Snowy Technical Standards	
SHL-ELE-156 (B)	***Annexure B - LV Switchboards*** ***General Low Voltage Electrical Requirements***

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This annexure forms part of the General Low Voltage Electrical Requirements Standard (SHL-ELE-156).

1. Scope

This Annexure sets out minimum requirements for Low Voltage AC and DC Switchboards.

The General Requirements and other relevant Annexures of SHL-ELE-156 must apply where applicable in designing and constructing Low Voltage AC and DC Switchboards.

Switchboards must be designed to achieve a minimum design life of 20 years.

This Annexure is intended to cover the requirements for main switchboards (MSB), Common Services Boards (CSB), Unit Auxiliary Switchboards, Main Station DC switchboards or similar heavy current boards (greater than 250A) which are connected to systems with significant fault levels.

For requirements specific to lighting and small power distribution boards, and low voltage enclosures refer to the following Annexures:

- Annexure C – Electrical Cubicles and Junction Boxes;
- Annexure M – Lighting and Power;

1.1. Applicable Standards

The design, manufacture and testing of equipment and components detailed in this annexure must comply with the requirements of all relevant Australian Standards or in the absence of appropriate Australian Standards, with relevant IEC, ISO or International Standard, together with the requirements of competent authorities having jurisdiction over all or part of the manufacture, installation or operation of the equipment, except where modified by this Annexure.

All works must comply with the requirements of the most recent releases of the regulations and standards noted in Snowy Standard SHL-ELE-156 - General Low Voltage Electrical Requirements. In the event of a conflict between different Codes, Standards or Regulations, the selection must be done as per 2.1.2 of SHL-ELE-156.

AS/NZS 61439 series cover Low-voltage switchgear and controlgear.

2. Safety Requirements

Switchboards must be designed, manufactured and tested with the safety requirements detailed in section 4 of the General Low Voltage Electrical Requirements (SHL-ELE-156) and the relevant sections of AS/NZS61439.

3. Technical Requirements

3.1. General

The electrical equipment installed in a switchboard must be new equipment complying with relevant Australian Standards for its operational duty. The equipment must be installed so that it maintains its operational rating when the switchboard circuits are fully operational and loaded, doors are closed and ambient temperature is at maximum

The switchboard equipment must be installed strictly in accordance with the manufacturer's instructions in all regards, particularly concerning enclosure size, temperature rise, clearances and maximum continuous current rating.

3.2. Design Life

The switchboard and its associated equipment must be designed for a minimum life duration of 20 years in the environment and for the switchboard's nominal duty. The equipment must also be suitable for a minimum of 1-year nominal continuous operation without maintenance at its nominal duty.

3.3. Site Climatic Conditions

All electrical components must be selected and installed such that all circuits can operate simultaneously at the full load rating at the worst climatic extreme detailed in the table below.

Condition	**Detail**	**Value**
Location	Southern NSW South Eastern SA Southern Victoria	- - -
Altitude	Above mean sea level	0-1000m[1]
Ambient Temperature (Dry bulb)	Minimum – Indoor Minimum – Outdoor	-5°C -15°C
	Typical Maximum	35°C
	Extreme Maximum	40°C
Relative Humidity	Minimum	10%
	Maximum – Indoor Maximum – Outdoor	50% 100%

[1] The altitude of any Snowy Scheme installations above 1000m are detailed in the project specific documentation.

3.4. AC Switchboards

Main Circuit Breaker units that are three or four pole withdrawable air circuit breakers (ACB's) must comply with the following requirements:

- Must have been tested by a recognised testing authority as per the relevant standards;
- Include a motor spring charge operating mechanism;
- Be fitted with an independent manual closing mechanism of the trip free type;
- Be fitted with safety shutters and a means for padlocking the shutters and circuit breaker to the "ISOLATED" position;
- All withdrawable circuit breakers must be interlocked to prevent withdrawal or insertion unless the circuit breaker is open;
- Withdrawable circuit breaker modules must be arranged such that it is possible to rack the circuit breaker in and out to the live busbars only with the module door closed;

Fixed Air Circuit Breakers (ACBs) are not preferable but can be used if there is a clear advantage over withdrawable ACBs for a particular application that comply with the requirements of above first three bullet points in Section 3.1.

The nominal voltage and steady state tolerances are site specific by design, and unless specified otherwise are as follows:

Hydro Power stations 240/415V AC (+10%, -15% for Unit Aux Boards and all other boards +10%, -10%);

Valley Power Station, Colongra and SA diesel 240/415V AC (+10%, -10%);

Laverton Power Stations 230/400V AC (+10%, -10%);

Control Voltages:

Refer Annexure J - DC Battery Supplies of ELE-156.

Hydro 250V DC system - 200V to 270V;

Gas 220V DC system -193V to 254V;

Gas 125V DC system -111V to 141V;

SA Diesel 110V DC system - 100V to 126V;

Substation DC systems -110VDC is preferable;

General 48V DC system - 44.4V to 56.4V;

Other voltages may be used in consultation with the asset specialist;

The equipment must be designed for correct continuous operation for frequency between 50Hz +/- 2%.

3.5. DC Switchboards

3.5.1. General

Main Circuit Breakers for DC Switchboards must be either Moulded Case Circuit breakers or combined fuse switches as required. These must be designed with an appropriate rating and with an appropriate number of breaker poles. As the DC system is unearthed, both poles must be protected.

The nominal voltages and tolerances are site specific and in some cases, unit specific, however all DC equipment must be designed for operational voltages as in Annexure J - DC Battery Supplies of ELE-156.

DC switchboards must not be installed in battery rooms.

3.5.2. Earth Fault Detection

All DC switchboards voltage 110V DC or higher that contain a DC busbar must be equipped with facilities for detecting DC earth faults.

3.5.3. De-rating of AC Breakers for DC applications

AC circuit breakers used for DC applications must be appropriately de-rated as per manufacturer's recommendations.

3.6. Incomer and Bus-tie and Feeder AC Circuit Breakers

3.6.1. Interlocking

If specified, supply incomers to switchboards must be interlocked with bus-tie circuit breakers or transfer switches to ensure that supplies are not paralleled at the board. If paralleling of supplies is part of normal operation then this interlock does not apply.

Backup generator connections must comply with AS 3010.

3.6.2. Measurement and Indication

Each incomer must be fitted with the following measuring and indicating facilities:

- As a minimum, real & reactive power, power factor, frequency, line/phase voltages and currents and harmonics must be provided through to SCADA and Historian (PI);
- Multifunctional power meter with door mounted LCD/LED display if protection relay does not provide the information to SCADA;
- Where the power meter is rated for phase-to-phase line voltage and terminals are appropriately shrouded, then direct connection of the power meter to the bus is allowable. Otherwise connection to the power meter from the bus must be from instrument transformers;
- Communication links from the power meter to the control system must be provided. Each circuit breaker, bus coupler and changeover switch must have clearly visible mechanical indicators to show circuit "OPEN" and "CLOSED". Facilities must be provided for locking circuit breakers in the "ISOLATED" positions. As a minimum, the following must be provided through to SCADA;
    - Spring charge
    - trip circuit monitoring
    - rack position (in service, test, withdrawn)
    - CB open/closed

- Bus voltage measurement must be provided for each bus section.
- Main Switch must be labelled as specified in AS 3000.

3.6.3. Tripping facilities

Each circuit breaker must be fitted with the following tripping facilities:

- Manual push button with direct mechanical linkage to the circuit breaker operating mechanism;
- Integral adjustable magnetic and inverse time thermal overcurrent and earth fault release. Separate relays are preferred depending on the location and the fault current distribution;
- Separate duplicated independent shunt trip facility;

3.6.4. Remote Operating Facilities

If the arc energy of the switchgear is above Cat 2 remote operation must be considered. Where remote operating requirements are specified, the following requirements must be considered:

- Switching is achieved through motorised/spring loaded circuit breakers triggers using station DC voltage;
- Automatic transfer;
- Break before make with an adjustable time delay;
- Facilities for remote racking of the switchgear.

Where practical, incomer circuit breakers must be provided with the facility for group settings to allow for reduced arc fault incident energy levels if personnel are within the switchroom.

If a remote local control panel is provided, the following requirements must be met:

1. Any switchgear with remote control capabilities will be operable from the associated switchboard's Local Operation Panel.
2. A dedicated Open/Close Control Selector Switch (CSS) must be provided for each remotely operable switchgear in the Local Operation Panel.
3. A Maintenance/ Local/ Remote CSS must be provided on the corresponding switchgear tier/ cabinet door.
4. The Local Operation Panel must be provided ready for connection back to terminals in the switchboard control cubicle.

3.6.5. Manual Operating Facilities

All incoming and outgoing feeder circuit breakers must be equipped with manual operating mechanisms.

3.6.6. Backup Generator Incomers

Generator incomers must be 4-pole, arranged in accordance with AS 3010 Figure 2.3. MEN link must be located in the LV switchboard and not at the generator.

If the LV switchboard is down-steam of a main switchboard, the generator incomer and switchboard MEN arrangement must be arranged in accordance with AS 3010 Figure 2.8. The MEN link must be located in the main switchboard.

3.7. Busbar and Connections

3.7.1. Fabrication

The busbars and connections must be of high conductivity copper, solid round-edged rectangular copper bar, be mechanically strong and must withstand all the stresses which may be imposed upon them in service due to fixing, vibration, fluctuations in temperature, short-circuit or other causes. The temperature rise over the cooling media of busbars and busbar connections must comply with AS 61439.1.

Material used for busbar connections or for supporting the connections must not be stressed to more than one quarter of its breaking load or one third of its elastic limit, whichever is the lower.

Bus bars must be fully insulated to avoid earth faults or phase to phase faults with the correct type of insulation rated for the designed maximum temperature and the over voltages applicable in service.

Main bus bars must be completely enclosed except for power take-offs and must be completely segregated from all other equipment and wiring, including extra-low-voltage busbars and wiring. All wiring passing through busbar chambers must be double insulated or enclosed in supported conduit and must not touch the busbars.

Busbar supports must be fabricated from rigid, non-hygroscopic insulating material. Number, location and method of installation must be in accordance with the design and for the maximum fault level and duration specified.

All busbar fabrication must be in accordance with the design verification report for the assembly.

3.7.2. Rating

Busbars must comply with AS/NZS 61439 in the following respects:

- The busbar system must be designed to withstand the designed fault level without overheating or distortion for 1 sec and must be in accordance with the manufacturer's DVR for short circuit withstand;
- Busbar rated nominal current must be a minimum of 120% of maximum connected load, nominal busbar ratings to Annex P of AS 61439.1;
- Busbar jointing, number and type of washers and torque settings must be in accordance with the manufacturer's DVR.
- Rating of vertical droppers must be in accordance with the manufacturer's DVR.

3.7.3. Markings

The phasing of AC bus bars must be identified by colour-coded bands in phase colours of red, white and blue and DC bus bars in red(positive) and black (negative) applied at regular intervals not exceeding 600 mm along the length of each bar. Colour coding must be a 25 mm minimum width PVC sleeve or painted strip encircling each busbar which can withstand busbar maximum designed operating temperature.

3.7.4. Name plate and Mimic

An engraved nameplate must be fitted to the switchboard in the vicinity of the incoming feeder main switch. The nameplate must include the following information:

maker's name

type, model and serial number

date of manufacture

standard (e.g. AS/NZS 61439.1)

type testing for arcing faults

nominal operating voltage, volts

nominal operating current, amps

rated short time current, kA for one second

peak withstand current

maximum ambient temperature rating, deg. C

form factor

degree of protection (i.e. IP rating)

Provide an approved mimic bus on the front of each switchboard assembly.

3.7.5. Jointing

The current carrying surfaces of busbar joints must be thoroughly cleaned to remove all traces of dirt and grease, and must be coated with a layer of corrosion-inhibiting jelly immediately prior to jointing. Connections must be secured with high-tensile steel bolts and washers for the application tensioned in accordance with manufacturer's instructions.

Busbars must be silvered or tinned at all busbar joints on both sides.

3.7.6. Bus duct enclosures

Where required, Switchboards must include suitable bus duct flanges and the necessary transitions and enclosed bus ducts, to provide connections through the main circuit breakers on to the transformer terminal chambers.

The bus duct enclosures must be metal of adequate rigidity and non-ventilated. Bus ducts longer than one metre in length must be fitted with an expansion joint.

3.7.7. Future Expansion

Design of the Switchboard busbar system must permit future expansions to both ends of the Switchboard. Switchboard extension tiers must have busbars arranged in a matching configuration to existing Switchboards.

All busbar ends must be drilled and supported to enable extension without modification to existing works other than by the removal of bolts, caps, tapes and other such expendable items. Transition tiers for busbar joints must not be permitted unless otherwise specified. Busbars must be mounted on non-hygroscopic insulators in a separate compartment.

3.7.8. Colour coding

Red, white and blue must be used for phase colours. Black must be used for neutral and green/yellow for earth.

3.7.9. Neutral bar in AC switchboards

A full size neutral busbar must extend the complete length of the switchboard and must have take-off points sufficiently separated from live conductors to allow safe connection of circuit neutrals. Neutral busbars and earth bars must be completely isolated from each other and must run the full length of the switchboard. Neutral bars must be located in the cabling zone as close as practicable to the gland plates.

Neutral bars must be drilled to accept the neutral connection of the external feeder circuits with sufficient spacing between holes to accommodate all of the neutral cable lugs.

The neutral bar must be colour coded using black PVC heat shrink tubing at 300 mm intervals.

3.7.10. Earth bar

The main earth bar and risers must be provided with suitable termination facilities for the connection of the earth conductors on all incoming and outgoing cables and must be provided in each vertical terminating zone.

Earth bars must extend the entire length of the switchboard adjacent to the outgoing cable gland plates. The earth bar must be colour-coded with green/yellow bands at maximum 300 mm intervals. The earth bar must be tapped and fitted with bolts, washers and spring washers to accommodate the earth connections for all incoming and outgoing cables, with 20% spare connections. Bolt hole diameters of 10mm and larger must be drilled through the earth bar and earth cables fixed with suitable nut, bolt and spring washers.

Doors, hinged escutcheons, gear trays and the switchboard chassis must be provided with a welded M6 thread earth stud and each stud directly connected to the switchboard main earth bar with a minimum 4mm2 flexible Green/Yellow insulated earth cable.

A minimum 6 x 32 mm copper main earth bar must be provided for the full length of the terminal zones and Switchboards. Each tier must have its own vertical earth bar which must be bolted to the main earth bar.

Inside cable zones the earth bar must be provided with the following:

- 4 x 12 mm bolted connections;
- 3 x 8 mm bolted connection for each starter cell serviced by the cable way;
- 1 x 36 hole double screw earth link;

Adjacent to each gland plate in each tier cabling zone the earth bar must have ten M6 tapped holes for termination of cable earth conductors. These must be arranged so as to allow easy access for connection and disconnection on Site.

3.7.11. MEN link

The MEN Link should be ONLY provided in the Main Switchboard.
A bolted link must be provided between the neutral busbar and the main earth bar. The link must be accessible, and easily removable.

3.8. Motor starter modules

3.8.1. Design

Motor starters must have been tested by a recognised testing authority for compliance with AS 60947 and AS61439.

Motor starter modules must be designed to include the contactor, motor protection equipment, control circuit MCB, auxiliary relays, etc, associated with each drive, as well as the short-circuit protective device.

Selector switches, indicating lights and instruments must be mounted on the module door. The starter modules must be jig-built to provide uniformity for each size of contactor and must be wired to standard wiring diagrams so that all modules of such size will be similar throughout the boards.

Where withdrawable starters are provided, automatic shutters (padlockable in "off" position) must be provided to cover vertical busbar attachment points.

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

Individual starters must be arranged with easy access to each item of equipment within the unit and clearly labelled. Contactors, fuses, coils, overload relays, etc., must be readily removable from the units for maintenance and inspection purposes.

Running the motors/auxiliaries in test mode must be possible from the control room by bypassing some of the interlocks. This is intended to be strictly a ‘testing facility’.

The following equipment must be included on the door, or front, of each starter:

- Circuit breaker or isolator operator;
- Selector switch if applicable;
- Identification plate;
- Drive ‘running’ lamp (Red);
- Drive ‘stopped’ lamp (Green);
- Drive ‘start’ push button (Green);
- Drive ‘stop’ pushbutton (Red);

All of the above equipment must be mounted such that they are not less than 600 mm or more than 2000 mm above the floor level.

Current monitoring must be provided to the local control system.

Coordination between the motor starter short circuit protection and the contactor breaking capacity must be Type 2 to Australian Standards.

Motor starters must be arranged to suit the following basic criteria:

- largest loads located adjacent to the incomer and at the bottom of tiers,
- all drives associated with a process on the same bus;
- all doors 800 mm or larger located on the same side to minimise space required within the switchroom;
- minimum height of the drive compartment - 200 mm;

Control voltage for motor starters must be 24V DC. Contactor coils must be 24 VDC. Other voltages may be used upon approval from SHL.

Control voltage must be sourced from redundant 24V power supplies fed from two different power sources to avoid a single point of failure.

3.8.2. Isolation and mechanical interlocking

Each motor starter module must be provided with an isolation device. Mechanical interlocking must be fitted to each motor starter module to ensure:

- Where withdrawable starters are provided, that starter module cannot be withdrawn or racked in unless the circuit breaker or isolator is in the “off” position;
- That the starter door cannot be opened unless the circuit breaker or isolator is in the “off” position;

3.8.3. Protection against contact of Live parts

All equipment in a module must be designed and selected to provide protection against unintentional contact to live parts with the cubicle door open to a degree of protection of at least IPXXB or IP2X.

3.9. Construction

3.9.1. Materials

Indoor and outdoor Switchboards must be constructed sufficiently rigid for direct fastening to the concrete floors and fabricated to accept in-service (normal and short circuit) switch operating forces without any permanent deformation. Material selection and painting should consider environmental conditions.

Outdoor Switchboards must be constructed of either marine-grade aluminium or 316 stainless steel and must have sloping roofs and gutters to direct rainwater away from doors. There must not be any opening in the roof of the Switchboard. The roof must be arranged to be separated from the top of the cubicle by a ventilated space.

Large panels and module doors must be adequately braced, using a minimum of 100 mm wide and 20 mm deep folded sheet metal, spot welded to the door or panel. Bracing when necessary must be arranged well clear of components and this must apply equally to initial and possible future additions. All sheet metal work must be flat and free from ripples, depressions and other surface defects.

Heavy equipment must be supported by a separate independent framework and must not rely on the enclosure sheeting.

3.9.2. Degree of protection

Electrical equipment is susceptible to damage or failure due to moisture and dust ingress into the enclosure. Switchboards must have, as a minimum, the following degree of object and water ingress protection in accordance with AS 60529:

- Indoor Switchboards: IP54 or as detailed in the project specific documentation.
- Outdoor Switchboards: IP56 or as detailed in the project specific documentation.

All outdoor equipment must be suitable for unprotected exposure to the weather, direct sunlight, dust and hose-down cleaning. The enclosures must be designed to limit the ingress of corrosive gases where located in corrosive environments.

3.9.3. Lifting points

Minimum of four adequately sized lifting lugs and structural members must be provided in each section of the Switchboards to facilitate handling. Lifting lugs must be fitted at points of suitable strength such that no distortion or fatigue will result from lifting. The removal of all lifting accessories must not provide access to any internal section of the panel.

3.9.4. Sealing

Switchboard modules must be sealed to restrict arc transmission in the event of a fault. Each phase of the connections between the busbars and the line side of functional unit protective devices must be individually supported and sealed to achieve better sealing i.e. the three phases must not be brought through the same hole into the module.

The switchboard door returns and seals must be consistent with the switchboard's IP conformance certificate, sealing description and accompanying DVR description.

3.9.5. Plinths

Switchboard support channel plinths must be more than adequate to provide rigid support to minimise flexing, and must be minimum 75mm high, 3mm thick and of hot-dipped galvanised or powder coated steel. Surface preparation and galvanising must be in accordance with AS 4680. The galvanised coating must only be applied after all welding and machining has been completed and all welding slag and machining chips removed.

Plinths must have external lugs for bolting to the floor and holes for inserting lifting bars. The design must size the plinth such that it is structurally certified for lifting the enclosure it is intended for without causing an unsafe situation and undue stresses on the Switchboard during lifting.

3.9.6. Corrosion protection

All structural steel used in construction that is exposed to atmospheric corrosion must satisfy AS 2312 – Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings.

Corrosion resistant materials, such as stainless steels, may be left uncoated but must be treated (passivated) so as to ensure that the corrosion resistance is active.

3.9.7. Vermin and insect proofing

Switchboards must be vermin and insect proof.

3.9.8. Arc rating

Switchboard assembly that has been designed to AS/NZS 61439.1 appendix ZC with tests completed as per ZD must be type tested to meet the requirements of arcing class C (all seven criteria) or alternatively Arc fault containment testing of the switchboard to IEC-TR61641.

The protection in every separate incoming or outgoing compartment of a switchboard must be in an arc ignition protection zone either by insulation up until the output terminals of the incoming protection or by the incoming protection being located in a separate compartment or switchboard.

The arc rating of the switchboard must be determined as part of the project arc-flash report at the point of installation of the switchboard in the power network. No distinction must be made between panel doors open vs. panel doors closed for classification of the switchboard arc flash incident energy.

Outgoing compartments containing multiple components must have a type test certificate for an arc tested zone for an Ip arc equal to the Icw of the switchboard.

Type test documentation must be provided to the employer for review along with details of the proposed switchgear and configuration in conjunction with the switchboards. No switchboard or switchgear must be procured prior to receiving this approval.

The AC switchboard rated under 250A and with a calculated fault level under 10kA (per the project specific power system analysis report) does not require certification for the arcing test and in such a situation the protection should be provided to minimise the arcing faults energy through basic protections.

Arc chutes must be provided to switchboards as necessary to suit the switchboard configuration, protection device selection and IP rating of the assembly. Arc chutes and ventilation outlets must be located such that emissions of flame or hot metal particles will not cause electrical breakdown in adjacent compartments, damage to building structures or pose a hazard to personnel. Emissions must be directed upwards and away from personnel. Arc chute design must be to the approval of SHL.

If protection discrimination cannot be achieved between upstream and downstream protection devices due to arc flash energy considerations, arc flash detection devices or Zone Selective Interlocking (ZSI) scheme must be utilised to ensure protection discrimination is maintained.

If arc flash detection is utilised, the preferred method of protection is optical and current detection type. The detection must trip the circuit breaker if light and abnormal current is detected. The arc flash protection method and arrangement must be approved by the SHL protection engineer.

Switchboards with motorised circuit breakers or air circuit breakers must be provided with a remote (not attached) control panel and be internally wired to accept remote switching and isolations to minimise the requirements for local operation.

Compartments with control circuits and sub distribution circuits must have separate arc containment and opening of the compartment doors must not compromise the integrity of any neighbouring compartment arc containment.

As part of the safety in design process, consideration must be given to use remote control and remote racking of main circuit breakers as one of the mitigation measures for arc flash hazards.

Consider Zone Selective Interlocking (ZSI) for the protection scheme or installation of IEC62606 compliant arc fault detection devices within the switchboard for better management of arc flash hazards.

3.9.9. Arc flash Labels

On the external of the front access door of the main control compartment of the Switchboard an arc flash label defining the mandatory PPE requirement for different categories must be fitted. An example is shown below. SHL has adopted the simplified two-category, arc-rated clothing system on Category 0, 2 and 4 PPE as per NFPA – 70E 2021 (Everyday Work Clothing for Categories 1 and 2 and Arc Flash Suit for Categories 3 and 4).

Refer arc flash procedure QP24-97 Arc Flash Work Management for Labeling.

On the external of each Switchboard incomer and motor starter door an arc flash label identifying the incident energy, maximum arc flash protection boundary and required PPE category (for doors closed and open) must be fitted.

All accessible Switchboard compartments including cable zones must have a label.

3.9.10. Fault Current Rating

Switchboard main busbar and droppers must be constructed to withstand, without thermal or mechanical damage, the short circuit stresses generated by the maximum fault level. The fault current withstand time must be for 1 second. The applicable fault level will be provided by SHL and must be given in the relevant Project Drawings.

Protective devices connected to the switchboard bus bar system, including but not limited to incomer ACB's, starter and feeder module CFS and MCCB units, must be rated for the switchboard fault current level nominated in the project drawings. Protective devices and settings must be approved by the SHL protection engineer. Electrical equipment within starter modules, feeder and distribution modules must be capable of withstanding the let through fault current from their respective short circuit protective devices.

Where a switchboard utilises busbars, the switchboard design must have been successfully tested in accordance with AS 61439.1 by a recognised Australian testing authority. The design tested must be applicable to the switchboard being supplied and include all incomers, functional units and busbar compartments.

The switchboard design must comply with the parameters specified in the switchboard's DVR. Pertinent parameters include:

- Busbar ratings.
- Busbar supports must be identical in material and mounting.
- Busbar phase centres.
- Busbar supports spacing.
- Creepage and clearance distances.
- Motor starting equipment and feeders must be the same equipment or approved alternative.

3.10. Isolation Requirements

Switchboards must be provided with main circuit breakers/isolators to isolate the switchboard in accordance with AS 3000.

3.11. Protection Coordination

Protective equipment must be fully coordinated so that no item is called upon to break fault current in excess of its fault rating and must be sized such that discrimination is achieved between upstream and downstream protective devices.

Power and control cable and Switchboard wiring protection must be such that the energy let-through by the protective device does not exceed the level permitted for that cable or wiring by AS 3008.

Cascading (or backup protection) is an acceptable method for protection coordination where the fault rating of the system exceeds the fault rating of a protective device. Cascading protection must only be used where both protective devices have been tested by the manufacturer and the cascading tables are readily available from the manufacturer.

3.11.1. Protective Device Substitution

Protective devices of the same manufacturer but of a different series, or devices from a different manufacturer, may be considered equivalent and be substituted for the original device if the requirement of the device manufacturer are complied with and the assembly manufacturer declares the performance characteristics to be the same or better in all relevant aspects to the series to the series used for verification such as;

- Breaking capacity.
- Limitation characteristics (I^2t, I_{pk}).
- Critical distances (safety perimeters).

Any requirement for device substitution must be detailed as part of the switchboard DVR.

3.12. Surge Protection

Main circuit surge diverters must be installed on the load side of the switchboard main incomer circuit breakers.

Main circuit surge diverters must comply with IEC 60643-11 Class I surge diverters.

Main circuit surge diverters which are entirely voltage limiting type and do not contain voltage switching components and must have a short circuit current rating not less than the site incoming L.V. supply prospective fault current level.

All surge protection systems must be installed in accordance with the manufacturer’s recommendations.

Surge diverters must be connected between the following terminals:

- phase and neutral;
- phase and earth;
- phase to phase (at multi-phase installations);

3.13. Form of Segregation

3.13.1. Switchboard and MCCs Rated at Greater than 250A

Switchboards must be metal clad, totally enclosed "dead-front", fully withdrawable type constructed to minimum Form 4a or 4b segregation according to AS/NZS 61439.1 or as stated in the project documentation. “Plug-in” type, Fixed type and Hybrid assembly may be acceptable with approval of SHL.

Suffixes ‘i’ and ‘h’ are not accepted. In DC switchboards non withdrawable configuration is acceptable.

If the form of separation within the switchboard incoming cubicle is Form 4a, all conductors and terminals on the line side of the incoming circuit breaker must be provided with a degree of protection of IP2X between phases and between phase and earth, by either insulation or insulated barriers.

Other forms of segregation may be acceptable for the compartments where the outgoing sub distribution feeders are located with the approval of SHL.

3.13.2. Distribution Board Rated Below 250A

Electrical cubicles and distribution board with a nominal current rating less than 250A must be constructed to minimum form 2bi and use a fully encapsulated insulation system. All conductors and terminals on the line side of the incoming circuit breaker must be provided with a degree of protection of IP2X between phases and between phase and earth, by either insulation or insulated barriers.

Use of internal functional unit housing (Suffix ‘h’) in addition to the above is also acceptable.

3.14. Cable zones

Switchboards must be supplied with vertical cable zones adjacent to each tier, and with a horizontal wiring enclosure running the length of the board. Adequate access must be provided from each vertical zone to the wiring enclosure.

Cable zones must be adequately sized, of minimum internal width 350 mm, and must be designed for ease of installation and maintenance of cables. Cable trays must be mounted over the full length of all cable zones to allow fastening of cables.

Cable zones must not be used for any form of termination.

3.15. Cable entry

Cable entry into the Switchboard is preferred to be bottom entry only unless specified otherwise.

3.16. Physical Capacity

Switchboards must incorporate 20% additional spare capacity both in terms of space for expansion and thermal load rating. Spare physical space must be calculated as follows:

- (total of tier heights – used tier height)/ (total of tier height);
- light and power, bus-way, programmable controller, marmusting, and incomer areas are NOT included as part of the calculation;

3.17. Equipment Layout

Access and emergency exit requirements of AS 3000 must be complied with while designing the layout of the Switchboards.

Equipment layout must be designed for ease of operation, fault finding and maintenance.

Free standing cubicles are preferred to have the following minimum and maximum dimensions:

- Width – minimum of 800 mm;
- Height - minimum of 2000 mm, maximum of 2200 mm;
- Depth - minimum of 650 mm, maximum of 800 mm;

Equipment inside cubicles must be arranged so as to allocate 20% of the width as an access way for cables, cable ducts, etc. This access way may be divided so that a portion of it is on either side of the cubicle. In no case must the divided portion be less than 50 mm wide.

Equipment tiers must be of sufficient size to allow ready routing and termination of power and control cables. Generally, outgoing power cable terminations must be located towards the front of the tier for easy access. It is preferred that the larger kW drive equipment have priority for ease of cable connection.

Equipment must be fixed such that any item can be maintained without dismantling or removing other equipment.

Live conductors must be protected so that they cannot be accidentally touched during normal operation, fault finding and maintenance.

Equipment and associated cable plugs and/or sockets must be clear of cubicle doors by not less than 75 mm.

Where applicable, equipment must be logically grouped into cubicles or suites of cubicles bolted together on a common frame. The maximum length of any suite of cubicles must be subject to acceptance by SHL.

All labels, indicating lights and other external equipment, must be neatly mounted to provide a uniform appearance of the complete assembly.

3.18. Equipment Mounting

No piece of equipment which is to be operated or viewed by an operator (push buttons, switches and meters) must be mounted more than 2000 mm or less than 300 mm above floor level. It must not be necessary to open any door or remove any cover that will expose live electrical equipment, in order to operate or reset any piece of equipment.

No piece of equipment must be mounted behind other equipment or in any manner denying free access for removal or maintenance. All equipment within modules must be mounted on equipment panels. Equipment must not be mounted in cells that have a nominal height of less than 300 mm so as to allow safe ease of access to perform maintenance and repair tasks.

Control terminals must be mounted so that the wire numbers on both sides of the terminal are readable from the front of the Switchboard with covers or doors open.

All equipment and devices are installed in such a manner that all necessary electrical clearances are observed and that the rating accuracy of devices is not impaired either thermally or electro-magnetically by the proximity of other devices or cables.

Self tapping screws or pop rivets must not be used for equipment mounting.

Equipment mounting plates must be constructed from the same material as the main switchboard structure, supported by four welded stainless steel studs and secured with a minimum of four stainless steel nuts. Large

equipment plates exceeding 1000 mm in any dimension must be 3.2 mm thick and secured with six welded stainless steel studs and nuts.

Welds must be full fillet welds ground and machined smooth and free from splatter.

Heavy equipment must be supported by a separate independent framework and must not rely on the enclosure sheeting.

All nuts, bolts and studs must be stainless steel.

For Outdoor Switchboards equipment must not be installed on the outer doors.

3.18.1. Door Mounted Devices

Equipment fitted to doors must, where possible, be restricted to pushbuttons, selector switches, indicating lamps, indicating instruments and LED screens.

It is preferred that relays are not door mounted. Relays which are fitted with indicators or flags must be either flush mounted to fixed panels or mounted within the cubicles with a glazed panel in the door in front of the relay. The glazed panel must be of sufficient size to allow switch room lighting to illuminate the face of the relay. All glazing materials must be of the laminated type to prevent shattering.

All studs and terminals of door mounted equipment must be effectively shrouded to prevent inadvertent contact with live metal when the door is in the open position. All shrouds must be removable and capable of re-installation. Where equipment is mounted and wired on doors, a means of earthing additional to that provided by hinges must be provided.

3.18.2. Door Mounted Equipment Cabling

Wiring connected to door mounted equipment must be made up into small enough groups so that the door can be opened and closed without applying any strain on the cables or the equipment.

Wiring must be secured by flexible spiral wrapping or insulating sleeves, must not be subject to undue flexing or twisting and must not foul other cables or equipment or rub on panel edges.

3.19. Internal Wiring

3.19.1. Size, Type and Colour

Low voltage internal control wiring must be V90 0.6/1kV grade PVC insulated flexible wire with a minimum size of 1.5 mm^2 and 15 strands. Where additional flexibility is required for connections to door or hinged panel mounted equipment, 32/0.25 mm flexible conductors must be used.

Wiring related to signals circuits of 50V or less, can be carried out in 100V grade PVC insulated flexible wire with a minimum size of 16/0.20 (0.5 mm^2)

Power wiring must be rated for 0.6/1kV and must be sized for the application in accordance with AS 3000 and AS 3008 Part 1; with a minimum size of 2.5 mm^2.

Internal wiring insulation colouring must comply with AS 3000. Specific colouring to be used on SHL installations must be as per below. The intent of the wiring colouring system is to identify hazardous voltages from ELV circuits.

Halogen free wiring to be considered for high fire risk areas after a risk assessment.

Function	Colour	Abbreviation
Extra Low Voltage (except CT & VT circuits)	Grey	GY
DC above ELV (ie>120Vdc)	Orange	OG
Three phase AC		
Red Phase	Red	RD
White Phase	White	WH
Blue Phase	Dark Blue	DBU
Neutral	Black	BK
Single phase 240Vac		
Active	Brown	BN
Neutral	Light Blue	LBU
Earth	Green/Yellow	GN/YE
CT wiring	Phase identified (as for 3 phase AC above)	
VT wiring	Phase identified (as for 3 phase AC above)	

Note: In communication panels Red and Blue are also used for 48V supplies and Red and Black are used for supplies of voltages less than 48V dc distribution systems. (ref AS/NZS 3015)

The purpose here is to identify power supplies from low energy communication signalling. (refer ISC panel installation standard).

The neutral colour will change after reaching the coil or link in the circuit.

Instrument transformer secondary wiring must be regarded as belonging to a particular phase until it becomes connected to a star point, at which time it will change to neutral (black).

3.19.2. Wiring Methods

Wiring must be neatly bunched and cleated or enclosed in PVC ducts with removable clip-on covers. PVC ducting must not be more than 75% full once all wiring has been installed. Bunching must be achieved by plastic cable ties. Metallic cable tying devices and plastic lacing is not acceptable.

The layout of cable ducts, wiring looms and control equipment must provide a minimum spacing of 50 mm between the duct or loom and the wiring termination points.

Ducting must be located with sufficient clearance to other equipment so that any core entering or leaving the duct is not bent in a radius of less than five times the radius of the insulated core, and the core identification ferrules and the cable terminator is straight and visible outside the duct.

Perforated tray and PVC ducting must be provided to support incoming cables and the individual cores running to terminals. Where it is necessary to install more than one row of terminals, alternate spacing between rows of terminals must be reserved exclusively for incoming cabling.

Joints must be made in conductors only at terminals (i.e. No inline joints).

Wiring connected to door mounted equipment must be made up into small enough groups so that the door can be opened and closed without applying any strain on the cables or the equipment.

No control wiring must be run in busbar compartments.

Low voltage wiring (typically power supply wiring) must not be run in the same duct as extra-low voltage wiring. Internal wiring layout design must ensure maximum separation between power and signal wiring.

3.19.3. Preformed and Ribbon Cable

Preformed and ribbon cables must be constructed so that the overall sheath of the cable is held by a clamp which must be an integral part of the plug or socket.

All preformed or ribbon cables within the cubicle must have adequate support at regular intervals to prevent any stress on the plug or socket, and to promote a neat appearance. All plug/socket combinations must be polarised to prevent incorrect connection. All preformed cable screens must be earthed and pins must be dedicated for this purpose in each plug and socket of the preformed cable.

3.19.4. Plugs and Sockets

Where plug and socket connections are used, either the male or female section of this connection must be mechanically attached to the mainframe such that the connectors can be inserted without damage to either the cables, pins or mechanical support. In-line connectors are not acceptable. Each plug and socket must be labelled with non-removable identification

3.19.5. Wiring Identification

Both ends of every cable or wire core must be identified with the “Grafoplast” or approved equivalent sleeve numbering system. The same numbering applies to the wires and not to the terminals; thus the two ends of any wire bear the same number. A wire looping between a number of terminals will have the same number at each termination. The numbers to be used to identify cubicle wiring are divided into functional groups as detailed in Electrical Plant Data sheet D-GEN-2-43. The Principle will issue wire numbers for the works.

3.20. Heaters

Anti-condensation heaters, with a nominal operating voltage of 230V AC, complete with adjustable thermostat (with nominal factory setting) must be provided in Switchboards containing control or relay equipment not located in air-conditioned Switchrooms, except where the external Switchboard surface area is less than 0.5m^2 (excluding bottom surface area) or as otherwise nominated by SHL.

The rating of the heaters must be 20W for each square metre of exposed surface area of the Switchboard. The surface temperature of the heaters must not exceed 60°C. Heaters must be provided with expanded aluminium covers to prevent accidental touching.

All Switchboards fitted with anti-condensation heaters must have ventilation openings in the doors which must be screened with vermin proof fine brass gauze or a suitable filter and arranged to minimise entry of dust and prevent entry of water.

3.21. Enclosure Lighting

Outdoor Switchboards must be fitted with internal lights within the outer door operated by a limit switch.

3.22. Gland Plates

Removable single piece 6 mm thick aluminium gland plates of adequate dimension to accept glands for all power and control circuits must be provided for all incoming and outgoing cables.

No single gland plate must be longer than 1000 mm. 20% allowance for future cabling must be made when sizing gland plates.

Gland plates must be separately earthed with cable sized in accordance with AS 61439.1.

No equipment, including cable ducts, must be mounted within 200 mm of the gland plates to provide access for cable termination and glanding.

Gland plate openings must be reinforced with 25 mm x 6 mm flat aluminium strips drilled and tapped with 6 mm holes.

Fixing holes for gland plates must be spaced a maximum of 150 mm apart.

Openings must be sealed with 25 mm wide neoprene gaskets glued to the switchboard.

3.23. Doors and Escutcheons

All Switchboard compartments other than busbar chambers and horizontal cable zones must have hinged doors.

Doors must be constructed from the same material as the rest of the switchboard. The switchboard opening must have a 120 degree return which seals against the gasket on the door. Foam rubber or foam plastic sealing strip must not be used.

Doors must have a minimum opening of 100 degrees for equipment access and must be equipped with retainers to hold the door in the open position. The main control compartment door must have a document holder fitted.

Doors with dimensions in excess of 1000 mm high and 450 mm wide must have a broad “U” stiffening channel down the centre of the door for the entire length.

All doors and escutcheons must have a minimum of 2 lift off chrome plated pintle hinges, and those over 1000 mm must have three hinges.

Outdoor Switchboards must be constructed with padlockable outer enclosure access doors for weather protection.

3.23.1. Locking Arrangement

All doors must be held closed with chrome plated 8 mm square quarter twin locks. Doors over 400 mm high must have a stainless steel three point locking system.

All escutcheons must be held closed with two stainless steel acorn head nuts. Escutcheons over 1000 mm high must have three such nuts.

The chosen locking arrangement must be consistent with the DVR.

3.24. Racks and Swing-Out Frames

Equipment mounted on swing-out frames must be accommodated in standard 19 inch racks. Racks carrying circuit cards must be fully accessible front and rear and, if necessary, the racks must be hinged. If hinged racks are employed, they must be sufficiently rigid to prevent deflection when opened out, but stiffeners must not obstruct access to connector pins and wiring. Provision must be made to lock the hinged rack firmly in either the open or closed position.

The rack hinge must be on the opposite side of the cubicle to the door hinge. When hinged racks are used front and rear, no field wiring terminations are permitted in that cubicle. Swing out frames must open at least 180°.

Front mounted edge connectors may not be used on any printed circuit cards or modules mounted on a swing-out frame.

Access to equipment mounted on swing-out frames must not be obstructed by cables, etc. Any swing-out frame must be engineered to allow practical use of extender cards.

Cables which are attached to equipment on swing-out frames must be installed so that they can flex without any detrimental effect.

Cables must be securely attached to both the swing-out panel and the cubicle and must be fully supported on the panel to the point of termination.

A separate earth, other than that which is provided by the hinges, must be provided to earth the swing-out frame(s).

3.25. Ventilation

Ventilation opening must be incorporated as required by the equipment manufacturer (i.e. variable speed drives, DC resistance starters, etc.).

Ventilation openings, where provided, must be vermin proof with non-corrosive material.

All switchboards must have a compliant test certificate or a ventilation design calculation provided as required by AS61439.1. The calculation must demonstrate the maximum temperature inside the panel must not exceed the maximum temperature specified by the switchboard component manufacturers. The ventilation study must include as a minimum:

- Itemised heat loss for each component within the cubicle.
- Maximum temperature rise for the unventilated cabinet.
- Maximum temperature rise for naturally ventilated cabinets.

A protective device may be substituted with a similar device from another manufacturer to that used in the original verification, provided that the power loss and terminal temperature rise of the device, when tested according to its product standard, is the same or lower.

Air intake and exhaust outlets must be provided with mesh screens to prevent vermin ingress and be made with non-corrosive material.

Where forced ventilation is proposed a thermostat must be provided inside the enclosure to control the operation of the ventilation fans and to provide an over temperature warning alarm to the local PLC. The thermostat warning temperature must be set to below the maximum design temperature of the enclosure.

3.26. Earthing

3.26.1. Metal Components

All metallic non-current carrying parts of the switchboard must be bonded together and connected to the earth bar.

3.26.2. Electrical Equipment

All electrical equipment must be provided with an earth termination.

Terminals intended for the termination of earthing conductors must be of proprietary manufacture coloured green and yellow. Painting of terminals is not acceptable

3.26.3. Doors and removable components

Doors, removable panels, racks and bases in enclosures must be provided with a welded M6 thread earth stud and bonded to the frame of the enclosure using flat braided flexible conductors such that the electrical continuity of exposed metal is maintained to the earthing terminal. Reliance on hinges for earth conductivity to doors, etc. is not acceptable and appropriately sized strapping must be used.

Withdrawable parts must be effectively earthed until they are completely isolated with all power and control connections disconnected.

3.26.4. Instrument and Mounted Equipment

All metal cases of instruments, relays, selector switches, etc. must be connected by continuously insulated and flexible earth cable of minimum 4mm^2 to the earth bar. All earthing connections must be arranged so that removal of one component must not affect continuity of the earthing conductor associated with any other component.

3.26.5. Earth Bar Connections

All necessary metals part of panel mounting, channels, gland plates must be bonded to the vertical earth bar and the main earth bar. The earth bar must be colour-coded with green/yellow bands at a maximum interval of 300mm.

All connection to the earth bars must be readily accessible without disturbing external wiring.

3.26.6. Connection to Station Earth

Switchboards must be connected to the main station earth at the nearest point to the equipment location. The

connection must be by insulated copper cable with minimum cross sectional area in accordance with AS 3000. The cable must be appropriately sized to the fault current rating of the largest supply to the Switchboard.

Typically, the connection to station earth will be 120 mm^2 for round cable and 25 x 3 mm for earth straps.

3.27. Segregation

3.27.1. Voltage

The following voltage of circuits must be segregated into separate cables and installations and where practicable run over separate routes or ducts:

- Low voltage power cables (above 50 VAC / 120 VDC and up to 1000 VAC / 1500 VDC);
- Low voltage control cables (above 50 VAC / 120 VDC and up to 1000 VAC / 1500 VDC);
- Extra low voltage power and control cables (below 50 VAC and 120 VDC);
- Signal cables – screened twisted pair;

It is preferred for voltages of the same category (i.e. 240 VAC or 125 VDC power cables) to be grouped together.

Power supply wiring must not be run in the same duct as signal wiring. Internal wiring layout design must ensure maximum separation between power and signal wiring.

In Switchboards where there are more than one DC or Essential AC supply these must be strictly segregated.

Protection A and B supplies must maintain segregation

3.27.2. Category

The following categories of circuits must be segregated into separate cables and where practicable run over separate routes or ducts and must use separate marmusting tiers:

- Protection, alarm, control and indication circuits and unit auxiliary circuits of one generator unit from those of another unit;
- ‘Duplicated AC and DC protection circuits of each unit from each other.
- Circuits from non-unit equipment.

3.28. Termination

3.28.1. Methods of Termination

General

All incoming cables are to be terminated at terminal blocks convenient to the point of entry cables, except main power cables, which must be terminated directly into the first device.

At each point of termination, each conductor/wire must be provided with an indelibly marked identification ferrule of the thread-on type which must be a firm fit over the insulation and must be manufactured from a non-combustible material. Spares must be identified with core and cable numbers. Ferrule numerals must be as shown on the wiring drawings.

Each end of each wire must be finished with a crimped wire lug. The lug used must be suitable for use on the terminal provided. Solid pin or bootlace type lugs must be used in all applications except when the terminal is not designed for such a lug. In this case the terminal manufacturer's recommendation for lug shape type must be met. For a stud terminal which is not designed for a pin lug a ring type lug is required.

All conductor strands must be effectively crimped in the terminal lug. If strands are broken or separated during conductor preparation, the termination must be re-made. Conductor insulation must end well inside the lug insulation.

Where ring type lugs are used the central hole must be within +5% of the stud size.

Supergrip lugs are acceptable and preferred by SHL.

All crimp lugs are to be 'control crimped' with an approved ratchet type crimping tool prior to fitting in the terminal. The crimping tool must be unidirectional, not bidirectional, and the crimps must be applied in the correct direction.

The lugs must be fitted strictly in accordance with the recommended size and in accordance with the manufacturer's instructions and only one conductor must be terminated in each lug.

Specifically designed lugs for two conductors are not preferred, prior approval is required from SHL Engineering for the use of such lugs where there is a justifiable reliability benefit.

It must be possible to check the tightness of all connections, by removing covers if necessary, when the switchboard is completely assembled.

Terminations must be tested for tightness (i.e. via a 'tug' test) to verify that the core is properly connected and is firmly held by the terminal. A regime of re-tightening of terminations should be considered following shipping of switchboards or following a period of in-service operation.

Specific requirements control and signal wiring

Control wiring conductors must be terminated so that there is no exposed live metal at the termination.

Earth screens of control cables must be earthed at a single end of each cable. Refer to Annexure K – Earthing for specific details.

Specific requirements for power cabling

For power wiring and cabling of cross-section 10 mm^2 and larger, bolted-type terminals must be used instead of tunnel-type, unless the equipment (circuit breaker or contactor) has tunnel type terminals. Where lugs are used for connections, suitable full-size bolts must be used. Bolted connections must be made with high-tensile, electroplated steel or phosphor bronze bolts, with a large flat washer and Belleville washer under the bolt head.

Lugs used must be of the full circle compression type and must be solid drawn, high conductivity tinned copper for power cables. Where lug holes are not big enough they must not be enlarged, but copper flags used. Solder lugs must not be used.

Where hand operated, the tools must be of the type which must not release until full compression is applied. Hexagonal crimping dies must be used on all cables of 70 mm^2 cross-section and above Heat shrink sleeve must be applied to lugs which are not of the pre-insulated type and must be of the respective phase colour (electrical tape must not be accepted as a substitute).

3.28.2. Terminals

Creepage and clearance distances at all terminals and terminations must be as per AS 61439.

Terminals for power and control wiring must be of the fully-insulated tunnel-type suitable for offset DIN-rail mounting. Terminals must be suitably sized for the cable cores which they are terminating, with a minimum size of terminal suitable for 6 mm^2 cable unless intended solely for the termination of 0.5 mm^2 signal cable, where the minimum size terminal must be 2.5 mm^2.

It is preferred that terminal strips are mounted vertically.

A minimum of 10 percent (%) spare terminals must be provided in all terminal strips.

Terminals must preferably be manufactured from melamine. Alternative materials must only be used with the approval of SHL.

Terminals must have recessed entry for cables, and have flat pressure-plates. Terminals having V-shaped pressure plates, or clamping screws bearing directly onto the cable strands are not acceptable.

Each terminal connection must take one wire or cable core only. Allowable exceptions are protection relays where multiple connections may be required to form a star point. Where terminal multiplication is required, additional terminals and bridging facilities specifically designed by the terminal manufacturer for this purpose must be used. Any such bridges must be insulated or recessed to prevent accidental contact with live metal.

Where bridging buses used on terminals are of the insulated type they must be premade for the terminal multiplication required. It is not acceptable to cut a longer bridge to achieve the required number, as this leaves an uninsulated surface which permits accidental contact with a live conductor.

Terminals for conductors operating at the same voltage must be grouped together. Separator plates specifically designed by the terminal manufacturer must be used to clearly separate groups of terminals in the same row but operating at different voltages.

Rows of terminals must be mounted with at least 100 mm on all sides and between terminal strips, and must not extend within 75 mm of door apertures, or within 300 mm of the floor of cubicles or other areas adjacent to gland plates for incoming and outgoing cables.

The distance between power cable terminations and gland plates must be:

- up to 25 mm² - 300 mm
- over 25 mm² up to 95 mm² - 350 mm
- over 96 mm² up to 185 mm² - 400 mm
- over 185 mm² - 450 mm.

Control wiring terminals must be positioned to allow normal access without the possibility of contact with live metal. Components adjacent to terminals must also have live parts effectively shrouded. Clear access must be maintained around terminal strips, and no equipment or cabling must be mounted in front of any terminals.

Terminals must be identified by numbers in black lettering on white, consecutively from top to bottom, or left to right. Multiple rows of terminals in the same enclosure must be identified by row and section numbers.

Terminals must be mounted on offset DIN rail (TS35) and fitted with end plates and end stops. Spare mounting rail must be provided in each terminal strip to allow for a minimum increase of 10% in the total number of terminals supplied.

Mounting rails must be mounted 45 degrees to the side of panels to allow front-on view of terminals.

Terminals must be of the following types:

- for AC circuits – feed-through terminals (Allen Bradley 1492-JX, where X is the terminal size);
- for DC circuits – feed-through terminals (Allen Bradley 1492-JX, where X is the terminal size);
- for test links – terminals with shrouded plug (Weidmuller WTL 6/1/STB);
- for signal circuits – knife disconnect feed-through (Allen Bradley 1492-JKD4). If terminals are mounted horizontally they must be mounted so that knife opens so it falls open and away from the terminal;

Other terminal types for specific applications may be used only with prior approval of SHL. Pick-a-back terminals are not acceptable.

Slide link terminals mounted on a vertical rail must be that “closing” of a circuit must move from left to right.

Slide link terminals must be vertically mounted so that “opening” of a circuit must require travel of the slide link from right to left. If terminals are mounted in horizontal rows (not preferred) they must be arranged so that loosening of the link-holding screws will allow the links to fail/fall down to the “closed” position, (i.e. all links should travel upwards to obtain a “circuit open” position).

Test blocks must be provided to enable injection of signals for testing and calibration of all metering and protection circuits and for the purpose of connecting recording and test instruments. Terminals with shorting links must be provided on current transformer secondary circuits. Automatic current transformer shorting must not be employed.

3.29. Design Verification

Design verification process must be established to comply with Section 10 of AS61439.1 covering Construction and Performance. Certificates of test for protective devices and other components in accordance with Australian Standard or another recognised equivalent international standard must be provided.

Verification certificates through assessment, comparison with tested reference design or testing complying with the requirements of table C.1 of AS 61439.1 and as agreed with SHL to be provided in the Design Verification Report (DVR). Design verification test certificates must include as a minimum the following:

- short circuit withstand tests on busbars (main and distribution).
- verification of making and breaking capacity.
- mechanical operation of circuit breakers, residual current devices (RCD) and switches.
- temperature rise tests.
- internal arc fault containment tests to AS61439.1 Appendix ZD (if arc containment switchboard is provided).
- type 2 coordination test between contactors and short circuit protection motor starters.
- Verification of degree of protection of the assembly.

Additionally, test certificates for arc fault containment tests to arcing class C of IEC-TR61641 (preferred) or AS61439.1 Appendix ZD must be provided (if arc containment switchboard is provided).

Type tests for circuit breakers and contactors must be carried out in accordance with the AS or IEC standards.

The Switchboard being supplied must be in no way inferior to the design specimen verified, and as a minimum must be checked for the following

- Busbar ratings must not be less than those tested.
- Busbar supports must be identical in material and mounting method to those tested.
- Busbar support spacings must not be greater than those tested.
- Phase centres must not be less than those tested.
- Creepage and clearance distances must not be less than those tested.

The feeder and motor starting equipment (circuit breakers, switch fuses, contactors, and overloads) must be the same equipment and in the same combination as that used in the design verification.

The test certificates should be held in the name of the company manufacturing or supplying the switchboard and components.

3.29.1. Design Verification Report (DVR)

All switchboards must be accompanied with a Design Verification Report (DVR) signed and approved demonstrating compliance with AS 61439.1. The DVR must be provided at design time and marked up to as-built status with submission of the switchboard's as-built documentation. The DVR must outline in detail how the assessment was undertaken and must provide cross reference to all documents reviewed to make the assessment including design drawings. All third party test certificates must be provided in the DVR.

The DVR must be provided as a standalone document and include the following:

- Short time fault current tests on busbars;
- Temperature rise tests;
- Degree of ingress protection and internal separation of the enclosure;
- Type 2 coordination tests between contactors and short circuit protection motor starters;
- Mechanical operation of circuit breakers and isolators;
- CB making and breaking capacity;
- Enclosure resistance to corrosion;
- Enclosure resistance to UV radiation;

3.30. Inspection and Testing requirements

3.30.1. Routine Test (Routine Verification)

The intent of the Routine Testing is to ensure that the Switchboard has been fabricated in accordance with the Specifications and any other relevant documentation (i.e. drawings and Standards etc), the equipment is complete, functional and ready for transportation.

Procedures for Routine Tests with supporting documentation must be submitted to Snowy Hydro Limited for approval and acceptance. Routine tests will not be conducted unless the test procedures complying with the agreed Inspection and Test Plan have been accepted and approved by Snowy Hydro Limited.

Information on Routine Tests Test results for all assets must be submitted prior to dispatching goods to site.

The Routine tests must comprise all the categories as per section 11 of AS 61439.1:

The switchboard must be inspected and tested prior to dispatch as per section 8.2& 8.3 of AS3000.

Certified test records must be provided immediately after completion of the tests. The test records must clearly describe the details of the tests and the test results.

Equipment must be checked against the Single Line Diagram to ensure that the correct type, rating and number of circuits have been installed and for consistency with test certificates and the switchboard DVR.

3.30.2. Site Acceptance Test

Inspection, site acceptance testing (SAT) and commissioning will be carried out to check the correct installation and prove the operation of each switchboard, in accordance with the Supplier's SAT and commissioning procedures.

The test plan must include but not limited to:

- Verification of the installation work (e.g. check mechanical installation, check electrical installation including all cables, terminations, identification, check external controls and interfaces);
- Insulation resistance tests;
- Earth Loop Impedance tests to each LV cable;
- Polarity test;
- Secondary injection tests;
- Functional test to prove the operation of each item of switchgear;
- Adjust all necessary settings, e.g. relay settings;
- Verify the operation of all (remote) trips, controls and output signals;

The supplier must submit a list of all test records and settings for all parameters associated with the main incomers, outgoing feeders, motor starters, bus couplers and control system in the SAT Report.

3.31. Documentation

At a minimum, the following documentation must be provided with the design and installation of a LV switchboard:

- General arrangements (internal and external)
- Single Line Diagrams
- Schematics
- Termination diagrams
- Installation details
- Cable schedule
- Equipment list and construction notes
- Label list
- AS 61439.1 compliance DVR
- Design report (as required)
- Manuals.

4. Specification Development

The following technical report provides some guidelines to be considered in writing a specification for switchboards.

Low Voltage Switchgear and Controlgear Assemblies: Guide to specifying assemblies (IEC TR 61439-0,Ed. 2 (2013) Mod) is another useful document to assist in writing technical specifications.

5. Spares and Tools

Spares to be provided for the following:

- Commissioning and startup spares;
- A list of spare parts and tools required for 20 years of operation and maintenance;
- Any special tools required for installation or major overhaul/repair;
- Software and programming tool;

Example Typical Technical Schedule as per AS 61439.2 Annex BB (user requirements)

Item	Characteristics	Units	AS/NZS 61439 Reference	Default Arrangement	Options listed in AS/NZS 61439	User Requirement (AC switchboard)
1.0	Electrical system					
1.01	Earthing System		- 5.6 - 8.4.3.1 - 8.4.3.2.3 - 8.6.2 - 10.5 - 11.4	Manufacturer's standard, selected to suit local requirements	- TT - TN-C - TN-C-S - IT - TN-S	TN-C-S
1.02	Nominal Voltage	V AC	- 3.8.9.1 - 5.2.1 - 8.5.3	Local, according to installation conditions	- max 1000VAC - max 1500VDC	415
1.03	Transient Overvoltages		- 5.2.4 - 8.5.3 - 9.1 - Annex G	Determined by the electrical system	- Category I - Category II - Category III - Category IV	Category III
1.04	Temporary Overvoltages	V	- 9.1	Nominal system voltage + 1200V	- None	1265
1.05	Rated Frequency fn	Hz	- 3.8.12 - 5.5 - 8.5.3 - 10.10.2.3 - 10.11.5.4	According to local installation conditions	- DC - 50Hz - 60Hz	50
1.06	Additional onsite testing requirements: wiring, operational performance and function		- 11.10	Manufacturer's standard, according to application	- None	Default and project specific requirements
2.0	Short-circuit withstand capability					
2.01	Prospective short circuit current at supply terminals Icp	kA	- 3.8.7	Determined by the electrical system	- None	Highest of 25kA or the site specific value
2.02	Prospective short circuit current in the neutral	kA	- 10.11.5.3.5	Max 60% of phase values	- None	60% of phase values
2.03	Prospective short circuit current in the protective	kA	- 10.11.5.6	Max 60% of phase values	- None	60% of phase values

	circuit					
2.04	SCPD in the incoming functional unit requirement		- 9.3.2	According to local installation conditions	- Yes - No	Yes
2.05	Coordination of short-circuit protective devices including external short-circuit protective device details		- 9.3.4	According to local installation conditions	- None	Yes, Ref. Drawings
2.06	Data associated with loads likely to contribute to the short-circuit current		- 9.3.2	No Loads likely to make a significant contribution allowed for	- None	yes
3.0	<u>Protection of persons against electric shock in accordance with IEC 60364-4-41</u>					
3.01	Type of protection against electric shock - Basic protection (protection against direct contact		- 8.4.2	Basic Protection	- According to local installation conditions	Basic Protection
3.02	Type of protection against electric shock - Fault protection (protection against indirect contact)		- 8.4.3	According to local installation conditions	- Automatic disconnection of supply - Electrical separation - Total insulation	Automatic disconnection of supply
4.0	<u>Installation environment</u>					
4.01	Location type		- 3.5 - 8.1.4 - 8.2	Manufacturer's standard, according to application	- Indoor - Outdoor	Site specific
4.02	Protection against ingress of solid foreign bodies and ingress of water		- 8.2.2 - 8.2.3	Indoor (enclosed): IP 2X Outdoor (min.): IP 23	- IP00 - IP2X - IP3X - IP4X - IP5X - IP6X	Min IP54 Indoor / Min IP56 Outdoor
4.03	Protection after removal of withdrawable part		8.2.101	Manufacturer’s standard	As for connected position / Reduced protection to manufacturer’ s	

					standard	
4.04	External mechanical impact (IK)		- 8.2.1 - 10.2.6	None	- None	- None
4.05	Resistance to UV radiation (applies for outdoor assemblies only unless specified otherwise)		- 10.2.4	Indoor: N/A Outdoor: Temperature Climate	- None	Site specific
4.06	Resistance to corrosion		- 10.2.2	Normal Indoor/Outdoor arrangement	- None	Normal indoor arrangement
4.07	Ambient air temperature - Lower limit	°C	- 7.1.1	Indoor: -5°C Outdoor: -15°C	- None	-15
4.08	Ambient air temperature - Upper limit	°C	- 7.1.1	40°C	- None	40
4.09	Ambient air temperature - Daily average maximum	°C	- 7.1.1 - 9.2	35°C	- None	35
4.10	Maximum relative humidity	%	- 7.1.1 - 9.2	Indoor: 50% @ 40°C Outdoor: 100% @ 25°C	- None	Site specific
4.11	Pollution degree (of the installation environment)		- 7.1.3	Industrial: 3	- 1 - 2 - 3 - 4	Min 3
4.12	Altitude	m	- 7.1.4	≤ 1000m	- None	< 1000
4.13	EMC environment		- 9.4 - 10.12 - Annex J	A B	- A - B	A
4.14	Special service conditions (e.g. vibration, exceptional condensation, heavy pollution, corrosive environment, strong electric or magnetic fields, fungus, small creatures, explosion hazards, heavy vibration and shocks, earthquakes)		- 7.2 - 8.5.4 - 9.3.3 - Table 7	No special service conditions	- None	None
5.0	Installation method					
5.01	Type		- 3.3 - 5.6	Manufacturer's standard	- Floor standing - Wall	Floor Standing

					mounted	
5.02	Stationary/Movable		- 3.5	Stationary	- Stationary - Movable	Stationary
5.03	Maximum overall dimensions & weight		- 5.6 - 6.2.1	Manufacturer's standard, according to application	- None	Manufacturer to state
5.04	External conductor type(s)		- 8.8	Manufacturer's standard	- Cable -Busbar -Trunking System	Cable
5.05	Direction(s) of external conductors		- 8.8	Manufacturer's standard	- None	Manufacturer's standard
5.06	External conductor material		- 8.8	Copper	- Copper - Aluminium	Copper
5.07	External phase conductor, cross sections & terminations		- 8.8	As defined within the standard	- None	As defined in supplied specifications
5.08	External PE, N, PEN conductors cross sections and terminations		- 8.8	As defined within the standard	- None	As defined in supplied specifications
5.09	Special terminal identification requirements		- 8.8	As defined within the standard	- None	As defined in supplied specifications
6.0	Storage and handling					
6.01	Maximum dimensions and weight of transport units		- 6.2.2 - 10.2.5	Manufacturer's standard	- None	Manufacturer to state
6.02	Methods of transport		- 6.2.2 - 8.1.6	Manufacturer's standard	- None	Crane
6.03	Environmental conditions different from the service conditions		- 7.3	As service conditions	- None	Not Applicable
6.04	Packing Details		- 6.2.2	Manufacturer's standard	- None	Manufacturer to state
7.0	Operating arrangements					
7.01	Access to manually operated devices		- 8.4		- Authorised persons - Ordinary persons	Authorised persons

7.02	Location of manually operated devices		- 8.5.5	Easily Accessible	- None	Easily Accessible
7.03	Isolation of load installation equipment items		- 8.4.2 - 8.4.3.3 - 8.4.6.2	Manufacturer's standard	- Individual - Groups - All	Individual
8.0	Maintenance and upgrade capabilities					
8.01	Requirements related to accessibility in service by ordinary persons; requirement to operate devices or change components while ASSEMBLY is energised		- 8.4.6.1	Basic Protection	- None	Basic Protection
8.02	Requirements related to accessibility for inspection and similar operation		- 8.4.6.2.2	No requirements for accessibility	- None	As per supplied specifications
8.03	Requirements related to accessibility for maintenance in service by authorized persons		- 8.4.6.2.3	No requirements for accessibility	- None	As per supplied specifications
8.04	Requirements related to accessibility for extension in service by authorised persons		- 8.4.6.2.4	No requirements for accessibility	- None	As per supplied specifications
8.05	Method of functional units connection		- 8.5.1 - 8.5.2	Manufacturer's standard	- None	Manufacturer's standard
8.06	Protection against direct contact with hazardous live internal parts during maintenance or upgrade (e.g. functional units, main busbars, distribution busbars)		- 8.4	No requirements for protection during maintenance or upgrade	- None	As per supplied specifications
8.07	Gangways		- 8.4.6.2.101	Basic protection	None	
8.08	Method of functional unit's connection NOTE This refers to the capability of removal and re-insertion of functional units.		- 8.5.101		F fixed connections D disconnect-able connections W withdrawable	WIP ra

					connections	
8.09	Form of separation		- 8.101		Form 1, 2, 3, 4	4
8.10	Capability to test individual operation of the auxiliary circuits relating to specified circuits while the functional unit is isolated		- 3.1.102, - 3.2.102, - 3.2.103, - 8.5.101, - Table 103		None	
9.0	Current carrying capacity					
9.01	Rated current of the ASSEMBLY I_{na} (amps)	A	- 3.8.9.1 - 5.3 - 8.4.3.2.3 - 8.5.3 - 8.8 - 10.10.2 - 10.10.3 - 10.11.5 - Annex E	Manufacturer's standard, according to application	- None	As per drawings
9.02	Rated current of circuits I_{nc} (amps)	A	- 5.3.2	Manufacturer's standard, according to application	- None	As per drawings
9.03	Rated diversity factor		- 5.4 - 10.10.2.3 - Annex E	As defined within the standard	- RDF for groups of circuits - RDF for whole assembly	As defined in project documentation
9.04	Ratio of cross section of the neutral conductor to phase conductors: phase conductors up to and including 16mm^2	%	- 8.6.1	100	- None	100
9.05	Ratio of cross section of the neutral conductor to phase conductors: phase conductors above 16mm^2	%	- 8.6.1	50% (min 16mm^2)	- None	100

10	Requirements for Short Circuit Withstand Capabilities for Arc Fault Contained Switchboard

10.1	Protection against internal	None	AS/ NZS 3000	Mandatory	None	YES

	arcing fault currents Applies to switchboards rated >800A.					
10.2	Guidelines for assemblies intended to provide increased security against the occurrence or the effects of internal arcing fault.	None	ZC	Informative only	Refer ZC6 and ZD	Implement the principles of ZC6 a) and c) in all installations and ZC6 b), d), and e) as required in the functional specification.
10.3	Internal arcing fault tests	None	ZD	Subject to arrangements	Standard or special tests to ZD or IEC TR 61641	Tested to arcing class C of IEC TR 51641
10.4	Selection of components	None	ZE	Manufacturer's standard	None	Manufacturer's standard