surges, power factor and operational duty that may require derating of the equipment.

No forced cooling shall be used to reduce the temperature of components to satisfy the limits specified.

The current rating of equipment shall be standardized to the figures specified hereunder.

3.2 Switchboard Busbars Assembly

3.2.1 Standard: IEC 60439-1

3.2.2 Class and Rating

System : 3-phase 4-wire

Insulation Material : Class A

Rated Current of Main Busbar : 400, 800, 1600, 2500A

Rated Short-time Withstand Current : 50 kA 3s or 80 kA 1s (2500A busbar)
and Duration 50 kA 1s (Up to 1600A busbar)
50 kA 0.2s (Fuse or MCCB
protected busbar)

3.2.3 Design of Busbars

Busbars shall comprise insulated or approved travelling-arc-proof solid copper bars rectangular in cross-section. Copper-clad or aluminium busbars will not be accepted.

Main busbars shall be accommodated in IP 54 busbar chambers at the top of the switchboard and shall be extensible at either end. Enclosures shall be mild steel sheet having minimum thickness of 2 mm. For busbars of 2500A, the chamber may be provided with ventilation louvres with enclosure designed to IP 43.

Unless busbars are type tested for heat run with the sleeved insulation, busbars shall be not less than the cross-sectional area based on Copper Development Council's recommendation, for a temperature rise not exceeding 50°C above the ambient, but derated by 30% for the insulation and IP 54 enclosure. Taking into account of the short time withstand current rating, the minimum size of insulated busbars with IP 54 enclosure shall be as follows:-

(a) ACB protected busbars:

<u>Current Rating</u>	<u>No. of Bars/Phase</u>	<u>Bar Size (mm)</u>
400A	1	63 x 6.3
	2	30 x 6.3
800A	1	75 x 6.3
	2	40 x 5
1600A	2	100 x 6.3
	3	75 x 6.3
	3	50 x 10
2500A	3	100 x 10
	4	63 x 10

(b) Fuse or MCCB protected busbars:

<u>Current Rating</u>	<u>No. of Bars/Phase</u>	<u>Bar Size (mm)</u>
300A or below	1	30 x 6.3
400A	1	40 x 6.3
600A	1	63 x 6.3
800A	1	75 x 6.3
	2	40 x 5

3.2.4 Layout of Busbars

The phase and neutral busbars shall be accommodated in the same compartments. The busbar orientation when viewed from the front of the board shall be neutral-L1-L2-L3 from left to right or from top to bottom. The busbar orientation of Incoming Supply and Bus-section Panels may be revised as deemed necessary to suit the requirements of power company.

Busbars at either end of a panel shall be joined to the adjacent panel with copper bars of similar cross-section as the busbars.

3.2.5 Busbars System Construction

3.2.5.1 Material

Busbars shall be hard drawn copper conductors to BS EN 13601.

The busbar insulation material shall be flame retardant. If heat shrinkable tubings are used for busbar insulation, it shall be suitable for insulation of copper conductors at maximum temperature of 90°C and shall be of black vinyl, matt-surfaced, of minimum thickness 0.86 mm when shrunk. Busbar phase designation shall be clearly indicated by colour labels at regular and prominent positions.

Joints throughout the complete system, inclusive of connections to switchgear, shall be insulated with moulded removable insulated covers. Designs involving taping of joints or components shall not be accepted.

3.2.5.2 Busbar Joints

Jointing of sections of busbars shall be by bolts & nuts complete with spring washers. Soldered, brazed, welded or riveted joints shall not be used in busbars. The length of overlap shall in no case be less than the width of the bar.

Joints between copper conductors shall be made after tinning or silver plating or other approved effective treatment for maintaining the conductivity of the joint.

Temperature rise at joints shall not exceed that permitted for busbars. Copper bar for joining two busbars at panel ends shall have elongated holes.

3.2.5.3 Busbar Supports

Busbar support insulators shall be of the same type as those used in the type test and the installation shall be in the same arrangement as that in the type test. Porcelain insulators shall not be used.

Insulators shall not be cemented into position but shall be mechanically fixed to ensure rapid interchangeability in the event of replacement.

3.2.6 Busbar Connections to Switchgear

Busbar down-droppers shall have the same short time rating as the main busbars.

Busbar down-droppers to motor starters or fuse-switches shall be accommodated in a separate enclosure to Form 4 to IEC 60439-1.

Fuses specified to be busbar mounted and connections for fuses tapped directly from busbar shall be as short as possible and in any event not exceeding 300 mm in length. Such busbars shall be of insulated copper of minimum 2-19 x 6.3 mm or as certified by short-circuit tests.

3.3 Air Circuit-Breakers (ACB)

3.3.1 Standards

Circuit-breakers : IEC 60947-2

Assembly : IEC 60439-1

3.3.2 Class and Rating

Type : Air-break, metalclad, horizontal withdrawable on retractable side runner rails and rollers

Degree of Protection : IP 32

Rated Short-time Withstand : 50 kA 3s or 80 kA 1s (2500A)
Current and Duration : 50 kA 1s (up to 1600A)

Rated Short-circuit Breaking : 50 kA
Current

Rated Operational Current : 400, 800, 1600, 2500A

3.3.3 Design Features

ACB shall either be provided with stored energy spring, solenoid or independent manual closing mechanism. Power operated closing mechanism shall be suitable for either battery supply or integral rectifier derived supply fed from busbar mounted fuses.

Facilities shall be provided for testing the ACB in the isolated and withdrawn position.

ACB fitted with solenoid closing mechanism shall incorporate anti-pumping circuit to prevent repetitive closing on a trip condition.

Where Bus-section ACB is specified, the Incoming Supplies ACB and Bus-section ACB shall be 4-pole and of the same make and model. Castell key interlocks type FK4 or equivalent shall be provided to prevent parallel operation of any two incoming supplies.

ACB operating and maintenance tools as specified in clause 3.17 of this specification shall be supplied.

3.3.4 Mechanical Interlocks

The following shall be provided:-

- (i) ACB cannot be plugged in or withdrawn when in closed position;
- (ii) ACB cannot be closed until fully plugged in or completely isolated;
- (iii) tripping of ACB cannot be initiated by attempted operation of any interlocked control;
- (iv) ACB cannot be 'slow-closed' except in the fully withdrawn position;
- (v) covers or doors giving access to live parts of the ACB cannot be removed or opened unless the ACB is fully isolated;
- (vi) with stored energy closing mechanism, operation of the ACB mechanism shall not be possible until the closing mechanism is fully charged.

3.3.5 Safety Shutters

A set of safety shutters shall be provided to cover the stationary isolating contacts. Shutters shall be opened automatically on insertion of the ACB and when closed shall prevent access to stationary isolating contacts. When the ACB is withdrawn the shutters shall be capable of being individually operated and of being padlocked in the closed position.

To facilitate high voltage and current injection testing via isolating contacts, a device shall be provided for fixing (not locking) shutters in the open position and for releasing them to the closed position. This device shall be arranged to be disengaged as soon as the ACB is pushed into the service position to ensure the restoration of the automatic features of the shutters in the event of an operator failing to release the shutters before putting the ACB into the service position.

Safety shutters shall be coloured and labelled with stencilled, white, 25 mm lettering as follows:-

Circuit	Feeder Shutters		Busbar Shutters	
	Background Colour	Character (White)	Background Colour	Character (White)
Incoming Supply	Red	INCOMER	Red	BUSBAR
Feeder	Yellow	FEEDER	Red	BUSBAR
Bus Section	-	-	Red	BUSBAR LHS/RHS

3.3.6 Components Specification

Contacts shall be self aligning. Main contacts shall be fitted with detachable arc chutes for each pole.

Operating mechanisms shall be trip-free. A mechanically operated visual indicating device shall be provided to indicate the ACB 'On' and 'Off' status. Indications for 'Service', 'Isolated', and 'Test' positions shall be provided. An integral pushbutton operating the tripping mechanism directly shall be provided for manual tripping. For stored energy spring closing mechanism, "spring charged" and "spring free" indicators shall also be provided.

Auxiliary switches shall be double-break type and shall have a positive wiping action when closing. ACB shall be fitted with the maximum number of auxiliary switches of the manufacturer's standard arrangement, but shall have not less than 2 pairs of normally closed and 2 pairs of normally open contacts. Auxiliary switches shall have rated thermal current of 6A minimum at rated voltage and frequency of the main circuit ACB.

3.4 Motor Starters

3.4.1 Class and Rating

Equipment Type	:	Air-break triple pole contactor starter
Isolator & Short-circuit Protection Device	:	IEC 60947-3 AC23 triple-pole and neutral fuse-switch
Components Standards	:	Contactors and motor-starters: IEC 60947-4-1 Assembly: IEC 60439-1

Degree of Protection : IP 32

Rated Operational Current : 16, 40, 80, 160, 315, 630, 780A

3.4.2 Design and Construction

Electromechanical contactors and motor starters shall comply with and type tested to IEC 60947-4-1. Each starter shall comprise a composite isolating and Short Circuit Protection Device (SCPD), and a front access swing panel for contactors, on/off controls and monitoring devices. The motor starter shall co-ordinate with the SCPD to provided Type "2" co-ordination to IEC 60947-4-1.

For starters above 160A, separate Form 4 enclosures shall be provided for SCPD. The swing panel shall be mechanically interlocked with the SCPD so that the door can only be opened when the SCPD is in off position. For smaller starters, a common cubicle may be used but the SCPD shall be in similar enclosure as that used in type tests. HBC fuses for capacitors and valve actuators shall be accommodated inside the swing panel.

Bare terminals such as nuts for connecting power cabling or contactors shall be shrouded by clear perspex sheet secured to the mounting plate. A warning label shall be affixed immediately adjacent to live parts.

3.4.3 Components Specification

Contactors

Contactors for assisted starting or forward/reverse running shall be fitted with mechanical and electrical interlocks.

For reduced voltage starters, all contactors shall be of identical rating and design, and rated for an operational current as declared for the motor starter. The phase orientation for L1-L2-L3 phases shall be arranged from left to right or top to bottom when viewed from the front of the panel.

The utilization category of starters shall be AC3 for induction motors, fans and water pump motors and AC4 for valve actuators and sump pumps.

Motor starters for AC3 utilization category shall be of both uninterrupted duty and intermittent duty Class 3 60% on-load factor. Starters for AC4 category shall be of intermittent duty Class 120 60% on-load factor.

The electrical and mechanical endurance of starters shall be a minimum of one million on-load and 5 million no-load operational cycles respectively for AC3 contactors, and 0.3 million on-load operational cycles for AC4 contactors.

Type test results shall be submitted for record to substantiate the derating factors applied to IP 54 enclosure for contactors of 315A and above.

Overload Protection Relays

Thermal type overload protection relays shall be used. The trip class of the overload protection relay shall comply with Table II of IEC 60947-4-1. The thermal overload protection relay shall be suitable for operation up to 40°C ambient temperature and shall have nominal setting range of 50 - 150% rated operational current.

3.5 Fuse Switchgears and Isolators

3.5.1 Standards, Class & Rating

Standard : IEC 60947-3

Equipment : Fault closing, on-load operated air-break, independent manual switching mechanism

Degree of Protection : IP 54

Rated Short-circuit Making Current : 50 kA rms at 415V

Rated Short-time Current : 20 times operational current 1s

Rated Operational Current : 16, 32, 63, 160, 315, 630A, 780A
(AC 32)

3.5.2 Design Features

Isolators up to 32A may be all insulated or metalclad. Isolators above 32A and fuse-switches of all ratings shall be metalclad. Switch-fuses may only be supplied for ratings up to 32A.

The utilization category shall be AC-22A or DC-22A for general application and AC-23A or DC-23A as appropriate for motor loads. Fuse-switches for motor loads shall be designed to Class 3 of intermittent duty to IEC 60947-3 (Appendix A).

The operating performance shall be tested in accordance with IEC 60947-3 (Clause 7.2.4.2). The number of operating cycles per hour shall not less than the figure stipulated in IEC 60947-3 (Table 4).

3.5.3 General Construction Features

Equipment for 3-phase a.c. circuits shall have integral neutral. Equipment for d.c. circuits shall be double-pole, double-break type.

Fuse-switches and switch-fuses shall be fitted with mechanical 'ON' and 'OFF' position indicators and facility for padlocking at the 'OFF' position.

Equipment above 32A shall be fitted with mechanical interlock to prevent access to the interior unless the switch is in the 'OFF' position. The interlock shall be capable of being defeated for inspection of contact alignment.

Interphase barriers shall be provided for fuses.

Live terminals and contacts for main contacts and auxiliary switches shall be effectively shrouded with transparent insulating covers.

Equipment above 100A shall be fitted with auxiliary switch banks for indication of status of the fuse-switches.

3.6 High Breaking Capacity Fuses

3.6.1 Standards Class and Rating

Standards: IEC 60269

Rated Breaking Current: 80 kA 415V 50 Hz or 40 kA 500V d.c.

3.6.2 Equipment Selection

Insulating shrouds shall be provided so that it shall not be possible to touch the fixed contacts by accident while inserting or withdrawing a fuse carrier.

Maximum power dissipation values and dimensions of fuse links shall conform with IEC 60269-2 (Tables 1 and 2).

Fuse bases and carriers for fuses of 2 - 20A shall be 20A units. Fuse holders of 200A and above shall be provided with a through-grip handle, silver plated contacts and screw locking device.

3.6.3 Mounting of Fuses

Fuses and links in the same circuit shall be mounted in adjacent positions in the same row.

For fuse flush mounted on panel front, external conductors shall be connected by stud terminals accessed from the rear of panel door.

3.7 Moulded Case and Miniature Circuit Breakers (MCCB & MCB)

3.7.1 General

MCCBs and MCBs shall comply with IEC 60947-2 and IEC 60898 respectively.

Triple pole units shall be of integral construction and not three single phase units mechanically strapped together. The closing mechanism shall be trip-free. Units shall be compensated for an ambient temperature of 5 - 40°C.

3.7.2 Additional Requirements - MCCB

MCCBs shall have utilization category B to IEC 60947-2 (Table 4) and meet the operational performance stipulated in IEC 60947-2 (Table 6). MCCBs serving as the incoming supply switchgear without an additional isolating device shall be of physically withdrawable pattern, fitted with padlocking facility at the isolated position.

MCCBs shall have independent manual closing mechanism, and be fitted with 24V d.c. shunt trip coil and integral core-balance current transformer and earth fault unit of 50 - 500 mA 0 -3 sec. time delay.

The unit shall have a magnetic or ambient compensated thermal direct acting over-current release with inverse time-current characteristics. At about 7 times the rated operational current, an instantaneous trip element shall trip the unit.

The rated short circuit breaking capacity shall be not less than 14 kA for frame size up to 100A, 22 kA for frame size 225/400A and 50 kA for larger frame size. The over-current release shall be adjustable.

3.7.3 Additional Requirements - MCB

The operating mechanism of the MCBs shall be thermal-magnetic type with inverse time-current characteristic to IEC 60898 (Table 6). The MCBs shall have tripping classification of Type B and have rated short circuit breaking capacity of 6 kA to IEC 60898.

3.8 Distribution Boards

3.8.1 Standard and Rating

Standard:	MCCB Board -	IEC 60439-1
	MCB Board -	IEC 60439-3

Busbar Rating: 100A and 200A

3.8.2 General Requirement

The MCB board shall be industrial type and factory built with metallic enclosure of minimum of 1.5 mm sheet steel thickness. Access doors for MCB board shall be easily removable and fitted with gaskets. Design of MCB / MCCB board shall allow easy removal and replacement of MCCB, MCB, isolating switch, or neutral and phase busbar at the front.

Cable or conduit entry to the MCB board shall be provided from top and bottom. Enclosure for MCB board shall have degree of protection of IP 32 to IEC 60529.

Integral front panel operated 100A on-load (fault-making and load-breaking) isolating switch to IEC 60947-3 with ON/OFF indicator and facility for padlock in the OFF position shall be provided in the MCCB board.

3.8.3 Additional Requirements of MCCB Boards

MCCB boards shall be type tested to IEC 60439-1. Enclosure for MCCB board shall have Form 3b separation or better and fabricated with 2 mm sheet steel thickness with IP 32 protection rating to IEC 60529.

3.8.4 Additional Requirements of MCB Boards

MCB boards shall be of Type A or Type B and type tested to IEC 60439-3. Type A MCB boards shall be suitable for flush or surface mounted and Type B MCB boards shall be suitable for surface mounted only. MCB boards shall incorporate HRC cartridge fuses and/or combinations of single pole and neutral and triple pole MCBs earth leakage circuit breakers (ELCB) where specified in the Particular Specification.

3.9 Current Transformers (C T)

3.9.1 Standards, Class & Rating

Standard : IEC 60044-1

Rated Voltage : 660V 50 Hz

Insulation Material : Class E

3.9.2 Design Features

Protective CTs shall have a short-circuit capacity and short-time rating as the switchgear.

The rated primary current shall be 10, 12.5, 15, 20, 25, 30, 40, 50, 60, 75 amperes and their decimal multiples.

The secondary circuit of each set (L1-L2-L3) of CTs shall be earthed at one point only. Means shall be provided for the earth connection by bolted copper links at readily accessible positions. Each earth wire shall be terminated on separated terminals. The CT rated thermal current shall match with the highest setting of overload/overcurrent protection relays.

CTs shall be of vacuum impregnated or epoxy encapsulated construction. CTs with compound filing or adjustable primary turns will not be accepted.

3.10 Relays and Timers

3.10.1 Relays - General

Relays shall be housed in dust and vermin-proof cases. Contacts shall be of the double-break type, except for auxiliary relays where single-break contacts may be used.

3.10.2 Protection Relays

Protection relays shall comply with IEC 60255. It shall be microprocessor based design and preferably fitted with drawout case. Relays shall be flush mounted on the front of panel.

The current transformer input terminals shall be automatically short circuited when the relay is withdrawn from the case.

Trip indication shall be provided. Upon initiation of the trip signal, the trip circuit supply shall be isolated.

Self-diagnostic, event log and fault record features shall be provided. Related data can be retrieved from the relay via communication port. Programming software for protection relays shall be provided.

3.10.3 Control and Auxiliary Relays

Case : Plug-in type with moulded terminals board of quick fastening, vibration-proof and moulded insulating material.

Relays Selection : Control relays shall be used in control circuit for control of power supplies of 80A and above, motor rated 40 kW and above, station control and tripping. Auxiliary relays may be used for control of power supplies below 80A and motor below 40 kW, alarm and indication. For standardisation, the use of control relays for all applications in one installation is preferred.

Contacts Rating : Contact rating for auxiliary relays shall be not less than 30% that of control relays. Contact rating for control relay shall be as below:-

Rated voltage	Rated thermal current	Rated operational current (0.1 million operations)
220V 50 Hz	16A	8A AC11
24V d.c.	16A	5A DC11 or 9A L/R <15 ms
110V d.c.	3.5A	0.7A DC11 or 2A L/R <15 ms

3.10.4 Electronic Timers

Electronic timers for general application shall be solid state plug-in type. Pneumatic timers will not be accepted.

Each timer shall incorporate 2 pairs of changeover contacts with contact rating similar to auxiliary relays.

The accuracy of the timer scale setting shall be within 5% of the time range.

3.11 Indicating Instruments

3.11.1 Standards

Indicating instruments shall comply with IEC 60051-1.

3.11.2 Design Features

Instruments shall be tested at 2kV rms for one minute.

Indicating instrument shall have flush mounting preferably be of pressed steel case, back connected, finished in phenolic semi matt black for single hole mounting.

Ammeters, voltmeters and frequency meters shall have a 240° scale with approximately 145 mm in length.

The bezel size shall be 95 x 95 mm except for power factor indicators which may be 115 x 115 mm.

3.11.3 Ammeters

Ammeters shall be of accuracy Class 1.5.

Ammeters for motor starter shall be capable of withstanding the starting current with a compressed overload scale over 100%.

3.11.4 Voltmeters

Voltmeters shall be of accuracy Class 1.5 and have expanded scales. The range shall be approximately 85 - 120% nominal and the zero shall be marked.

3.11.5 Frequency Indicators

Frequency indicators shall be scaled 48/52 hertz, Class Index 0.1 and burden not exceeding 1.5 VA.

3.11.6 Power Factor Indicators

Power factor indicators shall be suitable for unbalanced load and of accuracy Class 2.5.

3.12 Alarm Annunciator Equipment

3.12.1 General

Alarm annunciator equipment shall comply with WSD Standard Specification E-81-06.

Alternatively, alarm annunciator comprising a programmable logic controller (PLC) and a separate alarm fascia are also acceptable.

Alarm annunciator equipment shall comprise a flush mounted, multi-way display fascia housing lamp units with legends, the power supply equipment, logic and solid state circuitry cards, and an audible sounder.

The equipment supply shall be suitable for both 220V a.c. 50 Hz and 24V d.c. supply.

For up to 20 alarm points, the electronics may be integral with the alarm fascia. For larger systems, the electronics shall be separated from the fascia unit.

If required, automatic alarm acceptance after a preset time delay of 60 seconds shall be provided in addition to the normal manual 'accept' facility.

3.13 Panel Accessories

3.13.1 LED Indicating Lamps

LED indicating lamps shall be designed in compliance with IEC 60947-1 and IEC 60947-5-1. The degree of protection of the lamps shall be IP 65 or better to IEC 60529. They shall be of robust construction and designed for industrial application. The lamps shall be individual flush mounted units with minimum diameter of 22mm and of a shape matching that of the corresponding push-buttons. The casing material shall be metal bezel for general application and plastic bezel with chemical resistant double insulation for application in chemical environments.

Lamps shall be of high intensity LED for indoor bright environment and cluster LED lamps shall be used for outdoor applications. The lamps shall have high resistance to mechanical shock and vibration and shall be provided with a fuse to protect against short-circuits. 24V d.c. or 220V a.c. centre anoded lamps with Ba9s caps and with length not more than 30mm shall be supplied.

The service life of LED lamps without maintenance at rated voltage and ambient temperature of 25°C shall be 100,000 hours minimum. The current consumption of the lamp shall be not more than 20mA for 24V d.c. supply and 14mA for 220V a.c.

supply. At least five different colours (red, yellow, green, blue and white) shall be available for the lamp and its associated lens. The colour of the associated lens shall match that of the lamp. The viewing angle of the lamp shall be not less than 85°.

Rectangular indicating lamps for alarm annunciators shall also comply with the above requirements except that T6.8 lamp caps and with length not more than 45mm shall be used.

3.13.2 Selectors and Control Switches

(a) Standards and Rating

Equipment : IEC 60947-5-1, rotary action, air-break,
independent manual operated.

Rated Insulation Voltage : 600V 50 Hz or 300V d.c.

Rated Thermal Current : 16A

Switching Current : 220V 50 Hz 10A 0.65 p. f.
(0.1 million operations) 24V d. c. 10A L/R = 15 ms
110V d. c. 2.5A L/R = 40 ms

Endurance : 1 million mechanical operations,
120 on-load operations per hour.

(b) Design Features

For On/Off or Close/Trip selection, the switch shall turn clockwise for 'On' or 'Close' and anti-clockwise for 'Off' or 'Trip'.

Ammeter selector shall have make-before-break contacts for selection to read each of the three phase currents.

Voltmeter selector switches shall have break-before-make contacts for selection to read the three line voltages.

The selector shall be provided with identification label to indicate its function and the selected duty.

3.13.3 Push-button Switches

(a) Standard and Rating

Standard : IEC 60947-5-1 manufactured with inspection
requirements for full assessment

Rated Insulation : 600V 50 Hz or 300V d.c.
Voltage

Contact Type	: double break
Contact Rating	: same as control switches
Degree of Protection	: IP 40 - general application IP 54 - chemical installations or control boards
Endurance	: 1 million operations
Minimum Insulation Resistance	: 50 M-ohm

(b) Constructional Features

Push buttons shall have chromium plated polished solid metal brass body and ring, circular in shape and suitable for mounting on D22/D32 holes detailed in IEC 60947-5-1.

Units shall be designed for flush mounting on panel front.

Emergency stop push-button shall have red mushroom head, of the stay-put and turn to reset pattern. Emergency stop push-button mounted on the control panel shall be shrouded to prevent inadvertent operation.

Each push button shall be fitted with two pairs of changeover contacts.

3.13.4 Illuminated Push Buttons and Rectangular Push Buttons/Lamps

Standard	: IEC 60947-5-1 manufactured with inspection requirements for full assessment
Bezel	: 24 x 48 mm flush mounted on panel front
Lens	: 1.6 mm x thick, fire resistant plastic
Contacts	: 2 pairs of changeover contacts AC11 250V 2A DC11 24V 6A, 110V 0.4A
Endurance	: 1 million operations
Insulation Level	: 2 kV 50 Hz 1 minute, 50 M-ohm
Legend	: Engraved label. Labels up to 2 row x 8 letters be 4.5 mm high, 3 row x 12 letters be 3 mm high
Typical Application	: In control panels

3.13.5 Hours-run Meters

Hours-run meters shall be flush mounted synchronous clock devices with a digital indicator registering 9999.9 hours for 220V 50 Hz nominal supply.

3.13.6 Locking Facilities

Integral locks provided for selector switches of different functions shall be operated by different keys. 3 sets of keys shall be supplied for each lock. A lockable wall mounted cabinet shall be supplied to accommodate the keys. Hooks shall be provided in the cabinet for the keys which shall be identified with the key number.

3.13.7 Anti-condensation Heater

Anti-condensation heaters shall be provided for panels. The surface temperature of any part which is exposed shall not exceed 65°C. Heaters shall be so situated that no deterioration can cause to equipment or wiring adjacent to the heater. The heating circuit shall be provided with an individual ON/OFF switch and one set of HBC fuse and neutral link in fuse holders. Thermostats shall be mounted remote from the heaters and other sources of heat.

3.13.8 Interior Lighting

Each control console and station control and instrumentation panel shall be fitted with lighting fitting operated by a door switch.

3.14 Labels

3.14.1 General

Each panel and circuit section shall have identification labels both at the panel front and rear. Labels at panel interior may be fixed by screws or adhesive. Labels on the panel exterior shall be fixed with chromium plated screws. Integral labels for components such as push-buttons and indicating lamps, selectors, etc. may be used and fixed by manufacturers standard method.

Labels for selector switch shall indicate the operating function of the switch and the function identification of each selected position.

3.14.2 Size of Lettering

The ratio of height to width of character shall be 3:2 approximately. The size of characters shall be as below wherever practicable:-

<u>Type of Nameplate</u>	<u>Height of Character</u> (mm)
Board designation	20
Panel designation	15

Control console designation	10
Cubicle nameplate /selection designation	6
Circuit designation	4.5
Control equipment identification	3

3.14.3 Extent of Labelling

Labels shall be provided to identify every instrument, relay or item of control equipment and to provide warning of potentially dangerous circumstances.

3.14.4 Label Material

At panel interior, labels for identification shall have black characters on white surface and of laminated plastic. Warning labels shall be of similar material, but with red surface and white characters.

Labels fitted on panel exterior shall be of clear perspex rear engraved and filled in black. The back surface of each label shall be finished with a first coat of aluminium paint and a second coat of paint of the same colour as the panel external finish.

3.15 Power Supply Connections and Terminations

3.15.1 Selection of Conductors

Connection above 200A shall be of solid copper bars insulated with heat shrinkable insulating sleeving over the entire length. However, leads to motor starter auto transformers may be of PVC insulated PVC sleeved cables suitably fixed along the whole route. Both the normal current and effect of short circuit shall be the determining factors for sizing of conductors.

Connections up to 200A may be single core PVC insulated cables.

3.15.2 Sizing of Conductors

Conductors within switchgear panels shall be sized to match with the rating of the switchgear.

3.15.3 Standard Current Ratings for Stranded Copper Cables within Switchgear Panels

Switchgear Rating (A)	below 16A	16A	32A	63A	100A	160A	200A
Conductor Size (mm ²)	2.5	4	10	35	70	95	150

3.15.4 Cable Termination

Outgoing cables shall be terminated in a cabling compartment of the switchgear panel.

All panels shall be provided with bottom entry termination arrangements suitable for accepting power cables of the type and size specified in the Particular Specification.

For incoming supply panels, the minimum distance between the power cable terminals and the base of the switchboard shall be 700 mm.

The supporting framework at the cabling compartment of the panel shall be detachable to facilitate cabling work by the power company.

Terminations for external cables shall be as follows:-

Stranded Copper Conductor Cable Conductor Area mm ²	Minimum Distance between Terminal Centre Lines (mm)	Minimum Distance from Terminal to Gland Plate (mm)
630	95	450
500	90	400
400	85	500
300	77	450
240	72	400
185	67	355
120	57	280
70	44	225
50 and below	41	205

3.16 Cable Accessories

3.16.1 Cable Glands

Cable glands for unarmoured cables with elastomeric or plastics outer sheath shall be of brass to BS 6121 Type A4. Cable glands for armoured cables with elastomeric or plastics outer sheath shall be of brass to BS 6121 Type E1W. For single core cable, the cable gland shall be suitable for aluminium wire armour and the armour shall be insulated from earth.

The body of cable glands shall be stamped with identification for the size, type and manufacturer. Each cable gland shall be supplied with a brass gland backnut for plain hole fixing, slip-on copper earth tag with brass bolt and nut for the connection of an earth strip and a PVC gland shroud.

3.16.2 Terminals and Terminal Blocks

Terminals and terminal blocks shall be screw-type and designed to IEC 60947-7. Terminal bases and insulators for power cables shall be of epoxy resin or glass-fibre polyester high-pressure mouldings. Porcelain insulators will not be accepted.

Terminal bases for control wiring shall be of polyester or melamine mouldings or equal. Terminal blocks shall have ratings compatible with those of the application circuit under design.

3.16.3 Terminal Sockets

Compression type sockets shall be supplied.

Cable terminations for stud terminals shall be of the ring type. Stud holes in the palm of cable sockets shall have nominal diameters corresponding to the appropriate sizes of standard studs to BS 91 (Tables 1 and 2).

3.16.4 Cable Gland Plates and Split Boards

Gland plates shall be of brass not less than 4 mm thick of rigid construction to withstand the weight of cables.

Cable gland plates shall be fixed by bolts and nuts to the panel and shall be detachable to permit drilling. Cable gland plates shall be at least 300 mm from the floor which is not overhung over a cable trench.

The openings provided for cable entry to the panel shall be covered with split boards to prevent the entry of vermin. These boards shall be made of laminated densified wood.

3.17 Operating and Maintenance Tools for ACB

The following tools shall be supplied with each switchboard with ACB panel:-

- (a) One set of ACB operating and maintenance tools (including CB operating handles).
- (b) One set ACB earthing device.
- (c) One ACB handling truck.

A wall mounted cubicle shall be supplied to accommodate the tools stated in item (a) and (b) above.

4 INSPECTION AND TESTING

4.1 General

The complete switchboard and control panels supplied under the contract shall be inspected and witness-tested by an Independent Inspection Body (IIB) or Purchaser's representative at manufacturer's works prior to shipment. The Contractor shall inform the IIB or Purchaser's representative at least seven days before the intended date for the tests and inspection. The Contractor shall provide him with a complete set of drawings approved by the Purchaser.

A detailed test report shall be submitted within one week after tests to the Purchaser and IIB. Goods shall not be despatched until the Purchaser and the IIB have approved the test report.

4.2 Inspection

4.2.1 General

The scope of inspection shall in general cover the following:-

- (a) General inspection checks including physical dimensions, correct labelling, workmanship, quality, quantity, and standards.
- (b) Verification of routine test reports for current transformers, protection relays, energy meters and instrument.
- (c) Verification of calibration reports for testing instruments for tests witnessed by IIB.
- (d) Packing and protection checks.

4.2.2 Detailed Requirements

Inspection of panel steelwork shall be in stages generally as outlined below, but additional inspection may be carried out at the discretion of the Purchaser or the IIB and no claim for extra cost shall be raised by the Contractor.

- (a) After welding but before primer application.
- (b) After top coat painting but before mounting of components.
- (c) After assembly of components but before works testing.
- (d) Final inspection before packing.

The following shall be checked on inspection of the panel steelwork:

- (e) Panel steel plate thickness and panel construction to type test arrangement and approved drawings.

- (f) Rigidity of doors, covers and partition plates.
- (g) Quality of panel finishes.
- (h) Thickness and colour of paint finish.

The inspection shall be carried out on the completed assembly to assess the following:-

- (i) The principal dimensions of the equipment are correct.
- (j) The correct type and quantity of equipment are supplied.
- (k) Equipment is properly labelled for identification.
- (l) Equipment and components are easily accessible for maintenance.
- (m) All live terminals are properly shrouded for safety.
- (n) Wires are properly ferruled and terminated.
- (o) The equipment qualities are to the specified standards.

4.3 Witnessing of Tests

The following tests shall be carried out in the manufacturer's works and shall be witnessed by the IIB or Purchaser's representative:-

(a) Circuit-breakers

The following routine tests in accordance with IEC 60947-2 shall be carried out:-

- (i) Power frequency voltage withstand tests on the main circuit.
- (ii) Voltage withstand tests on control and auxiliary circuits.
- (iii) Insulation resistance tests on the main circuit and auxiliary circuits.
- (iv) Mechanical operating tests.
- (v) Milli-volt drop test.

(b) Metal-enclosed Switchgear

The following routine tests in accordance with IEC 60947 shall be carried out:-

- (i) Power frequency voltage tests on the main circuit.
- (ii) Dielectric tests on auxiliary and control circuits.

- (iii) Primary injection test up to rated current to measure the spill currents of current transformers and to initiate operation of protective relays and tripping of ACB/contactors.
- (iv) Milli-volt drop test for busbars.
- (v) Mechanical operation tests for switchgear.
- (vi) Tests of auxiliary electrical, pneumatic and hydraulic devices.
- (vii) Verification of correct wiring.
- (viii) Verification of interlocking facilities and correct operation of control and protection circuitries.

4.4 Tests not Required to be Witnessed

(a) Current Transformers

The following routine tests in accordance with IEC 60044-1 shall be carried out:-

- (i) Verification of terminal markings.
- (ii) Power frequency tests on primary winding (where applicable).
- (iii) Power frequency tests on secondary winding.
- (iv) Over-voltage interturn tests.
- (v) Determination of errors at rated burden.
- (vi) Determination of rated knee-point e.m.f., magnetizing current and secondary winding resistance.

(b) Protection Relays and Instruments

The relays, energy meters and instruments shall be tested at manufacturer's works for verification of correct operation and calibration.