WATER SUPPLIES DEPARTMENT

STANDARD SPECIFICATION E-15-01

HIGH VOLTAGE SWITCHBOARD

I N D E X

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1. GENERAL

1.1 Scope

This Specification covers the design, construction, inspection and testing requirements of high voltage switchboards with draw-out type circuit breaker.

1.2 Standards

Equipment shall comply with the latest editions and amendments of the relevant International Electrotechnical Commission (IEC) / British Standards (BS).

In particular, the high voltage switchboard shall comply with the following standards:-

IEC 62271-1	High-voltage switchgear and controlgear – Part 1: Common specifications for alternative current switchgear and controlgear
IEC 62271-100	High-voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers
IEC 62271-200	High-voltage switchgear and controlgear – Part 102: AC metal-enclosed switchgear and controlgear for rated voltages above 1kV and up to and including 52kV
IEC 61869-1	Instrument transformers – Part 1: General requirements
IEC 61869-2	Instrument transformers – Part 2: Additional requirements for current transformers
IEC 61869-3	Instrument transformers – Part 3: Additional requirements for inductive voltage transformers
IEC 60255-1	Measuring relays and protection equipment – Part 1: Common requirements

IEC 60502-4	Power cables with extruded insulation and their accessories for rated voltages from 1kV up to 30kV – Part 4: Test requirements on accessories for cables with rated voltages from 6kV up to 30kV
IEC 60947-5-1	Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements - Electromechanical control circuit devices
IEC 60947-7-1	Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment - Terminal Blocks for Copper Conductors
IEC 60099-4	Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems
IEC 60099-5	Surge arresters – Part 5: Selection and application recommendations
IEC 61238-1-1	Compression and mechanical connectors for power cables – Part 1-1: Test methods and requirements for compression and mechanical connectors for power cables for rated voltages up to 1kV (Um = 1.2kV) tested on non-insulated conductors
IEC 62053-21	Electricity metering equipment (a.c.) - Particular requirements - Part 21 : Static meters for active energy (classes 0, 5, 1 and 2)
IEC 60269-1	Low-voltage fuses
IEC 60282-2	High-voltage fuses – Current-limiting fuses
IEC 60898	Electrical accessories – Circuit breakers for overcurrent protection for household and similar installation
IEC 62053-23	Electricity metering equipment (a.c.) - Particular requirements - Part 23 : Static meters for reactive energy (classes 2 and 3)
IEC 62056-21	Electricity metering - Data exchange for meter reading, tariff and load control- Part 21 : Direct local data exchange

BS 6121	Mechanical Cable glands – Requirements and test methods
BS 12467	Fibre-cement flat sheets – Product specification and test methods
BS 4800	Schedule of paint colours for building purposes

1.3 Type Test Certification

The switchboard shall be of a type tested model. The Contractor shall provide the necessary certification to satisfy that the relevant type tests have already been performed on essentially similar equipment.

Type test certificates of short circuit tests shall be issued by the Association of Short Circuit Testing Authorities UK (ASTA) or other equivalent internationally recognized authority. Type tests shall be carried out in accordance with the requirements of the relevant IEC/BS. For SF_6 circuit breakers, all type tests for current switching and dielectric strength shall be conducted at the lowest permissible gas filling pressure.

The following type tests shall be performed on the switchboard and controlgear:-

1. Types tests of circuit breakers to IEC 62271-100

   - Short-time withstand current and peak withstand current tests
   - Short-circuit current making and breaking tests
   - Single-phase short-circuit tests
   - Capacitive current switching tests
   - Magnetizing and small inductive current switching tests
   - Mechanical operation tests
   - Dielectric tests
   - Temperature-rise test
   - Measurement of the resistance of the main circuit
   - Rated current switching test at gas pressure of 1 bar (SF6 circuit breakers only)

2. Types test of metal-enclosed switchgear and controlgear to IEC 62271-200

   - Dielectric tests
   - Measurement of the resistance of the main circuit
   - Short-time and peak withstand current tests
   - Verification of making and breaking capacities
   - Temperature-rise test
   - Mechanical operation tests
   - Pressure withstand and gas tightness tests of gas-filled compartments

3. Type tests of voltage transformers to IEC 61869-3

   - Temperature-rise test
   - Impulse tests on primary winding
   - Determination of errors
   - Short-circuit withstand capability test

4. Type test of current transformers to IEC 61869-2

   - Short-time current tests
   - Impulse tests on primary windings
   - Temperature-rise test
   - Determination of errors

The type test reports with complete details including the test arrangement and test results shall be submitted to supplement the test certificates when requested.

The equipment supplied shall be strictly in accordance with the design of the type tested equipment.

2. SWITCHBOARD DESIGN AND CONSTRUCTION

2.1 Standards

Switchboard and switchgear panels shall be metalclad and comply with IEC 62271-200.

2.2 General Design Information

2.2.1 Class and Rating

Rated voltage	12 kV, 7.2 kV, 3.6 kV
Number of poles	3
Earthing of system	Solid
System frequency	50 Hz ±2%
Installation type	Indoor
Power supply for circuit breaker operation, controls and protection	110V d.c. ±15%
Power supply for auxiliary equipment	220V ±10% 1-phase 50 Hz ±2%
Degree of protection	IP3X
Insulation class	Class B

2.2.2 Site Operating Conditions

Altitude above sea level	1000 m
Maximum ambient temperature :-	
Average over 24 hours	35^{o}C
Peak over any 4 hours	40^{o}C
Minimum ambient temperature	0^{o}C
Average yearly temperature	30^{o}C
Relative humidity	Up to 98%

2.3 Panel Layout

Switchboards shall consist of free-standing panels fitted together to form a continuous board of uniform height and shape when viewed from the front. Switchboards shall be extensible at both ends.

Forced ventilation shall not be necessary under an ambient temperature of 40^{o}C and below. Ventilating grills, where required, shall not be located on the top of a panel.

The height of panels shall be not greater than 2700 mm.

Indicating and control instruments shall be positioned between 900-1800 mm above floor level. Protective relays and instruments on the panel front shall be flush mounted.

Control and auxiliary relays shall be mounted in a separate low voltage compartment with access through a lockable hinged door. Any parts which generate vibration during operation e.g. contactor coils and circuit-breaker operating mechanisms, shall be mounted such that vibration shall not be transmitted to other parts of the panel.

The circuit breaker compartment shall be accessible through a hinged door fitted with a perspex window for viewing the mechanical status indicator of the circuit breaker. No equipment shall be fitted on this access door.

Busbars and current transformers shall be contained in separate chambers at the upper section of the switchboard and shall be accessible through bolted covers only.

Apparatus on different panels with similar functions shall be located at a similar physical position.

All functional equipment such as selectors, indicators and protective relays associated with a panel shall be housed within that panel. Installation of such components on a neighbouring panel is not acceptable.

Termination blocks for control wiring shall be located at least 150 mm from the base of the compartment. Identification ferrules for cables shall be so arranged as to be visible without the need to dismantle any other compartment cover or to remove any adjacent panel component.

2.4 Panel Steelwork

Panels shall be made of steel sheet suitably braced to form a rigid structure.

The panel steelwork shall be phosphate treated prior to application of epoxy powder coating. The paint work shall be of high quality and the total minimum dry film thickness of the paint coating shall be 25 microns. Details of the colour of the final paint coating shall be submitted for approval.

The final paint coating shall be semi-matt of colour to BS 4800 shade 18B21 (light grey).

2.5 Panel Door Fittings

The panel door shall be internal arc-fault proof type. All other associated equipment shall comply with the following requirement as specified below:-

(i) The internal arc-fault proof door shall be designed for the operator to rack in or withdraw out the circuit breaker carriage with the switchboard panel door closed smoothly.

(ii) The Contractor shall ensure that the design and the dimensions of the door are compatible to different rating of the circuit breaker carriages and the switchboards.

(iii) An inspection window shall be provided in the door for the operator to view the mechanical status indicator of the circuit breaker carriage and the operations of busbar and cable shutters during the circuit breaker carriage racking up or down. The window shall be made by transparent polycarbonate sheet.

(iv) The door shall be made of steel sheet with thickness of not less than 2mm suitably braced to form a rigid structure. The steelwork shall be phosphate treated to IEC 12467 prior to application of epoxy powder coating. The paint work shall be of high quality in compliance with ESI Standard 98-1 or equipment. The minimum dry film thickness of the paint coating shall be 50 microns. The final paint coating shall be semi-matt of colour to BS 4800 shade 18B21 (light grey).

(v) The door shall be type tested according to IEC 62271-200 to prove the operator is safe for racking the circuit breaker carriage into/out from the service position with the panel door closed. The inspection window and shutter for the operation handle of the door shall pass the type test for internal arc-fault current 25kA for duration of 1 second.

(vi) The type test certificates and reports concerning the door under the test conditions shall be submitted for the Engineer’s assessment and approval during equipment submission stage.

(vii) The Contractor shall ensure that the installation of the door shall not obstruct the smooth operation of different brands of circuit breaker carriage in the switchboard. The Contractor shall be responsible to check the conditions and design features of each brand of circuit breaker carriage prior to commencement of site work.

(viii) The Contractor shall be responsible to confirm the door is compatible to the existing interlock system and racking mechanism of the circuit breaker carriage. Suitable modification works shall be carried out in the switchboard for the smooth operation of circuit breaker carriage if deemed necessary.

(ix) The door shall allow the operator to insert the circuit breaker carriage into the “Circuit Earth” position with the panel door closed in the switchboard equipped with the earth bar for circuit earthing.

(x) The door shall allow the operator to insert the circuit breaker carriage into the "Busbar Earth" position with the panel door closed in the switchboard equipped with the earth bar for busbar earthing.

(xi) Special operation handle for the racking of the circuit breaker carriage shall be provided with the doors. At least two (2) sets of operation handle shall be provided.

2.6 Switchboard Earthing

The metal-cladding of the switchgear shall be connected to earth in a manner that any part of the switchgear can withstand a fault of 20kA for 3 seconds.

An earthing conductor running the entire length of the metal-enclosed switchgear shall be provided. The cross-sectional area of the earthing conductor shall be not less than 30 x 6 mm with earth terminals of not smaller than M8. All non-current carrying metallic parts shall be effectively connected to the earthing conductor, including provision for bonding cables sheaths and armouring.

2.7 Reference Voltage

The reference voltage for under-voltage and over-voltage relays shall be taken from the load side of the voltage-transformer secondary fuses installed in the incoming supply panel via bus wiring.

Where the switchboard consists of two or more incoming supply panels and bus-section panels, the reference voltage bus-wires shall be linked through normally open auxiliary switches on the bus-section circuit breakers and the incoming supply circuit breakers such that the reference voltages from each voltage-transformer will not be connected in parallel.

2.8 Bus Wiring

Bus wiring shall be used for auxiliary power supply and small wiring between panels. Bus wiring leads shall be provided by the switchboard manufacturer with PVC insulated copper cables terminated on terminal blocks.

Minimum cable size shall be 4 mm^2. Cables connected to 32A fuses, 63A fuses and 80A fuses shall be of minimum 6 mm^2, 16 mm^2 and 35 mm^2 respectively.

For auxiliary power supply, each set of terminals shall be segregated by plastic barriers and provided with individual plastic covers.

Ends of bus wiring for panels may be disconnected for transportation. The manufacturer shall provide wiring details for reconnection on site.

3. SWITCHBOARD EQUIPMENT AND AUXILIARIES

3.1 Busbars and Busbar Connections

3.1.1 Standards

The busbar system shall comply with IEC 62271-200.

3.1.2 Class and Rating

Busbars shall be three-phase and comprise separate sections for each circuit-breaker.

The rated current of busbars shall be 630A, 1250A and 2000A.

The rating of busbars including busbar connections and primary isolating contacts shall match the rating of the corresponding circuit breakers as detailed in Clause 3.2.2.

3.1.3 Material

Main busbars shall comprise horizontally mounted, PVC-sheathed or epoxy encapsulated, solid copper bars. Copper-clad or aluminum busbars will not be accepted.

Porcelain type insulators shall not be used. Insulators shall be mechanically fixed and not cemented into position to ensure rapid interchangeability in the event of replacement.

Joints shall be insulated with moulded removable insulated covers. Designs involving taping of joints or components shall not be accepted. The insulation material and moulding shall be provided.

There shall be no visible corona discharge on the busbar system.

3.1.4 Busbar Joints and Supports

Jointing of sections of busbars shall be done by mechanical means. Soldered, braced, welded or riveted joints will not be accepted for busbar jointing.

Jointing faces of copper conductors shall be tinned or silver plated, or other approved treatment to maintain effective conductivity of the joint.

Busbar jointing bolts, nuts, and fixing accessories shall be provided for switchboard installation. The recommended torque for tightening the bolts shall be stated in the maintenance manual.

Extension busbar trunking shall be provided, where specified, to permit segregation of the switchboard into sections. Such extension busbar trunkings shall be manufactured by the switchboard manufacturer.

3.2 High Voltage Circuit Breaker

3.2.1 Standards

High voltage circuit breakers shall comply with IEC 62271-100.

3.2.2 Class & Rating

Circuit breakers shall be of triple pole and indoor type.

The rated current shall be 630A, 1250A and 2000A.

The other ratings shall be as follows:-

System voltage and fault rating	3.3 kV 140 MVA	3.3 kV 225 MVA	6.6 kV 225 MVA	11 kV 380 MVA
Rated voltage to IEC 62271	3.6 kV	3.6 kV	12 kV	12 kV
Rated lightning withstand voltage (peak)	40 kV	40 kV	75 kV	75 kV
Rated transient recovery voltage (peak), parameters to IEC 62271	6.2 kV	6.2 kV	20.6 kV	20.6 kV
Rated short-circuit breaking current (r.m.s. a.c. component) and rated short time duration	40 kA 1s or 25 kA 3s	50 kA 1s or 40 kA 3s	31.5 kA 1s or 20 kA 3s	31.5 kA 1s or 20 kA 3s
Min. rated current of incoming supply and bus-section circuit breakers	1250A	2000A	630A	630A

Circuit breakers for pumpsets and power transformer feeders shall be capable of breaking a minimum current of 20% of the rated operational current of the connected equipment with power factor 0.05 lagging (no-load magnetizing current of the connected equipment).

3.2.3 Construction Features

3.2.3.1 Housing

The circuit breaker shall be of the vertical isolation horizontal drawout pattern truck unit. The design shall be such that the truck will be located accurately in its housing to ensure good alignment between the fixed housing and the contact assembly at the truck.

3.2.3.2 Circuit and Busbar Earthing

Circuit and busbar earthing shall be effected by the circuit breaker without the requirements of any loose attachments. The earthing connection shall be completed by closing the circuit-breaker in the normal manner.

Selection of circuit or busbar earth position shall be possible only after the circuit-breaker has been fully isolated and raising of the circuit-breaker shall be possible only at the selected positions. It shall be by a fully interlocked and labelled position selector, which shall be designed to permit padlocking in any position.

Facilities shall be provided on all incoming and feeder circuit-breakers for earthing the circuit side. However, only the incoming supply panels and bus-section panels shall be provided with facilities for busbar earthing.

3.2.3.3 Circuit Testing Facilities

Facilities shall be provided for testing the circuit-breaker operation in the fully isolated status and at any selected circuit position using normal control functions. Where control circuits and interlock circuits are broken in the test position, a jumper lead and plug assembly of each size and type necessary to connect all such circuits shall be provided to facilitate testing. Jumper leads which only connect the tripping and closing circuits shall not be acceptable.

3.2.3.4 Mechanical Interlocks

Mechanical interlocks shall be provided to cater for the following functions in any selected positions:-

(i) with the circuit-breaker in the closed position, the circuit-breaker truck cannot be plugged in or withdrawn;

(ii) circuit-breaker cannot be closed until fully plugged in or completely isolated;

(iii) tripping of circuit-breaker cannot be initiated by attempted operation of any interlocked control;

(iv) circuit-breaker cannot be 'slow-closed' except in the fully withdrawn position;

(v) covers giving access to live parts of circuit-breakers cannot be removed or opened unless the circuit-breaker is fully isolated and withdrawn.

With the circuit-breaker plugged in and closed to an earth position, tripping shall only be effected by the manual tripping button on the operating mechanism which shall be lockable at the closed position.

3.2.3.5 Key Interlock

Key interlocks shall be provided at the switchgear panels as specified below:-

(i) Incoming supply and bus-section panels

Where the switchboard consists of two or more incoming supply panels, key interlock shall be provided, in addition to electrical contact interlocks, in the incoming supply panels and bus-section panels such that the incoming supplies shall not be permitted to operate in parallel or to earth 'live' busbars.

The key interlock shall not prevent racking the circuit breaker into service position. The interlocking function shall be effective on the service and busbar earth positions but not on the circuit earth position.

(ii) Station auxiliary transformer feeder panels

Key interlock shall be provided in the station auxiliary transformer feeder panel to prevent opening the front and rear double-leaf doors of the enclosure of the epoxy resin encapsulated type station auxiliary transformer unless the associated circuit breaker is withdrawn from the service position and closed to the circuit earth position to earth the transformer supply cables.

(iii) Pump starter panels

Key interlock shall be provided in the pump starter panel to prevent opening the door of the corresponding pump-motor power factor correction capacitor panel unless the associated circuit breaker is withdrawn from the service position and closed to the circuit earth position to earth the motor and capacitor supply cables.

The keys and the locks shall be mass manufactured equipment of a proven design. The keys shall not be interchangeable for different interlock applications. Tripping of a closed circuit-breaker shall not occur if an attempt is made to remove the key trapped at the switchgear panel.

The Contractor shall submit for approval the detailed key interlock scheme together with the technical brochures for all keys, interlocks and necessary key exchange boxes within one month after award of Contract. Within one month after approval, the Contractor shall deliver the keys and door interlocks specified below for passing to the respective equipment suppliers for installation:-

(i) for each station auxiliary transformer feeder panel, two extra keys for the interlock at the switchgear panel, key exchange box, four sets of keys and door interlocks for the transformer enclosure.

(ii) for each pump starter panel, two extra keys for the interlock at the switchgear panel and one set of the door interlock for the power factor correction capacitor panel

The Contractor shall however make available the interlock keys used at the switchgear panels in order to verify the correct operation of the key interlock system during the witnessed inspection and tests at works.

3.2.4 Components

3.2.4.1 Operating Mechanisms

The circuit-breaker operating mechanism shall be of stored energy operation by means of a motor charged spring mechanism.

The mechanism shall be of the trip-free type. Operating mechanisms for the interrupter units shall be positively coupled to ensure simultaneous operation of the three phases.

The operating mechanism shall be provided with anti-pumping protection facilities.

The motor charged spring mechanism shall be provided with means for charging the springs by hand and a lockable shrouded mechanical push button for releasing the springs. Interlocks shall be provided to prevent simultaneous charging of the operating springs by manual means and by the motor. A 'spring charged' and 'spring free' indicator shall be provided.

Operating handles for lowering/raising, slow closing and manual spring charging of the circuit breakers shall be provided.

Electrical tripping by the shunt trip coil shall be rendered inoperative when the circuit breaker is closed at earth position.

3.2.4.2 Operating Indicators & Manual Tripping Facility

Positively driven mechanically operated indicating devices shall be provided to indicate whether a circuit-breaker is open or closed, in service, isolated or earthed position. A 4-digit mechanical operation counter shall be provided at each circuit breaker to register the number of mechanical operations.

An integral push-button for direct manual tripping of the circuit breaker shall be provided. Pad-locking facility shall be provided to prevent unauthorized tripping of the circuit breaker at the earth position.

3.2.4.3 Safety Shutters

Safety shutters shall be provided to cover each three phase group of stationary isolating contacts. Shutters shall be automatically driven from the circuit-breaker's rack-in or rack-out operation and when closed shall prevent access to stationary isolating contacts. 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 circuit-breaker 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 circuit-breaker into the service position.

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

Circuit	Feeder Orifice Shutters		Busbar Orifice Shutters	
	Background Colour	Character (White)	Background Colour	Character (White)
Incoming Supply	Red	Danger Incomer	Red	Danger Busbars
Transformer	Red	Danger Feeder	Red	Danger Busbars
Motor	Yellow	-	Red	Danger Busbars
Voltage Transformer	Red	Danger Incomer	-	-
Bus Section	-	-	Red	Danger LH/RH Busbars

3.2.4.4 Primary Isolating Contacts

Isolating contacts fingers shall be of silver plated copper and self-aligned type. Gauging devices shall be provided for checking the correct engagement of the contact assembly with the stationary isolating contacts.

One set of three phase test plugs for current injection tests shall be provided for each size of primary isolating contacts.

3.2.4.5 Auxiliary Switches

Auxiliary switches shall be of double-break type and shall be positively driven in both directions.

The necessary auxiliary switches for the control functions specified shall be incorporated with a minimum of two pairs of normally open and two pairs of normally closed contacts (not changeover contacts). The contacts shall be rated for 10A operational current, and shall be capable of breaking at least 2A at 110 d.c. with a L/R time constant not less than 20 ms.

Auxiliary switches shall be used for tripping and closing interlocks. The use of repeat relays for this purpose shall not be acceptable.

3.2.5 SF_6 Circuit Breaker

SF_6 circuit breakers shall be metalclad, i.e. the gas tank shall be made of metal. A pressure switch shall be provided on the SF_6 gas compartment to monitor the gas pressure and to give a two-stage pressure low alarm and lockout feature. Local and remote alarms shall be initiated and the breaker shall be inhibited from closing whenever the gas pressure drops below the first stage preset level. The circuit breaker shall be prevented from operation and a second alarm shall be initiated whenever the gas pressure falls to the second stage level below which it is incapable of performing its rated duty. A gas pressure gauge shall be fitted at the front of the gas compartment to facilitate pressure checking without the need to dismantle any cover. Means shall be provided in the gas compartment for gas topping up.

The circuit breaker shall be capable of interrupting its rated normal current with SF_6 gas at atmospheric pressure. The sealing of the gas compartment shall be designed so that SF_6 gas shall not need replenishment within the service life of the circuit breaker. The gas leakage shall not exceed 1% per annum at site ambient temperature.

Facilities shall be provided to enable checking the extent of contact wear, e.g. an external contact indicator, without the need to dis-assemble the gas compartment. Means shall also be provided to allow access to the contacts of the interrupter units for necessary inspection and maintenance. All contact assemblies shall be replaceable. Safeguards shall be provided to prevent incorrect replacement of contacts.

The designed electrical and mechanical life shall be at least 5,000 and 10,000 cycles respectively. The circuit breaker shall be capable of undergoing 40 cycles of fault breaking operations at 50% rated short-circuit breaking current or equivalent without any need of opening up the tank for inspection or contact replacement.

Instructions for post-fault maintenance, gas top-up, frequency of checking contact wear, contact and seal replacement shall be clearly detailed in the manual.

3.2.6 Vacuum Circuit-Breaker

The vacuum circuit-breaker shall be designed in compliance with IEC 62271 - 100.

All exposed live conductors in the circuit breaker truck shall be fully insulated or separated by insulated partition sheets.

The circuit-breaker shall be capable of interrupting rated short-circuit fault currents for at least 20 times without the need of maintenance or interrupter replacement.

Visual contact wear indicator or equivalent to monitor the severity of the main contact erosion of circuit-breaker shall be provided.

The chopping current of circuit-breaker shall not exceed 5A.

Surge suppression devices shall be installed in each pump starter panel for suppression of steep voltage rise and spikes generated due to motor switching. The surge suppression devices shall be of metal-oxide without gaps in compliance with IEC 60099-4. The ratings of the surge suppression devices shall be in compliance with the selection and application recommendations specified in IEC 60099-5.

3.3 Voltage Transformers

3.3.1 Standards

Voltage transformer (VT) shall comply with IEC 61869-3.

3.3.2 Class and Rating

The secondary voltage shall be 110V. The rated output per phase at a power factor 0.8 lagging shall be not less than 75VA. The minimum output shall be capable of supplying all panels in the system.

The rated voltage factors shall be 1.2 continuous and 1.9 for 30- second duration. Ratings of the VT shall be as follows:-

System nominal voltage	3.3kV	6.6 kV	11 kV
Rated highest equipment voltage	3.6 kV	7.2 kV	12 kV
One minute power frequency test voltage (r.m.s.)	10 kV	20 kV	28 kV

VT shall have a measuring accuracy class 1 and a protective accuracy class 3P.

3.3.3 Construction Features

Each VT shall have a rating plate marked with all data recommended in IEC 61869-3. The VT shall be of metal-enclosed and safe-to-touch design.

VT shall have separate windings for primary and secondary and shall be dry-type cast resin encapsulated and natural air cooled or other approved type.

The primary winding shall be protected by fuses to IEC 60282-1. These fuses shall be removable only when the VT is at the isolated position. Secondary circuit fuses and/or MCBs shall be provided and shall be readily accessible for replacement.

A set of safety shutters shall be provided to automatically cover the opening accessible to the fixed isolating contacts when the VT is withdrawn. Particulars of shutters shall be identical to those for circuit-breakers. Means shall be provided to padlock the shutters in the closed position.

Padlocking facilities shall be provided to lock the VT in the service position. Access to the HV live parts shall not be possible in this position.

3.4 Current Transformers

3.4.1 Standards

Current transformers (CT) shall comply with IEC 61869-2.

3.4.2 Class and Rating

CT shall be rated for 50 Hz operation and compatible with the circuit breaker's ratings.

3.4.3 Design Features

The rated secondary current shall be 1A or 5A.

The rated primary currents in amperes shall be (10), 12.5, (15), (20), 25, (30), 40, (50), 60, (75) and their decimal multiples. The preferred values are those given in brackets.

The accuracy class of measuring CT shall be Class 1 and the class and accuracy limit factor of protective CT shall be Class 5P10. In addition, the Contractor shall provide calculations to substantiate the rated burden of CT proposed is greater than all load burdens connected to the CT.

For dual ratio CT, all the secondary terminals shall be wired to a terminal block and clearly identified.

The secondary circuits of each CT shall be earthed at one point only. Bolted copper link at readily accessible position shall be provided for CT earthing. Each earth wire shall be terminated on separate terminals.

CT shall be of epoxy resin encapsulated type.

CT rating labels shall be fitted on the CT and on a prominent place on the exterior of the CT chamber. For dual ratio CT, the ratio in use shall be clearly indicated on a label.

3.5 Relays and Timers

3.5.1 Protective Relays

Protective relays to IEC 60255-1 shall be provided.

Protective relays and trip circuit supervision relays shall be of withdrawable type housed in cases. The relays shall be flush mounted. For current operated relay, a feature shall be incorporated to short circuit the secondary terminals of the CT when it is withdrawn from the case.

Solid-state or microprocessor based protection relays shall be provided as specified in the Particular Specification. Test terminal blocks with a CT shorting feature shall be installed adjacent to the relays to facilitate testing. A complete set of portable instrument (notebook computer, software and accessories) for the configuration and testing of digital relays shall be provided if required in the Particular Specification.

Operation indication shall be provided for each protective element and within the same relay. The relay shall have a hand-reset device operable without opening the relay access cover except for undervoltage relay, which shall be equipped with self-reset contacts and a hand-reset operation indicator.

A relay test plug for each type of test terminal block shall be provided.

3.5.2 Control & Timer Relays

Control and timer relays shall be of plug-in type, rack mounted, provided with cable connection terminal and anchored by quick fastening vibration-proof devices. Timers shall be of solid-state type. Contacts shall be rated as follows:-

Control relays

Rated thermal current:	16A 220V a.c. 3.5A 110V d.c.

Timer relays

Rated thermal current:	2A 220V a.c. 0.5A 110V d.c.

3.6 Low Voltage Fuses and Miniature Circuit Breakers (MCBs)

3.6.1 Standards

Fuses and fuse holders shall comply with IEC 60269-1. MCBs shall comply with IEC 60898.

3.6.2 Class and Rating

For fuses, the voltage rating shall be 415V, 50 Hz or 500V d.c. The rated breaking capacity of fuses shall be 80 kA at 415V, 50 Hz or 40 kA at 500V d.c.

For MCBs, the operating mechanism of the MCBs shall be thermal-magnetic type with inverse time-current characteristic to IEC 60898 Table 7. The MCBs shall have tripping classification of Type B and have rated short circuit breaking capacity of 6kA to IEC 60898.

3.6.3 Components

Fuse bases and carriers shall be of plastic moulded insulating material of an approved make. Fuse bases and carriers for fuses of 2-20A shall be 20A units.

Fuse bases and carriers shall be colour coded, white for isolating links, light green for tripping control and black for other fuses.

3.6.4 Mounting

Fuses and links in the same circuit shall be mounted in adjacent positions in the same row. Live terminals and contacts of fuse holders shall be effectively shrouded such that no live parts shall be exposed when the fuse is withdrawn or when the panel door is opened.

3.7 Indicating Instruments

Ammeter and voltmeter shall have bezel dimensions of 95 x 95 mm. The indicator accuracy shall be of Class 1.5 and shall have a scale length not less than 145 mm on 240^{o} angular deflection. The indicator shall be finished in phenolic black and suitable for flush panel mounting.

The ammeter for motor starter panel shall have a compressed scale above the rated circuit current to cater for motor starting current. Voltmeter shall have an elevated scale with range of around 90-120% of the nominal value. Frequency indicator shall be scaled 48-52 Hz and of accuracy Class 1.0.

Power factor indicator shall be of accuracy Class 2.5 having bezel dimensions of 95 x 95 mm.

3.8 Panel Auxiliary Equipment

3.8.1 Selector and Control Switch

The selector and control switch shall be of rotary type with minimum contact rating of 30A thermal and 16A 220V a.c. 0.4 p.f. lagging. All function selector switches shall have spade type handle and key lockable in any selected position. The locks for the same function selector switch in all switchboard in a station shall use a common key.

Handles of control switches for circuit-breakers shall turn clockwise for closing and anti-clockwise for tripping and shall be of the pistol-grip type. Control switches shall be clearly labelled as "trip-neutral-close", with spring return to the neutral position. A mechanical interlock shall be fitted to prevent repetitive closing without moving first to the trip position, and the handle shall be capable of being locked in the neutral position.

3.8.2 Hour-run Meter

Hour run meter shall be a synchronous clock device with a digital indicator registering 9999.9 hours and connected to either the 220V 50 Hz or the 110V d.c. control supply. The meter shall be fitted with a mechanical push-to-reset button.

3.8.3 Indicating Lamp

Indicating lamp shall be rectangular or circular shape of diameter 32 mm. 220V a.c. lamp shall be fitted with step-down transformer for 6.3V a.c. lamp bulb. Alternatively, LED type indicating lamp with equivalent brightness may also be acceptable.

"Running" or "On" indicator shall be positioned on the right side of the "off" indicator when arranged in a row.

3.8.4 Pushbutton

Pushbutton shall be of matching shape with indicating lamp. It shall have not less than 2 change-over contacts with a minimum contact rating of 30A thermal and 16A 220V a.c. 0.4 p.f. lagging.

Emergency stop pushbutton shall have a red mushroom head of stay-put and turn-to-reset type.

3.8.5 Anti-condensation Heater

Anti-condensation heaters shall be fitted to each switchboard panel and the associated isolator switch and control thermostat shall be provided.

3.8.6 Locking Facilities

Padlocks and keys shall be supplied for the lockable devices of the switchgear panels. The key shall be unique for each padlock and fitted with an identification plate indelibly marked with the panel and function type reference. Two keys shall be supplied for each lock.

A key and padlock cabinet shall be supplied for each switchboard. Hooks shall be provided for all keys and locks each identified with the key number. The key cabinet shall be fabricated from mild steel sheets complete with lockable hinged doors.

3.8.7 Labels and Warning Notice

Each switchgear and relay panel shall be fitted with circuit labels on both the front and the rear. Labels shall be fixed by screws on the non-detachable parts of the panel at a height of 1350 mm or above. The characters on the panel labels shall be 10 mm high.

The components shall be individually labelled.

"DANGER - HV LIVE TERMINALS" warning notices shall be attached to the access covers of the cable boxes, CT chambers and busbar chambers.

Warning labels with red inscription of “DANGER - CT TERMINATION” shall be affixed to the terminals of CT circuits.

3.9 Energy Meter

The meter shall be programmable polyphase integrated energy and maximum demand meter. The accuracy class for kWh and kVArh shall be Class 1 to IEC 62053-21 and Class 2 to IEC 62053-23 respectively. The meter shall be provided with three programmable digital/pluse outputs and three programmable 0-20mA d.c. analogue output for remote indications.

The meter shall be of transformer operated type. The reference voltage shall be 110V 50Hz 3-phase derived from the voltage transformers at the incoming supply panels. The rated current shall be 1A derived from the measuring current transformers at the incoming supply panels or the pump starter panels.

Meter configuration, programming and data retrieval, which shall be multi-level password protected, shall be made via an optical communication port using IEC 62056-21 protocol with the use of a personal computer and/or via fieldbus communication.

All necessary interface probe cable, licensed softwares for meter configuration, programming, data retrieval and load profile data conversion to standard worksheet application software shall be provided.

3.10 Summation Meter Cubicle

A meter cubicle shall be provided for each station for housing the summation metering equipment where the power system has two or more incoming supplies. A set of epoxy resin encapsulated summation current transformers of accuracy class 0.5, rated output of 5VA minimum and rated secondary current of 1A, and voltage selection relays shall be provided for the following summation meters:-

(i) Maximum demand meters for on-peak and off-peak period, and
(ii) Energy consumption meters for on-peak and off-peak periods.

The cubicle shall be fabricated from 2mm thick sheet steel, of IP54 protection index and suitable for wall-mounting. The cubicle shall be provided with epoxy powdered coating. The final coat shall be semi-matt of colour BS4800 shade 18B21 (light grey). Detachable cable gland plate shall be provided. The cubicle shall have a front access hinged door fitted with a glazed window.

The meters shall be mounted inside the cubicle with necessary mounting brackets to facilitate viewing the meter display through the glazed window. The voltage selection relays shall be flush mounted on the access door.

The maximum demand and energy consumption meters shall have flexible programming capabilities for complex tariff configuration, which are based on daily and weekly schedules as well as exceptional days, and shall have facilities for load profile storage and remote meter reading. The data storage capacity shall be sufficient to store one value every 30 minutes for 90 days viz. total 4320 values. The meters shall be fitted with real time clock and calendar supported by an internal battery. The registered data shall be transferred to non-volatile memory on power failure. A sealable push-button shall be provided at the front of the meter for resetting the maximum demand data.

The terminals for current transformer connections shall be provided with short links. The terminals for voltage supplies shall be provided with fuses and link.

3.11 Power Supply Terminations

3.11.1 Termination Provision

The cable termination box shall be suitable and have sufficient space for the termination of the power supply cables specified in the Particular Specification. In general, it shall meet the termination requirements of the following XLPE insulated armoured copper conductor cables:-

No. of Cores	Cable Sizes (mm^2)		
	630A panel	1250A panel	2000A panel
1-3c	300	-	-
2-3c	300	-	-
3-1c	300	1000	-
6-1c	300	1000	1000
9-1c	-	1000	1000

Cable lugs and cable glands shall be supplied to match the external cables. Insulated glands shall be provided for single-core power supply cables. Where more than one cable enters the cable box, the clearance between adjacent glands shall be sufficient to permit satisfactory cable termination.

Cable glands shall be connected to the earth bar by flexible copper conductors of not less than 20 kA 1-second rating.

The cable lugs for the termination shall be designed in compliance with IEC 61238-1.

The Contractor shall provide the cable termination kits to meet the termination requirements as specified in the Particular Specification.

3.11.2 Cable Termination Compartment

The cover of the compartment shall be interlocked against the earthing switch of the panel in a way that the cover can be opened only when the HV circuit of the panel is earthed by the earthing switch via the circuit-breaker.

The cable termination compartment shall be designed for bottom entry of cables.

3.12 Cable Accessories

3.12.1 Terminal Bases and Bushings

Terminal bases and bushings shall be epoxy resin or glass-fibre polyester high-pressure mouldings. Porcelain bushings shall not be accepted.

3.12.2 Terminal Sockets for Power Cables

Cable terminal lugs shall be fabricated from hard-drawn cadmium copper with the socket portion locally annealed for crimping. The lug shall be tinned throughout.

Fixing bolts, nuts and washers for the cable sockets shall be supplied.

Stud holes in the palm of cable sockets shall have nominal diameters compatible with the bolts.

3.12.3 Mechanical Cable Glands

Cable glands for elastomeric or plastic insulated cables shall comply fully with BS 6121 type E1W. Suitable shrouds, slip-on earth tags and backnuts shall be supplied with the cable glands.

3.12.4 Small Wiring

Wires shall be black for both a.c. and d.c. connections and yellow/green for earth connections.

Each end of the wire shall be provided with a crimp lug. Wiring shall be run in a neat manner and shall enable its being examined without the removal of cleats.

Numbered interlocking ferrules of white PVC with black characteristics shall be provided for cable core identification. Ferrules shall be capable of being fitted firmly to cable cores.

3.12.5 Terminal Blocks

Terminal blocks shall comply with BS EN 60947-7-1. It shall be single-level feed-through, screw or screwless type connection, DIN rail-mounted, vibration and corrosion resistant, and modular design suitable for harsh industrial environment.

All a.c. and d.c. supply bus wiring terminals shall be fully shrouded and identified. Terminal blocks for current transformer secondary connections shall be provided with maintenance shorting links and clamps.

3.13 Spares and Tools

The following spare parts and tools shall be provided in addition to other spares and tools recommended by the Contractor:-

1. A shunt trip coil of each circuit breaker rating.

2. A closing spring release coil of each circuit breaker rating.

3. 100% high voltage fuses of each type and rating used, subject to a maximum of 3 for each size.

4. A wall mounted cubicle with front access door for housing the spare fuses.

5. One set of operating and maintenance tools (including CB operating handles) complete in a carrying case (as mentioned in Clause 3.2.4.1).

6. One set of 3-phase HV test plugs of each switchgear panel rating complete in a carrying case (as mentioned in Clause 3.2.4.4).

7. Padlocks and keys in a cabinet (as mentioned in Clause 3.8.6).

8. A relay test plug for each type of relay casing (as mentioned in Clause 3.5.1).

9. One set of single- and multi- finger type test plugs complete with plug links for the test block (where applicable).

10. One spring charging motor.

11. One spare circuit breaker truck for pump starter panel.

12. Portable SF_6 gas detector (where applicable).

If specified, the following non-consumable spares and tools shall be included in the lists of recommended spares and tools:-

13. 2 control relays of each type and rating used.

14. 1 timer relay of each type and rating used.

15. 1 three-phase set of protection CT for the incoming supply panel.

16. 1 three-phase set of protection CT for pump starter panel of each rating.

17. 1 motor protection relay.

18. 1 probe interfacing cable for programmable energy meter.

19. 1 complete set of licensed programming and load conversion software for the programmable energy meter (as mentioned in Clause 3.9).

4. INSPECTION AND TESTING

4.1 General

The complete switchboard supplied under the Contract including spares and tools shall be inspected by the Independent Inspection Body (IIB) at manufacturer's works prior to shipment. Tests carried out on the completely assembled switchboard shall be witnessed by the IIB. Inspection and test reports/certificates together with test arrangement drawings, circuits, calculations, and test results shall be submitted within one week after the inspection and testing.

4.1.1 Inspection

The scope of inspection shall cover the followings:-

1. General inspection checks including physical dimensions, workmanship, quality, quantity, and standards.

2. Verification of test reports for routine tests of switchboard carried out during manufacturing stages.

3. Verification of routine test reports for current transformers, voltage transformers, protection relays and instruments.

4. Verification of calibration reports of testing instruments for tests witnessed by IIB.

5. Packing and protection checks.

4.1.2 Witnessing of Tests

The following tests to IEC 62271-200 carried out on the completely assembled switchboard shall be witnessed by the IIB at the manufacturer’s works:-

(i) Power frequency voltage withstand tests on the main circuit.

(ii) Insulation resistance tests on the main circuit.

(iii) Measurement of the resistance of the main circuit.

(iv) Mechanical operation tests.

(v) Verification of interlocking facilities and correct operation of control circuitry.

4.2 Metal-enclosed Switchgear Panel

The following routine tests as specified in IEC 62271-200 shall be performed on the switchgear panel:

(i) Power frequency voltage withstand tests on the main circuit.

(ii) Insulation resistance tests on the main circuit and auxiliary circuits.

(iii) Measurement of the resistance of the main circuit.

(iv) Mechanical operation tests.

(v) Verification of correct wiring and performance of the CT operated protection relay circuitry by primary current injection at rated CT primary current.

(vi) Verification of interlocking facilities and correct operation of control circuitry.

4.3 Circuit Breakers

The following routine tests as specified in IEC 62271-100 shall be performed on the circuit-breaker:-

1. Power frequency voltage withstand tests on the main circuit.

2. Measurement of the resistance of the main circuit.

3. Mechanical operation tests.

4. Insulation resistance tests on the main circuit and auxiliary circuits.

5. Gas pressure check (for SF_6 circuit breaker).

4.4 Switchgear Panels

The works tests shall include routine tests as follows. The test requirements shall be in accordance with IEC 62271 - 200.

1. Power frequency voltage tests on the main circuit.

2. Dielectric tests on auxiliary and control circuits.

3. Measurement of the resistance of the main circuit.

4. Mechanical operation tests.

5. Tests of auxiliary electrical, pneumatic and hydraulic devices.

6. Verification of correct wiring.

7. Verification of interlocking facilities and correct operation of control circuitry.

4.5 Voltage Transformers

Routine tests as specified in IEC 61869-3 shall be performed on the voltage transformers.

4.6 Current Transformers

Routine tests as specified in IEC 61869-2 shall be performed on the current transformers.

4.7 Protective Relays and Instruments

The relays and instruments shall be tested at relay and instrument manufacturer's works for verification of correct operation and calibration.

4.8 Summation Meter Cubicle

The correct wiring of the programmable energy meter, summation CT and voltage selection relays (where applicable) shall be verified at manufacturer’s works.

- End of this Specification -