HV Switchgear and Controlgear Standard (up to 33kV)

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1. Executive Summary

This standard defines the minimum requirements for the design, materials, fabrication, testing and packaging ready for shipment to site of HV switchgear and controlgear up to 33kV associated with all new and upgraded Snowy Hydro Limited (Snowy Hydro) installations.

The primary outcomes of this standard are to achieve a clear definition of HV switchgear requirements in consideration with the following key areas:

- Design and construction of the switchgear to provide safe, reliable and economical service.
- Ensure compliance with Australian and IEC standards as applicable to the switchgear and switchboards.
- Ability to integrate into Snowy Hydro's existing HV systems infrastructure.

2. Scope

The intent of the standard is to classify all new and upgraded HV (up to 33kV) switchgear assets to be installed within Snowy Hydro. The existing HV infrastructure within the Snowy Hydro network was reviewed and it was identified that the equipment can be classified into the following areas.

- Primary switchgear applications
    - Switchboards and switchgear installations near power generating assets (hydro, diesel and gas generation)
    - Installations with typically higher fault levels
- Secondary switchgear applications
    - Switchboards and switchgear installations for reticulated and auxiliary power distribution
    - Installations located further downstream from generating assets with lower fault levels
- Distribution applications
    - Ring main units installed standalone or integrated with transformers, typically within a kiosk substation
- Overhead equipment
    - Reclosers, air break switches and drop out fuses equipment installed between an overhead to ground equipment transition

This technical standard specification must be read in conjunction with the associated project specification, drawings and any documents annexed to the project specification. The use of this specification will require an established design of the HV system, which must provide all the relevant design information not covered in this specification to enable the manufacture of the HV switchboards, RMUs and overhead switchgear.

Excluded from this standard is the following:

- Transformers and kiosk substations – this is to be specified in a separate standard. This standard only covers the HV switchgear that may be installed within a kiosk substation.

- Pre-fabricated transportable switchrooms – This standard only specifies the requirements for the HV switchgear installed within the room. Refer to Snowy Hydro's LV standard SHL-ELE-156 Appendix A for the switchroom specifications and requirements.

2.1. Applicable Standards

All electrical works must comply with current laws and regulations, and with the relevant Australian Standards and Codes including annexures that are current at the date when the works are undertaken, or to the extent that there is no conflict, then with the relevant international Standards and Codes. Where a Standard or Code is named in this document, it must take precedence over any other Standards or Codes.

2.1.1. Priority of Standards

In the event of a conflict between Standards or Codes, the standards appearing first in the following list must take precedence over those later in the list:

- Statutory regulations in force in relevant State;
- Standards and Codes named in this document or the appendices;
- Australian Codes and Standards/International Standards and Codes

2.1.2. Acts and Regulations

<u>New South Wales Acts and Regulations</u>

Legislative requirements to be complied with include, but are not limited to:

- Electricity Supply Act 1995
- Electricity Supply (General) Regulation 2018
- Service and Installation Rules 2006
- Environmentally Hazardous Chemicals Act 1985
- Work Health and Safety Act 2011
- National Electricity Act 1997
- Electricity (Consumer Safety) Act 2017
- Work Health and Safety Regulation 2017
- Building and Development Certifiers Act 2018

<u>Victoria Acts and Regulations</u>

Legislative requirements to be complied with include, but are not limited to:

- Environment Protection (Prescribed Waste) Regulations 1998
- Electricity Safety Act 1998
- Occupational Health and Safety Act 2004 and Occupational Health and Safety Regulations 2017
- Electrical Safety (Installations) Regulations 1999
- Electrical Safety (Network Assets) Regulations 2009
- National Electricity Act 1997 and National Electricity Act 2005
- Energy Safe Victoria Act 2005

- Electrical safety (General) regulations 2019
- Vic Compliance Codes and codes of practice
- WorkSafe Victoria
- Professional Engineers Registration Act 2019

South Australia Acts and Regulations

Legislative requirements to be complied with include, but are not limited to:

- Electrical Act (1996)
- Electricity (General) Regulations 2012
- Occupational Health, Safety and Welfare (SafeWorkSA) Amendment Act 2005
- Work, Health and Safety Regulations 2012
- Work Health and Safety Act 2012 (SA)
- Environment Protection Act 1993
- Plumbers, Gas Fitters and Electricians Act 1995
- SA Codes of Practice
- Development Act 1993
- Professional Engineers Regulation 2019

Queensland Acts and Regulations

For design works undertaken from Queensland based companies or engineers, legislative requirements to be complied with include, but are not limited to:

- Professional Engineers Act 2002
- Professional Engineers Regulation 2019

2.1.3. Standards

All equipment must comply with all relevant sections of this specification and, except where otherwise specified herein, must conform to the relevant Australian Standards (AS) or otherwise where lacking such publications, of the International Electrotechnical Commission (IEC).

Standard	**Description**
AS 1033.1	High voltage fuses - Expulsion type (for rated voltages exceeding 1000V)
AS 1307.2	Surge arresters - Part 2: Metal-oxide surge arresters without gaps for a.c. systems
AS 1319	Safety Signs for the Occupational Environment
AS 1627.4	Code of Practice for the Preparation and Pre-Treatment of Metal Surfaces prior to Protective Coating
AS 1768	Lightning Protection
AS 1882	Earth and Bonding Clamps

AS 2067	Substations and high voltage installations exceeding 1 kV a.c.
AS/NZS 3000	Australian/New Zealand Wiring Rules
AS 60265.1	High Voltage Switches – Switches rated for voltages above 1kV and less than 52kV.
AS 60529	Degrees of protection provided by enclosures (IP Code)
AS/NZS 60137	Insulated bushings for alternative voltages above 1kV
AS 61869.2	Instrument transformers – Additional Requirements for current transformers
AS 61869.3	Instrument transformers – Additional Requirements for inductive voltage transformers
AS 61439.2	Low voltage switchgear and controlgear assemblies
AS 62271.1	High voltage switchgear and controlgear common specifications
AS 62271.100	Part 100: High-voltage alternating current circuit-breakers
AS 62271.102	Part 102: Alternating disconnectors and earthing switches
AS 62271.103	Part 103: High voltage Switches for rated voltages above 1 kV and less than 52 kV
AS 62271.105	Part 105: Alternating current switch-fuse combinations
AS 62271.106	Part 106: High voltage alternating current contactors and contactor based motor starters
AS 62271.200	Part 200: AC metal-enclosed switchgear and controlgear for rated voltage above 1 kV up to and including 52 kV
AS 62271.201	Part 201: AC insulation-enclosed switchgear and controlgear for rated voltages above 1kV and up to and including 52kV
AS 62271.202	Part 202: High voltage / Low voltage prefabricated substations
IEC 60051	Direct acting indicating analogue electrical measuring instruments and accessories
IEC 60071	Insulation co-ordination
IEC 60255	Measuring relays and protection equipment
IEC 61010	Safety requirements for electrical equipment
ENA DOC 001	National Electricity Network Safety Code

3. Definitions

3.1. Specification Guidance Table

A template of a HV switchgear specification guidance table is attached in Appendix A to summarise key requirements for the Snowy Hydro's various switchgear applications. An instance of this specification table is to be prepared by the Snowy Hydro project engineer for each package to be procured and must be completed by the prospective vendors during the tender process for evaluation by Snowy Hydro.

3.2. Abbreviations

Word and/or picture	**Definition**
AC	Alternating Current
ACB	Air Circuit Breaker
ACR	Automatic Circuit Recloser
AFLR	Arc Fault Rating - All Sided Protection for Switchboards / Switchgear (Front, Lateral, Rear) as per AS 62271-200
AIS	Air Insulated Switchgear
AS	Australian Standard
CB	Circuit Breaker
CT	Current Transformer
DC	Direct Current
FAT	Factory Acceptance Test
GIS	Gas Insulated Switchgear
HDPE	High Density Polyethylene
HSE	Health, Safety and Environment
HV	High Voltage
IEC	International Electro-technical Commission
IED	Intelligent Electrical Device
IP	Ingress Protection
LV	Low Voltage

NC	Normally Closed
NO	Normally Open
OEM	Original Equipment Manufacturer
PF	Power Factor
PVC	Polyvinyl chloride plastic
RMU	Ring Main Unit
SCADA	Supervisory Control and Data Acquisition
SEF	Sensitive Earth Fault
SF6	Sulphur Hexafluoride
Snowy Hydro	Snowy Hydro Limited
SLD	Single Line Diagram
VCB	Vacuum Circuit Breaker
VT	Voltage Transformer
XLPE	Cross-Linked Polyethylene

4. General Equipment Requirements

4.1. Safety

All designs must take adequate measures to protect the safety of maintenance and operation personnel and the general public. External doors to all equipment must be lockable to restrict unauthorised access in addition to requirements for internal equipment to be lockable listed throughout this document.

All electrical design and installation works undertaken for any project must be carried out with the greatest regard and attention to safety. The suppliers must comply with all the safety requirements of relevant Standards and Acts listed in this document.

4.2. Design Life

The HV switchgear and control gear assemblies must have a design lifetime of at least 25 years, under the service conditions specified and maintained according to the Supplier's recommendation.

Designs must incorporate the appropriate techniques and technology, in conjunction with the selection of appropriate equipment to minimise the life cycle costs whilst satisfying the operation and maintenance requirements.

4.3. Reliability

All switchgear designs must have a proven track record for reliable performance to ensure minimal disruptions to Snowy Hydro's network. All equipment must be designed and supplied such that a failure of a single item or a fault in a particular area of an installation is confined to the associated part of the installation and does not affect the continuous operation of the remaining parts of the installation, where possible.

Evidence must be supplied with the tender showing equivalent installations in other industrial environments and statistical data such as mean time between failures and failure mode and effect analysis. Where this is not possible, intensive reliability testing must be performed at the manufacturer's premises and must be in addition to normal type testing requirements referenced in section 8.1.

4.4. Service Conditions

Environmental conditions and any specific design, installation, operation or maintenance criteria for particular works of any specific project (not included in this specification), such as availability of space, capacitor bank connections and ratings, power transformer connections and ratings, layout arrangement, cabling and interface connections, will be stated in the Snowy Hydro project specifications.

4.4.1. Site Conditions

All switchgear under 1000m altitude must be designed for operation under "normal service conditions" stipulated in Clause 2.1 of AS 62271.1 for normal service with the following exceptions:

- The ambient air temperature range must be between -10˚C and +40˚C, and
- The relative humidity must be between 5% to 100%.

Where any site conditions differ from the conditions specified above, such as altitudes above 1000 m, the design and manufacture of the switchgear must be compliant with Clause 2.2 of AS 62271.1 "Special service conditions".

4.5. Network Voltage Levels

The following table defines generic voltage parameters found throughout Snowy Hydro's power network. In general, all equipment must be designed for the voltage to vary by up to -6% to +10% of the nominal voltage, and up to ±5% frequency variation.

Table 1 Snowy Hydro Network Voltages

High Voltage Supplies	3.3kV AC, 3 phase, 50 Hz 6.6kV AC, 3 phase, 50 Hz 11kV AC, 3 phase, 50 Hz 33kV AC, 3 phase, 50 Hz
Low Voltage Supply	415V AC, 3 phase, 50 Hz 240V AC Single phase, 50 Hz
Protection, Control, Intertrips & tripping supply	110 VDC, or the station DC voltage (new installation preference) 48 VDC (existing sites only), or 120 VDC (existing sites only), or 220 VDC (existing sites only), or 250 VDC (existing sites only)
Signals and PLC controls	24 VDC

4.6. Equipment Insulation Ratings

All HV switchboards and switchgear must have minimum ratings shown in the table below. Note that the ratings shown are the minimum rating, this rating can be changed to suit specific project requirements in accordance with Snowy Hydro project specifications.

Table 2 Minimum Switchgear Requirements

Description	Unit	Requirement				
Norminal System Voltage	kV	3.3	6.6	11	22	33
Rated Equipment Voltage	kV	3.6	7.2	12	24	36
Power Frequency Withstand Voltage	kV_{rms}	10	20	28	50	70
Lightning Impulse Withstand Voltage	kV_{peak}	40	60	95	125	170
Minimum Fault Current Withstand	kA-s	12.5	16	20	25	31.5
Rating Fault Current Withstand Duration	s	1				

4.7. Tagging and Labelling

Each piece of equipment must be fitted with either a traffolyte or a stainless steel engraved nameplate with clear identification and title and must be clear and legible. The following table stipulates the minimum labelling requirements for each piece of equipment.

Table 3 Minimum Labelling Requirements

Equipment	Label Requirements
Switchboard	Switchboard Identifier Switchboard Description
Compartment / Panel Door	Equipment Identifier/Number Equipment Description (i.e. Incomer, Feeder)
Circuit Breakers, Isolators, Fuses	Equipment Identifier Circuit Rating
Relays, Instruments, Pushbuttons, Switches	Equipment function Position Indication
CTs / VTs	Rating and ratio CT/VT Class CT/VT Burden Knee Point Voltage

Duplicate labels must be provided for CTs and VTs to be affixed to a readily viewable position such as the ELV or control cubicles of the switchgear.

In locations where dangerous situations could inadvertently be created, warning sign(s) or caution notice(s) should be installed, identifying the danger point(s). This should be either in a compartment or on the outside of an assembly.

'Danger – High Voltage' labels must have white lettering on a red background and be compliant with Snowy Hydro's High Voltage Danger Sign Requirement Standard SHL-GEN-131. These must be affixed to the front of any removable panel which contains high voltage equipment.

4.8. Accessibility

All installations are to provide suitable and adequate facilities to allow ease of operation, maintenance and fault finding. All operational equipment must be accessible and operable from ground level without the use of ladders or platforms. All local equipment operations must be available with doors closed. Operated items such as handles, switches, instruments or relays must not be above 2000mm or below 500mm above ground level.

4.9. Interchangeability

The installations are to be designed to maximize the interchangeability of components and assemblies as far as practical to improve flexibility and reduce the spare parts inventory.

4.10. Design Considerations

For the design of new HV installations or modification of existing HV installations, the expected design requirements would be a minimum of the following:

- Load calculations,
- Protection coordination studies,
- Cable sizing studies,
- Volt drop calculations,
- Short circuit determination,
- Arc flash assessment,
- CT selection calculations (including knee point voltage),
- Any other relevant studies highlighted by the project scope documents.

All power systems modelling should be done using the latest available version of Power Factory unless approved otherwise by Snowy Hydro.

5. Switchgear Specifications

Snowy Hydro's HV infrastructure (up to 33kV) has been categorized into four areas – primary switchgear, secondary switchgear, ring main units, and overhead switchgear. This section must specify the minimum requirements of switchgear to be installed in each category. Each section specifying a category contains all the required content such that each category may be read independently of all others.

The key areas of each category are summarised below.

- Primary Switchgear – Refer to Section 5.1
  Highest level of integrity switchgear, intended to be installed close to the generation source with higher fault levels and/or high arc fault incident energies (PPE category 2 or above). Some higher-level features included within this category:
  - All switchgear must be withdrawable,
  - Additional redundancy features (refer to Section 5.1.11),
  - Additional protection measures such as busbar differential protection,
  - Additional arc flash protection (refer to Section 5.1.10), and
  - All circuits must have circuit breakers with IEDs to achieve higher levels protection.
  - DC control and auxiliary circuits must be supplied from a charger/rectifier with battery backup
- Secondary Switchgear – Refer to Section 5.2
  Intended to be installed further from the generation source with lower fault levels, with less requirements than primary switchgear above. Less stringent features include:
  - Switchgear may be fixed or withdrawable,
  - Only IAC classification required for Arc flash protection (refer to Section 5.2.10), and
  - Additional switchgear options available to select such as isolators & fuses
- Ring Main Units – Refer to Section 5.3
  Intended to be installed before the final power distribution in the network or in remote areas where it is typically installed in a kiosk. This category includes:
  - Switchgear must be fixed (non-withdrawable)
  - Considerations for remote installations where communications or auxiliary power is unavailable
- Overhead Switchgear – Refer to Section 5.4
  - Standalone equipment intended to be installed in the overhead to ground equipment transition.

5.1. Primary Switchgear

Primary switchgear must be installed within a metal-clad switchboard in an indoor environment. The switchboard must be free-standing and comprise of individual switchgear panels that are suitably constructed to accommodate all equipment referenced in this standard. The switchboard must be readily extendable at either end - the busbars must be pre-drilled at both ends for this purpose.

All required IEDs and control equipment is to be installed in a control cabinet which is separate to the HV switchboard unless otherwise approved by Snowy Hydro. The cabinet must be installed outside the arc flash boundary of the HV switchboard with sufficient room for operation. The exact location must be approved by Snowy Hydro.

5.1.1. Panel Types

All panels must be modular within the switchboard to provide segregation between the HV compartment and LV compartment, however the busbar compartment may be continuous. Each compartment partition must be earthed. A mimic diagram must be displayed on the front of the panel to show clear indication of the physical connections within the panel.

The switchboard should consist of the following compartments:

- Busbar compartment
- Switchgear compartment
- Bus-Tie compartment
- Joggle zone compartment (if applicable)
- Cable termination compartment, including:
    - Current transformers
    - Voltage transformers (if applicable)
- Bus voltage transformers compartment (if applicable)
- LV compartment
- Control equipment cabinet incorporating all specified IEDs, separate from the HV switchboard.

Switchgear panels must comprise of circuit breakers and/or earth switches and may require current transformers (CTs) or voltage transformers (VTs) installed in adjacent panels depending on the switchgear application. All primary switchgear must have bus differential protection installed with associated CTs installed in relevant locations.

- Generation Incomers must include a minimum of:
    - Circuit breaker panel including an earth switch on the cable side
    - CTs for bus differential protection
    - Additional CTs dependant on the protection and metering application
    - Cable VTs located in the cable compartment
    - Adjacent Bus VT
- Motor Feeders must include a minimum of:
    - Circuit breaker panel or motor starter panel including an earth switch on the cable side
    - CTs for bus differential protection (installed in the cable compartment)

    - Additional CTs & VTs located in the cable compartment (dependant on the protection application)
- Bus-ties must include a minimum of:
    - Circuit breaker panel
    - Bus differential CTs
    - Separate earthing switches on each HV bus
- Other Circuit Feeders (e.g. transformer feeders or distribution network feeders) must include a minimum of:
    - Circuit breaker panel including an earth switch on the cable side
    - CTs for bus differential protection
    - Additional CTs dependant on the protection application
- Miscellaneous Panels (e.g. bus risers, metering panels, joggle zones) must contain a minimum of:
    - CTs / VTs within panel as required dependant on metering or protection application

Specific details of the switchgear and the number and location of CTs and/or VTs will be detailed on the project documentation. The physical installation requirements of the CTs and VTs is discussed in Section 6.7; for all other specifications of the CTs and VTs refer to Snowy Hydro's protection standard SHL-ELE-102.

By default, all primary switchgear must be withdrawable, however switchgear must be assessed on a case-by-case basis to the application being considered – some switchgear may not require rack in/out functionality and this will be stated on project documentation.

Withdrawable switchgear must have the following requirements:

- Connection to and isolation onto the bus should be by means of suitable contacts mounted on robust insulators. Means must be provided to ensure accurate alignment of the trucks and contacts.
- Trucks should be horizontally withdrawable and must be fitted with wheels to allow for easier removal for inspection and maintenance. A trolley must be provided for all sized panels within the switchboard.
- The racking mechanism must be suitable for remote operation.
- Provide indication for clear identification of the position of the switchgear truck, e.g. racked in, earthing position, racked out (isolated).
- Any metallic parts must remain connected to earth in the test and disconnected positions and in any intermediate position.

5.1.2. Circuit Breakers

The circuit breakers must be factory-assembled, 3 phase, motorised spring charged, and capable of manual and remote operation. Circuit breakers must be either vacuum or SF6 insulated types and must fully comply with AS 62271.100.

Circuit breakers must be located adjacent to each other on a common busbar. The switchgear must be suitable for operation at the voltage as required and must be rated for the specified making and breaking short circuit currents as referenced in Section 4.6. The circuit breaker must also be capable of supplying the inrush current of transformers or motors if applicable. The

switching duty of circuit breakers must be appropriate for the intended frequency of operation of the circuit.

All circuit breakers, at a minimum, must be equipped with the following features:

- Motorised spring charged closing device with anti-pumping relay
- Stored energy spring mechanism for motor charging and emergency manual operation
- Mechanical push buttons for closing and opening, with padlockable covers to prevent unauthorised operation
- Mechanical visual indicators for switch position and mechanism position
- Mechanical counter
- Auxiliary signalling contacts
- Spring charge remote indications
- Voltage presence indicators
- Lockable in the open position by a padlock
- Trip free operation
- Capability to connect to a remote panel for additional controls

The circuit breaker must have a mechanical endurance rating of class M2 as defined in AS 62271.100. A contact wear indicator must be provided with the recommended replacement point clearly marked, and capable of being easily read or measured during maintenance checks. The contacts of the interrupter must be held open by a positive fail-safe device.

Trip circuit supervision must be provided for each trip circuit (inclusive of all wiring, the resistor and indication) which will monitor the trip circuit supply, trip coil and the other elements in each of the trip circuits for both when the circuit breaker is open or closed. In normal operation, recharging of the operating springs must commence immediately and automatically upon completion of the closing operation. The trip coil and close coils must be rated to be continuously energised.

The number auxiliary contacts (both NO & NC) of each circuit breaker is project specific and will be specified in Snowy Hydro's project specification. All contacts must be wired to terminals within the LV equipment compartment.

Means must be provided for local manual tripping of the circuit breaker, by a mechanical pushbutton. The mechanical trip pushbutton must be fitted on the front of the cubicle and must be shrouded or flush mounted in order to prevent accidental operation.

Every circuit breaker feeder must have facilities to permit them to be tested with their primary connections isolated and separated from all sources of voltage. It must be possible to functionally operate the circuit breaker in any position (e.g. service, test or disconnected positions) for testing and adjustment purposes.

5.1.2.1. Vacuum Circuit Breakers

Vacuum circuit breakers must utilise sealed-for-life vacuum interrupters complying with AS62271-100. Means must be provided for testing the units for loss of vacuum without the removal of the units. All three pole interrupter units must be readily accessible for inspection and maintenance.

The contacts must be protected from burning or welding during the operation of the circuit breaker. The contacts of the interrupter must be held open by a positive fail-safe device independent of the interrupter vacuum. The closing arrangement must be designed to give a positive closing action whilst overcoming the contact hold open device. The vacuum circuit breaker must not produce any x-rays when switching under load or fault conditions.

5.1.2.2. SF6 Circuit Breakers

SF_6 insulated circuit breakers must comprise of three single low pressure units in modular form and designed for easy removal and replacement. The design of the interrupting mechanism and contacts must be such that the energy dissipated in the SF6 gas is low and does not cause appreciable degradation of gas. The unit must be capable of interrupting fault current with no adverse effects in the event of SF6 pressure loss down to atmospheric pressure.

Means must be provided to allow checking of the SF6 gas pressure during maintenance. There must be local indication and an alarm on low SF6 gas pressure conditions. Local gas pressure indication must be available at all times in any operational position. An accessible connection must be provided to allow the refilling of SF6 when low.

The circuit breaker must be designed so that the moisture content of the SF6 gas is maintained sufficiently low to avoid condensation forming on the internal insulating surfaces of the circuit breaker. Means must be provided for dealing with the decomposition products of the SF6 gas caused by arcing. The circuit breaker must be designed to protect the main contacts from burning during the operation of the circuit breakers.

5.1.3. Earth Switches

All earthing switches for primary switchgear applications must be motorised and capable of manual and remote operation. The switches must have fault make capacity as specified in Section 4.6, and a minimum electrical endurance class E1 according as per AS 62271.102. Earthing switches must be lockable by means of a padlock.

Earthing switches must be provided on the cable side of each outgoing circuit breaker. An earthing switch must be provided to earth each busbar system of each section. The bus earthing switch may be located on the bus side of the incoming HV circuit breaker, on the bus-tie circuit breaker, or in a separate panel within the switchboard. A mechanical interlock must be provided to prevent the bus-tie earth switch being closed when the bus is live. Cable side earthing switches must also be interlocked to prevent the associated switching device from being withdrawn unless it is closed.

The number of auxiliary contacts for each earthing switch is project specific. All contacts must be wired to terminals within the LV equipment compartment.

5.1.4. High Voltage Motor Starters

Motor starters units must form an integral part of the switchboard, be three phase, withdrawable, direct on-line, be fitted with vacuum or SF6 contactors and must fully comply with the requirements of AS 62271.106. The minimum mechanical endurance for contactors must be greater than 100,000 no load operations for latched contactors, and 300,000 for unlatched contactors. Motor starters must provide at a minimum protection against single phasing, motor overload, under/over voltage, short circuit and earth faults.

The outgoing circuits must be protected by IEDs and rated for the fault current specified on the project documentation. The busbars of the motor starter units up to the point of attachment to the IED must be capable of carrying the prospective three phase short circuit specified on the project documentation.

Contactors must be capable of making inrush current for the motor load, continuously carrying its normal rated current, carrying and breaking its rated short circuit breaking current as specified on project documentation. Short circuit protection of contactors must be by the IED co-ordinated with contactor capability to provide Type 'C' damage classification as per AS 62271.106.

A test or maintenance position must be incorporated in the starter to allow all functions of the contactor to be tested.

Large drives with a low demand of starting, may utilise only a circuit breaker in lieu of a contactor as a motor starter as specified on project documentation. The circuit breaker must also be fitted with a no-volt release which monitors the circuit breaker trip circuit voltage. Loss of trip circuit voltage must trip the circuit breaker.

5.1.5. Mechanical Interlocking

Interlocking devices must be provided to prevent an incorrect sequence in the operation of withdrawal or replacement of the movable portion of the switchgear and to ensure against inadvertent exposure of live parts.

Interlocking must ensure that:

- Connection/disconnection of a CB to the busbar is not possible unless the CB is open.
- Closing the panel's earth switch is not possible when the CB is closed or racked in.
- Closing the CB is not possible when the panel's earth switch is closed.
- Closing the CB is not possible unless it is in service, in the test position, or fully withdrawn.
- Access to the cable compartment is not possible unless the cable-side earth switch is closed.
- Closing the busbar earthing switch is not possible when the incoming CB or bus-tie CB is closed.

Where specified in project documentation, key interlocking must be implemented for upstream and/or downstream circuits at the switchboard and coordinated with the remote equipment.

The key interlocking scheme at the HV switchgear must include the following features as a minimum:

- Prevent closing of local earth switches onto cables that are not isolated remotely
- Prevent closing of remote circuits onto cables earthed locally at the switchboard
- Enforce a 2 out of 3 interlocking scheme for dual, non-parallel incomers

5.1.6. Busbar

The design of the switchboard must incorporate a copper busbar system for the full length of the switchboard and must be fully rated for the switchboard's lightning impulse withstand voltage as per Section 4.6. The maximum busbar temperature under any conditions must be limited to 90°C (with an ambient temperature of 40°C). Access to the busbars must only be possible through the removal of clearly marked cover plates secured by captive fasteners.

Single or dual busbar systems may be utilised and must be installed in a separate insulated compartment to all other switchgear and be mounted on non-hygroscopic insulators. Insulated bus bars must be installed on all primary switchgear applications. Insulated busbars such as epoxy encapsulation or solid dielectric heat shrink sleeves may be used and must be approved by Snowy Hydro. The insulating material must be non-hygroscopic, high tracking index, slow aging type.

Each switchboard must be fitted with copper earth bar(s) capable of handling the fault level detailed on project documentation, be atleast a minimum of 30x6 mm (or equivalent cross sectional area) and run the whole length of the switchboard, which must be bonded to all metal parts not intended to be live. All external metal parts must be equipotentially bonded to earth via green/yellow PVC insulated 0.6/1 kV grade with conductor not less than 4 mm^2 cross sectional area. Gland plates and cubicle doors must be connected to the cubicle body with flexible braided bolted earth connectors.

The earthing busbar must be located in a position where high voltage cable sheaths and/or screens can be readily bonded to it. This earthing busbar must be connected to the station earthing grid at a minimum of two points, one at either end of the earthing busbar.

5.1.7. Shutters

Each circuit breaker and contactor compartment that has withdrawable switchgear must be equipped with shutters, which must automatically close off all access to the busbars and live HV circuits whenever the switchgear is withdrawn. Facilities must be provided for padlocking the busbar and circuit shutters in the closed position when the switchgear is withdrawn. A stop must also be provided to hold the shutter open for testing purposes.

Shutters must provide a minimum degree of protection not less than IP 2X. The shutter mechanism must be such that the busbar and circuit spout shutters are operated independently. It must be possible, when the circuit breaker or contactor is isolated, to lock each shutter independently in the closed position with a padlock,

5.1.8. Insulation of Enclosure & Compartments

Both air insulation and epoxy cast resin insulation of switchboards and internal compartments are acceptable. Gas insulation such as SF6 gas is not to be used for switchboard insulation and may only be used on individual switchgear where the equipment is sealed to ensure no gas leakage.

5.1.9. Loss of Service Continuity Category

Each of the switchboards must have designation LSC2B-PM to AS62271.200. That is, service continuity applies to other compartments of the switchboard, including cable compartments, when any main circuit compartment is opened. This must be achieved through use of metal partitions between each functional unit and metal shutters.

5.1.10. Arc Flash Protection

All switchboards and switchgear must be arc fault contained in accordance with AS 62271-200. The internal arc withstand IAC classification for the switchboard must be AFLR with minimum time duration of 1s for the specified switchboard rated fault current (refer to Section 4.6), to ensure

operator safety. The arc fault energy must always be subjected away from the front and sides of the switchboard, providing protection to personnel from arc fault(s).

Indoor or containerised equipment must be designed and constructed to contain and / or direct arc fault energy by utilising arc vents /chutes out of the switchroom or to a cable pit below. The switchboard manufacturer must be responsible for coordinating the capabilities of the switchboard with Snowy Hydro for the building or switch room design, to ensure that the intended arc containment system is achieved. Arc vents or chutes must:

- Vent to a safe area external to the switch room or building, to an area where there are no hazardous areas or gases present.
- Ensure that exhaust gases do not present any additional risk to assets or personnel and must not be directed at or towards other plant or areas accessible to personnel.
- Form part of the type tested switchboard.
- Be fitted with insect/vermin proof membranes, along with approved weatherproof covers.
- Be installed so they do not compromise the integrity of the building.

The switchboards must have appropriate signage to indicate the operational protection requirements for that piece of equipment. Each circuit must be fitted with arc flash labelling on the front of the panel clearly showing the arc flash hazard incident energy and minimum category PPE.

Additional arc flash protection may be specified in project documentation such as:

- Active arc flash detection via fibre optic sensors with overcurrent detection
- Current limiting fuses
- Arc-Killer earth switches
- Relay protection maintenance mode (see section 6.9)

The active arc flash detection system must have the following minimum requirements:

- Fibre optic based detection sensors with LED indicators for each sensor;
- Fast semiconductor based trip output of less than 10ms;
- Have alarm contacts,
- Spare capacity to allow for switchboard expansion,
- A separate arc flash detection panel mounted on the front of the switchboard,
- Have current transformer inputs to allow for simultaneous overcurrent detection.

5.1.11. Redundancy and Backup Protection

The following redundancy and backup protection must be supplied with all primary switchgear applications:

- All circuit breakers must have two trip coils to provide redundancy in the trip circuit.
- Circuit breaker failure protection schemes must be available on all protection devices to allowing tripping of the upstream protection device.
- All components must be protected from primary and backup protection schemes as specified in Snowy Hydro's Protection Standard SHL-ELE-102.

Additionally, condition monitoring of switchgear may be required for high availability switchgear and specified on project documentation to analyse mechanical and electrical wear allowing for preventative maintenance.

5.1.12. Remote Operation

All primary switchgear must be capable of being operated remotely, primarily through SCADA. Additional remote operation options include installing a local control panel in the vicinity of the switchboard or a remote racking unit may be specified in project documentation. The remote racking unit must be capable of racking in & out all withdrawable panels from a safe location outside the arc boundary and preferable outside the switchroom.

The local control panel must be a separate wall mountable panel provided with control facilities for an operator to manually perform the following actions to any one of the circuit breakers in the switchboard:

- Circuit breaker open/close
- Earth switch open/close
- Circuit breaker rack in/out
- Local / remote / service selector switch to restrict actions from SCADA when operating locally or under maintenance
- Maintenance mode selector switch (if required) – refer to Section 6.9

The above feature must also be facilitated with interfaces for remote operation via Snowy Hydro's SCADA system. Remote operation from the SCADA system must be via suitably rated interposing relays included within the local control panel.

The mounting location for the local control panel is site specific and at a minimum must be located outside the switchboards arc flash boundary. Preferably the panel should be located externally or in a separate room, such that all possible risks associated with operating the switchboard via the local control panel are minimised.

5.1.13. Indication

Indication must be provided on each circuit breaker or isolator to indicate whether the associated main incomer or feeder cable is energised. In addition a separate facility must be provided to indicate the "dead" condition of all HV busbars and cables within the switchboard when the corresponding circuit breaker has been opened. As a minimum, LED electrical indicators must be visible on the front panel of the switchboard, without opening the cubicle doors, with self-testing functions to ensure correct operation.

Status indication lamps must be removable plug type that allows the circuit to be tested. Indication lights of LED type indicating circuit breaker open, closed and fault tripped must be provided and coloured accordingly:

- Red - Equipment running, CB closed
- Amber - Fault or alarm
- Green - Equipment stopped, CB open
- White - Status Indication

5.1.14. Spare Cubicles

Where indicated on project documentation, spare feeders may be required. Spare cubicles must be provided within the switchboard and be of the same size as the surrounding feeders. Spare panels must be supplied with necessary components and accessories to enable future works to be completed without the need for de-energising the switchgear panel, adjacent switchgear panels, and associated control or protection panels. All upstream equipment in the switchboard must be rated to allow for the additional spare circuit, with the assumption that the circuit will be the same size as the largest feeder being supplied.

5.1.15. Switchboard Construction

The switchboard must be metallic and constructed of machine-folded sheet steel of at least 2mm thick. External parts of the switchgear should be of insulating material, provided that HV parts are completely enclosed by metallic partitions or shutters intended to be earthed.

All sheet metal should be suitably braced. Bracing should be arranged well clear of components, and this should apply equally to initial and possible future additions. All sheet metal work should be flat and free from ripples, depressions and other surface defects.

5.1.16. Ingress Protection

Ingress protection for the indoor switchboard must be a minimum of IP 41. The degree of protection for shutters and between compartments must be a minimum of IP 3X. All live parts must be protected or shrouded and labelled for protection against accidental contact. LV compartments of the switchboard must have atleast IP 2X protection when open to protect against any live components.

5.1.17. Internal Wiring

All wiring must be coloured and installed in accordance with the requirements AS/NZS 3000. Minimum insulation rating of all cabling must be V90, however the use of X-110 insulation is preferred. Minimum wiring sizes are specified in Snowy Hydro's protection standard – refer to Section 4.6 and 4.7 of SHL-ELE-102 Protection Design Standard.

All internal wiring between panels or cubicles must be hard wired for functionality such as inter-tripping, interlocking and CB blocking. Communication protocols may be used for status however core functionality and safety related items must be via hardwiring only.

All cubicle wiring must be neatly installed in wiring looms or in rigid PVC ducting with covers in such that wiring can be readily checked against schematics. Where cabling is installed to a panel door, the arrangement must be such that the opening of the panel must not cause the wiring to twist longitudinally and not bend or rub on a panel edge or face. Back of panel wiring must be so arranged that access to relays, switches and other apparatus is not impeded.

Termination of all wiring utilising lugs or pins must be in accordance with Snowy Hydro's LV standard SHL-ELE-156 Annexure D. All wires must have ferrules at each terminal and the numbering must be in accordance with project schematic and wiring diagrams. The same ferrule number must not be used on wires in different circuits within the same cubicle. Each end of every circuit breaker trip circuit wire must be fitted with a red ferrule engraved 'TRIP' in addition to the numbered ferrules. All conductors must be terminated with accepted crimping lugs, separate lugs being used for each conductor.

5.1.18. Cable Entries

Incoming and outgoing HV cables must be terminated within the cable compartment of the switchboard. All cabling must be bottom entry and suitable provision must be made for glanding and termination of all cabling shown in the project documentation. Bottom cable entries must be standard through a blank, removable, non-ferrous gland plates and must be connected to earth. Separate, dedicated gland plates must be provided for control cables. An option for top entry of the control cables into the LV equipment compartment must also be provided. All spare entries must be plugged to maintain the switchboard IP rating.

5.1.19. Anti-Condensation Heaters

A thermostatically controlled anti-condensation heater with isolation must be provided in each cable compartment. The heater wiring must be supplied from a 240 V ac supply, be bus-wired to each cubicle and must be segregated from all other wiring.

A separate circuit protected by a MCB and separate terminals must be provided for each heater, to permit testing of each inaccessible heater. All associated terminals must be fully shrouded with applicable danger labels fitted. Heaters and thermostats must be chosen such that they are capable for continuous service for the entire life of the switchboard.

5.1.20. Surge Arresters

A requirement for surge arresters may be stated on project documentation to be installed on the incoming line side of the switchboard. They must be connected to the cable side of each incomer circuit breaker and be connected from phase to earth. The surge arresters' ratings must be in accordance with AS 1307.2 and have the following specifications:

- Gapless metal oxide type,
- Hermetically sealed construction
- Equipped with a pressure relief device to prevent excess pressure causing shattering during faults

5.1.21. Paralleling of Supply

Parallel supply requirements may be specified on project documentation and must include the following requirements as a minimum:

- Differential protection of the parallel supplies
- Directional overcurrent / earth fault protection of the parallel supplies
- Synchronous check protection between supplies
- Interlocks to prevent any asynchronous closures

5.1.22. Bushfire Safety

Remote stations within Snowy Hydro's network are deemed to have a high bushfire risk and must be stated on project documentation. In these scenarios switchgear must implement Sensitive Earth Fault protection to detect high-impedance faults. Switchboards installed within or supplying circuits to areas with a high bushfire risk must be selected to allow for installation of Core-Balance CTs.

5.2. Secondary Switchgear

Secondary switchgear must be installed within a metal-clad switchboard in an indoor environment. The switchboard must be free standing and comprise of individual switchgear panels that are suitably constructed to accommodate all required relays and equipment referenced in this standard. The switchboard must be readily extendable at either end - the busbars must be pre-drilled at both ends for this purpose.

5.2.1. Panel Types

All panels must be modular within the switchboard to provide segregation between the HV compartment and LV and control equipment compartment, however the busbar compartment may be continuous. Each compartment partition must be earthed. A mimic diagram must be displayed on the front of the panel to show clear indication of the physical connections within the panel.

The switchboard should consist of the following compartments:

- Busbar compartment
- Switchgear compartment
- Bus-Tie compartment
- Current transformers and cable termination compartment
- Voltage transformers compartment (if applicable)
- LV and control equipment compartment

Switchgear panels must comprise of circuit breakers, isolators and/or earth switches and may require CTs dependant on the protection application. Panels may be fixed or withdrawable in secondary switchgear applications. The following panel types are available:

- Incomers
    - Circuit breaker panel
- Transformer feeders
    - Circuit breaker panel or isolator with HV fuse combination
- Distribution feeders
    - Circuit breaker panel
- Bus-Tie
    - Circuit breaker panel or isolator panel
    - Separate earthing switches on each HV bus

Secondary switchgear may be withdrawable if specified on project documentation and must be assessed on a case-by-case basis to the application being considered. Where required, withdrawable switchgear must have the following requirements:

- Connection to and isolation onto the bus should be by means of suitable contacts mounted on robust insulators. Means must be provided to ensure accurate alignment of the trucks and contacts.
- Trucks should be horizontally withdrawable and must be fitted with wheels to allow for easier removal for inspection and maintenance. A trolley must be provided for all sized panels within the switchboard.
- The racking mechanism must be suitable for remote operation.

- Provide indication for clear identification of the position of the switchgear truck, e.g. racked in, earthing position, racked out (isolated).
- Any metallic parts must remain connected to earth in the test and disconnected positions and in any intermediate position.

5.2.2. Circuit Breakers

The circuit breakers must be factory-assembled, 3 phase, motorised spring charged, and capable of manual and remote operation. Circuit breakers must be either vacuum or SF6 insulated types and must fully comply with AS 62271.100.

The circuit breakers must be located adjacent to each other on a common busbar. The switchgear must be suitable for operation at the voltage as required and must be rated for the specified making and breaking short circuit currents as referenced in Section 4.6. The circuit breaker must also be capable of supplying the inrush current of transformers if applicable. The switching duty of circuit breakers must be appropriate for the intended frequency of operation of the circuit.

All circuit breakers, at a minimum, must be equipped with the following features:

- Manual and motorised spring charged closing device with anti-pumping relay
- Stored energy spring mechanism for motor charging and emergency manual operation
- Mechanical push buttons for closing and opening, with padlockable covers to prevent unauthorised operation
- Mechanical visual indicators for switch position and mechanism position
- Mechanical counter
- Auxiliary signalling contacts
- Spring charge local and remote indications
- Voltage presence indicators
- Lockable in the open position by a padlock
- Trip free operation
- Capability to connect to a remote panel for additional control

The circuit breaker must have a mechanical endurance rating of class M2 as defined in AS 62271.100. A contact wear indicator must be provided with the recommended replacement point clearly marked, and capable of being easily read or measured during maintenance checks. The contacts of the interrupter must be held open by a positive fail-safe device.

Trip circuit supervision must be provided for each trip circuit (inclusive of all wiring, the resistor and indication) which will monitor the trip circuit supply, trip coil and the other elements in each of the trip circuits for both when the circuit breaker is open or closed. In normal operation, recharging of the operating springs must commence immediately and automatically upon completion of the closing operation. The trip coil and close coils must be rated to be continuously energised.

The number auxiliary contacts (both NO & NC) of each circuit breaker is project specific and will be specified in Snowy Hydro's project specification. All contacts must be wired to terminals within the LV equipment compartment.

Means must be provided for local manual tripping of the circuit breaker, by a mechanical pushbutton. The mechanical trip pushbutton must be fitted on the front of the cubicle and must be shrouded or flush mounted in order to prevent accidental operation.

Every circuit breaker feeder must have facilities to permit them to be tested with their primary connections isolated and separated from all sources of voltage. It must be possible to functionally operate the circuit breaker when in any position (e.g. service, test or disconnected positions) for testing and adjustment purposes.

5.2.2.1. Vacuum Circuit Breakers

Vacuum circuit breakers must utilise sealed-for-life vacuum interrupters complying with AS62271-100. Means must be provided for testing the units for loss of vacuum without the removal of the units. All three pole interrupter units must be readily accessible for inspection and maintenance.

The contacts must be protected from burning or welding during the operation of the circuit breaker. The contacts of the interrupter must be held open by a positive fail-safe device independent of the interrupter vacuum. The closing arrangement must be designed to give a positive closing action whilst overcoming the contact hold open device. The vacuum circuit breaker must not produce any x-rays when switching under load or fault conditions.

5.2.2.2. SF6 Circuit Breakers

SF_6 insulated circuit must comprise of three single low pressure units in modular form and designed for easy removal and replacement. The design of the interrupting mechanism and contacts must be such that the energy dissipated in the SF6 gas is low and does not cause appreciable degradation of gas. The unit must be capable of interrupting fault current with no adverse effects in the event of SF6 pressure loss down to atmospheric pressure.

Means must be provided to allow checking of the SF6 gas pressure during maintenance. There must be local indication and an alarm on low SF6 gas pressure conditions. Local gas pressure indication must be available at all times in any operational position. An accessible connection must be provided to allow the refilling of SF6 when low.

The circuit breaker must be designed so that the moisture content of the SF6 gas is maintained sufficiently low to avoid condensation forming on the internal insulating surfaces of the circuit breaker. Means must be provided for dealing with the decomposition products of the SF6 gas caused by arcing. The circuit breaker must be designed to protect the main contacts from burning during the operation of the circuit breakers.

5.2.3. Isolators / Fuse Isolators

The isolators and fuse-isolator units must be vacuum or SF6 insulated, suitable for making the fault current and breaking the rated load current and must comply with AS 62271.103 and AS 62271.105. It must also be capable of making and breaking the magnetising current of transformers or other load as specified in the project documentation. Isolators must be rated with a mechanical and electrical endurance of M2 and E2 as per AS 62271.103. Fused units must be capable of clearing the specified fault without damage to the switchgear. All units should have a similar external arrangement and operation regardless of rating.

The isolator panel must have mechanical push buttons for opening and closing. The isolator operating mechanism must have a mechanical indicator to show whether the circuit is 'Open', 'Closed' or in the 'Earth' position (where integral earth switches are used). Isolators must be capable of being operated both locally and remotely. Isolators must be provided with motor operating mechanism for remote closing and opening.

A substantial gate or similar device must be provided to prevent an isolator or fuse-isolator being inadvertently moved to the closed position. It must be possible to padlock the isolator mechanism in all positions.

The number of auxiliary contacts for each isolator is project specific. All contacts must be wired to terminals within the LV equipment compartment.

5.2.4. Earth Switches

All earthing switches for secondary switchgear applications must be motorised and capable of manual and remote operation. The switches must have fault make capacity as specified in Section 4.6, and a minimum electrical endurance class E1 according as per AS 62271.102. Earthing switches must be lockable by means of a padlock.

Earthing switches must be provided on the cable side of each outgoing circuit breaker. An earthing switch must be provided to earth each busbar system of each section. The bus earthing switch may be located on the bus side of the incoming HV circuit breaker, on the bus-tie circuit breaker, or in a separate panel within the switchboard. A mechanical interlock must be provided to prevent the bus-tie earth switch being closed when the bus is live. Cable side earthing switches must also be interlocked to prevent the associated switching device from being withdrawn unless it is closed.

The number of auxiliary contacts for each earthing switch is project specific. Contacts must be wired to terminals within the LV equipment compartment.

5.2.5. Mechanical Interlocking

Interlocking devices must be provided to prevent an incorrect sequence in the operation of withdrawal or replacement of the movable portion of the switchgear and to ensure against inadvertent exposure of live parts.

Interlocking must ensure that:

- Connection/disconnection of any switchgear to the busbar is not possible unless the switchgear is open.
- Closing the panel's earth switch is not possible when the CB is closed or racked in.
- Closing the CB is not possible when the panel's earth switch is closed.
- Closing the CB is not possible unless it is in service, in the test position, or fully withdrawn.
- Access to any fuse compartment is not possible unless isolated.
- Closing the earthing switch of the fuse is not possible unless the fuse switch is open.
- Access to the cable compartment is not possible unless the cable-side earth switch is closed.
- Closing the busbar earthing switch is not possible when the incoming switchgear or bus-tie is closed.

Where specified in project documentation, key interlocking must be implemented for upstream and/or downstream circuits at the switchboard and coordinated with the remote equipment.

The key interlocking scheme at the HV switchgear must include the following features as a minimum:

- Prevent closing of local earth switches onto cables that are not isolated remotely
- Prevent closing of remote circuits onto cables earthed locally at the switchboard

5.2.6. Busbar

The design of the switchboard must incorporate a copper busbar system for the full length of the switchboard and must be fully rated for the switchboard's lightning impulse withstand voltage as per Section 4.6. The maximum busbar temperature under any conditions must be limited to 90°C (with an ambient temperature of 40°C).

The busbar system must be in a separate insulated compartment to all other switchgear and be mounted on non-hygroscopic insulators. Dual busbar systems must not be provided for secondary switchgear. Access to the busbars must only be possible through the removal of clearly marked cover plates secured by captive fasteners.

Each switchboard must be fitted with copper earth bar(s) capable of handling the fault level detailed on project documentation, be atleast a minimum of 30x6 mm (or equivalent cross sectional area) and run the whole length of the switchboard, which must be bonded to all metal parts not intended to be live. All external metal parts must be equipotentially bonded to earth via green/yellow PVC insulated 0.6/1 kV grade with conductor not less than 4 mm^2 cross sectional area. Gland plates and cubicle doors must be connected to the cubicle body with flexible braided bolted earth connectors.

The earthing busbar must be located in a position where high voltage cable sheaths and/or screens can be readily bonded to it. This earthing busbar must be connected to the station earthing grid at a minimum of two points, one at either end of the earthing busbar.

5.2.7. Shutters

Where withdrawable switchgear is installed, the compartment must be equipped with shutters which must automatically close off all access to the busbars and circuit whenever the switchgear is withdrawn. Facilities must be provided for padlocking the busbar and circuit shutters in the closed position when the switchgear is withdrawn. A stop must also be provided to hold the shutter open for testing purposes.

Shutters must provide a minimum degree of protection not less than IP 2X. The shutter mechanism must be such that the busbar and circuit spout shutters are operated independently. It must be possible, when the circuit breaker or contactor is isolated, to lock each shutter independently in the closed position with a padlock,

5.2.8. Insulation of Enclosure & Compartments

Both air insulation and epoxy cast resin insulation of switchboards and internal compartments are acceptable. Gas insulation such as SF6 gas is not to be used for switchboard insulation and may only be used on individual switchgear where the equipment is sealed to ensure no gas leakage.

5.2.9. Loss of Service Continuity Category

Each of the switchboards must have designation LSC2B-PM to AS62271.200. That is, service continuity applies to other compartments of the switchboard, including cable compartments, when any main circuit compartment is opened. This must be achieved through use of metal partitions between each functional unit and metal shutters.

5.2.10. Arc Flash Protection

The switchboards and switchgear must be arc fault contained in accordance with AS 62271-200. The internal arc withstand IAC classification for the switchboard must be AFLR with minimum time duration of 1s for the specified switchboard rated fault current (refer to Section 4.6), to ensure operator safety. The arc fault energy must always be subjected away from the front and sides of the switchboard, providing protection to personnel from arc fault(s).

Indoor or containerised equipment must be designed and constructed to contain and / or direct arc fault energy by utilising arc vents /chutes out of the switchroom or to a cable pit below. The switchboard manufacturer must be responsible for coordinating the capabilities of the switchboard with Snowy Hydro for the building or switch room design, to ensure that the intended arc containment system is achieved. Arc vents or chutes must:

- Vent to a safe area external to the switch room or building, to an area where there are no hazardous areas or gases present.
- Ensure that exhaust gases do not present any additional risk to assets or personnel and must not be directed at or towards other plant or areas accessible to personnel.
- Form part of the type tested switchboard.
- Be fitted with insect/vermin proof membranes, along with approved weatherproof covers.
- Be installed so they do not compromise the integrity of the building.

The switchboards must have appropriate signage to indicate the operational protection requirements for that piece of equipment. Each circuit must be fitted with arc flash labelling on the front of the panel clearly showing the arc flash hazard incident energy and minimum category PPE.

5.2.11. Remote Operation

All secondary switchgear must be capable of being operated remotely, primarily through SCADA. Additional remote operation options include installing a local control panel in the vicinity of the switchboard or a remote racking unit may be specified in project documentation. The remote racking unit must be capable of racking in & out all withdrawable panels from a safe location outside the arc boundary and preferable outside the switchroom.

The local control panel must be a separate wall mountable panel provided with control facilities for an operator to manually perform the following actions to any one of the circuit breakers in the switchboard:

- Circuit Breaker/Isolator Open/Close
- Earth Switch Open/Close
- Switchgear Rack in/out (if applicable)
- Local / remote / service selector switch to restrict actions from SCADA when operating locally or under maintenance

- Maintenance mode selector switch (if required) – refer to Section 6.9

The above feature must also be facilitated with interfaces for remote operation via Snowy Hydro's SCADA system. Remote operation from the SCADA system must be via suitably rated interposing relays included within the local control panel.

The mounting location for the local control panel is site specific and at a minimum must be located outside the switchboards arc flash boundary. Preferably the panel should be located externally or in a separate room, such that all possible risks associated with operating the switchboard via the local control panel are minimised.

5.2.12. Indication

Indication must be provided on each circuit breaker or isolator to indicate whether the associated main incomer or feeder cable is energised. In addition a separate facility must be provided to indicate the "dead" condition of all HV busbars and cables within the switchboard when the corresponding circuit breaker has been opened. As a minimum, LED electrical indicators must be visible on the front panel of the switchboard, without opening the cubicle doors, with self-testing functions to ensure correct operation.

Status indication lamps must be removable plug type that allows the circuit to be tested. Indication lights of LED type indicating circuit breaker open, closed and fault tripped must be provided and coloured accordingly:

- Red - Equipment running, CB closed
- Amber - Fault or alarm
- Green - Equipment stopped, CB open
- White - Status indication

5.2.13. Spare Cubicles

Where indicated on project documentation, spare feeders may be required. Spare cubicles must be provided within the switchboard and be of the same size as the surrounding feeders. Spare panels must be supplied with necessary components and accessories to enable future works to be completed without the need for de-energising the switchgear panel, adjacent switchgear panels, and associated control or protection panels. All upstream equipment in the switchboard must be rated to allow for the additional spare circuit, with the assumption that the circuit will be the same size as the largest feeder being supplied.

5.2.14. Switchboard Construction

The switchboard must be metallic and constructed of machine-folded sheet steel of at least 2mm thick. External parts of the switchgear should be of insulating material, provided that HV parts are completely enclosed by metallic partitions or shutters intended to be earthed.

All sheet metal should be suitably braced. Bracing should be arranged well clear of components, and this should apply equally to initial and possible future additions. All sheet metal work should be flat and free from ripples, depressions and other surface defects.

5.2.15. Ingress Protection

Ingress protection for the indoor switchboard must be a minimum of IP 41. The degree of protection for shutters and between compartments must be a minimum of IP 3X. All live parts must be protected or shrouded and labelled for protection against accidental contact. LV compartments of the switchboard must have atleast IP 2X protection when open to protect against any live components.

5.2.16. Internal Wiring

All wiring must be coloured and installed in accordance with the requirements AS/NZS 3000. Minimum insulation rating of all cabling must be V90, however the use of X-110 insulation is preferred. Minimum wiring sizes are specified in Snowy Hydro's protection standard – refer to Section 4.6 and 4.7 of SHL-ELE-102 Protection Design Standard.

All internal wiring between panels or cubicles must be hard wired for functionality such as inter-tripping, interlocking and CB blocking. Communication protocols may be used for status however core functionality and safety related items must be via hardwiring only.

All cubicle wiring must be neatly installed in wiring looms or in rigid PVC ducting with covers in such that wiring can be readily checked against schematics. Where cabling is installed to a panel door, the arrangement must be such that the opening of the panel must not cause the wiring to twist longitudinally and not bend or rub on a panel edge or face. Back of panel wiring must be so arranged that access to relays, switches and other apparatus is not impeded.

Termination of all wiring utilising lugs or pins must be in accordance with Snowy Hydro's LV standard SHL-ELE-156 Annexure D. All wires must have ferrules at each terminal and the numbering must be in accordance with project schematic and wiring diagrams. The same ferrule number must not be used on wires in different circuits within the same cubicle. Each end of every circuit breaker trip circuit wire must be fitted with a red ferrule engraved 'TRIP' in addition to the numbered ferrules. All conductors must be terminated with accepted crimping lugs, separate lugs being used for each conductor.

5.2.17. Cable Entries

Incoming and outgoing HV cables must be terminated within the cable compartment of the switchboard. All cabling must be bottom entry and suitable provision must be made for glanding and termination of all cabling shown in the project documentation. Bottom cable entries must be standard through a blank, removable, non-ferrous gland plates and must be connected to earth. Separate, dedicated gland plates must be provided for control cables. An option for top entry of the control cables into the LV equipment compartment must also be provided. All spare entries must be plugged to maintain the switchboard IP rating.

5.2.18. Anti-Condensation Heaters

A thermostatically controlled anti-condensation heater with isolation must be provided in each cable compartment. The heater wiring must be supplied from a 240 V ac supply, be bus-wired to each cubicle and must be segregated from all other wiring.

A separate circuit protected by a MCB and separate terminals must be provided for each heater, to permit testing of each inaccessible heater. All associated terminals must be fully shrouded with applicable danger labels fitted. Heaters and thermostats must be chosen such that they are capable for continuous service for the entire life of the switchboard.

5.3. Ring Main Units

Ring Main Units (RMUs) may be installed as a standalone unit or as part of an outdoor kiosk substation. The RMU must be metal enclosed to AS 62271.200 and be free standing suitable for installation within a kiosk or a standalone enclosure.

In some remote areas where a RMU will be installed, communication facilities and auxiliary power may not be available. Batteries should be considered first in these applications to facilitate auxiliary power before a self-powered design is considered and must be approved by Snowy Hydro. Regardless of auxiliary power availability, a standalone RMU must be supplied with a LV and control compartment capable of installing these facilities in the future. For RMU's within kiosk installations this compartment may be in a separate section of the kiosk.

5.3.1. Panel Type

All panels must be modular within the RMU to provide segregation between all HV, LV and control equipment in adjacent panels, however the busbar compartment may be continuous. Each compartment partition must be earthed. Switchgear within the RMU must be fixed (non-withdrawable). A mimic diagram must be displayed on the front of the panel to show clear indication of the physical connections within the panel.

The RMU may comprise of the following panels:

- Circuit breaker panel
- Fuse-Isolator panel
- Isolator panel
- Metering panel including VTs
- Direct cable connection panel

Any CTs required for protection purposes must be located within the cable compartment.

5.3.2. Circuit Breakers

The circuit breakers must be factory-assembled, 3 phase, spring charged and must be fitted with an integral earth switch. Circuit breakers must be either vacuum or SF6 insulated types and must fully comply with AS 62271.100. All circuit breakers must be capable of manual and remote operation irrespective of auxiliary power availability and communication facilities at the RMU.

The circuit breakers must be located adjacent to each other on a common busbar. The switchgear must be suitable for operation at the voltage as required and must be rated for the specified making and breaking short circuit currents as referenced in Section 4.6. The circuit breaker must also be capable of supplying the inrush current of transformers if applicable. The switching duty of circuit breakers must be appropriate for the intended frequency of operation of the circuit.

All circuit breakers, at a minimum, must be equipped with the following features:

- Stored energy spring mechanism
- Spring charging closing device:
    - Manual charging where no auxiliary power is available. Must be able to be retrofitted on site with motor charging capabilities
    - Motorised charging where auxiliary power is available.

- Voltage presence indicators
- Mechanical push buttons for closing and opening
- Mechanical visual indicators for switch position and mechanism position
- Mechanical counter
- Auxiliary signalling contacts
- Spring charge remote indications
- Lockable in the open position by a padlock
- Trip free operation

The circuit breaker must have a mechanical endurance rating of class M2 as defined in AS 62271.100. A contact wear indicator must be provided with the recommended replacement point clearly marked, and capable of being easily read or measured during maintenance checks. The contacts of the interrupter must be held open by a positive fail-safe device.

Trip circuit supervision must be provided for each trip circuit (inclusive of all wiring, the resistor and indication) which will monitor the trip circuit supply, trip coil and the other elements in each of the trip circuits for both when the circuit breaker is open or closed. In normal operation, recharging of the operating springs must commence immediately and automatically upon completion of the closing operation. The trip coil and close coils must be rated to be continuously energised.

The number auxiliary contacts (both NO & NC) of each circuit breaker is project specific and will be specified in Snowy Hydro's project specification. All contacts must be wired to terminals within the LV equipment compartment.

Means must be provided for local manual tripping of the circuit breaker, by a mechanical pushbutton. The mechanical trip pushbutton must be fitted on the front of the cubicle and must be shrouded or flush mounted in order to prevent accidental operation.

Every circuit breaker feeder must have facilities to permit them to be tested with their primary connections isolated and separated from all sources of voltage. It must be possible to functionally operate the circuit breaker when in any position (e.g. either the test/service or disconnected/isolated positions) for testing and adjustment purposes.

Continuity of the secondary circuits should be ensured when the circuit breaker is in the service position, and means should be provided for completing the secondary connections when the circuit breaker is isolated, in order to permit the circuit breaker to be operated for test purposes.

5.3.2.1. Vacuum Circuit Breakers

Vacuum circuit breakers must utilise sealed-for-life vacuum interrupters complying with AS62271-100. Means must be provided for testing the units for loss of vacuum without the removal of the units. All three pole interrupter units must be readily accessible for inspection and maintenance.

The contacts must be protected from burning or welding during the operation of the circuit breaker. The contacts of the interrupter must be held open by a positive fail-safe device independent of the interrupter vacuum. The closing arrangement must be designed to give a positive closing action whilst overcoming the contact hold open device. The vacuum circuit breaker must not produce any x-rays when switching under load or fault conditions.

5.3.2.2. SF6 Circuit Breakers

SF_6 insulated circuit must comprise of three single low pressure units in modular form and designed for easy removal and replacement. The design of the interrupting mechanism and contacts must be such that the energy dissipated in the SF6 gas is low and does not cause appreciable degradation of gas. The unit must be capable of interrupting fault current with no adverse effects in the event of SF6 pressure loss down to atmospheric pressure.

Means must be provided to allow checking of the SF6 gas pressure during maintenance. There must be local indication and an alarm on low SF6 gas pressure conditions. Local gas pressure indication must be available at all times in any operational position. An accessible connection must be provided to allow the refilling of SF6 when low.

The circuit breaker must be designed so that the moisture content of the SF6 gas is maintained sufficiently low to avoid condensation forming on the internal insulating surfaces of the circuit breaker. Means must be provided for dealing with the decomposition products of the SF6 gas caused by arcing. The circuit breaker must be designed to protect the main contacts from burning during the operation of the circuit breakers.

5.3.3. Isolator / Fuse-Isolator Units

The isolators and fuse-isolator units must be vacuum or SF6 insulated, suitable for making the fault current and breaking the rated load current and must comply with AS 62271.103 and AS 62271.105. It must also be capable of making and breaking the magnetising current of transformers or other load as specified in the project documentation. Isolators must be rated with a mechanical endurance of M2 as per AS 62271.103. Fused units must be capable of clearing the specified fault without damage to the switchgear. All units should have a similar external arrangement and operation regardless of rating.

The isolator panel must have mechanical push buttons for opening and closing and must be fitted with an integral earth switch. The operating mechanism must have a mechanical indicator to show whether the circuit is 'Open', 'Closed' or in the 'Earth' position. Isolators must be capable of being operated both locally and remotely regardless of communication facilities at the RMU. Isolators must be capable of being fitted with a motor operating mechanism for remote closing and opening. Motorised and remote operation requirements must be stated on project documentation.

A substantial gate or similar device must be provided to prevent an isolator or fuse-isolator being inadvertently moved to the closed position. It must be possible to padlock the isolator mechanism in all positions.

The number of auxiliary contacts for each isolator is project specific. Contacts must be wired to terminals within the LV equipment compartment.

5.3.4. Earth Switches

Earthing switches within RMUs are only required to be operated manually and must have a fault make capacity as specified in Section 4.6, and a minimum electrical endurance class E1 according as per AS 62271.102. Earthing switches must be lockable by means of a padlock. Earth switches are to be integral with the associated isolator or circuit breaker unit.

The number of auxiliary contacts for each earthing switch is project specific. Contacts must be wired to terminals within the LV equipment compartment.

5.3.5. Mechanical Interlocking

Interlocking devices must be provided to prevent an incorrect sequence in the operation of withdrawal or replacement of the movable portion of the switchgear and to ensure against inadvertent exposure of live parts.

Interlocking must ensure that:

- Closing the panel's earth switch is not possible when the CB is closed.
- Closing the CB is not possible when the panel's earth switch is closed.
- Access to any fuse compartment is not possible unless isolated.
- Closing the earthing switch of the fuse is not possible unless the fuse switch is open.
- Access to the cable compartment is not possible unless the cable-side earth switch is closed.

Where specified in project documentation, key interlocking must be implemented for upstream and/or downstream circuits at the switchboard and coordinated with the remote equipment.

The key interlocking scheme at the HV switchgear must include the following features as a minimum:

- Prevent closing of local earth switches onto cables that are not isolated remotely
- Prevent closing of remote circuits onto cables earthed locally at the switchboard

5.3.6. Busbar

The design of the RMU must incorporate a copper busbar system for the full length of the RMU and must be fully rated for the lightning impulse withstand voltage as per Section 4.6. The maximum busbar temperature under any conditions must be limited to 90°C (with an ambient temperature of 40°C). The busbar system must be in a separate insulated compartment to all other switchgear and be mounted on non-hygroscopic insulators.

The RMU must be fitted with copper earth bar(s) capable of handling the fault level detailed on project documentation, be atleast a minimum of 40x3 mm (or equivalent cross sectional area) and run the whole length of the RMU, which must be bonded to all metal parts not intended to be live. All external metal parts must be equipotentially bonded to earth via green/yellow PVC insulated 0.6/1 kV grade with conductor not less than 4 mm^2 cross sectional area.

The earthing busbar must be located in a position where high voltage cable sheaths and/or screens can be readily bonded to it. This earthing busbar must be connected to the station earthing grid at a minimum of two points, one at either end of the earthing busbar.

5.3.7. Insulation of Enclosure & Compartments

Both air insulation and epoxy cast resin insulation of the RMU internal compartments are acceptable. Gas insulation such as SF6 gas is not to be used for the RMU insulation and may only be used on individual switchgear where the equipment is sealed to ensure no gas leakage.

5.3.8. Loss of Service Continuity Category

The RMU's loss of service category must be LSC2A-PM to AS62271.200. That is, service continuity applies to other compartments of the RMU, including cable compartments, when any main circuit compartment is opened. This must be achieved through use of metal partitions between each functional unit.

5.3.9. Arc Flash Protection

The RMU must be arc fault contained in accordance with AS 62271-200. The internal arc withstand IAC classification for the RMU must be AFLR if installed standalone, or AFL if installed within a kiosk. A minimum arc fault duration of 1s for the specified fault current (refer to Section 4.6), to ensure operator safety. The arc fault energy must always be subjected away from the front and sides of the switchboard, providing protection to personnel from arc fault(s).

The RMU must have appropriate signage to indicate the operational protection requirements for that piece of equipment. Each circuit must be fitted with arc flash labelling on the front of the panel clearly showing the arc flash hazard incident energy and minimum category PPE.

5.3.10. Remote Operation

RMU's must be capable of being operated remotely regardless of communication facilities at the RMU. Control signals such as opening and closing of switchgear and isolators must be wired back to terminals within the control compartment to allow for a remote connection to SCADA.

5.3.11. Indication

Indication must be provided on each circuit breaker or isolator to indicate whether the associated main incomer or feeder cable is energised. In addition, a separate facility must be provided to indicate the "dead" condition of all HV busbars and cables within the RMU when the corresponding circuit breaker has been opened. As a minimum, LED electrical indicators must be visible on the front panel of the RMU, with self-testing functions to ensure correct operation.

Status indication lamps must be removable plug type that allows the circuit to be tested. Indication lights of LED type indicating circuit breaker open, closed and fault tripped must be provided and coloured accordingly:

- Red - Equipment running, CB Closed
- Amber - Fault or Alarm
- Green - Equipment stopped, CB Open
- White - Status Indication

5.3.12. RMU Construction

The RMU must be metallic and constructed of machine-folded sheet steel of at least 2mm thick and suitable braced. Bracing and supports must be coordinated with the kiosk vendor if applicable to ensure appropriate fixings are provided to secure the RMU. For standalone RMUs the stand must raise the equipment above ground level to allow for HV cable entries without the use of a cable trench.

The enclosure of the RMU must be painted in accordance with Snowy Hydro's Protective Coatings standard SHL-GEN-123. External parts of the internal switchgear should be of insulating material,

provided that HV parts are completely enclosed by metallic partitions or shutters intended to be earthed.

5.3.13. Ingress Protection

Ingress protection for the RMU itself must be a minimum of IP 3X. It must be installed within an appropriate enclosure or kiosk with a minimum IP41 for indoor installations and IP55 for outdoor installations. All live parts must be protected or shrouded and labelled for protection against accidental contact. Any LV compartments must have atleast IP 2X protection when open to protect against any live components.

5.3.14. Internal Wiring

All wiring must be coloured and installed in accordance with the requirements AS/NZS 3000. Minimum insulation rating of all cabling must be V90, however the use of X-110 insulation is preferred. Minimum wiring sizes are specified in Snowy Hydro's protection standard – refer to Section 4.6 and 4.7 of SHL-ELE-102 Protection Design Standard.

All internal wiring between panels or cubicles must be hard wired for functionality such as inter-tripping, interlocking and CB blocking. All cubicle wiring must be neatly installed in wiring looms in such that wiring can be readily checked against schematics.

Termination of all wiring utilising lugs or pins must be in accordance with Snowy Hydro's LV standard SHL-ELE-156 Annexure D. All wires must have ferrules at each terminal and the numbering must be in accordance with project schematic and wiring diagrams. The same ferrule number must not be used on wires in different circuits on the same cubicle. Each end of every circuit breaker trip circuit wire must be fitted with a red ferrule engraved 'TRIP' in addition to the numbered ferrules. All conductors must be terminated with accepted crimping lugs, separate lugs being used for each conductor.

5.3.15. Cable Entries

Incoming and outgoing HV cables must be terminated within the cable compartment of the RMU. All cabling must be bottom entry and suitable provision must be made for glanding and termination of all cabling shown in the project documentation. Bottom cable entries must be standard through a blank, removable, non-ferrous gland plates and must be connected to earth. Separate, dedicated gland plates must be provided for control cables (if applicable). All spare entries must be plugged to maintain the RMU IP rating.

5.3.16. Surge Arresters

A requirement for surge arresters may be stated on project documentation to be installed on the incoming line side of the switchboard. They must be connected to the cable side of each incomer circuit breaker and be connected from phase to earth. The surge arresters' ratings must be in accordance with AS 1307.2 and have the following specifications:

- Gapless metal oxide type,
- Hermetically sealed construction
- Equipped with a pressure relief device to prevent excess pressure causing shattering during faults

5.3.17. Bushfire Safety

RMUs may be installed in remote locations and may be deemed to have a high bushfire risk which must be stated on project documentation. In these scenarios switchgear must implement Sensitive Earth Fault protection to detect high-impedance faults. RMUs installed within areas with a high bushfire risk must be selected to allow for installation of Core-Balance CTs.

5.4. Overhead Switchgear

This section describes the requirements for standalone overhead switchgear to provide protection for overhead to ground HV transitions in an outdoor environment.

5.4.1. Switchgear Type

The following types of overhead switchgear are available to select for Snowy Hydro's HV network:

- Automatic Circuit Reclosers (ACR)
- Load Break Switches
- Air-Break Switches
- Drop-out Fuses

Each switchgear must be provided as a complete standalone package and must be provided with mounting facilities and ground level control cabinets where required.

5.4.2. Automatic Circuit Reclosers & Load Break Switches

Reclosers and load break switches must be epoxy resin insulated, suitable to single pole mounting on either concrete or timber poles, comprise of an SF6 insulated interrupter and must be fully compliant with AS 62271.201. Enclosure of the tank and cabinet must be made of stainless steel. The switchgear must be arc fault contained and be designed to vent the pressure away from the operator in the event of an internal arc fault.

The unit must be supplied with the pole mounting bracket suited to the pole specified in the project documentation. The bracket and tank wall must be of adequate strength to limit distortion, with both the top and bottom bracket capable to carry the total weight of the unit alone.

HV Bushings must be of high-quality glazed porcelain and be compliant with AS 60137. The bushing terminals must be clearly marked on the line and load sides and be supplied with insulated covers for wildlife protection. Bushing terminals must be selected to suit the line and load side insulated jumper leads. Surge Arrestors must be installed on all line and load side phases.

Provision must be made for an operator to manually open the switchgear via a standard operating stick. Indication of the switchgear status must be clearly visible from the ground (up to 8m below the switchgear). Indication must be standard – closed must be coloured red and display '1' or 'On' and open must be green and display '0' or 'Off'. In addition, there must be a local control cabinet mounted at the base of the pole to allow operation of the switchgear (see section 5.4.4). Additionally, allowance must be made within the cabinet for remote operation via SCADA.

Provision must be made to ensure all exposed metal of the switchgear and cabinet is adequately earthed. External earth lugs must be provided on all equipment. An earthing strap must be provided between the lid and the tank of the switchgear.

The switchgear must either be self-powered or utilise voltage transformers to supply LV power to operate the closing mechanism of the switchgear.

The tripping mechanism of the recloser must be spring charged. The standard rated operating sequence of the recloser must consist of time intervals between successive operations as follows:

Open – 0.1 s – Close, Open – 1s – Close, Open – 1s, Close, Open – 60s

5.4.3. Air-Break Switches

The air break switch must be ganged, unenclosed, made up of components of non-corroding materials and must comply with AS 62271.103. The switch must be provided with a pole mounting bracket capable of being mounted on either top pole or mid pole arrangements. A positive alignment mechanism must be provided for ease of installation so that the switch is always mounted in the same position on the mounting bracket.

The insulator must be a single piece, fully vitrified non-puncturable porcelain with cap type end fittings. The insulator must be of adequate mechanical strength class to withstand the loads applied during the opening and closing cycles.

Provision must be made to ensure all exposed metal of the switchgear is adequately earthed, with earth lugs provided on all exposed metal surfaces.

All electrical contact surfaces are to be silver plated to ensure that the thickness of plating provides durability of the contact surfaces for the design life as per Section 4.2.

Manual operation of the switch must be achieved by utilising a standard operating stick to either rotate an operating handle or a stick actuator mounted mid-pole. Means must be provided to lock open the switch via a padlock on the operating handle or actuator. Remote operation requirements of the switch must be specified in project documentation.

Additional indication of the switch status must be clearly visible from the ground (up to 8m below the switch). Indication must be standard – closed must be coloured red and display ‘1’ or ‘On’ and open must be green and display ‘0’ or ‘Off’.

If specified on project documentation, motorised remote operation of the switchgear must be offered to be controlled via SCADA or a control cabinet mounted at the base of the pole (see section 5.4.4). Auxiliary power must be provided via pole mounted voltage transformers to supply LV power to operate the closing mechanism of the switchgear.

5.4.4. Control Cabinet

A control cabinet must be mounted below the switchgear on the pole for operation and mounted no higher than 1800mm above ground level. The door must be capable of being padlocked in the closed position. The cabinet must be suitable for installation outdoors and have a minimum IP55 rating. Adequate space must be left in the cabinet for communications equipment if specified under the project documentation.

The control cabinet must be connected to the switchgear by a single multi-core control cable. The multi-core cable must be UV rated and include a screen to be terminated to earth at the cabinet end. Entry of the control cable into the Control Cubicle must be from the bottom.

All indication and controls must be via similar style LEDs or mechanical pushbuttons within the cabinet. The following controls and indication must be available within the cabinet.:

- Switchgear status
- Trip / Open switchgear
- Close (single operation - no auto-reclosing)
- Auto reclose function On/Off toggle (reclosers only)
- Local / remote operation toggle
- SF6 Gas Low Alarm

All control and indication signals must be wired to terminals within the control panel to allow for remote operation through SCADA.

5.4.5. Current Transformers

Current transformers must be included within the recloser enclosure for protection functionality and must be complaint with AS 61869.2 and specifications in Snowy Hydro's protection and design standard SHL-ELE-102 Section 4.3.

5.4.6. Voltage Transformers

Requirements for voltage transformers must be stated on the project documentation or may be required to supply auxiliary power to the switchgear. The voltage transformers must be compliant with AS 61869.3 and specifications in Snowy Hydro's protection and design standard SHL-ELE-102 Section 4.4.

Overhead voltage transformers must be suitable for outdoor use and supplied with brackets appropriate for pole mounting. The bracket must be of adequate strength to minimise distortion. HV Bushings must be of high-quality glazed porcelain and be compliant with AS 60137.

5.4.7. Drop-out Fuses

Drop-out fuses must be of the expulsion type with speed class 'K' (fast operation) and comply with AS 1033.1. The hinge and latch mechanisms of the unit must be constructed of corrosion resistant metals and must include no ferrous parts other than stainless steel. All electrical contact surfaces are to be silver plated to ensure that the thickness of plating provides durability of the contact surfaces for the design life as per Section 4.2.

The insulator must be a single piece, fully vitrified non-puncturable porcelain in accordance with AS 2947. The insulator must be fitted with a bracket suitable for pole mounting and be of adequate mechanical strength to withstand the loads applied during the opening and closing cycles.

Fuse units must be designed and constructed such that on closing the fuse carrier there must be no additional stress must be applied to the fuse link which could cause it to fail.

A flipper spring mechanism must be incorporated into the design of the fuse carrier to assist the fuse link ejection. Lifting rings of 25 mm nominal internal diameter must be provided on the bottom end and on the top of the fuse tube to enable the removal and replacement of the fuse tube using a standard operating rod fitted with a hook-link stick.

6. Protection and Control

This section provides the protection and control requirements primarily around the physical installation within the switchboard. It must be read in conjunction with Snowy Hydro's protection design standard SHL-ELE-102 which provides the functional protection requirements.

6.1. Type of Relay

The functions of protection and control of the switchgear must be from a numerical relay compliant with Snowy Hydro's protection standard SHL-ELE-102 Section 4.12. Each switchgear bay must have its own dedicated protection relay located in a separate panel to the associated switchgear. For primary switchgear applications, the projection relays must be located in a separate cabinet outside of the arc flash boundary of the switchboard.

The relay cases must be the flush, panel mounting type, and effectively seal the panel cut-outs. Setting of any parameters must be possible both by laptop and manually at the panel. Test blocks must be provided on the door of all LV panels with relays to allow for testing without disconnection of any wiring.

Each protection relay must have the following functions as standard:

- Local operation and remote monitoring (via SCADA)
- Display of positions, measurements and settings
- Event recording and disturbance recording
- Capable of self-supervision and have a watchdog output
- Continuous protection scheme monitoring including trip circuits and communication systems (refer to SHL-ELE-102 Section 4.12.4)
- Tripping function isolation capability (refer to SHL-ELE-102 Section 4.12.1).

In the case of interruption of the auxiliary power supply, the relay's entire software, all saved data and the counters must be preserved in a non-volatile manner without batteries.

6.2. Backup Batteries

All primary and secondary switchboards must be provided with backup battery facilities for auxiliary, control and tripping supplies. Battery hold-up times is project specific and sizing must be approved by Snowy Hydro.

6.3. Self-Powered Relays

Self-powered relays are not preferred within Snowy Hydro operations and must only be accepted within RMU switchgear applications where there is no auxiliary power available and prior approval has been given by Snowy Hydro. Where utilised, self-powered relays must have facility for connection of an auxiliary power supply if one is to be installed at a later date. In all other applications the relay must be powered by the available auxiliary power supply to ensure all protection functionality is available.

In certain RMU scenarios where a high level of protection is required, a battery system must be included within the package to provide auxiliary power. The battery hold-up time is project specific and must be approved by Snowy Hydro.

6.4. Protection Elements

The protection elements of each relay must be selected in accordance with project documentation and Snowy Hydro's protection design standard SHL-ELE-102. All protection functions for each project must be approved by a Snowy Hydro protection engineer. Protection relays may require some or all of the following protection elements:

- Time delay and instantaneous over current (50/51)
- Time delay and instantaneous earth fault (50/51G)
- Differential protection (87)
- Directional overcurrent (67)
- Synchronous check (25)
- Undervoltage (27)
- Overvoltage (59) & neutral overvoltage (59N)
- Under/Over frequency (81)
- Line differential (87L)
- Thermal overload (49)
- Trip circuit supervision (95)
- Circuit breaker failure scheme (50BF)
- Sensitive earth fault

6.5. SCADA Communications

Signalling and communications to SCADA must be over DNP 3 ethernet and as per project documentation. All SCADA communications for each project must be approved by a Snowy Hydro protection and controls engineer. All switchgear status, relay faults, alarms, and switchgear control (where motorised switchgear is available) must be available in SCADA, such as:

- CB open / closed status
- Isolator/contactor open / closed status
- Earth switch open / closed status
- Fuse tripped
- Local/remote operation selected
- SF6 insufficient alarm
- Trip circuit healthy
- Protection trip alarm
- Switchgear mechanical fault alarm
- Relay internal fault
- CB / Isolator / Earth Switch Control – trip / open / close

6.6. Substation Automation

Where specified in project documentation, automation protocols such as IEC61850 must be available on the protection relays for transfer of protection signals or measured values between

protection devices and to the SCADA (via DNP 3) or station bus. The standard IEC 61850 for substation communication includes transfer of information from substations to control systems and is also intended to allow transfer of protection signalling via GOOSE messages between protection devices.

Where IEC 61850 is not required, the protection and interlocking system operation must be independent of any communications system. Intertrips and automatic operations must be hardwired between relays and/or the stations control system to ensure there is no reliance on communication infrastructure.

6.7. Instrument Transformers

Instrument transformers must comply with the functional requirements stated in Snowy Hydro's protection design standard, refer to SHL-ELE-102 Section 4.3 and 4.4. This section stipulates additional physical installation requirements for these transformers not specified in the protection standard.

Current and voltage transformers must be epoxy resin moulded type and constructed to safely withstand the mechanical and thermal stresses set up by a short circuit equal to the full short circuit rating of the switchgear. They must also be capable of withstanding power frequency voltages equal to the HV switchgear's rating for one minute without damage the effects of an accidental open circuit in the secondary circuit with full load in the primary.

Voltage transformers must be protected by both primary and secondary fuses and must be installed on or adjacent to the VT. Secondary fuses must be accessible when the primary side is live. Fuses must be capable of being replaced without interrupting the primary sides supply and without interfering with the operating position of the circuit breaker. For primary switchboards, voltage transformers must be withdrawable.

Current transformers must be of the PX class type and must have transient performance analysis carried on each CT. The secondary windings of each set of current transformers must be earthed at one point only per core and such connection to the earth bar must be made through a removable link placed in the LV equipment compartment. All other connections from the secondary windings, including where multi ratio current transformers are specified, must be brought out and connected to test/disconnected type terminals in the LV equipment compartment.

The star point of the voltage transformer primary winding must be earthed internally through an accessible and removable link, sufficiently insulated to allow the primary winding to be tested at any time, with the link removed, to the full test voltage set in AS 61869.3 for "non-earthable" voltage transformers.

6.7.1. Current Transformer Polarity

The polarity of the primary and secondary windings of each instrument transformer must be clearly indicated with P1/P2 and S1/S2 markings and labels must be fitted in an accessible position to indicate the duty of each transformer. Polarity of the CT must be as per Snowy Hydro's protection standard SHL-ELE-102 section 4.3.4.1. The polarity must be shown on the manufacturer's drawings.

6.7.2. Current Transformer Location

Current transformers must be mounted in the cable compartment of switchboards or RMUs as detailed on project documentation. Provision must be made to be able remove the current transformers without major disassembly of the compartment.

In order to maintain appropriate protection, CTs must be positioned such that the zone of protections overlap. I.e., for outgoing feeders, a line differential CT must be installed closer to the circuit breaker than an overcurrent CT to ensure overlapping protection. Care must also be taken to overlap duplicated A/B protection schemes which may be required as specified in Snowy Hydro's protection standard SHL-ELE-102.

6.8. Instruments and Meters

All indicating instruments must be to IEC 60051 accuracy Class 1.0 and must not be damaged by the passage of fault currents up to the maximum fault current of the switchgear. All indicating instrument scales must be clearly divided and marked. All ammeters must be calibrated in amps and all voltmeters must be calibrated in volts.

Normal range of the meters must be 0-120 percent of full load value. Minimum scale readings must not be less than 10 percent of the full load reading. All instruments must be calibrated in the attitude in which they will be mounted as stated on the project documentation. Instrument glasses must be coated with anti-reflective material.

6.9. Maintenance Mode

A maintenance mode switch must be included if specified on project documentation to lower arc flash requirements with faster protection settings at the cost of protection device coordination. The selector switch must be located either at the entry to switchroom, on the control panel door, or as an external input to the protection control circuit. There must be indication on the front of the panel to indicate maintenance mode is active and must provide an alarm to SCADA to ensure maintenance mode is not inadvertently left active.

7. Metering

This section provides the metering requirements within the switchboard where specified in project documentation and must be read in conjunction with Snowy Hydro's protection design standard SHL-ELE-102. Metering relays minimum measurement accuracy must be defined in the project documentation.

Note that revenue metering CT/VT cores must not be utilised for power monitoring (and vice versa).

7.1. Revenue Metering

Revenue metering will be a separate device to the protection IED with overall accuracy as required by the Supply Authority and comply with all local metering regulation and rules. NATA calibration and test certificates must be provided for CTs where connected for revenue metering purposes.

7.2. Power Monitoring

Power monitoring requirements for operational purposes must be stated on project documentation. Minimum monitoring signals are stated below for various circuit types. All signals must be communicated through to SCADA for remote monitoring.

For high voltage incomers, with voltage and current instrument transformers, the following signals must be available on the power monitor:

- Current
- Voltage
- Power factor
- Frequency
- Power kW (total and per individual phase)
- Reactive Power kVAr (total and per individual phase)
- Apparent Power kVA (total and per individual phase)
- Power factor
- Maximum demand kW / kVA
- Voltage and Current Harmonic Distortion per phase up to the 40^{th} harmonic

For feeder circuits, the following signals must be available at the power monitor:

- Current;
- Power kW
- Maximum demand kW

The selected power monitor must also have historical data recording functionality and integrate into the historical database specified in Snowy Hydro's project documentation. In addition to recording all values above, the following must also be available:

- Minimum / Maximum instantaneous values for all above signals
- Waveform recording
- Time stamping
- Event recording

8. Factory Testing and Delivery

Inspection and Test Plans (ITPs) must be developed and implemented to cover the supply of all products and services associated with this specification. The ITP must include all the inspection and testing requirements nominated in this specification and related standards; the ITP must also contain the relevant acceptance criteria for the inspection and testing performed and the records that will be generated as evidence that the test has been performed and meets requirements.

On completion of all tests and before dispatch of HV Switchgear from the supplier's works, the supplier must provide a full set of test documents for approval. The test documents must include, but not be limited to type tests, routine tests and factory tests described in the subsequent sections.

Snowy Hydro may specify hold points or witness points on the ITP where critical steps in fabrication or testing are identified. Designated hold points must not proceed unless a Snowy Hydro representative is present at the hold point or has approved documentation required for the hold point. Typically, a hold point will be specified on the factory acceptance testing, and witness points will be specified on functional testing such as protection device operation, interlocking and secondary injection testing.

8.1. Type Test

The switchboard must have been type tested in accordance with the relevant sections of AS 62271.200 and switchgear as detailed in AS 62271.100, 102, 103 and 105. Type Tests must be carried out with supervision and certification by a recognised testing authority.

Type test certificates for each of these tests will be accepted where it can be demonstrated that the switchgear supplied is of a similar design to previously type tested switchgear.

8.2. Routine Test

The switchboard must be factory tested for the routine tests as detailed in AS 62271.200 and switchgear as detailed in AS 62271.100, 102, 103 and 105 as applicable.

Routine testing must include:

- Power-frequency voltage test on the busbar
- Insulation resistance test of all circuits with the associated circuit breakers
- Dielectric withstand tests on the main, auxiliary and control circuits
- Partial discharge tests (for primary switchgear only)
- Earth continuity tests
- Polarity test
- Resistance of main current paths including the main busbars, bus-section breakers
- Mechanical operation and interlocking checks
- Primary injection to demonstrate correct ratio and polarity of CTs, and correct operation of instrument and protection circuits
- Secondary resistance, polarity and excitation characteristics of all CTs
- Testing of all protection devices by primary or secondary injection test
- CB opening and close timing checks

- Protection relay functionality and calibration checks
- Function testing prior to the factory inspection test
- Inspection of auxiliary and control circuits for verification of control within circuit diagrams and wiring diagrams

8.3. Factory Inspection Test

Notification of factory inspection test along with a factory ITP must be submitted to Snowy Hydro. The factory ITP must be approved before testing can commence. The switchboard must be factory accepted by Snowy Hydro prior to shipping the switchboard to project site. Primary switchgear must be factory tested as a complete, assembled unit in the same configuration as intended to be installed on site.

All functional aspects of the switchgear and/or switchboard must be tested and verified, including:

- Visual inspection of all equipment assessing the quality of the manufacture and overall finish
- Check of the rating plate, nameplate and any additional markings and labels required
- Functional check of switchgear operations, protection relays and control circuits including local and manual controls and simulation of remote controls
- Primary and Secondary injection testing must be performed on protection relays and meters.
  All protection testing must use the Doble protection suite of test plans.
- CT loop resistance and CT polarity testing
- Functional checks to ensure operation of protection relays, operation of circuit breakers, opening and closing operations must be performed
- Functional check of withdrawable switchgear functionality including racking facilities both for local/manual operation and simulation of remote operation (if applicable)
- Functional testing of all interlocking between switches, doors, and earth switches
- Functional testing of control and indication circuits and devices
- Functional testing of communications systems including SCADA communication
- IEC 61850 functionality testing, including latency and network performance tests under high activity loads, eg bus zone trips.
- Inspection of all circuits and wire numbers to verify drawing accuracy.

8.4. Spare Parts and Tools

The manufacturer must supply spare parts critical for the operation of the switchgear. In addition, the manufacturer must guarantee sufficient critical spares are stored in country to minimise lead times when the equipment is required. As a minimum, the following spare parts must be required for each type or rating of switchgear:

- Critical Switchgear components, 1 of the following for each type of switchgear:
    - Handles / Pushbuttons
    - Trip coil
    - Close coil
    - Spring charge motor
    - Fuses (supplied as a set)
    - Indication Lamp/LED
    - Instrument Meters/Gauges
    - Vacuum interrupter bottle (if vacuum circuit breakers are used)
- Critical switchboard components (if applicable):
    - Circuit breaker trolley for each size of panel
    - Remote racking unit (if required on project documentation)
    - Anti-condensation heater

The switchboard manufacturer must nominate a spare parts list covering the recommended spares, tools and test equipment, along with unit prices for Snowy Hydro's consideration.

8.5. Required Documentation

Documentation supplied for the switchboard must include the following.

- The guaranteed performance detail as provided by the manufacturer
- Test reports and certificates consisting of all test procedures and results to prove compliance with this specification and Australian Standards
- Manuals containing all information required for operation and maintenance of the switchboard.
- General arrangement and cross-sectional drawings showing all dimensions, construction, the position of all external connections, indicators and fastening devices, provisions for lifting the equipment and its approximate weight
- Complete drawing suite detailing all electrical connections – e.g. schematic diagrams for power, protection and control and interconnections. Typical drawing sets must not be used.
- Assembly and installation procedures suitable for assembly by a third party electrical contractor
- Functional specifications for control and protection devices

All drawings must be provided in native format in addition to pdf.

8.6. Packing and Transportation

Packing and transportation must comply with Snowy Hydro's packing and shipping standards supplied with the project documentation. All equipment must be designed to withstand both dynamic and static loading and transportation accelerations expected to be experienced under standard freight handling procedures. If required, transportation supports must be provided for loading and transporting the assembled and completed packages such as prefabricated switchrooms and switchboards.

Individually shipped panels must be shipped on pallets suitable for lifting via a forklift for ease of handling between the shipping location and final switchboard location. All individually shipped components must be numbered sequentially and indicate the total number of components shipped (e.g. 1/10, 2/10 etc.) to allow easier confirmation all components have been received. All necessary assembly components and special tools required to re-assemble the switchgear and/or switchboard must be included with clear instructions.

9. References

- SHL-ELE-102 Protection Design
- SHL-ELE-128 Earthing Design
- SHL-ELE-156 General LV Electrical Requirements
- SHL-GEN-123 Protective Coatings
- SHL-GEN-131 High Voltage Danger Sign Requirements

Appendix A Snowy Hydro HV Switchgear Specification Guidance

Switchgear Characteristic	SHL Standard Reference	Default Snowy Hydro Requirement	Project-specific Snowy Hydro Requirement	Vendor Offer
Nominal Switchgear / Switchboard Ratings				
Nominal Voltage	See Section 4.6 Table 2			
Rated System Voltage				
Voltage Withstand				
Lightning Impulse Withstand				
Short Circuit Current				
Design Life	4.2	25 years		
Switchgear Specification				
Circuit Breaker Insulation	5.1.2, 5.2.2, 5.3.3	Vacuum or SF_6		
Isolator Insulation	5.2.3, 5.3.3	Vacuum or SF_6		
Withdrawable	5.1.1, 5.2.1, 5.3.1	PRI, SEC – Yes RMU – No O/H – N/A		
Motorised Operation	5.1.2, 5.2.2, 5.3.2, 5.4	PRI, SEC – Yes RMU, O/H – No		
Mechanical Pushbutton Operation	5.1.2, 5.2.2, 5.2.3, 5.3.2, 5.3.3, 5.4.4	Yes		
Remote Operation	5.1.12, 5.2.11 5.3.10	PRI, SEC – Yes RMU, O/H – No		
Live Line Indication	5.1.13, 5.2.12, 5.3.11	Yes		
Dead Busbar Indication	5.1.13, 5.2.12, 5.3.11	Yes		
Busbar earthing facilities/switch	5.1.3, 5.2.4	PRI, SEC – Yes RMU – No O/H – N/A		
External Local Control Panel	5.1.12, 5.2.11 5.3.10, 5.4.4	PRI, O/H – Yes SEC, RMU – No		

Switchgear Characteristic	SHL Standard Reference	Default Snowy Hydro Requirement	Project-specific Snowy Hydro Requirement	Vendor Offer
Redundant CB trip coils	5.1.11	PRI – Yes SEC, RMU, O/H – No		
CB Auxiliary Contacts	5.1.2, 5.2.2, 5.3.2	Project Specific		
Isolator/Earth Switch Auxiliary Contacts	5.1.3, 5.2.3, 5.2.4, 5.3.3, 5.3.4	Project Specific		
All switchgear padlockable	5.1.2 - 5.1.3, 5.2.2 – 5.2.4 5.3.2 – 5.3.4 5.4.3 – 5.4.4	Yes		
Mimic diagram on front of switchgear	5.1.1, 5.2.1, 5.3.1	Yes		
Key Interlocks	5.1.5, 5.2.5, 5.3.5	Project Specific		
Mechanical Endurance	5.1.2, 5.2.2, 5.2.3, 5.3.2, 5.3.3	M2		
Earth Switch location	5.1.3, 5.2.4, 5.3.4	Cable-side		
Switchboard / RMU / Enclosure Specification				
Lockable Doors	4.1	Required		
Component Insulation	5.1.8, 5.2.8, 5.3.7, 5.4.2	PRI, SEC, RMU - Air / Epoxy cast resin O/H - Epoxy cast resin		
Compartment Partitions	5.1.1, 5.2.1, 5.3.1	Metallic, earthed		
Busbar maximum temperature	5.1.6, 5.2.6, 5.3.6	90°C		
Earth busbar size	5.1.6, 5.2.6, 5.3.6	Suited to fault level. Minimum sizing: PRI, SEC – 30x6 mm RMU – 40x3 mm		
Shutters	5.1.7, 5.2.7	PRI, SEC – Yes RMU - No O/H – N/A		

Switchgear Characteristic	SHL Standard Reference	Default Snowy Hydro Requirement	Project-specific Snowy Hydro Requirement	Vendor Offer
LSC Category	5.1.9, 5.2.9, 5.3.8	PRI, SEC – LSC2B RMU – LSC2A O/H – N/A		
Arc Fault Containment	5.1.10, 5.2.10, 5.3.9	PRI, SEC – AFLR RMU – AFL/AFLR O/H – N/A		
Arc Fault Venting	5.1.10, 5.2.10	Project Specific		
Surge Arrestors	5.1.20, 5.3.16	Project specific		
Enclosure IP Rating	5.1.16, 5.2.15, 5.3.13	Indoors – IP41 Outdoors – IP55		
Cable Entries	5.1.18, 5.2.17, 5.3.15, 5.4.4	Bottom Entry		
Protection Specification				
Protection Relay	6.1 SHL-ELE-102 4.12	Numerical, IEC 60255 compliant		
CT Type	6.7	Epoxy cast resin		
VT Type	6.7	Epoxy cast resin		
CT Class	SHL-ELE-102 4.3.2.3	PX Class, Project Specific		
Secondary CT rating	SHL-ELE-102 4.3.2.2	1 A		
VT Class	SHL-ELE-102 4.4.3.3	Minimum 0.5M		
Secondary VT rating	SHL-ELE-102 4.4.2.2	110/√3 V		
Test Links Installed	SHL-ELE-102 4.8	Yes		
Battery Backup	6.2	PRI, SEC – Yes RMU, O/H – No		
Battery Hold-up Time	6.2	Project Specific		
Circuit Breaker Failure Protection	5.1.11	PRI – Yes SEC, RMU, O/H – No		

Switchgear Characteristic	SHL Standard Reference	Default Snowy Hydro Requirement	Project-specific Snowy Hydro Requirement	Vendor Offer
Bus Differential Protection	5.1.1	PRI – Yes SEC, RMU, O/H – No		
SEF Protection	5.1.22, 5.3.17	Project Specific		
Metering Specification				
CT Class	SHL-ELE-102 4.3.2.3	Project Specific		
VT Class	SHL-ELE-102 4.4.3.3	Minimum 0.5M		
NATA Calibration	7.1	Required for revenue metering		
Power monitoring	7.2	Project Specific		
Testing & Delivery Requirements				
Type Testing	8.1	Required		
Routine Testing	8.2	Required		
Factory Inspection Testing	8.3	Required		
Additional Tools Required	8.4	Switchgear trolley Remote Racking Unit Critical Spares		

PRI – Primary Switchgear
SEC – Secondary Switchgear
RMU – Ring Main Units
O/H – Overhead Switchgear