Protection Design

1. Executive Summary

This standard sets out the requirements for the scope for design of protection systems.

It is written to provide good electrical industry practice in protection system design and installation.

It will also provide conformity between protection schemes installed in all Snowy Hydro locations.

2. Scope

This standard applies to any new or altered Snowy Hydro protection systems.

The inclusion of additional functionality, extensions, relocation or modification, including to the housing or cabinet are considered an alteration for the purposes of this standard.

This standard does not apply where the alteration is only for the like-for-like replacement of a failed protection device.

An exemption from the application of parts of this standard may be provided under exceptional circumstances by the Manager Controls and Protection. Any exemptions must be obtained in writing prior to commencing design.

This standard is to be read in conjunction with other Snowy Standards, in particular SHL-ELE-156 General LV Electrical 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 General Electrical Requirements document, it must take precedence over any other Standards or Codes.

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 the relevant State;
- Standards and Codes named in this document or the annexures;
- Australian Standards and Codes;
- International Standards and Codes

2.1.1. New South Wales Acts and Regulations

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

- Electricity Supply Act 1995
- Electricity Supply (General) Regulation 2001
- Service and Installation Rules 2006
- Environmentally Hazardous Chemicals Act 1985
- Work Health and Safety Act 2011
- National Electricity Act 1997
- Electricity (Consumer Safety) Act 2004

2.1.2. Victoria Acts and Regulations

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 2007
- Electrical Safety (Installations) Regulations 1999
- Electrical Safety (Network Assets) Regulations 1999
- National Electricity Act 1997 and National Electricity Act 2005
- Energy Safe Victoria Act 2005

2.1.3. South Australia Acts and Regulations

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

- Electrical Act (1996)
- Electricity (General) Regulations 1997
- Occupational Health, Safety and Welfare (SafeWorkSA) Amendment Act 2005
- Work, Health and Safety Regulations 2012
- Environment Protection Act 1993
- Plumbers, Gas Fitters and Electricians Act 1995

2.1.4. Australian and International Standards

Electrical plant and equipment must be designed, supplied, installed and commissioned in accordance with the requirements of the specified Australian Standards, the following specific codes and standards; and any other relevant standards and regulations. These include, but are not limited to:

AS 1000	The International System of Units (SI) and its Applications
AS 1024	Direct recording electrical measuring instruments and their accessories
AS 1029	Low Voltage Contactors
AS 1046	Letter Symbols for use in Electrotechnology
AS 1100	Technical Drawing

AS 1101	Graphical Symbols for General Engineering
AS/NZS 1102	Graphical Symbols for Electrotechnology
AS 1125	Conductors in Insulated Electric Cables and Flexible Cords
AS 2067	Substations and HV installations
AS 2360	Measurement of fluid flow
AS 2373	Electric cables - Twisted pair for control and protection circuits
AS 2381	Electrical equipment for explosive gas atmospheres – Selection, installation and maintenance
AS/NZS 3000	Wiring Rules
AS/NZS 3008.1.1	Electrical installations - selection of cables - Cables for alternating voltages up to and including 0.6/1kV - Typical Australian installation conditions
AS 3010	Electrical installations - Generating sets
AS 3013	Electrical installations - Classification of the fire and mechanical performance of wiring system elements
AS/NZS 3017	Electrical installations – Verification guidelines
AS 3080	Information technology - Generic cabling for customer premises (ISO/IEC 11801:2011, mod)
AS 3808	Insulating and sheathing materials for electric cables
AS 3100	Approval and Test Specification - General requirements for electrical equipment
AS/NZS 3111	Approval and test specification for miniature over-current circuit-breakers
AS 3560	XLPE Power cables for rated voltages up to 1kV
AS 3820	Essential service requirements for electrical equipment
AS 4024	Safety of Machinery (all parts)
AS 4029	Stationary Batteries (Parts 1-3)
AS 4044	Battery Chargers for Stationary Batteries
AS 4070	Recommended practices for protection of low-voltage electrical installations and equipment in MEN systems from transient overvoltages
AS 4086	Secondary batteries for use with stand-alone power systems.
AS 4428	Fire detection, warning, control and intercom systems - control and indicating equipment (all parts)

AS 4509	Stand-alone power systems (Parts 1 and 2)
AS 4702	Polymer Cable Protection Covers
AS 4802	Local Area Networks
AS 4853	Electrical hazards on metallic pipelines
AS/NZS 5000	Electric cables - Polymeric insulated
AS/NZS ISO/IEC 24702	Telecommunications Installations - Generic cabling - Industrial premises
AS 60034	Rotating electrical machines (All parts)
AS 60038	Standard Voltages
AS 61869	Instrument Transformers
AS 60060	High-voltage test techniques
AS/NZS 60076	Power transformers (all parts)
AS/NZS 60079	Explosive atmospheres
AS 60146	Semiconductor converters (Parts 1.1, 1.2, 1.3 and 2)
AS 60529	Degrees of protection provided by enclosures (IP Code)
AS/NZS IEC 60947	Low-voltage switchgear and controlgear (all parts)
AS 61000	Electromagnetic compatibility (EMC)
AS IEC 61131	Programmable controllers (all parts)
AS 61204.1	Low voltage power supply devices D.C. output - Performance characteristics
AS 61386	Conduits and Fitting for Electrical Installations (all parts)
AS 61439	Low-Voltage switchgear and controlgear assemblies
AS IEC 61508	Functional safety of electrical/electronic/programmable electronic safety related systems.
AS IEC 61511	Functional safety – safety instrumented systems for the process industry sector
AS 62040	Uninterrupted Power Systems (UPS)
AS 62026	Low-voltage switchgear and control gear - Controller-device interfaces
AS/NZS 61000	Electromagnetic compatibility (EMC) (All parts)
AS/NZS IEC	Testing of balanced communication cabling in accordance with ISO/IEC 11801

61935	- Installed cabling
AS 62599	Alarm systems (all parts)
AS/ACIF S009:2020	Installation requirements for customer cabling (Wiring Rules)
AS/ACIF S008:2020	Requirements for customer cabling products
AS/NZS CISPR 11	Industrial, scientific and medical equipment—Radio-frequency disturbance characteristics - Limits and methods of measurement
AS/NZS CISPR 14.1	Electromagnetic compatibility - requirements for household appliances, electric tools and similar apparatus
AS/NZS CISPR 22	Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement
BS 6739	Code of practice for instrumentation in process control systems: installation design and practice
IEC 60051	Direct Acting Indicating Electrical Measuring Instruments and Accessories
IEC 60071	Insulation co-ordination
IEC 60073	Basic and safety principles for man-machine interface, marking and identification – Coding principles for indication devices and actuators
IEC 60255	Measuring relays and protection equipment
IEC 60258	Direct recording electrical measuring instruments and their accessories.
IEC 60269	Low-voltage fuses
IEC 60304	Standard colours for insulation for low-frequency cables and wires
IEC 60478	Stabilised power supplies dc output
IEC 60584	Thermocouples
IEC 60688	Electrical measuring transducers for converting A.C. and D.C. electrical quantities to analogue or digital signals
IEC 60751	Platinum Resistance Elements (PT100)
IEC 60793	Optical Fibres
IEC 61010	Safety requirements for electrical equipment
IEC 61158	Fieldbus
IEC 61850	Communication Networks in Substations
IEC 61869	Instrument Transformers (Parts 1-5)

IEC 62443-2	Security for industrial automation and control systems
IEC 62443-3	Industrial communication networks - Network and system security
IEC ISO 80000	Quantities and units
IEC TR 61869-102	Instrument transformers - Part 102: Ferroresonance oscillations in substations with inductive voltage transformers
IEC TR 61869-103	Instrument transformers - The use of instrument transformers for power quality measurement
IEEE 142	IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
IEEE 450-2002	Recommended practice for maintenance, testing, and replacement of vented lead-acid batteries for stationary applications
IEEE 484-2002	Recommended practice for installation design and installation of vented lead-acid batteries for stationary applications
IEEE 485-2010	Recommended practice for sizing lead-acid batteries for stationary applications
IEEE 979	Guide for Substation Fire Protection
IEEE 1050	Guide for Instrumentation and Control Equipment grounding in Generating Stations
IEEE 1613	Environmental and Testing Requirements for Communications Networking Devices in Electric Power Substations
IEEE C37.90.1	Surge Withstand Capability
ANSI IEEE C37.2	Electrical Power System Device Function Numbers, Acronyms, and Contact Designations
EN 50081-2	Electromagnetic compatibility. Generic emission, Industrial environment
EN 50082-2	Electromagnetic compatibility. Generic immunity, Industrial environment
EN 55011	Limits and methods of measurement of radio disturbance
EN 61000	Electromagnetic Compatibility (EMC)
ENA EG1	Substation earthing guide
NFPA 70E	Standard for Electrical Safety in the Workplace
NER	National Electricity Rules

2.2. Units of Measure

The metric (SI) system must be used for electrical work in accordance with the provisions of AS ISO 1000 and IEC ISO 80000. All data, drawings, information and calculations must be presented in the metric unit system. Where British or American units are used by Suppliers, the equivalent SI units must be indicated on the drawing together with the non-SI original value.

3. Definitions

The following terms have the meanings given to them in the table below for the purposes of this standard.

Word and/or picture	**Definition**
CT	Current transformer
VT	Voltage transformer
Protection Engineer	An electrical engineer employed by Snowy Hydro suitably qualified and experienced with protection systems.

4. Technical Requirements

4.1. Nomenclature

Duplicate protection schemes are termed A and B protections. Where duplicate protection schemes are installed, they shall be fully redundant.

Single protection schemes shall only be installed where remote backup provides sufficient fault clearing time without risking system security or damage to plant. Details shall be provided to a Protection Engineer to confirm these details.

4.2. Compliance

Plant covered by a connection agreement shall meet the automatic access standards within the National Electricity Code.

4.3. Current Transformers

4.3.1. General

The design on the current transformer must comply with the requirements of AS 61869 and IEC 61869

The installation of current transformers must ensure that the current transformer primary and secondary connections are readily accessible.

4.3.2. Ratings

4.3.2.1. Primary

The primary current rating of current transformers shall be selected to be greater than the plant nominal rating, and rounded to the nearest suitable rating.

It shall be confirmed that the protection or metering device can provide adequate functionality with the selected ratio.

4.3.2.2. Secondary

Every current transformer secondary shall be rated at 1 amp. If the primary current rating is greater than 6000 amps, the secondary current rating may be increased to 5 amps. This will require the approval of a Protection Engineer.

4.3.2.3. Class

The class of the current transformer shall be selected during the design phase.

The class selected shall include analysis of the X/R ratio, resistance of terminations and cables, and provide an allowance for increased fault levels.

Protection current transformers shall be PX class.

The class selection will require the approval of a Protection Engineer.

4.3.3. Connections

All current transformers shall be connected in star.

4.3.4. Polarity

4.3.4.1. Protection

All protection current transformer polarity wiring shall be connected away from the zone it is protecting.

4.3.4.2. Metering

4.3.4.2.1. Busbars

All metering current transformer polarity wiring for circuits associated with busbars shall be connected towards the busbar.

4.3.4.2.2. Generators

All metering current transformer polarity wiring for circuits associated with generators shall be connected towards the star point.

4.3.4.2.3. Others

In other applications the metering current transformer polarity wiring shall be toward the source of supply.

4.3.5. Earthing

The star point of every current transformer set shall be earthed.

Individual phase transformers will be wired to a local junction box to form a four wire set. This four wire set will be cabled to the required panel. It is in this panel that the current transformer star point will be earthed.

The point in a circuit that is to be earthed varies according to the type of circuit. Except for some busbar protection circuits, the point at which the connection to earth is made is always the same, namely inside the protection or metering cubicle where the connection is taken to a link which is connected to the earth bar.

4.3.5.1. Protection

The current transformers for protection circuits shall be earthed in the protection cubicle.

4.3.5.2. Busbar Protection

High impedance circulating current busbar protection current transformer circuits shall be earthed at the kiosk or switchyard summation junction box where the associated bus wires are formed and not in the busbar protection relay cubicle.

In some instances the current transformer circuits are cabled into the relay room. Examples include some low impedance systems and modern numerical busbar protection relays. In these instances the CT star points shall be earthed in the protection cubicle.

4.3.5.3. Metering and Instrumentation

Current transformers used for metering only shall be earthed in the metering cubicle and those used for instruments only, in the control cubicle.

4.3.5.4. Multiple Uses

When current and voltage transformers are associated with more than one cubicle, the earth connection shall be made in the first cubicle to which the connections are taken, usually the protection cubicle.

4.3.5.5. AVR

Current transformers used for AVR purpose only shall be earthed in the AVR cubicle.

4.3.6. Sharing of Current Transformers

There will be no sharing of current transformers between the A and B protection schemes. Each protection scheme will have dedicated current transformers. One current transformer may supply more than one relay within a protection scheme.

Some transformers have limited cores within the HV turrets. Currently, each core provides a transformer and line protection. Although the CT core is shared between the transformer and line protections, there is not sharing of cores between A and B protections.

New low burden relays allow the use of slip on current transformers to provide full duplication and segregation of the protection schemes. Where possible, different items of plant will not share current transformer cores.

However, sharing of current transformers will require the approval of a Protection Engineer.

Regardless, there will be no sharing of current transformers between the A and B protection schemes.

4.3.7. Access

There shall be ready access to the current transformer primary and secondary connections.

4.4. Voltage Transformers

4.4.1. General

The design on the voltage transformer must comply with the requirements of AS 61869 and IEC 61869.

The installation of voltage transformers must ensure that the voltage transformer primary and secondary connections are readily accessible.

Where possible, different items of plant except protection systems, excitation systems and energy meters shall not share voltage transformer cores. However, sharing of voltage transformers will require the approval of a Protection Engineer.

Regardless, there will be no sharing of voltage transformers between the A and B protection schemes. If both schemes are using the same VT, failure of VT signal to both protection schemes simultaneously shall not prevent a fault clearance. Where this is not achievable VT circuit failure alarm shall be configured.

4.4.2. Types of Transformers

4.4.2.1. Below 35 kV

Transformers below 35 kV shall be either three single phase units or one five limb three phase star connected unit.

Single phase units shall be connected between the phase and earth. The HV star point of multiphase units shall be earthed.

In some generator protection systems, the voltage transformer needs to be connected to the generator star point rather than earth. In these situations a second set of voltage transformers shall be used for this purpose. These voltage transformers shall have a fully insulated neutral, and the connection between the voltage transformer star point and the generator star point shall be rated to the generator voltage.

Rack out units on integrated switchgear are acceptable.

Three limb three phase units are not acceptable.

4.4.2.2. Above 35 kV

Three single phase units shall be installed above 35 kV.

Single phase units may be installed for busbar voltage monitoring. The instrument transformer is then generally connected to white phase. However, this may change in consultation with a Protection Engineer.

4.4.3. Rating

4.4.3.1. Primary

The primary rating shall be the same as the rated system phase to phase voltage

Single phase units shall be rated at the rated system phase to phase voltage ÷√3.

If there is a risk of ferro resonance, the primary rating shall be the rated system phase to phase voltage.

4.4.3.2. Secondary

The secondary rating shall be 110 volts phase to phase.

Single phase units shall be rated at 110 ÷√3 volts.

If there is a risk of ferro resonance, the secondary rating shall be 110 volts. This will maintain the correct ratio, and provide a knee point above the worse case voltage rise eliminating the risk of ferro resonance.

4.4.3.3. Class

The class and VA rating of the voltage transformer shall be selected during the design phase. The class selection will require the approval of a Protection Engineer.

The VA rating per phase will be either 50, 100 or 200 VA per phase. 200 VA is preferred for older plant. For new low burden installations the VA rating can be 50 VA. Any change from these values shall require the approval of a Protection Engineer.

The class shall meet requirements for AEMO metering accuracy. In any case the class shall be 0.5M or better.

4.4.4. Connection

Voltage transformer secondaries for general use are connected in star.

Open delta windings are permitted for directional earth fault protection. Whilst an open delta connection allows the installation of a 200 Ω 200 Watt resistor for ferro resonance elimination, the preferred option is a higher primary and secondary rating.

Three phase four wire voltage signals will be cabled to each cubicle that requires voltage signals.

4.4.5. Earthing

The secondary neutral star point of every voltage transformer set shall be earthed.

Existing circuits were white or yellow phase earthed. As areas are updated, the earthing will be changed to neutral earthing. Care must be taken during the transition period not to couple the earthing and short the white phase voltage transformer secondary.

Individual phase transformers will be wired to a local junction box to form a four wire set. This four wire set will be cabled to the required panels.

The neutral will be earthed at the first distribution point. For multi use voltage transformers, this may be the first junction box. For single use voltage transformers, this may be the protection, metering or AVR cubicle.

The non polarity terminal of any open delta winding shall be earthed.

4.4.6. VT Wiring

Three phase four wire VT signals shall be cabled to each cubicle that requires VT signals, even if not all three phase and neutral wires are required for the functions within the cubicle.

The exception is auto synchronising, where typically single phase wiring may be installed.

If the auto synchroniser requires three phase VT wiring, three phase four wire signals shall be installed.

4.5. Neutral Earthing Transformer

4.5.1. Primary

The primary voltage rating of the transformer shall be greater than 1.3 × the rated phase to neutral voltage.

The selection of the neutral earthing transformer, the secondary voltage rating and resistance value requires the approval of a Protection Engineer.

4.5.2. Earthing

The neutral earthing transformer high voltage winding is earthed to the local earth grid.

The secondary winding is earthed at the neutral earthing transformer to the local earth grid. The earthing conductor size shall be equal to or greater than the conductor size between the transformer and neutral earthing resistor.

The neutral earthing transformer secondary will not be earthed at the protection panel. This is a change from the previous practice of earthing only in the protection panel with 2.5 mm^2 cable. It was deemed to be more appropriate to earth the high current circuit at the high current area with an earth capable of conducting the high current.

4.6. Cabling

All cabling shall be either PVC/PVC, or X-HF-110 insulated with HFS-110-TP sheath and be overall copper screened.

The screen shall be earthed at one end only. This end shall be the major panel end. The screen at the unterminated end shall be insulated by covering with heat shrink.

The cable temperature rating shall be V90 or greater.

All cores within the cable shall be clearly numbered.

All cores shall be seven strands or greater.

4.6.1. Current Transformer

All current transformer cabling except for shaft current transformers shall be 6 mm^2. Shaft current transformer cabling shall be 2.5 mm^2.

4.6.2. Voltage Transformer

All voltage transformer cabling shall be 2.5 mm^2.

4.6.3. DC Cabling

In addition to the following rules, cables shall be sized to carry the maximum load current according to AS 3008.

4.6.3.1. Above 120 volts DC

All DC cabling above 120 volts DC shall be 2.5 mm^2.

4.6.3.2. Below 120 volts DC

Protection DC cabling below 120 volts DC may be Dekoron or B50 1.5 mm^2 twisted pair.

Any circuits in series with a trip coil shall be at least 2.5 mm^2.

Any DC supply cabling shall be 2.5 mm^2.

4.6.4. RTD Cabling

RTD cabling may be either:

- Dekoron or B50 1.5 mm^2 twisted pair with each pair screened as well as an overall cable screen.
- 2.5 mm^2 cable as per DC cabling requirements.

4.7. Panel Wiring

All panel wire shall be greater than 15 strands. The wire temperature rating shall be V90 or greater.

The use of X-HF-110 insulated wiring is preferred.

4.7.1. Current Transformer

4.7.1.1. Size

All current transformer panel wiring shall be 2.5 mm^2 or greater.

4.7.1.2. Colour

Wire colours shall be phase identified red, white, blue, neutral (black) and earth (green/yellow).

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

4.7.2. Voltage Transformer

4.7.2.1. Size

All voltage transformer panel wiring shall be 1.5 mm^2 or greater.

4.7.2.2. Colour

Wire colours shall be phase identified red, white, blue, neutral (black) and earth (green/yellow).

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

4.7.2.3. Location

Voltage transformer circuit protection devices - such as a circuit breaker or a fuse link combination – will be mounted at appropriate locations.

If mounted horizontally, the live side wiring shall terminate at the top. If mounted vertically, the live side wiring shall terminate at the left hand side.

4.7.3. DC

4.7.3.1. Size

All DC panel wiring shall be 1.0 mm^2 or greater. Any circuits in series with a trip coil shall be at least 2.5 mm^2. This will include power supplies.

4.7.3.2. Colour

DC wiring greater than 120 volts shall be coloured orange.

DC wiring less than or equal to 120 volts shall be coloured grey.

4.7.4. Grouping

Circuits of a similar voltage shall be grouped together when located on the same terminal strip.

4.7.5. Crimp Lugs

Crimp lugs shall be of the double grip or bootlace type and sized appropriately for the wire.

Two wires shall not be terminated under one screw unless they are terminated with a single lug that is specifically designed to fit two wires.

4.8. Links

4.8.1. Function

This section describes the use of test links. These are used for trip and control isolation. The use of terminal strips is covered in another section.

4.8.2. Type

The current test links used by Snowy Hydro are Weidmuller WTL6/1/STB. The part number is 1016900000.

4.8.3. Mounting

Links shall be mounted on TS35 open din rail. All links will have a dedicated unambiguous number.

4.8.4. Operation

4.8.4.1. Indication

All links shall have a clear indication of their position.

4.8.4.2. Closing Direction

All links mounted on horizontal rail shall fall closed.

All links mounted on vertical rail shall close when the link is moved from left to right. The link will be “left right closed”.

4.8.4.3. Tripping Direction

Horizontally mounted links shall be designed that the trip signal moves from positive to negative down the link.

Vertically mounted links shall be designed that the trip signal moves from positive to negative from left to right through the link.

4.8.4.4. Test Points

Tests points shall be provided for all current transformer terminals, voltage transformer terminals and for all trip circuits. Links shall have 4 mm test sockets on both sides of the link.

4.8.5. Isolation Links

Drawings E-M1-116-14/1 and E-M1-116-20/1 are examples of major and minor isolation links.

4.8.5.1. Major Isolation Links

Links that perform a major isolation are mounted on the front of the protection panels. These links include circuit breaker failure, circuit breaker trip, main field switch trip, electrical shutdown and mechanical shutdown. These links may be used for isolation for access conditions.

4.8.5.2. Minor Isolation Links

Minor isolations include individual trip signals to the shutdown relay, control isolation and isolation of individual circuit breaker trip signals. These links are located at the rear of the protection panel.

4.9. Terminal Strips

4.9.1. Type

The terminal strips for DC protection connections are Allen Bradley 1492-J4. The terminal markers are Allen Bradley 1492-M6X12.

The terminal strips for AC protection instrument transformer connections are Allen Bradley 1492-J10. The terminal markers are Allen Bradley 1492-M7X12.

4.9.2. Mounting

Terminal strips shall be mounted on TS35 open din rail. All terminals will have a dedicated unambiguous number.

4.9.3. Commoning of Terminals

Two or more wires shall not be terminated under one screw. Commoning of terminals shall be provided by means of screw mounted, solid and visible bridging pieces.

4.9.4. Grouping

Circuits of a similar nature shall be grouped together and terminals in AC circuits above 110 volts 50Hz AC and DC circuits above 120 volts shall be appropriately segregated.

In panels where there is more than one DC circuit, care shall be taken to ensure strict segregation between the positives or negatives that originate from "A" or "B" battery systems.

Where the positive and negative of the supply are situated in consecutive order on the same terminal strip, a barrier shall be placed between the two to provide protection against accidental shorting of the links.

4.10. Power Supplies

4.10.1. DC Supplies

4.10.1.1. Voltages

Snowy Hydro uses a range of battery supplies, depending upon the site location and loading.

The Snowy Scheme hydro stations use 250 V DC unearthed.

Valley Power and Laverton use 125 V DC unearthed.

Field sites use 48 V DC positive earthed.

Some small hydro sites use 24 V DC unearthed or 48 V DC unearthed.

4.10.1.2. Unearthed Batteries

Unearthed batteries are used to allow the protection system to be single fault tolerant. The condition of any unearthed battery is monitored by an earth fault relay. This relay effectively creates a high resistance earth reference at the centre of the battery.

4.10.1.3. New Sites

It is preferred that new sites use 110 volt unearthed batteries. The voltage selected will depend upon station loading and safety requirements. The battery voltage will be selected in consultation with a Protection Engineer.

4.10.1.4. Redundancy

2N redundancy shall be maintained in DC and battery systems.

A and B Protection schemes must not be supplied from the same battery bank or from the same DC supply system.

4.10.1.5. Alarms

Alarms of the DC and Battery systems shall be connected to the SCADA system.

Battery bank to DC bus connection status shall be monitored.

4.10.2. AC Power Supplies

No AC power supplies will be used in protection schemes.

It is recognised that some rotor earth fault relays require an AC auxiliary supply. However, modern relays will run on a DC supply. The use of AC power supplies for this function will require the approval of a Protection Engineer.

4.11. Fuses and Circuit Breakers

Every circuit breaker shall have an auxiliary change over contact to provide status of the circuit breaker position.

4.11.1. Visible Break Isolation

Some locations require a visible break on the low voltage circuitry for isolation purposes. These locations typically have a transformer that can step up the applied voltage to high voltage. Examples of these locations include voltage transformer secondaries and auxiliary transformer secondaries.

The isolation at these sites shall provide a visible break. This is often provided by fuses and links. The isolation shall be capable of being locked with the Snowy Hydro lockout system.

4.11.2. Circuit Breaker Isolation

Isolations of circuits downstream of the visible break isolation may be circuit breakers. Isolation of the DC supplies can be by a suitably rated circuit breaker.

Attention is drawn to the greater fault breaking capacity of HRC fuses when compared to circuit breakers. Fuses may be the only alternative.

4.12. Protection Relays

All new protection relays shall be numerical relays. All Protection relays shall comply with IEC 60255.

Preference is to use SEL relays for the A protection, and GE relays for the B protection.

Where a single protection is installed, SEL relays are preferred.

All protection scheme related programmable logic must be applied in devices that comply with IEC 60255.

4.12.1. Isolation of Tripping Functions

Each protection element shall be capable of being isolated without the use of software changes.

This is generally achieved by one of two methods

1. Each trip is individually mapped to a separate relay output contact. These contacts are then externally connected through trip links to provide the tripping function.
2. The relay has the internal tripping elements mapped to a trip output contact. The trip can be isolated by depressing a button on the relay panel. Isolation of the trip shall also initiate an alarm to annunciate the trip isolation.

4.12.2. Digital Input Ratings

The digital inputs on any protection relay shall not assert if the applied voltage is less than ½ rated DC supply voltage. This is to avoid operation on a DC earth fault.

Some relays are ordered with a single digital input voltage. Other relays allow a programmable pickup level. The settings file configuration shall ensure the correct digital input operating value is selected.

4.12.3. All or Nothing Relays

Programmable all or nothing relays are preferred. Single function traditional relays may be installed if required to match existing systems. The selection of all or nothing relays shall require the approval of a Protection Engineer.

4.12.4. Protection Scheme Monitoring

All critical high voltage protection schemes shall incorporate continuous monitoring of the critical elements such as protection relays, trip circuits and related communication systems.

4.12.5. Indications

Protection relays shall be equipped with operational indicators and SCADA indicators.

4.13. Test Socket Blocks

Relay AC signals shall be connected through test socket blocks. The preferred device is a Reyrolle 2RMLG02.

Reyrolle 2RMLG01 units are used for synchronising circuits. The circuit breaker close signals are wired in terminals 13-14 and 15-16.

4.14. Cubicles

4.14.1. Type

Cubicles containing protection relays shall use 19" rack construction.

Cubicles shall be fully enclosed. And provide sufficient ventilation with air filters where necessary.

Cubicles shall comply with requirements listed in SHL-ELE-156 and SHL-GEN-123.

4.14.2. Sizing

All protection relay cubicles shall be 800 mm wide, 2000 mm high and 800 mm deep.

4.14.3. Internal Equipment

Each cubicle shall contain an interior light controlled by a door switch and a double RCD protected 240 V power point.

If the cubicle is mounted in an area subject to moisture it will have a thermostatically controlled heater, set to 20˚C. A variable thermostat is preferred.

And, If the cubicle is mounted in an area where maximum ambient temperature is above 35ºC, the cubicle shall have a thermostatically controlled fan, set to 35˚C. A variable thermostat is preferred.

4.14.4. Access

Rear access is preferred to all protection cubicles. If the cubicle is required to be front access, the front door and swing frame will operate through greater than 180˚ to allow access to the cubicle internals.

All cubicle designs shall require the approval of a Protection Engineer.

4.14.5. Layout

Vertical spacing of at least 2 vertical rack units is required between equipment in protection panels.

If the relay size is less than 5 vertical units, 5 vertical units shall be allowed. This is in addition to the 2 unit spacing between relays.

4.14.6. Earthing

A 25 × 3 mm copper earthing bar shall be installed in the bottom of each protection cubicle.

Current and voltage transformer earthing shall be through isolation links. This removes the need to disconnect wires for insulation resistance testing.

4.15. Design

All designs shall require the approval of a Protection Engineer.

4.15.1. Wire Numbers

Wire numbers shall be allocated according to the wire numbering scheme employed at the site. For existing hydro sites this will be allocated according to D-GEN-2-43.

Typicaly, protection system wire numbers adhering to D-GEN-2-43 are allocated by following table.

Function	Series
Unit A protection	400
Unit A CB trip	1400
Unit B protection	2400
Unit B CB trip	3400
Pipeline A protection	4400
Pipeline B protection	5400
Busbar A protection	6400
Busbar B protection	7400
Transformer A protection	8400
Transformer B protection	9400

4.15.2. Cable numbers

Cable numbering is according to SHL-ELE-156, Annexure D.

4.15.3. Device numbers

Device numbers shall be allocated according to drawing D-GEN-2-22.

4.15.4. Typical Drawings

Typical drawings are as follows.

- E-M1-116-14 Generator circuit breaker control.
- E-M1-116-20 Generator DC protection circuits.
- E-M1-116-21 Unit AC measurements.
- E-M1-116-27 Transformer DC protection circuits.
- E-M1-116-40 Pipeline guard valve control diagram.
- E-M1-116-46 Pipeline protection circuit diagram.
- E-M1-116-68 Transformer and line AC protection circuits.
- E-M1-116-69 Generator AC protection circuits.

- E-M1-366-1 Instrument transformer positions.
- E-M1-366-2 Instrument transformers polarities and terminal markings.
- E-M1-373-56 Unit protection panel layout and material list.
- E-M1-377-82 Generator protection wiring diagram.
- E-M1-116-86 Transformer protection wiring diagram.

4.16. Protection Functions

4.16.1. Generator Protection - Greater than 1 MVA/Diesel and Gas Generators Greater than 3 MVA

Generators greater than 1 MVA shall be protected by two fully duplicated and segregated protection systems. Relays for each system shall be from different manufacturers.

The protection system shall consist of the follow functions as a minimum

- Generator differential
- Generator parallel winding protection where parallel stator winding are installed
- Over voltage
- Neutral displacement where the generator star point is impedance earthed
- 100% stator earth fault
- Stator dynamic braking over current if dynamic braking is installed
- Negative phase sequence
- Accidental energisation
- Distance backup
- Pole slip
- Field failure
- Over fluxing
- Current checked circuit breaker failure
- Low energy non pallet checked circuit breaker failure
- Rotor earth fault
- Shaft over current
- Over frequency
- Under voltage when running as a synchronous condenser or pump
- Under frequency when running as a synchronous condenser or pump
- 32L Low Forward Power interlock to inhibit CB open on hydro generator non urgent trips
- RTD based thermal overload

Rotor earth fault shall be an alarm on salient pole generators and is not required to be duplicated. It shall be a trip on cylindrical machines. Due to the difficulty of providing duplicated rotor earth fault protection, this function can be a single unit on the A protection.

The generator differential protection may be disabled when dynamically braking at less than 5 Hertz.

When the generator is directly connected to the generator step up transformer, the A protection may have an overall differential and the B protection generator differential and transformer differential protection functions.

Cylindrical machines may also have the following protection functions

- Under frequency when on line
- Under voltage when on line
- Reverse power

Asynchronous generators will not have field failure, rotor earth fault or over frequency protection installed. If they are capable of self excitation they shall have over frequency protection.

The National Electricity Rules provide protection functions required for connection to the electricity grid. This list provides those functions.

Some generators in the existing fleet do not conform exactly to this standard (e.g. SA Diesel sites). Any variation to this standard will require consultation with a SHL protection engineer and appropriate approval.

4.16.2. Generator Protection - Less Than 1 MVA/Diesel and Gas Generators Less than 3 MVA

Generators less than 1 MVA shall be protected by at least one protection system. The preferred relay supplier is SEL.

The protection system shall consist of the follow functions as a minimum

- Generator restricted earth fault
- Over voltage
- Negative phase sequence
- Accidental energisation
- Distance or over current
- Over fluxing
- Current checked circuit breaker failure
- Rotor earth fault
- Shaft over current
- Over frequency

4.16.3. Transformer Protection - Greater than 1 MVA or 22 kV

Transformers greater than 1 MVA or 22 kV shall be protected by two fully duplicated and segregated protection systems. Relays for each system shall be from different manufacturers.

The protection system shall consist of the follow functions as a minimum

- Transformer biased differential with unrestrained highset.
- Restricted earth fault on star connected windings. This will be duplicated on windings greater than 132 kV.
- Over fluxing
- Main tank Buchholz on the A protection, main tank PRV operated on the B protection.
- Tap changer tank Buchholz on the A protection, tap changer tank PRV operated on the B protection.
- Residual voltage on delta windings without an earth fault current reference
- Current checked circuit breaker failure
- Top oil over temperature

- Winding over temperature
- Oil low level as a backup protection for Bucholz relay

Hermetically sealed distribution transformers - between 1 MVA-2.5MVA

The design shall be approved by a protection engineer and follow functions as a minimum,

- Transformer biased differential with unrestrained highset.
- Restricted earth fault on star connected windings.
- Over fluxing
- Pressure relief valve with trip signal to protection relay.
- Residual voltage on delta windings without an earth fault current reference
- Current checked circuit breaker failure
- Top oil over temperature
- Winding over temperature
- Oil low level

The oil and winding temperatures shall be by RTDs connected to the transformer protection relays. These RTDs shall be duplicated. Dry type transformers shall have duplicated temperature RTDs. The temperature protection shall be Pt100 RTD.

4.16.4. Transformer Protection Less Than 1 MVA or 22 kV

Transformers less than 1 MVA or 22 kV shall be protected by protection schemes appropriate to their sizing and fault level.

Distribution substations shall be sufficiently protected by HV and LV fuses, protection relays or protective devices approved by the SHL's Protection Engineer.

Transformers in power stations shall be protected by differential or over current protection. The cost of differential protection has dropped to the extent that differential protection with LV overcurrent elements is the preferred option.

Where two transformers are connected in parallel differential protection is required.

Over temperature protection shall be installed on transformers that normally carry load (including intermittently energised transformers). Oil temperature protection and a PRV shall be installed on oil filled transformers. Winding temperature protection shall be installed on dry type transformers. The temperature protection shall be Pt100 RTD.

4.16.5. Busbar Protection Greater Than 22 kV

Busbars shall be protected by duplicated and segregated protection systems. They shall operate on the 1 out of 2 principle with no check and discriminating zones.

The busbar protection shall be of the numerical low impedance type. Preferred suppliers are SEL and GE.

Low impedance protection allows simpler circuit breaker failure configuration.

4.16.6. Busbar Protection Greater, Less Than or Equal to 22 kV

Outdoor busses are generally protected by remote backup if the fault level is low enough. If the fault level is too high a single low impedance busbar protection system shall be installed with additional coverage provided by remote backup.

4.16.7. Metal Clad Switchgear Busbar Protection

Metal clad switchgear shall have either arc detection or busbar differential protection installed.

Arc detection shall have an instantaneous over current and earth fault check.

Preferred manufacturers are SEL, RMS and GE.

Frame leakage protection shall not be installed.

4.16.8. Lower Voltage Main Switchboards

Low Voltage Main Switch Boards shall comply with SHL-ELE-156 General LV Electrical Requirements.

In addition, the switchboard protections shall comply with AS/NZS 3000:2018 clause 2.5.5.3 Limitation of the harmful effects of a switchboard internal arcing fault.

If protection discrimination cannot be achieved between upstream and downstream protection devices due to arc flash energy considerations, arc flash detection devices must be utilised to ensure protection discrimination is maintained.

And, if arc flash energy level requirements prescribed in SHL-ELE-156 General LV Electrical Requirements in Annexure B cannot be achieved by short circuit protection devices, arc flash detection devices must be utilised to ensure low arc flash energy levels. .

Busbar protection/zone selective interlocking can be only implemented on LV switchboards with the approval of the SHL.

Electronic Trip Units for Low Voltage ACB Protection

Applications where the primary protection device is an Electronic Trip Unit (ETU) instead of a protection relay. Electronic Trip Unit shall meet following requirements,

- ETU must be a High Specification type.
- ETU shall support energy monitoring functions according to IEC 61557-12
- All statuses shall be able to communicate over ethernet using DNP3, IEC61850 or Modbus TCP, in that order of preference.
- ETU shall have event recording, waveform tracking for faults and self diagnostic functions.
- Data collectors/concentrators must be provided, as required in the control section of the switchboard.
- Rating plugs should be chosen to suit the rated capacity of the load rather than the maximum circuit breaker rating, as applicable.
- Zone Selective Interlocking (ZSI) feature to be provided as an option.

4.16.9. Reverse Blocking Busbar Schemes

Reverse blocking busbar schemes, or zone selective interlocking schemes, shall not be installed in high voltage systems.

4.16.10. Outdoor Junction Boxes and Terminal Boxes

IP Rating for outdoor Junction boxes and for Terminal boxes shall be IP 65 or higher.

5. References

- SHL-ELE-156 General LV Electrical Requirements
- SHL-GEN-123 Protective Coatings