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Snowy Technical Standards

SHL-ELE-156 (C)	***Annexure C - Electrical Cubicles and Junction Boxes General Low Voltage Electrical Requirements***

Technical Specialist
Sisira Karunaratne
Electrical Engineer

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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 the requirements for Electrical cubicles and Junction Boxes for low voltage installations.

Electrical cubicles, distribution boards up to 250A and Junction boxes must be designed and constructed conforming to the General Electrical Requirements and this Annexure.

Electrical cubicles complying with this Annexure are generally provided for assemblies of items such as electronic equipment, indicating instruments, control, alarm and protection devices, indicating lights, electrical relays, switchgear and wiring terminations.

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 approval by SHL.

Protection, control and metering equipment for power plants must be housed in separate cubicles.

Electrical cubicles and junction boxes must be designed and constructed such that they can be operated and maintained live by personnel without the need for arc-rated PPE. If this cannot be achieved, then the enclosure must be treated as a switchboard and must comply with the requirements detailed in Annexure B – Low Voltage Switchboards.

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 specification.

All works must comply with the requirements of the most recent releases of the regulations and standards noted herein. In the event of a conflict between different Codes, Standards or Regulations, the highest requirement must apply.

Relevant standards include, but are not limited to:

Standard	**Title**
AS 1307.2	Surge Arrestors - Metal-oxide arresters without gaps for AC systems
AS 1319	Safety signs for the occupational environment
AS 1566	Copper and copper alloys – Rolled flat products
AS 1627	Metal finishing – Preparation and pre-treatment of surfaces

AS 2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings
AS 3000	Wiring rules
AS 3008	Electrical installations – Selection of cables – cables for alternating voltages up to and including 0.6/1 kV – Typical Australian installation conditions
AS 3017	Electrical installations – Verification guidelines
AS 3100	Approval and Test Specification – General requirements for electrical equipment
AS 3111	Approval and Test Specification – for Miniature overcurrent Circuit Breakers
AS 3190	Approval and Test Specification – Residual Current Devices (Current-operated Earth Leakage Devices)
AS 3820	Essential service requirements for electrical equipment
AS 4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
AS 60044	Instrument transformers
AS 60529	Degrees of protection provided by enclosures
AS 60947	Low-Voltage switchgear and controlgear (all parts)
AS 61204.1	Low voltage power supply devices D.C. output – Performance characteristics
AS 61439	Low-Voltage switchgear and controlgear assemblies (all parts)
AS 62026	Low-voltage switchgear and control gear – Controller-device interfaces (all parts)
IEC 60269	Low voltage fuses

2. Safety Requirements

Electrical cubicles and junction boxes must be designed, manufactured and tested in accordance with the safety requirements detailed in the General Electrical Requirements.

3. Technical Requirements

3.1. General

All equipment installed in electrical cubicles and junction boxes 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 cubicle's circuits are fully operational and loaded, doors are closed and ambient temperature is at maximum.

All 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

Electrical cubicles and junction boxes and their associated equipment must be designed for a minimum life duration of 20 years in the environment and for its nominal duty. The equipment must also be suitable for a minimum 1-year normal 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%

3.4. Construction

3.4.1. Materials

Custom made cubicles must be constructed of folded and welded panel quality sheet metał not less than 2.0mm thick for indoor switchboards and 3.0mm thick for outdoor switchboards. Sufficiently robust-off the shelf cubicles may be approved.

Free standing cubicles must have the following minimum and maximum dimensions:

Width minimum of 600mm

Height minimum of 2000mm, maximum of 2200mm

Depth minimum of 650mm, maximum of 800mm

Rittal enclosures are preferred by SHL. For free standing indoor cubicles Rittal Cubicle PS4808.600 (2000 X 800 X 800mm) with plinth 2848.200 and handle (SZ2455.000) are preferred in a protected environment.

Each cubicle must be fitted with a 100mm base frame.

Doors must be hung on robust hinges that allow easy removal of the door. For specially manufactured cubicles, the ``lift-off" type is preferred. All doors must be provided with padlockable lever type handles to actuate the latching mechanism. This mechanism must be of the wedge type to ensure that the dust seal gasket is sufficiently depressed to give an effective seal when the door is closed. For doors in excess of 1200mm height,

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

the latches must engage in at least three points – bottom, centre and top. All doors must have stops to prevent them swinging back and damaging adjacent equipment. The minimum door opening angle must be 120 degrees.

In general, manually operated control devices must be mounted on fixed control panels which can be operated without opening cubicle doors.

A protective door with an appropriately sized full height plexi-glass window must be mounted in front of the cubicle where there are indication LEDs and relay targets that are required to be viewed to operate the plant, otherwise solid doors must be used. The plexi-glass window must allow an unimpeded view of any indication LEDs and relay targets. Equipment must not be fitted to the protective door unless approved by SHL.

Doors and/or any removable covers must be sealed by neoprene covered closed cell foam rubber gaskets. Neither plain plastic nor natural foam rubber must be used. The surface involved in forming the seal must be at least as wide as the gasket material.

Self-tapping screws must not be used for cubicle construction. Each cubicle (excluding control panels) must be fitted with a front and rear door for full cubicle access. All forms of fasteners must be fitted with anti-vibration washers. Where bolts and nuts are used to secure any equipment within the cubicles, the nuts must be captive on the panel or equipment they secure.

Where a cubicle contains fluids under pressure, compartments must be provided to prevent damage to equipment by fluid leakages or discharges.

All components and materials must be free from:

- Asbestos
- Ceramic fibre
- Chlorofluorocarbons
- Polychlorobiphenyls (PCB) and their isomers
- Radioactive material (unless otherwise specified in the project specification).
- Mercury.
- Lead

3.4.2. Degree of protection

Electrical cubicles are susceptible to damage or failure due to moisture and dust ingress and must have a minimum degree of protection rating of IP54 for protected environments and IP56 for external environments to AS 60529.Cubicles must be totally vermin proof.

Cubicles mounted externally must be fitted with an overlapping canopy. The canopy must extend a minimum of 60 mm out from the cubicle.

3.4.3. 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.

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).

3.4.4. Painting

The cubicle to be finished in accordance with Annexure N – Paint and Corrosion.

3.4.5. Heaters

Anti-condensation heaters, 230V AC, complete with thermostat must be provided in electrical cubicles containing control or relay equipment not located in air-conditioned Switchrooms, except where the external electrical cubicle 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 cubicle. The surface temperature of the heaters must not exceed 100^0C. Heaters must be provided with expanded aluminium covers to prevent accidental touching.

All cubicles 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.

3.4.6. Cubicle lighting

20W Fluorescent Luminaires with diffusers or an LED equivalent must be provided to light the inside of each cubicle large enough to be worked inside. Luminaries must be controlled by a fully enclosed door-actuated switch. Where the cubicle with a front and rear door fitted, door-actuated switches must be provided on both doors. Luminaries must be fitted at both the front and the rear side of the cubicle unless it can be demonstrated that one luminaire provides sufficient light.

3.4.7. Socket outlet

Each cubicle large enough to be worked in or that contains an electronic device such as a PLC or a protection relay must have a dedicated double socket special purpose outlet installed for connection to a portable appliance tester. This must be RCD protected. The circuit and switchboard where the circuit originates must be identified on these circuits.

Testing Facility

Provision must be made within the facility to test the earth leakage circuit breaker protective device. Rotary selection switches for connecting the active of each circuit to the SPO's active pin. All associated devices must be fixed in the compartment, not on the escutcheon which can be freely opened away.

3.4.8. Power supply

Power for cubicle heaters and lighting must be obtained from the SHL's Miscellaneous Power and Lighting Boards. Terminals must be separate from control & protection wiring and must have a suitably labelled shroud.

3.4.9. Cooling and Ventilation

Ventilation

All Electrical Cubicles must have a compliant test certificate or ventilation design calculation completed prior to commencing manufacture. The calculation must demonstrate that the maximum temperature inside the panel must not exceed the maximum rating specified by the component's manufacturer.

Ventilation opening must be incorporated as required by the equipment manufacturer.

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

Fans

Naturally cooled equipment is preferred but, where forced air circulation is necessary to ensure that internal temperature remains at least 10^0C below the most critical ambient temperature rating of any component, fans must be provided.

Cooling air fans must not be fitted to cubicle doors.

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 to the local PLC. The thermostat warning temperature must be set to below the maximum design temperature of the enclosure.

Cooling air fans must be readily accessible for maintenance. Fans must be protected to prevent contact by personnel working on any equipment within the cubicle.

Filters

An approved type of washable filter mounted in a robust frame must be used for cooling air filtering.

Wherever filters are placed within any cubicle, they must be readily accessible for maintenance. Filters must be suitably rated to at least the IP rating of the electrical enclosure.

3.4.10. Gland plates

Detachable gland plates of sufficient size and number must be provided for either top or bottom cable entry or both, except that outdoor cubicles must not have top entry. Gland plates for single core cables must be of non-ferrous material. Floor-mounted indoor cubicles may have their bottom entry gland plates substituted by channel-mounted cable clamps for cable support. Where channel-mounted clamps are provided for cable support, alternative methods for prevention of vermin entry, and spread of fire or smoke are required.

3.4.11. Protection against contact of Live parts

All equipment in a cubicle (including terminals, busbars, control devices and meters mounted on the doors) 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.

Escutcheons must be provided over any exposed copper bus. Escutcheons must have a minimum of 2 lift off chrome plated pintle hinges, and those over 1000 mm must have three hinges. All escutcheons must be held closed with two stainless steel acorn head nuts. Escutcheons over 1000 mm high must have three such nuts. The use of non-hinged escutcheons must be approved by SHL.

All equipment in a cubicle 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. This level of protection must be obtained by recessing the live conductors wherever possible rather than by the use of removable barriers. Perspex covers may be used to shroud any exposed low voltage terminals.

Where the terminals or components within a cubicle are predominately at ELV voltage, the protection against unintentional contact to live parts of LV and higher voltage parts in the cubicle must be by enclosures. The enclosure must be labelled warning the voltage enclosed.

Miscellaneous power and lighting functions at greater than ELV voltages within a cubicle must be enclosed to meet the requirements of protection against contact to live parts.

3.4.12. Form of Segregation

Electrical cubicles and distribution boards 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.

3.4.13. Labelling

All equipment within the cubicles must be clearly labelled and labels must be clearly visible after all equipment and wiring is in place, and in its operational state.

The following devices mounted in cubicles must have a unique identification system to avoid incorrect connection or application:

- Modules, cards and card racks.
- Plugs and sockets of connecting and interconnecting cables.
- Power cable termination terminals of different voltage types, and differing voltage levels.
- Relays and their sockets (where there is a group within a cubicle with similar physical appearance but having different applications or coil voltages).
- Switches, circuit breakers and/or fuses must be clearly labelled for circuit and rating and must be logically to reflect the type of supply voltage which they control.

3.4.14. Earthing

Earthing Terminals

Each cubicle must have an earthing terminal of brass or stainless steel connected to its frame. The earthing terminal must be complete with washers and nuts. The nuts must be fitted with a locking device.

The construction of the cubicle frame must be such that the electrical continuity of exposed metal (doors, racks bases etc.) is maintained to the earthing terminal. Reliance on hinges for earth conductivity to doors etc. is not acceptable and appropriate sized strapping must be used.

Earthing Busbar

A copper earth bar 25mm X 3mm must be fitted to each cubicle, running the full internal width at the point of entry of the cables. All parts of the electrical cubicle which are required to be earthed must be effectively connected to the earth bar.

The earth bar must be connected to the cubicle earthing terminal. All metal parts of the electrical panel must be bonded to the earth bar.

The earth bar must be drilled and tapped and fitted with holes spaced at 20mm along the entire length and attached to the frame of the cubicle.

Unearthed DC cubicles do not require an earth bar, a suitable earth stud for equipotential bonding must be provided.

Connection to the Main Earth

The cubicle must be connected to the main station earth at the nearest point to the equipment's location. The connection must be copper of minimum cross sectional area of 70mm^2 (smaller connection may be acceptable for single small enclosures that are radially connected to the station earth).

The connection at the main station earth must be compression connectors or CAD welded.

Instrumentation Earth Bar

An isolated instrument earth bar with 20% spare capacity must be provided in the PLC marshalling terminal compartment. The instrument earth bar must be bonded to the main earth bar with a single 4mm^2 G/Y PVC cable.

3.5. Field Panels

Field panels must be erected strictly in accordance with the manufacturer's installation instructions.

In general, floor mounting panels must be screwed to the floor using masonry anchor bolts.

The bases of all floor mounted panels must be grouted after installation in order that surface irregularities in the concrete floor must be filled.

Where they are wall mounted they must be firmly bolted into position such that the top of the panel is approximately 2 m above floor level unless specified otherwise. The top of adjacent wall mounted units must be aligned.

Unless otherwise shown on the drawings, motor isolators and “start/stop” stations must be installed within 2 m of the respective motor and in a location from which the respective motor is easily identified and the motor is clearly seen.

3.6. Marshalling Boxes and Junction Boxes

If cables are marmusted or terminated external to the cubicles, marshalling boxes and junction boxes (J-boxes) manufactured in accordance with the following requirements must be used.

Marshalling boxes and J-boxes must have a degree of protection of at least IP56 to AS 60529, and be constructed of impact resistant plastic, sheet metal or cast aluminium.

Plastic boxes intended for use in direct sunlight must be ultra-violet resistant.

Where fabricated sheet steel marshalling boxes are used, paint colour and application system must be as specified in Annexure N – Paint and Corrosion.

Covers must be removable or hinged, and must maintain the degree of protection when closed. Covers must have captive fasteners with a maximum of four on smaller boxes and eight on larger boxes.

All marshalling boxes and junction boxes must be adequately sized according to the equipment and the number of terminals contained therein. The minimum clearance required around and between terminal strips to the sides of the box, gland plates, or wiring ducts must be 100mm.

Where applicable, field-mounted instrumentation, such as transmitters or relays, may be located within marshalling boxes, where approved by the SHL. Where electrical switching equipment is also contained within marshalling boxes, the boxes must be suitably ventilated to prevent ozone and temperature build-up, without reduction in the degree of protection of the enclosure.

3.7. Design

3.7.1. Protection related devices

General

Miniature Circuit Breakers must be used for the purpose of circuit isolation and protection except as follows.

Fuses must only be used for fault limiting and when required for isolation of secondary feeds to equipment to achieve a visible break. (eg VT secondaries and transformers)

Fuses may also be used for further discrimination in ELV control circuits where the overall circuit is protected by Miniature CB.

Isolating switches may be used for providing a system of isolating circuits where the protection function for the circuits must be provided by a separate device.

Circuit protection isolation devices - If mounted horizontally, the live side wiring must terminate at the top. If mounted vertically, the live side wiring must terminate at the left-hand side.

Labelling of Circuit Isolation and Protection Devices (Low Voltage)

Labels must be provided adjacent to Circuit Isolation and Protection Devices bases. These labels must contain the following information as a minimum:

- device number
- circuit description
- phase identification (for 2 or 3 phase circuits), active/neutral
- identification (for single phase circuits) or positive/negative identification (for DC circuits)
- fuse rating (in accordance with the approved drawings) (fuse only)
- any other information which may assist in the unambiguous identification, isolation or replacement of the fuses.

Where distribution boards are provided, the following requirements must apply in addition to those above:

- each phase must be clearly marked;
- each isolation/protective device must be uniquely numbered;
- A circuit identification schedule must be provided in a protective pocket located on the inside of the fuse-board enclosure door, with circuit descriptions typed or neatly written by the Contractor. The circuit identification schedule must be a registered drawing.

Identification of Circuit Isolation and Protection Devices (Low Voltage)

In circuit diagrams and wiring diagrams, all circuit Isolation and protection Devices must be designated by an appropriate letter together with a serial number. Each circuit isolation and protection device must have a unique designation number for that cubicle. In addition, it is preferable that each circuit isolation and protection device has a unique designation number for a system (circuit diagram).

The circuit isolation and protection devices in cubicles must be located to aid the visibility of isolation status. They must be grouped and arranged logically to provide clarity on the circuits isolated. In general, main Isolation devices must be at the top with minor isolations lower in the panel.

3.7.2. Future capacity

Electrical enclosures, marshalling boxes and J-boxes incorporate 20% additional spare capacity both in terms of space for expansion and thermal load rating.

Sufficient terminals must be provided in marshalling boxes and J-boxes for the termination of all the cores for cables entering the box. This includes all spare cores. Terminals for spare cores are not to be included as part of the 20% additional spare capacity.

3.7.3. Control Voltage

Control voltage must be as per project specification.

3.7.4. Equipment clearance

Electrical enclosures, marshalling boxes and J-boxes must be designed and installed so that the clearance requirements are met in accordance with AS 3000.

3.7.5. Equipment mounting

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

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

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

Self-tapping screws must not be used for equipment mounting. Where nuts and bolts are used and nuts are not readily accessible, Nutsert fasteners or approved equivalents must be used. Anti-vibration washers must always be used.

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

3.7.6. Voltage segregation

Voltages in excess of ELV within cubicles must be shrouded to prevent inadvertent contact with live metal by personnel, and be physically separated from all other terminals and labelled.

3.8. Wiring

3.8.1. 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 mm2 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 mm2)

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 minimum size of 2.5 mm2.

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.

Function	**Colour**	**Abbreviation**
Extra Low Voltage (except CT & VT circuits)	Grey	GY
DC above ELV (i.e.>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 signaling. (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).

3.8.2. Wiring Methods

General

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 tie. 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 50mm 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.

Wiring between terminals must be point-to-point and free from wire splicing and T connections. The routing of wireways must be such that unused cubicle areas are kept free from wiring to facilitate the installation of future equipment.

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.

Control cables must be dedicated to one unit of plant and contain one voltage group. Power and instrument cables must be segregated in accordance with BS 6739. Internal wiring layout design must ensure maximum separation between power and signal wiring.

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.

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.

3.8.3. 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 – Low Voltage 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 spring locking 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).

3.8.4. 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 WTL6/1/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 travel 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.

3.9. Cable entry

Electrical cubicles in protected environments can be either top or bottom cable entry. All outdoor cubicles, marshalling boxes and J-boxes must be bottom entry.

3.10. Installation

To allow site handling and installation, each cubicle must be constructed as a single unit, with the facility for final installation as a group of cubicles. This requirement includes the provision of individual cubicle side panels and lifting attachments.

No equipment or accessory must be mounted on building cladding unless otherwise shown on the drawings and approved on site.

Where required, paintwork must be touched up after the equipment has been installed.

All mounting plates and brackets must be free of burrs and sharp edges and must have adequate space to attach equipment identification labels.

Cables, cable ladders, brackets, poles and fittings must be kept clear of, and supported independently of, stairs and platform handrails. A clearance of 100 mm must be maintained from all top rails of handrails.

All marshalling boxes and J-boxes must be fitted with designation labels. Where the designation label is fitted to a removable cover, a label must also be fitted to the fixed section of the box.

Example Technical Schedule as per AS 61439.2 Annex BB

Item	Characteristics	Units	AS/NZS 61439 Reference	Default Arrangement	Options listed in AS/NZS 61439	User Requirement
1.0	Electrical system					
1.01	Earthing System		- 5.2	Manufacturer's standard, selected to suit local requirements	- TT - TN-C - TN-C-S - IT - TN-S	TN-C
1.02	Nominal Voltage	V AC	- 5.3	Local, according to installation conditions	- max 1000VAC - max 1500VDC	400

1.03	Transient Overvoltage		- 5.4, - 5.5	Determined by the electrical system	- Category I - Category II - Category III - Category IV	Category III
1.04	Temporary Overvoltage	V	- 5.5	Nominal system voltage + 1200V	- None	1265
1.05	Rated Frequency fn	Hz	- 5.6	According to local installation conditions	- DC - 50Hz - 60Hz	50
1.06	Additional on site testing requirements: wiring, operational performance and function		- 5.7	Manufacturer's standard, according to application	- None	
2.0	Short-circuit withstand capability					
2.01	Prospective short circuit current at supply terminals Icp	kA	- 6.2	Determined by the electrical system	- None	25
2.02	Prospective short circuit current in the neutral	kA	- 6.3	Max 60% of phase values	- None	60% of phase values
2.03	Prospective short circuit current in the protective circuit	kA	- 6.4	Max 60% of phase values	- None	60% of phase values
2.04	SCPD in the incoming functional unit requirement		- 6.5	According to local installation conditions	- Yes - No	Yes
2.05	Coordination of short-circuit protective devices including external short-circuit protective device details		- 6.6	According to local installation conditions	- None	Yes, Ref. Drawings
2.06	Data associated with loads likely to contribute to the short-circuit current		- 6.7	No Loads likely to make a significant contribution allowed for	- None	Not applicable
3.0	Protection of persons against electric shock in accordance with IEC 60364-4-41					
3.01	Type of protection against electric shock -		- 7.2	Basic Protection	- According to local	Basic Protection

	Basic protection (protection against direct contact				installation conditions	
3.02	Type of protection against electric shock - Fault protection (protection against indirect contact)		- 7.3	According to local installation conditions	- Automatic disconnection of supply - Electrical separation - Total insulation	Automatic disconnection of supply
4.00	Installation environment					
4.01	Location type		- 8.2	Manufacturer's standard, according to application	- Indoor - Outdoor	Outdoor/ Indoor
4.02	Protection against ingress of solid foreign bodies and ingress of water		- 8.3	Indoor (enclosed): IP 2X Outdoor (min.): IP 23	- IP00 - IP2X - IP3X - IP4X - IP5X - IP6X	IP56/ IP 54
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)		- 8.4	None	- None	- None
4.05	Resistance to UV radiation (applies for outdoor assemblies only unless specified otherwise)		- 8.5	Indoor: N/A Outdoor: Temperature Climate	- None	
4.06	Resistance to corrosion		- 8.6	Normal Indoor/Outdoor arrangement	- None	Normal indoor arrangement
4.07	Ambient air temperature - Lower limit	°C	- 8.7	Indoor: -5°C Outdoor: -15°C	- None	-15
4.08	Ambient air temperature - Upper limit	°C	- 8.7	40°C	- None	40

4.09	Ambient air temperature - Daily average maximum	°C	- 8.7	35°C	- None	35
4.10	Maximum relative humidity	%	- 8.8	Indoor: 50% @ 40°C Outdoor: 100% @ 25°C	- None	100
4.11	Pollution degree (of the installation environment)		- 8.9	Industrial: 3	- 1 - 2 - 3 - 4	1
4.12	Altitude	m	- 8.10	≤ 1000m	- None	< 1000
4.13	EMC environment		- 8.11	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)		- 8.12	No special service conditions	- None	None
5.0	Installation method					
5.01	Type		- 9.2	Manufacturer's standard	- Floor standing - Wall mounted	Floor Standing
5.02	Stationary/Movable		- 9.3	Stationary	- Stationary - Movable	Stationary
5.03	Maximum overall dimensions & weight		- 9.4	Manufacturer's standard, according to application	- None	Manufacturer to state
5.04	External conductor type(s)		- 9.5	Manufacturer's standard	- Cable - Busbar Trunking System	Cable
5.05	Direction(s) of external conductors		- 9.6	Manufacturer's standard	- None	Manufacturer's standard

5.06	External conductor material		- 9.7	Copper	- Copper - Aluminium	Copper
5.07	External phase conductor, cross sections & terminations		- 9.8	As defined within the standard	- None	As defined in supplied specifications
5.08	External PE, N, PEN conductors cross sections and terminations		- 9.9	As defined within the standard	- None	As defined in supplied specifications
5.09	Special terminal identification requirements		- 9.10	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		- 10.2	Manufacturer's standard	- None	Manufacturer to state
6.02	Methods of transport		- 10.3	Manufacturer's standard	- None	Crane
6.03	Environmental conditions different from the service conditions		- 10.4	As service conditions	- None	Not Applicable
6.04	Packing Details		- 10.5	Manufacturer's standard	- None	Manufacturer to state
7.0	Operating arrangements					
7.01	Access to manually operated devices		- 11.2		- Authorised persons - Ordinary persons	Authorised persons
7.02	Location of manually operated devices		- 11.2	Easily Accessible	- None	Easily Accessible
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		- 12.2	Basic Protection	- None	Basic Protection

8.02	Requirements related to accessibility for inspection and similar operation		- 12.2	No requirements for accessibility	- None	As per supplied specifications
8.03	Requirements related to accessibility for maintenance in service by authorized persons		- 12.3	No requirements for accessibility	- None	As per supplied specifications
8.04	Requirements related to accessibility for extension in service by authorised persons		- 12.4	No requirements for accessibility	- None	As per supplied specifications
8.05	Method of functional units connection		- 12.6	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)		- 12.5	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 reinsertion of functional units.		8.5.101		F fixed connections. D disconnect-able connections W withdrawable connections	W
8.09	Form of separation		8.101		Form 1, 2, 3, 4	5
8.10	Capability to test individual operation of 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 3		None	
9.0	Current carrying capacity					
9.01	Rated current of the	A	- 13.2	Manufacturer's	- None	As per

	ASSEMBLY			standard, according to application		drawings
9.02	Rated current of circuits	A	- 13.3	Manufacturer's standard, according to application	- None	As per drawings
9.03	Rated diversity factor		- 13.4	As defined within the standard	- RDF for groups of circuits - RDF for whole assembly	
9.04	Ratio of cross section of the neutral conductor to phase conductors: phase conductors up to and including 16mm2	%	- 13.5.2	100	- None	100
9.05	Ratio of cross section of the neutral conductor to phase conductors: phase conductors above 16mm2	%	- 13.5.3	50% (min 16mm2)	- None	100