Design of substation secondary systems

SDI 526

Amendment No 4
1 November 2019

Revision History

Supersedes SDI 526 amendment 3.

The standard has been rewritten all shading in the document has been removed.

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Document Control

Documentation content coordinator:	Substation Secondary Design Manager
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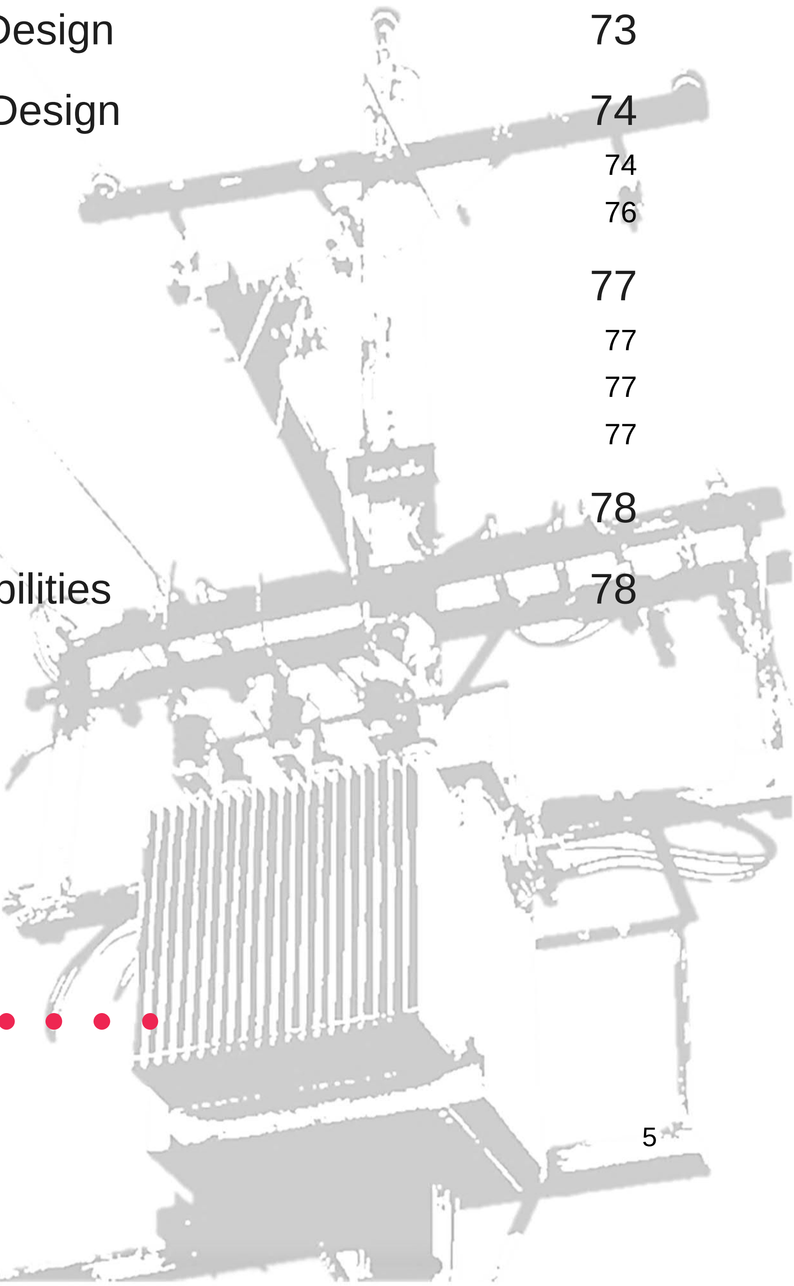
Contents



1 Documentation Scope

The purpose of this instruction is to outline the high level technical requirements for the design of the company's substation secondary systems to meet the objectives of Company Policy 9.2.5 – Network Asset Design.

Substation secondary design is concerned with the design of systems that are required for the safe control, monitoring and operation of the primary power network within a substation.

This network standard applies to the design of new secondary systems and where practical, to the refurbishment design of existing secondary systems.

1.1 Overview

The elements of each substation secondary systems are connected via wiring that are generally marshalled in control panels. The scope of this standard is primarily concerned with the design of the control panels that are associated with individual substation secondary systems. This standard comprises of two parts.

Part 1 provides general requirements that are common to all secondary design systems. These requirements include:

- secondary design application and principles;
- control panel design; and
- wiring and cabling design.

Part 2 provides specific requirements for control panel design that are related to individual substation systems. These systems include:

- control of primary equipment;
- SCADA systems;
- protection systems;
- communication systems;
- substation auxiliary supply systems;
- metering; and
- load control.

1.2 Relationship to Other Company Standards

There are company standards that define the various equipment, technical requirements and configuration of each element in the substation secondary system. These standards are referenced below in Section 2 and must be read in conjunction with this standard.

Of special interest is Equipment Technical Specification ETS0014 – Control panel fabrication and installation, which specifies the technical requirements for the fabrication and installation of control panels that are designed to this standard.

2 Protection of High Voltage Plant References

External Regulations
Electricity Supply Act 1995 (NSW)
Electricity Supply (Safety and Network Management) Regulation 2014
ENA National Electricity Network Safety Code (Doc 01-2008)
Work Health and Safety Act 2011
Work Health and Safety Regulation 2017

External Standards
AS/NZS 3000:2018 – Electrical Installation "Wiring Rules"
AS 2067:2016 – Substations and high voltage installations exceeding 1kV a.c.
AS 2650:2005 – Common specifications for high-voltage switchgear and control gear
AS 2700:2011 – Colour Standards for General Purposes
AS1100.101 1992 (R2014) – Technical Drawing; General Principles
AS 60529:2004 (R2018) – Degrees of Protection provided by enclosures (IP Code)
AS/NZS 60269.2: 2013 – Low Voltage Fuses part 2
AS/NZS 2344:2016 – Limits of electromagnetic interference from overhead a.c power lines and high voltage equipment installations
AS 4437:1996 – Solderless crimped connection - general requirements, test methods and practical guide
AS 4506:2005 (R2017) – Metal Finishing -Thermoset Powder Coatings
AS 60947.1:2015 – Low voltage switchgear and control gear Part 1: General rules
AS 60947.7.1:2015 – Low voltage switchgear and control gear Part 7.1: Ancillary equipment - Terminal blocks for copper conductors
IEC 60445:2017 – Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals and conductor terminations

Company Policies and Procedures
Company Policy 9.1.2 – Reliability Principals
Company Policy 9.2.1 – Network Planning
Company Policy 9.2.2 – Network Protection
Company Policy 9.2.5 – Network Asset Design
Company Policy 9.2.10 – Network Asset Ratings
Company Policy 9.7.1 – Network Asset Construction
Company Policy 9.9.1 – Network Asset Maintenance
Branch Procedure TTB 0046 – Safety Assurance for the Asset Standards and Design Branch's Project Design Process
Branch Procedure TTB 0053 – Design process for Asset Standards and Design Branch Projects
Branch Workplace Instruction WTB 0014 – Substation Electrical Design Plans

Company Standards
Automation Design Instruction ADI 0006 – Substation Communication Systems
Automation Design Instruction ADI 0012 – Substation Automation Systems
Earthing Design Instruction EDI 516 – Major substation earthing design, construct and commissioning
Equipment Technical Specification ETS 0014 – Control Panel Fabrication and Installation
Equipment Technical Specification ETS 0018 – Audio frequency injection control equipment
Protection Design Instruction PDI 1000 – Protection of High Voltage Plant
Standard Asset Data SAD 0006 – Transmission Drawing Standard
Substation Design Instruction SDI 503 – Transmission & Zone Substation Fire Detection, Control and Suppression Systems
Substation Design Instruction SDI 505 – Minimum Design and Construction Requirements for Transmission and Zone Substations and Switching Stations
Substation Design Instruction SDI 511 – Auxiliary AC Supplies and Switchgear
Substation Design Instruction SDI 513 – Substation batteries and battery chargers
Substation Design Instruction SDI 529 – Light and Power
Substation Design Instruction SDI 547 – Alarm and Tripping Requirements in SF6 and Dry Air Equipment

Other
Electrical Design Guides (EDG)
Electrical Base Designs

3 Definitions and Abbreviations

Abbreviation	Meaning
ACO	Auto Change Over
ASP	Accredited Service Providers
AFIC	Audio Frequency Injection Control
Aux	Auxiliary
CB	Circuit Breaker
DOM	Digital Output Module
DSP	Design Service Provider
EDG	Electrical Design Guide
EE	Endeavour Energy
ETS	Equipment Technical Specification
HMI	Human Machine Interface
HV	High Voltage
F/L	Frame Leakage
I/O	Input / Output
IP	Ingress Protection
LAN	Local Area Network
LCC	Local Control Cubical
LV	Low Voltage
MCB	Miniature Circuit Breaker
Min	Minimum
Max	Maximum
RIV	Radio Interference Voltage
P&C	Protection and Control
PIES	Protection Indication and Equipment Schedule
POM	Pulsed Output Module
SAS	Substation Automation System
SCADA	Supervisory Control and Data Acquisition
SiD	Safety in Design
SLD	Single Line Drawing
SMU	Substation Management Unit
UFLS	Under Frequency Load Shed

Term	Definition
Base Design	Sets of *"seed"* drawings that can be used as a starting point or base for site specific design.
Bay	That part of a switchyard used to interconnect circuits to the main bus. Typically, bus section bays, feeder bays and transformer bays. Usually a bay consists of a CB and its associated equipment.
Bus	A conductor that distributes power to sub circuits.
Control Panel	Generic name for an enclosure used to mount and wire protection and control equipment.
Control Cubical	A medium to small sized control panel.
Dedicated Wire Number	A wire number that is associated with a specific function, typically an ac, dc supply or special trip wire.
General Wire Number	A wire number that is classed for general use.
Kiosk	A free-standing control cubical that is usually installed in the switchyard.
Legacy Design	Existing design from an earlier or redundant standard.
Local Control Cubical	A manufacturer designed control cubical used for the control of equipment supplied to the company.
Marshalling Cubical	A control cubical, designed as a connection point for incoming and outgoing cables.
Network Security	Design systems that reduce the risk of unintentional loss of supply.
Open	Opening of a circuit breaker by manual or automatic control systems
Primary System	Those parts of the network that transport and distribute power.
Protection Scheme	A protection scheme consists of a number or protection components protecting a specific zone which generally trips a specific trip coil.
Secondary Systems	Control systems that control, monitor and operate the primary system.
Trip	Opening of a circuit breaker by protection systems.
Zone	The section of network for which a particular protection scheme is intended to provide protection coverage.

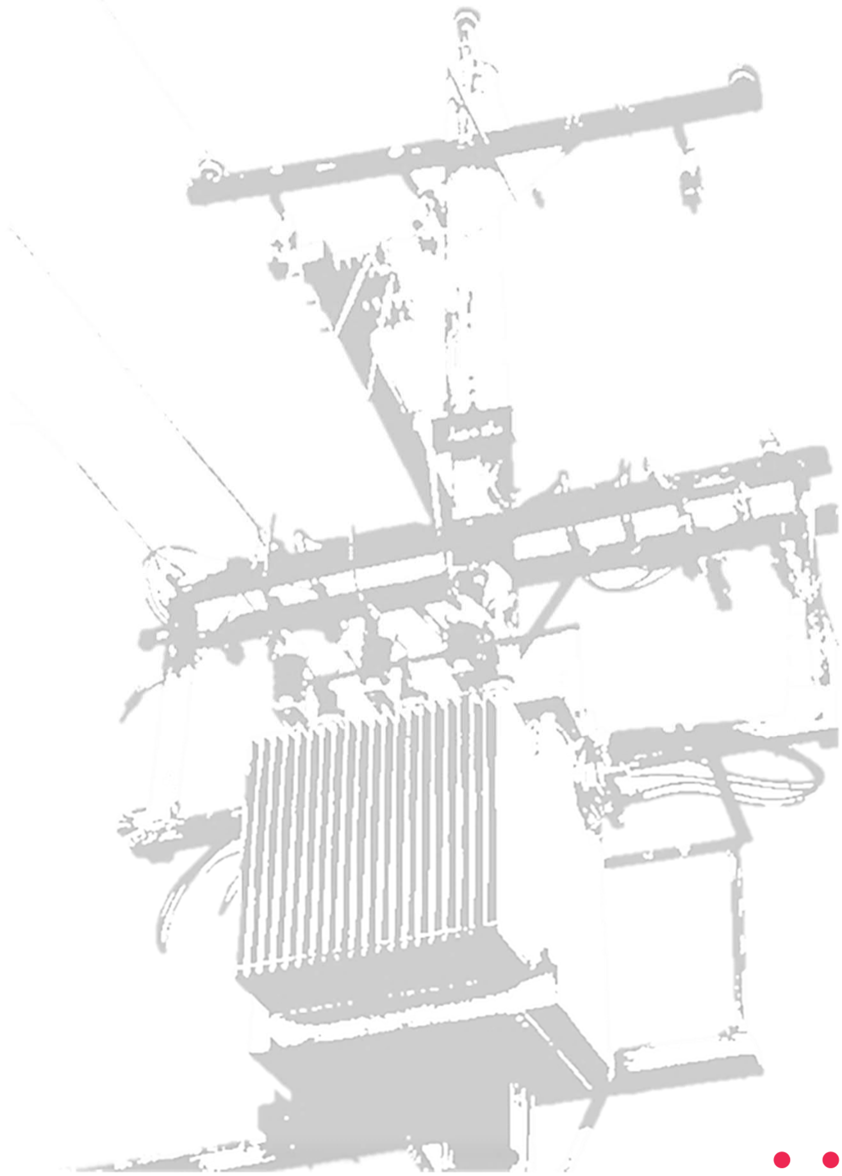
NOTE: See Company Standard PDI 1000 – Protection of High Voltage Plant Appendix A for a list of recommended protection definitions

PART 1 – GENERAL DESIGN

Application, Principles, Control Panel General Arrangement, Wiring System and Cable System Design

Sections 4 to Section 8

Part 1 of this standard is concerned with the general design requirements of substation secondary systems. Part 1 specifies the generic requirements common to all secondary system design. It must read in conjunction with Part 2 which specifies specific secondary system design.



4 Application

This standard is to be applied to the design of secondary systems for new transmission and new zone substations by internal company designers, or their agents.

4.1 Exceptions

Subject to approval of the Substation Secondary Design Manager, deviation from this standard is permitted for the design of secondary systems for: -

a) primary equipment that is supplied as part of a company contract;
b) contestable substations;
c) augmentation of existing secondary systems; and
d) secondary systems using digital substation technologies.

4.1.1 Design of equipment supplied under a company contract

The design of major primary equipment supplied to the company, is subject to a tender and contract evaluation process. Where ever it is practical, it is preferred that the secondary design of the contract equipment complies with all aspects of this standard. However, for various commercial reasons this may not always be economically viable.

Variations to this secondary design standard may be accepted if the contract design complies with all the following conditions

a) complies with the objectives of Company Policy 9.2.5 – Network Asset Design;
b) complies with relevant Australian or International Standards;
c) complies with the relevant Equipment Technical Specification;
d) tender drawings outlining the company's secondary design requirements are included as a part of the tender process; and
e) the equipment secondary design is reviewed and approved by the Secondary Design Manger.

Company substation secondary designers may provide technical assistance as required to manufacturer's preparing the contract drawings.

4.1.2 Contestable substation secondary design

Accredited Service Providers (ASP) may be engaged by HV customers to design and build substations that are to be integrated into the company's HV network. If the substation is to be fully, (or partly) maintained, or operated by the company then the substation design provided by the ASP, must comply to this standard.

The designs will be reviewed by the company's Substation Secondary Design Section however the responsibility for the design lies with the ASP. The design review will make a statement regarding the suitability of the design, notifying the ASP, that the company has either an "*objection*" or "*no objection*" to their designs. Reasons for the objection will be provided.

Technical support shall be given to the ASP during the development of those parts of the secondary design that will be used by the company's operational and maintenance personnel.

4.1.3 Management of legacy design

The application of this standard during an augmentation or amendment of an existing secondary design may cause a conflict with an earlier or redundant standard.

If there is a significant Safety in Design risk with the existing design, then the existing installation is to be redesigned to the current standard (1).

For all other circumstances a judgement is to be made by the designer as to the most appropriate application of the standard. In this situation consideration is to be given to the following circumstances:-

a) issues associated with network security;
b) the cost of compliance verses the benefit of compliance;
c) the time and effort to comply verses the project timeline;
d) extent of the scope, (for example, is the scope of the noncompliance clearly defined); and
e) the impact on construction, operation and maintenance staff as a consequence of inconsistent design and standard creep at a site.

The design decision that best meets these considerations is to be implemented after consultation with the appropriate stakeholders.

NOTE:
(1) Safe design of structures code of practice July 2014, page 4; WorkCover NSW catalogue No. WC03839

A person conducting a business or undertaking who alters or modifies a design without consulting the original or subsequent designer will assume the duties of a designer. Any changes to the design of a structure that may affect the health and safety of those who work on or use the structure and must be considered by the person altering or modifying a design.

4.1.4 *Secondary systems using digital substation technologies*

Standards are currently being developed for the implementation of digital technology into substation secondary systems. This emerging technology will impact on existing secondary design principles with the merging of secondary systems such as SCADA and protection and the replacement of interpanel wiring by communication systems.

Variations from Company Standard SDI 526 – Control cabling, panels and terminations, may be required for the implementation of this technology during the refurbishment of conventional substations. These variations shall be managed through consultation with stakeholders by the company's secondary system working groups.

This standard shall be used as an interim guide for the design of new digital substations until a new standard has been approved.

5 Substation Secondary Design Principles

Company Policy 9.2.5 – Network Asset Design, provides the framework for the design of the company's electrical network. When preparing substation secondary design, the designer must be conversant with this policy and the application of the following secondary design principles.

5.1 Safety Assurance

Safety Assurance is a confidence that company policies, procedures and practices systematically manage safety in the workplace (1) .

The designer of substation secondary systems shall manage the risks to health and safety that may be associated with the design. The design must take into consideration the human capacity, both physically and mentally, to construct and maintain the asset over the whole life cycle of the asset.

NOTE:
(1) refer to policy 9.2.5.

5.1.1 Safety in Design

Work Health and Safety regulation mandates that designers undertake a specific safety assurance activity known as a Safety in Design *(SiD)* review. Safety in Design is a systematic risk assessment and stakeholder consultation process, designed to eliminate or control hazards in the work place early in the design process.

Branch Procedure TTB 0046 – Safety Assurance for the Asset Standards and Design Branch's Project Design Process, describes how safety is to be managed and integrated into the design or redesign of network assets. Electrical Design Guide 001, Safety in Design, is a company training manual that provides guidance on the implementation of SiD principles, the participation in SiD workshops and the preparation of SiD reports.

5.1.2 Design process

Safety assurance of design requires that the design process be managed in a planned and systematic way by competent designers and that safety be incorporated into the design process.

Substation secondary designers shall follow the design process outlined in the Branch Procedure TTB 0053 – Design Process for Asset Standards and Design Branch Projects. This procedure manages the planning, review, verification, approval, authorisation and validation of substation secondary design.

Branch Workplace Instruction WTB 0014 – Substation Electrical Design Plans, provides the framework for the arrangement and documentation of various design activities such as design reviews, detail design tasks and design approval.

5.2 Design Criteria

During the design process, consideration shall be given to the following design criteria.

5.2.1 Compliance

Substation secondary design is to comply with the relevant Australian, International and company standards. The design must also comply with the requirements of the project definition. Design review, design verification and design approval shall be undertaken by competent designers.

If construction has not commenced twelve months after the design has been issued, then the currency of the design shall be rechecked for compliance.

5.2.2 Network security

Substation secondary design shall consider the impact of an unintentional loss of supply. This is especially important for the design of protection and control circuitry which must have clearly labelled test links that are configured in a consistent and logical layout.

5.2.3 Economic and sustainable design

Substation Secondary design shall consider the cost impacts of the design over the whole of life of the asset. These costs shall include cost to the environment, disposal costs, operational cost, construction cost, design costs and material cost.

Consideration shall be given to expected life of equipment and the implications for future refurbishment or replacement design. Substation secondary systems such as SCADA, communications and protection have a typical asset life of 10 years where as the substation has a typical asset life of 45 years (1).

NOTE:

(1) Refer to policy 9.2.5 am8; table 1- Guide to Asset Lives

5.3 Design Standardisation

The standardisation of design is an efficient means of managing compliance, project costs, operational safety and asset management. Electrical Design Guides (EDG) and Base Designs may be used in the preparation of secondary design.

5.3.1 Electrical design guides

The purpose of the Electrical Design Guides is to provide context and support to company standards, procedures and other design documentation. These guides are design aids written specifically for company substation designers and are not intended for the public or general publication.

The guides provide background history into legacy design, training, education and interpretation of company design standards and procedures. The guides will assist company substation secondary designers, to apply design principles in a consistent manner.

5.3.2 Base designs

Base designs are sets of *"seed"* drawings that can be used as a starting point, (for example, a base) for site specific design. Base designs have been through a design review process to check for compliance to the standards and can be used to apply design principles in a consistent manner.

It should be noted that base designs are not standard or template designs. Base designs have preconfigured many of the elements of this standard; however, unlike a standard or template drawing they must be modified to suit the design brief and other design specification.

5.4 Secondary System Design Drawings

Drawings are the primary means of recording and communicating detail design used for the construction and maintenance of secondary systems. Drawings shall conform with AS1100.101 technical drawing principles and Company Standard SAD 0006 – Transmission Substation Design. Electrical Design Guide EDG004, provides guidance and discussion on drafting and drawing production for company designers.

Secondary system designs shall be combined into a set of drawings and a cover page, per bay or panel, as per Company Standard SAD 0006 – Transmission Substation Design. The cover sheet shall provide an overview of the drawing set with a safety in design statement and network security caution. Standard hazard icons shall be used through the drawing to identify potential safety and network security hazards within the design. A short description of the hazards are to be listed on the cover page.

5.4.1 Naming conventions

The designs shall use a consistent naming convention throughout the design documentation. The IEEE device number may be used as a guide for the identification of secondary equipment [(1)]. In situations where a device has multiple functions, then the primary function shall be used to name the device.

If more than one device function number is required, then a forward slash and relay number shall be appended to the function number.

EXAMPLE:

The No.1 overcurrent earth fault and sensitive earth fault relay would use the function of 51/1 and the No.2 overcurrent earth fault and sensitive earth fault relay would use the function number 51/2. The primary function of relay is overcurrent protection (IEEE device number 51)

The name of protection relays shall be placed above a dashed box that is to be drawn around the relay elements. The manufacture’s relay type shall be placed in the top LHS of the dashed box and the relay function number shall be placed in the top LHS of the dashed box.

EXAMPLE:

If a P142 relay is used as the No.1 overcurrent earth fault and sensitive earth fault relay , then the naming convention would

- *place No.1 OC/EF & SEF above the dashed box*
- *place the relay type P142 in the top LHS of the dashed box*
- *place the function device number 51/1 in the top RHS of the dashed box*

NOTE:

(1) A list of device numbers is tabled in the appendix Company Standard PDI 1000 – Protection of high voltage plant.

6 Control Panel General Arrangement and Design

A fundamental element of substation secondary design is the control panel. Control panels are enclosures used to install the secondary equipment in a logical and consistent manner. The arrangement and general design of control panels shall comply with the following requirements.

6.1 Control Panel General Arrangement

6.1.1 Control panel types

There is a range of different types of control panels used in the company's network. Refurbishment design must give due consideration to the application of this standard when amending existing control panels as discussed in 4.1.3.

NOTES: Range of panel types are discussed in Company Standard ETS 0014 – Control panel fabrication and installation, Section 5.1.

6.1.2 Arrangement of control panels in substation control rooms

The control panel layout design shall provide sufficient access for operational and maintenance staff to safely work and move around the control room. The control panel service area shall comply with AS2067:2016 clause 5.5.4 which requires a minimum 600mm clearance around panels including open doors.

Additionally, the control room panel layout design shall:-

a) position the station HMI near the main exit;
b) position the AC and DC panels away from the SCADA panels;
c) group the panels in a logical order according to function;
d) consider the installation of future panels; and
e) provide a consistency in panel layouts so that the equipment is neatly aligned across panels.

6.1.3 Control panel numbering

Control panels are to be numbered in a sequence from left to right when facing the panel. A label is to be fixed in the same location on each panel.

6.2 Control Panel Construction Design

Company designed control panels are to be designed to the following panel construction requirements.

6.2.1 Service conditions

The service conditions are in accordance with the indoor standard requirements of AS2650:2005 – Common specifications for high-voltage switchgear and control gear, clause 2.1. Additional requirements may be indicated in this document as appropriate.

The equipment shall also be designed for operation in the following extended conditions:

a) Altitude <1000m;
b) Maximum ambient temperature 40 deg. C;
c) Minimum ambient temperature 5 deg. C;
d) Average index of mean relative humidity:9:00am - 95%; and
e) Condensation.

6.2.2 Noise level and radio interference voltage (RIV)

The equipment may be installed in a residential area near family residences. The design of the panel is to consider noise and radio interference voltages. These voltages shall be kept to levels that comply with AS/NZS 2344:2016.

6.2.3 Panel dimensions

The design of panel dimensions shall be of a suitable size:-

a) to mount possible future panel equipment;
b) to fit through doorways and passages in substation; and
c) to allow access for construction, maintenance and operation activities.

Endeavour Energy swing frame P&C panels shall generally be 2000mm high and 800mm wide, depending on the quantity of equipment being installed, and typically 600mm deep.

6.2.4 Panel material

Panels shall be designed and constructed of material capable of withstanding the mechanical, electrical and thermal stresses as well as the effects of humidity, which are likely to be encountered in normal service.

6.2.5 Surface finish

The panel design shall specify appropriate protection for internal and external panel surfaces. Enclosures shall be protected against corrosion by the use of suitable material or by the application of suitable protective coatings to the exposed surfaces.

All powder coating procedures shall be conducted in accordance with AS 4506:2005 – Metal Finishing - Thermoset Powder Coatings.

6.2.6 Panel ingress protection rating

The panel design shall specify the degree of protection for enclosures. The minimum IP rating for indoor enclosures shall not be less than IP53, and the minimum IP rating for outdoor enclosures shall not be less than IP65, in accordance with AS 60529:2004.

The design of panel openings such as cable entries and cover plates shall ensure that, when the cables are properly installed, the above specified degree of protection will be obtained.

6.2.7 Panel fixing and support

Panels shall be designed so that they are self-supporting and shall not rely on other panels to remain rigid. Free standing panels shall be designed so that they do not topple over and are securely fixed to the floor.

6.2.8 Panel footing

Panel designs that include support plinths shall be strong enough to allow the panels to be rolled on steel rods on the floor during installation. These plinths may be used to group panels for transport.

6.2.9 Panel lifting and transportation

Panels shall be designed, so that they can be transported without stress or damage to the panels. The design shall specify the lifting facilities required. If separate lifting facilities are required, other than for example, normal slings and ropes, these shall be supplied with the panels.

6.2.10 Panel doors

Control panel doors are to be designed so that it moves freely without fouling equipment on adjacent panels and permits adequate access to equipment at the back and sides of the panel.

The doors shall open through 120 degrees and the devices mounted on the door shall be secure when the door is in the open position.

The design of the door shall be such that bracing or stiffeners are not required. The design of hinges, door handles and locking mechanisms shall be of suitable quality.

Suitable measures shall be taken to ensure that tension is not placed upon wiring or terminations when opening doors.

6.2.11 Panel earthing

Panels shall be designed to earth the panel's exposed conductive surfaces and associated equipment through suitable panel earthing facilities such as earth busbar, earth links or earth studs.

6.2.12 Panel ventilation

Each panel shall be fitted with adequate ventilation to prevent the build-up of heat inside the panel.

6.2.13 Cable entry

Panels shall be designed for top or bottom control cable entry. A gland plate and cable glands shall be used to maintain IP ratings for outdoor cubicles. Consideration in the design shall be given for the need to install future control cables

6.2.14 Panel ducting

The panel design shall include the appropriate use slotted wiring ducts for wire management to minimise the use of wiring looms.

6.2.15 Panel lighting

The panel shall be designed to have adequate internal and external lighting. Individual cubicles shall have an internal light fitted to the top of the panel and wired through a door activated switch so that the light is automatically activated when the door is opened.

It is preferred that panel lighting uses an extra low voltage system such as 12Vac LED lighting or 24Vdc LED lighting. If a 230Vac system is used then wiring must be double insulated and run separated from control wiring and all exposed terminals must be shrouded and fitted with a caution label.

The supply of equipment lighting shall originate from the station AC supply panel and not the general power and lighting distribution board.

6.2.16 Control room panel heating (anti condensation)

Control room panels shall be designed without the need for anti-condensation heaters. However, if anti-condensation heaters are required, their use is subject to the approval of the Substation Secondary Design Manager.

6.2.17 Protection against fire hazard

Provision in the panel design shall be made to manage the impact of fire. The panels shall include appropriate circuit design and protections so that internal faults or overload conditions will not cause fire hazards. The design and components shall have a power rating higher than necessary under normal conditions.

6.2.18 Protection against arc fault

AC supply panels are to be designed to reduce the probability and consequences of LV arc faults. Where possible the AC supply panel should be segregated from other panels.

6.2.19 Protection against electric shock

Separation shall be maintained between 230V AC wiring and DC control, protection and signalling wiring.

Where terminals carry 230V AC wiring they shall be shrouded by a non-conducting substance to prevent accidental contact and they shall have a warning label fitted either on the terminal or in an approved position adjacent to the terminals. The warning label shall have the words **WARNING 230 VAC** using white lettering on a red background with a minimum letter size of 5mm. An electric shock hazard Icon must be added to the drawing adjacent to the hazard.

6.2.20 Control panel layout general arrangement

The Control Panel layout shall be designed with the following requirements:-

a) Panel relays, meters, switches, links and other equipment are to be flush or semi projection mounted;
b) Location of panel equipment shall provide suitable access to the wiring and terminations as required for construction and maintenance;
c) Consideration shall be given for the future replacement of equipment;
d) Consider the use of removable panel plates for short life cycle equipment;
e) Panel equipment is not to be mounted too high or too low for operational and maintenance staff to access. The minimum height for equipment above the ground is 300mm;
f) Sufficient space behind equipment mounted on the panel door shall be allowed for wiring and cable maintenance and installation;
g) Avoid mounting equipment on the side and top of the panel; and
h) Lockable control panel switches must not be mounted above test links.

6.2.21 Panel functionality and purpose

Panels are to be designed to marshal and integrate secondary equipment for a single purpose or function. They are to be related to a piece of equipment, bay, protection zone or control function.

Well defined control panel functionality assists operators and maintenance technicians to clearly identify the purpose of the secondary system within the panel and its associated primary equipment.

EXAMPLE: Single purpose control panel functionality:-

- *33kV Feeder 341, Protection & Control Panel;*
- *132kV Section 1, No1 Busbar Protection;*
- *415VAC Supply Panel;*
- *33kV Feeder 341, Intertrip Panel; and*
- *11kV feeder AP2347, Protection and Control Panel.*

Protection schemes located on the same panel are to be segregated and where possible the No1 Protection is to be arranged on the top half of the panel and clearly separated from the No2 Protection arranged on the bottom half of the panel.

Combining diverse functionality into one panel should be avoided but may be necessary in some circumstances. In these cases, an approved means such as a 10mm thick black line is to be painted across the panel to delineate the two secondary systems.

TransGrid (formerly Elcom), E-type quarter panels, (for LBU or Circuit Breaker control panels), are to be replaced with half panels for each individual purpose to minimise unintended tripping of inservice equipment and difficulties obtaining system outages.

EXAMPLE: Multi-purpose control panel functionality: -

- *Station Metering (Top half panel) and AFIC control (bottom half panel);*
- *Station Frame Leakage (Top half panel) and 11kV UFLS (bottom half panel); and*
- *33kV Bus Section 1-2 (Top half panel) and 33kV Bus Section 2-3(bottom half panel).*

Clear identification of the function and purpose of a control panel will minimise unintended operation of inservice equipment. Each control panel shall be clearly labelled with its relationship to the primary equipment and its functionality.

A clear label describing the function of the control panel is to be fixed in a consistent location on each panel.

6.3 Protection Test Links Design

The approved test links used by the company for protection are specified in Company Standard ETS 0014 – Control Panel Fabrication and Installation. Further information and guidance is available from EDG 103 Protection & Control Test Links.

Protection test links are a controlled method for the disconnection and reconnection of protection wiring, (without the removal of wiring from terminals). Protection test links are used as circuit isolation or as test injection points. This functionality creates a risk that protection test links may be operated incorrectly and cause unintentional consequences.

The arrangement and identification of protection test links is therefore an essential requirement for the isolation and testing of protection circuitry. Consultation with P&C specialist is encouraged when preparing protection test link design to identify protection test link requirements for

a) Protection testing and fault-finding purposes;
b) Special in-service conditions where part of a protection scheme may need to be made non-operational; and
c) The connection of temporary protection.

Generally, the test link design shall consider: -

a) keeping the number of test links used in a circuit to a minimum;
b) two links in series shall not be used except with the approval of the Substation Secondary Design Manager;
c) Unambiguously identify the function of the link;
d) #1 and #2 protection links are to be segregated from each other;
e) Locate links in a prominent position for restoration checks; and
f) Standardisation of link design.

6.3.1 Link mounting arrangement

Test links shall be flush mounted as follows;

a) Test links are to be mounted vertically on the front panel or panel door;
b) Test links are to be touch safe or covered by an approved means when there is no outer panel door;
c) Links are to be mounted in the centre of a full-size panel, bottom of top half panels or top of bottom half panels;
d) Links are to be mounted in horizontal rows and are to be numbered numerically from the top LHS link to the bottom RHS link;
e) Holes drilled for future links are to be filled with black plastic plugs; and
f) Links are to be mounted so that if the slide link is left loose, then it will fall into the closed position.

6.3.1.1 Link colour

The colour of a test link is used to identify the circuit function as follows: -

- BLACK CT circuits (including pilot wire AC circuits);
- WHITE VT circuits between the VT and the protection relay (see Note 1);
- GREY DC circuits for protection trip isolation; and
- RED DC circuits for trip isolation to in-service equipment (see Note 2).

NOTES:

1. *VT test sockets and plugs have replaced white eugaquip VT test links. White eugaquip VT links may be used on legacy panels if they cannot be replaced.*

2. *Red coloured links shall be used to isolate the outgoing wires to another protection scheme that is likely to unintentionally trip in-service equipment, during maintenance activities.*

EXAMPLES: Applications where red links shall be used

- *CB fail trip output;*
- *Low SF_6 trip to busbar protection schemes (including frame leakage).*

6.3.1.2 Protection test link number label

Each protection test link is to have a unique number which shall be affixed adjacent to the link (1). The protection test link number in the circuit diagram shall use the prefix “LK” before each link number, for example LK1, LK2, LK3 etc.

NOTE:

(1) *For Eugaquip links the link number is to be engraved on a trafolyte label with black text on a white background. The protection test link number label is to be 10mm wide and extend to the end of the link row. The test link number label is to be mounted beneath the front and rear of each test link row.*

6.3.1.3 Protection test link description label

All protection test links shall have a test link description label mounted directly above the link. Two labels may be required, one for the front and one for the rear of the panel. Each label shall be made from trafolyte 25mm high, 16mm wide and shall use a 2mm black text font on a white a background.

The test link description link label is to unambiguously describe the function of the protection test link. Refer to EDG 104 for guidance on label standard texts. Labels are to be fixed to the panel with double backed tape.

Some special grouped labels may be required for UFLS or BBP tripping. In these cases, a header shall be used to identify the circuit to be tripped in lieu of the protection test link number.

6.3.2 Order of protection test links

Protection test links for each protection scheme shall be grouped together. If the No.1 and the No.2 protection test links are mounted on the same panel then they shall be clearly segregated and labelled.

Protection test links are to be grouped in the following sequence, from left to right, as viewed from the front of the panel. Consideration should be given to the use of spaces for future links and for defining a clear physical separation between test link groups.

- Special DC trip output links (1)
- DC trip output (outgoing trips to other panels)
- DC trip local (trip relays within the panel)
- DC trip input (incoming trips from other panels)
- HV Supply CT (2)
- LV Supply CT (2)
- VT Supply (3)
- DC Supply Positives (4)
- DC Supply Negatives.

NOTES:

1. *Special arrangement for tripping multiple circuit breakers where a clean contact is used to bring a trip positive and a trip output into a protection scheme, these two (2) links shall be grouped in pairs. These links shall be grouped separately from other links, with at least one (1) link width separation between each pair of links.*

   On schemes where two (2) signals (for example CB trip and intertrip) are initiated from a pair of contacts with a common terminal, the three (3) links shall be grouped together.

2. *A separate set of isolation links shall be provided for each individual set of CT links. This allows for the separate isolation of any three phase set of CTs from the schemes they supply. Where practical a space is required between set of CTs. Grouping of CTs is mandatory for BBP CTs on summation panels.*

3. *VT test sockets and plugs have replaced white eugaquip VT test links. White eugaquip VT links may be used on legacy panels if they cannot be replaced.*

4. *The DC supply groups are typically joined together at the relay supply positive and relay supply negative links.*

6.3.3 Test link connection conventions

A convention (1) shall be used to connect wiring to protection test links to reduce incidences of unintentional inservice trips. The design shall indicate the connection of wiring to the bottom of the test link by the letter *"B"* adjacent to the test link and the letter *"T"* adjacent to the top of the link.

The following conventions shall be used for the connection of wiring to CT and VT test links. As a general principle the wiring to the relay windings is from the top of the test link.

a) Wiring from the CT and VT shall be connected to the bottom of the link. Wiring to the relay CT and VT windings shall be from the top of the link.
b) CT star points shall be the last CT link. The top of the star point link is to be connected to the relay neutral winding.
c) If the CT wiring is connected between two relays on the same panel then the wiring from the first relay is connected to the bottom of the test links between the relays. The wiring to the second relay is from the top of the test links.
d) If the CT wiring is connected between two relays on separate panels then extra outgoing links are required for relay testing on the first panel. The first relay output links will be in series with the second relays input test links on the second panel. Connections to the two relays shall be from the top of the test links on each panel.

There are two basic principles for the connection of equipment dc wiring to test links as set out below. If there is a conflict between the principles, then principle 1 takes precedence over principle 2.

Principle 1: *External dc wiring is connected to the bottom of the link*.
Connection of dc wiring to and from adjacent panels or coming into the panel from other equipment shall be wired to the bottom of the test link, with connections to the associated relays wired to the top of the link.

Principle 2: *Internal dc wiring trips down the link.*
Connection of dc wiring between relays on the same panel shall be from the output of the first relay to the top of the link between them. Wiring to the input of the second relay shall be from the bottom of the link between them.

NOTES:

(1) For guidance on test link arrangements refer to EDG 103 Protection and Control Test Link Design
(2) The convention is needed for network security to standardise the way CT may be shorted or bypassed during inservice protection testing or checks

6.4 Control Panel Label Design

A label is required for all panel equipment. The label design shall be specified in schedules on the control panel layout and material list. Typical schedules include the equipment label schedule, terminal group carrier label schedule, No.1 protection link schedule and No.2 protection link schedules.

6.4.1 Standard label schedules

The label schedule is to specify the label identifier, size, text height, quantity and inscription. The standard label sizes are specified in the Table below. Where practical standard size labels shall be used. A clean font style such as Arial is to be used for label texts and may be condensed to fit with in label size. All texts are to be centred in the label.

Table 6.1 – Standard control panel label (refer to dwg 514478)

Size Width x Height	Text Height	Characters per line *	Application
16 x 25 mm	2 mm	3 lines at 12 characters	Eugaquip test link
25 x 25 mm	2 mm	5 lines at 12 characters	Control fuse & link
25 x 25 mm	3 mm	3 lines at 9 characters	General Use
25 x 16 mm	2 mm	3 lines at 12 characters	Fuse & link
35 x 16 mm	2 mm	2 lines at 16 characters	TB group carrier
50 x 16 mm	3 mm	2 lines at 18 characters	Panel equipment
50 x 16 mm	7 mm	1 line at 8 characters	General use
75 x 16 mm	3 mm	2 lines at 26 characters	Panel equipment
75 x 25 mm	10 mm	1 lines at 8 characters	Panel number
100 x 16 mm	3 mm	2 lines at 35 characters	Panel equipment
150 x 16 mm	5 mm	1 line at 28 characters	Panel equipment
250 x 30 mm	10 mm	1 lines at 27 characters	Half panel name
250 x 50 mm	10 mm	2 lines at 27 characters	Panel Name

*NOTE: * Typical values to be use as a guide to the design of the inscription.*

6.4.2 Label inscription design

The design shall use common description of equipment and functionality through the design documentation.

6.5 Panel Equipment

The design and specification of panel equipment shall comply with the following requirements.

6.5.1 Protection equipment

Protection relays and their fundamental configuration are specified in company design schedules (PIES; Protection, Indication and Equipment Schedule) by the Protection Section. The configuration of the relay inputs and outputs have been standardised for most applications and will align with base design drawings.

Relays shall be installed where possible on separate removable panels on the P&C panel so that they can be replaced without the need for reconfiguration of the panel steelwork.

Relays shall be designed in a position that permits access to all terminal by maintenance technicians. Sufficient space is to be considered for the relay wiring loom (typically a minimum of 50mm) between relays, that are mounted on a door, and the panel back plane.

Each protection relay digital input shall have an associated test or isolation link. Clean contacts are preferred for relay outputs which will require a test link on the supply side and a test link on the load side of the output contact.

Relay supply positive and relay supply negative isolation links are required for the protection relay auxiliary supplies. The isolation links are required to disconnect the relay auxiliary supply from the general panel wiring when undertaking panel insulation testing to prevent damaging the auxiliary supply circuit.

Relays are to be earthed as per the manufacture’s recommendations. In some cases, separate earthing for the relay chassis and relay modules are required with a multistrand earth wire.

6.5.2 Fuses and Fuse-Links

The preferred panel fuse to be used is a totally enclosed fuse holder, which complies with the specifications of AS/NZS 60269.2:2013 for fuse links with offset contacts, class gG.

Panel fuse-links are white fuse holders that use a solid copper link inserted in the fuse carrier for circuit isolation purposes. To differentiate between a fuse and a fuse-link, in enclosed fuse holders, then the following colour convention shall be used:

a) Fuse – Black fuse holder
b) Fuse-link – White fuse holder

It is preferred that protection fuses and fuse-links are mounted vertically on the front panel to facilitate protection maintenance and restoration of secondary systems before they are returned to service. Fuses shall be clearly labelled with a description that unambiguously describes the function of the fuse or fuse-link. The label shall be fixed in a position that clearly is associated with the fuse or fuse-link

The rating of general use HRC fuse cartridges, are to be selected to provide overload and short circuit protection.

The selection of fuses shall be such that discrimination is achieved for maximum fault conditions on the circuit and sensitive enough to detect the minimum fault expected on the circuit. The nominated fuse link rating is to be recorded in the drawing, above the fuse symbol and engraved on the fuse label.

6.5.3 Switches

The standard switch to be used on company designed control panels is the Kraus and Naimer C26 range switch.

The use of switches are to be minimised in design but should be used for:

a) The control of the closing and opening of circuit breakers and primary equipment
b) Ease of use for the operators of secondary systems; for example, if there is a need to reconfigure or operate a device repeatedly.
c) For isolation or reconfiguration of multiple circuits or wiring in lieu of isolation links

Control switches required for the operation of primary plant are to be located on the front of the control panel and shall be clearly visible and accessible, typically 1.0m to 1.8m above the ground level. Circuit breaker control switches shall not be mounted in positions where a person brushing passed the panel may inadvertently operate the switch.

Control panel switches shall be clearly labelled using an escutcheon plate. The labelling shall clearly identify the function and switching options available. A switch label is required on the rear of the panel.

Consideration shall be given to the location and orientation of switches to enable access to switch terminals by maintenance technicians.

Lockable switches shall be used for situations where

a) switching control is restricted to network operators. In this situation a NB1 lock is required
b) switching control is located out of sight or remote from the device that may be out of service for maintenance. In this situation a SS1 lock is required.

Lockable switches shall not be positioned directly above eugaquip or open links. This to prevent metal key ring objects dangling into and shorting the links.

NOTES: Refer to Electrical Design Guides EDG 106 and EDG 203.

6.5.4 MCB

Miniature Circuit Breakers or MCB’s can be used on ac circuits, typically 230Vac power distribution boards or 110Vac VT supply circuits. When specifying mcb in the design the following conditions shall be considered.

Fault calculations shall be undertaken for the specification of the mcb fault rating. The fault rating of the mcb must exceed the maximum expected fault that the mcb may need to break. The mcb curve characteristics shall be selected for grading with upstream and downstream protection devices. Consideration shall be given to inrush and circuit overload to minimise nuisance tripping.

MCB specified for use in VT supplies shall use an auxiliary contact for SCADA status indication and alarming.

MCB specified shall have a mechanism to lock the mcb in the open position for circuit isolation. A facility is required so that a Danger or Warning tag can be inserted.

6.5.5 Auxiliary control relays

Auxiliary control relays are used for a variety of design function and purposes. Auxiliary control relays shall be specified with appropriate contact make and break ratings unless protected by contact arc suppressors. It is preferred to specify auxiliary relays that are available on the company vocab. Standardisation of the auxiliary relays assists maintenance technicians when replacing faulty relays in the field.

Auxiliary control relays used with SCADA, POM and DOM circuits are to have free-wheeling diodes connected across the relay coil to prevent back emf damaging the SCADA output relay contacts.

Auxiliary relays shall not be used to extend or multiply CB pallet switches for time sensitive or critical protection circuits. They may be used for indication and general purpose circuits.

7 Control Panel Wiring and Termination Design

The design of the wiring systems for company purpose built control panels shall comply with the following requirements.

7.1 General Requirements

7.1.1 Panel wiring system

The panel wiring system includes all the elements that are needed to safely provide the functionality specified for the control of the equipment. These elements include control panel wiring, bus wiring, control cables, terminals, links, switches, relay and protection devices.

The panel wiring system shall be designed to: -

a) identify the function of the wiring;
b) be of adequate rating; such as current carrying capacity and volt drop;
c) provide reliable electrical continuity;
d) protect from electric shock;
e) protect from short circuit and overload conditions; and
f) provide adequate support and protection from mechanical damaged.

7.1.2 Control panel wiring

Control panel wiring are single insulated conductors that are installed within the control panel. Control panel wiring shall generally be flexible tinned copper wire with PVC insulation rated at 0.6/1kV and comply with AS/NZS 3000:2018 – Electrical Installation "Wiring Rules".

7.1.3 Control panel bus wiring

Control panel bus wiring is interpanel wiring and can be either single insulated conductor enclosed in ducts between panels or double insulated control cables. The bus wiring is to include any tee wiring from the bus terminals to panel fuses or links.

7.1.4 Control cables

Control cables are double insulated multicore cables used to connect wiring from the control panel to wiring in other panels or equipment. Control cables are to be screened and earthed.

7.1.5 Power cables

Power cables are double insulated multicore cables used to supply 230Vac single phase or 400Vac 3phase power to substation equipment and for general light and power applications.

7.1.6 Wiring termination

All control panel wiring, and cables are to be terminated by an approved method.
NOTE: Refer to Company Standard ETS0014 – Control Panel Fabrication and Installation, Section 7.

7.1.7 Earthing of panel wiring and equipment

All panel equipment, CT secondary wiring and VT secondary wiring shall be adequately earthed as per Section 10.3.4 and 10.4.3.

7.1.8 Panel light and power wiring

The wiring used for light and power circuits are to be segregated within the panel from dc control wiring where possible. A warning or caution note is to be added to the drawings to identify 230Vac wiring.

Control panel lighting supply shall originate from the AC panel and not the building services light and power distribution board.

The installation of GPOs on control panels should be avoided where possible, to reduce LV circuits in control panel. A GPO shall be mounted on the wall at either end of the control panel board. This arrangement reduces power leads running across the floor when undertaking protection maintenance.

7.1.9 Control panel wiring and parallel conductors

Control panel conductors are not to be paralleled to increase the current carrying capacity of a conductor without authorisation of the Substation Secondary Design Manager. A dispensation is given for the wiring between the CT test link and 5A relays on 11kV feeders.

7.2 Control Panel Wiring Design

7.2.1 Control panel wiring conductor size

The conductor size shall be of sufficient size to carry the expected continuous and short time currents.

The table below specifies the minimum conductor size and stranding for control panel wiring to be used in company purpose built control panels and LCC panels supplied by manufacturers.

The conductor stranding selected should suit the wiring application. For fixed wiring application, seven stranded general wiring may be use. For situations with tight bending radii or where the wiring will undergo physical stress associated with vibration or movement then multi-stranded flexible wiring should be used.

Table 7.1 -
Minimum conductor sizes for company control panels and manufacturer's LCC

Function	Conductor Size	Conductor Stranding
Protection and metering CT & VT wiring	2.5 mm2	General wiring 7/0.67 Flexible wiring 50/0.25
230Vac circuits (such as heater, panel and light)	2.5 mm2	General wiring 7/0.67 Flexible wiring 50/0.25
110Vdc dc supply Bus wiring	2.5 mm2	General wiring 7/0.67 Flexible wiring 50/0.25
110Vdc SCADA, P&C wiring	1.5 mm2	General wiring 7/0.50 Flexible wiring 30/0.25
Analogue and digital signal wiring	0.5 mm2	16/0.2
Earthing panel steelwork	6 mm2	84/0.30 or braid equivalent
Earthing Panel equipment	2.5 mm2	50/0.25

7.2.2 Control panel wiring colour

Control panel wiring conductors shall be clearly identified to indicate their intended function as an active, neutral or earth, (refer to AS 3000:2018 – Electrical Installation "Wiring Rules", clause 3.8 and Table 3.4) or as dc control wiring. The table below specifies control panel wiring conductor colour to be used in company purpose built control panels and LCC supplied by manufacturers.

Table 7.2 - Control panel wiring conductor colour for company control panels and manufacturer's LCC

Type of conductor	Colour code
Three phase CT and VT wiring	Red, White, Dark Blue (according to phase), Black (neutral or star point)
Single phase CT and VT wiring	Red (polarity) Black (non polarity)
Three Phase 400Vac wiring	Red, White, Dark Blue (according to phase), Black (neutral).
Single Phase 230Vac wiring	Red or Brown (active) Black or Light Blue (neutral)
Single Phase 230Vac flexible cord	Brown (active) Light Blue (neutral)
DC Control wiring	Grey
SCADA & Communications	Grey
Earthing connections	Green/Yellow

7.2.3 Control panel wire number

Every control panel wire shall be clearly and permanently identified with a wire number fitted adjacent to each end termination in accordance with Company Standard ETS 0014 – Control Panel Fabrication and Installation clause 7.1.2. The wire number is to comply with the company's wire number system and must be shown on drawings.

7.3 Wire Numbering System

The following wire number system is to be used in company designed control panels. It is based on AS 2067:2016 – Substations and high voltage installations exceeding 1kV a.c, appendix E (Informative). The wire number system has a defined wire numbering structure and a set of rules to manage how they are applied.

7.3.1 Wire number structure

The company wire numbering system uses a particular structure to create a wire number. This structure consists of 4 elements known as the wire number prefix, wire number identifier, wire number suffix and a bay identifier as per the table below.

Table 7.3 – Company wire number structure

Element	Description	Character	Comment
prefix	describes the wires function	1x Alpha	* General & Dedicated
Wire ID	four digit number	4x Numeric	
suffix	(optional) used in special situations	1x Alpha	
Bay ID	Bay identifier for interpanel wiring	Alpha numeric	

*NOTE: * Wire prefixes are classed as general use or as dedicated to a specific function. The prefix class effects the way a wire number is incremented in a circuit*.

7.3.2 Wire number prefix

The wire number prefix is used to identify the general circuit function as per the table below and the rules that determine how the wire number is to be incremented.

Table 7.4 – Wire Number Prefix derived from AS2067:2016 (Table E1)

Alpha	Circuit Function	Increment Rule	Alpha	Circuit Function	Increment Rule
A	CT wiring (excluding O/C)	General	N	Tap changer control	General
B	CT wiring busbar protection	General	O	Not used	
C	CT wiring O/C protection	General	P	BBP tripping circuit	General
D	CT wiring metering	General	Q	Not Used	
E	VT wiring	General	R	Interlocking circuits	General
F	Not used		S	Not used	
G	Not used		T	Pilot wire protection	General
H	AC supply	Dedicated	U	Not used	
J	DC supply	Dedicated	V	Not Used	
I	Not Used		W	Not used	
K	General control wiring	General	X	SCADA	General
L	Local alarm and indication	General	Y	Not used	
M	Motor control wiring	General	Z	Not Used	

7.3.3 Wire number identifier

Wire numbers are to have a maximum of 4 digits and have defined subsets or ranges of numbers. The organisation of the wiring identifier into subsets makes it easier to prevent wire number duplication and assists in creating new numbers when amending existing design. The subsets also provide some meaning to circuits when technicians are fault finding.

The basic wiring subsets may be incremented by multiples of 100's or 1000's (known as grouping) to prevent duplication of wire number within the same panel. Grouping of the wire number can be used for numbers requiring the identification of multiple voltages or bus sections within the control panel.

NOTE:
Refer to Electrical Design Guide EDG102 for guidance on the application of the company's wire numbering system.

7.3.3.1 General use wire number identifier ranges

Wire number identifiers have a range of basic subsets for general use, as defined in the tables below.

Table 7.5 – CT and VT basic wiring number range

Subset	A phase range	B phase range	C phase range	Neutral range
No1 Protection	10 to19	30 to 39	50 to 59	70 to 79
No2 Protection	20 to 29	40 to 49	60 to 69	80 to 89
Metering; Indication	10 to19	30 to 39	50 to 59	70 to 79

NOTE: Add 100, 200, 300 etc to the basic wire number identifier for panels with wiring for multiple voltages or for grouping

Table 7.6 – DC wiring number ID range

Subset	Range
CB Control	1 to 99
No1 Protection	100 to 199
No2 Protection	200 to 299
UFLS	300 to 399
General Purpose	400 to 799
Transformer Mech Box	800 to 899
Dedicated Wire Numbers	900 to 999

NOTE: Add 1000, 2000, 3000 etc to the basic identifier for panels with wiring for multiple voltages or grouping

EXAMPLE :

If a control panel has wiring from multiple voltages, in the same panel, such as a transformer's 33kV and 11kV wiring, then the wiring may be grouped by:-

- *adding 100 to the 33kV basic wire CT & VT number range;*
- *adding 200 to the 11kV basic CT & VT number range;*
- *adding 1000 to the 33kV basic dc protection number range; and*
- *adding 2000 to the 11kV basic dc protection number range.*

Thus

- *A phase 33kV No1 protection; CT & VT wiring will range from 110 – 119 etc;*
- *A phase 33kV No2 protection; CT & VT wiring will range from 120 – 129 etc;*
- *A phase 11kV No1 protection; CT & VT wiring will range from 210 – 219 etc; and*
- *A phase 11kV No2 protection; CT & VT wiring will range from 220 – 229 etc.*

- *33kV No1 protection; dc wiring will range from 1100 – 1199 etc;*
- *33kV No2 protection; dc wiring will range from 1200 – 1299 etc;*
- *11kV No1 protection; dc wiring will range from 2100 – 2199 etc; and*
- *11kV No2 protection; dc wiring will range from 2200 – 2299 etc.*

7.3.3.2 Wire number identifiers ranges for dedicated prefixes

Wiring number identifiers have been defined for a specific function associated with their prefix. These prefixes include J numbers for dc supplies, H numbers for AC power supplies and a K900, P900 and X900 series for dc wiring.

As these wire numbers are dedicated to a specific function and are incremented by the wire number suffix. Dedicated wire numbers are defined in the following tables.

Table 7.7 – DC Bus Supplies (Prefix J)

Circuit	+ ve	- ve		Circuit	+ ve	- ve
11/22kV No.1 Protn	J1	J2		LVCB Spring Charge Supply #1	J55	J56
11/22kV Control	J11	#		HVCB Spring Charge Supply #1	J57	J58
11/22kV No.2 Protn	J21	J22		SFU Control Supply positive	J59	-
33kV No.1 Protn	J3	J4		DC Emergency Lights	J61	J60
33kV Control	J13	#		SMU/ DIU rack supplies	J63	J62
66kV No.1 Protn	J5	J6		POM positive	J65	-
66kV Control	J15	#		DIM Supply	J67	J66
66kV No.2 Protn	J25	J26		LVCB Spring Charge Supply #2	J71	J70
132kV No.1 Protn	J8	J8		HVCB Spring Charge Supply #2	J73	J72
132kV Control	J18	#		SEF Control	J75	J74
132kV No.2 Protn	J28	J28		Medical Emergency supply	J77	J76
11kV Aux Control	J9	J10		Security Supply	J79	J80
11kV Aux Switchgear Protn	J19	J10		Low SF6 Management supply	J81	J82
BB Blocking cbf/BBP	J31	J32		PQM supply	J83	J84
LV BBP No.1 Protn	J33	J34		Arc Detection supply	J85	J86
LV BBP No.2 Protn	J35	J36		MUX supply	J87	J88
HV BBP No.1 Protn	J37	J38		Communication supply	J89	J90
HV BBP No.2 Protn	J39	J40		Station Main DC Supply	J91	J92

Circuit	+ ve	- ve		Circuit	+ ve	- ve
Capacitor Supply No.1	J41	J42		Station Battery	J93	J94
Capacitor Supply No.2	J43	J44		DC Panel Control	J95	J96
Capacitor Supply No.3	J45	J46		Battery 70% tap	J97	-
UFLS Supply	J47	J48				
Isolator / ES Control Supply	J49	J50				

Depends on which battery supply is connected or if a common negative is used.

Table 7.8 – AC Bus Supplies (Prefix H)

Circuit	Aph	Bph	Cph	Neutral
HVCB heater supply	H1			H101
LVCB heater supply		H2		H102
Aux CB heater supply			H3	H103
UFLS 50Hz supply		H41		H141
Protection relay ac supply	H42			H142
AFIC injection supply	H50	H51	H52	H150
Control panel lights	H56			H156
Control panel SPO		H57		H157
Control room Distribution Board	H60	H61	H62	H160
SCADA GPO			H63	H163
Battery charger supply	H65	H66	H67	H165
Transformer cooler control supply	H70	H71	H72	H170
Oil separator supply	H73	H74	H75	H173
Capacitor bank supply	H80	H81	H82	H180
No.1 ac supply	H90	H91	H93	H190
No.2 ac supply	H95	H96	H97	H195

Table 7.9 – Dedicated 900 series wire numbers

Wire ID	Dedicated Function		Wire ID	Dedicated Function
K900	Stn SEF enable bus		X900	Fire Alarm Isolated
K901	Stn SEF inhibit bus		X901	Fire Alarm Operated
			X902	Fire Alarm Faulty
P901	132kV No.1 CB Fail Trip (to BBP)		X903	Security Armed / Disarmed
P902	132kV No.2 CB Fail Trip (to BBP)		X904	Security Alarm Operated
P911	66kV No.1 CB Fail Trip (to BBP)		X905	Security Alarm Equipment Fail
P912	66kV No.2 CB Fail Trip (to BBP)		X930	STU By-pass switch manual status
P921	33kV No.1 CB Fail Trip (to BBP)		X931	Medical Emergency pushbutton operated
P922	33kV No.2 CB Fail Trip (to BBP)		X932	Medical Emergency siren operated
P931	11kV No.1 CB Fail Trip (to BBP)		X933	Station SEF Auto Status
P932	11kV No.2 CB Fail Trip (to BBP)		X950ME	Medical Emergency Siren Control
P933	11/22kV Buswire – Blocking Bus (BB Blocking)		X951SEF	Station SEF Auto Control
P934	11/22kV Buswire – CBF/ BBP Bus (BB Blocking)		X999	Oil Separator Alarm
P935	11/22kV Buswire – Relay Fail Bus (BB Blocking)			

7.3.3.3 Wire number suffix

A suffix can be added to the wire number identifier to prevent duplicating wire numbers, for incrementing dedicated wire number identifiers or to add more functional information.

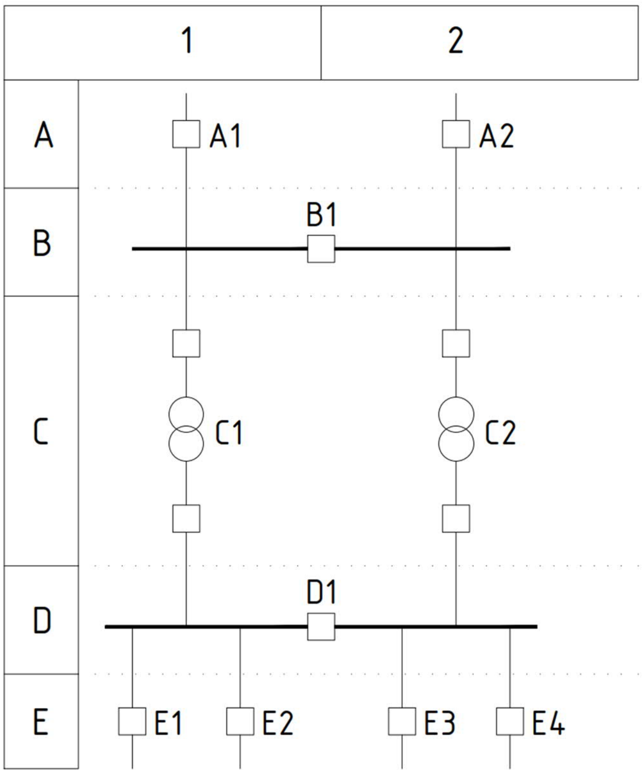
EXAMPLE: Common Wire number suffix

C SCADA CB Close command
T SCADA CB open (Trip) command
R SCADA tap changer Raise command
L SCADA tap changer Lower command

7.3.3.4 Bay identifier

The bay number identifier is constructed from an alpha numeric code derived from overlaying a grid onto the substation single line drawing. The equipment row is a letter (from HV to LV) and the equipment column is a number (from left to right). The letter "Z" is reserved for BBP Zones.
The bay number identifier is augmented to the wire number with a forward slash or hyphen character.

Figure 7.1 – Bay Identifier Grid



EXAMPLE:
Bay /A2 is the 2nd HV feeder
Bay /D1 is the 1st LV Bus Section CB
Bay /E3 is the 3rd LV Feeder.

NOTE: Refer to the electrical design guide EDG102 for information on legacy bay number systems and for more examples of bay identifier numbering.

7.3.3.5 CT ratio wire numbers

The preferred wiring numbering for CT ratio wiring, from the CT terminals to the CT termination block is:

a) A number for the CT core (1, 2, 3, 4, 5)
b) Followed by a letter for the phase (A, B, C)
c) Followed by the CT ratio tap (S1, S2, S3, S4, S5)

EXAMPLE: Three phase 2 tap CT

1AS1 – core 1, A phase, tap S1
1AS2 – core 1, A phase, tap S2

1BS1 – core 1, B phase, tap S1
1BS2 – core 1, B phase, tap S2

1CS1 – core 1, C phase, tap S1
1CS2 – core 1, C phase, tap S2

7.3.4 Wire number rules

The following rules are to be used to develop wiring numbers:-

a) All wires that are terminated together must have the same wire number;
b) No duplication of wire numbers are permitted within a control panel;
c) Wire numbers are to increment when passing through a switch, fuse, relay contact or other device;
d) Bay Identifier can be dropped from the wire number on the panel side of the terminal block unless there are duplicate wire numbers, for example, tripping panel;
e) Dedicated wire numbers maintain their functional number and increment the suffix element as they progress through the circuit;
f) General wire numbers increment numerically as they progress through the circuit; and
g) Wire numbers closest to the supply source are to be lower than wire numbers further from the source.

7.3.5 Incrementing wire numbers

Wire numbers can be incremented by either incrementing the 4 digit wire number identifier or by incrementing the wire number suffix. The method used is dependant whether the wire number is dedicated for use for a specific circuit function or is for general use.

7.3.5.1 Dedicated wire number rule

For dedicated wire numbers, the wire number identifier represents a specific sub function related to the prefix and does not change or increment. A dedicated wire number is incremented via the wire number suffix.

EXAMPLE: Wire Number J7A

J Prefix DC Supply (Dedicated prefix function)
7 Wire ID 132kV No1 Protection Positive (Specific sub function)
A Suffix 1st point

This wire number would increment J7A, J7B, J7C etc and can always be identified by the "J7" as 132kV No1 Protection Positive.

7.3.5.2 General use wiring number rule

The wire number identifier is for general use and increments numerically.

EXAMPLE: Wire Number K1

K Prefix General Control Wire (General function)
1 Wire ID CB Control
- Suffix Not required

This wire number would increment K1, K2, K3 etc

7.4 Termination Block Design

Wiring must be terminated by an approved termination method and connected to an approved terminal refer to Company Standard ETS 0014 – Control Panel Fabrication and Installation, Section 7.

7.4.1 Terminal block general arrangement

The termination layout design must provide sufficient space for installation, inspection and testing of wiring. The terminals are to be arranged into functional terminal groups blocks. These terminal block groups would be typically

a) DC Supply;
b) CT & VT Supply;
c) Protection & Control;
d) Interpanel Tripping; and
e) SCADA.

Each terminal block group is to be located on the terminal rail in a clear relationship to the panel equipment. For example; if the No.1 protection equipment if it is located on the top half of the panel then the No.1 terminals are also to be located on the top half of the panel.

The terminal blocks groups are to be spaced along the terminal rail with a minimum of 100mm between terminal blocks group to allow for addition terminals or future terminal rearrangement.

7.4.1.1 Terminal identification

Each terminal block group is to be identified using an “X” and a terminal group block number.

Table 7.10 – Terminal Block Number

Group Block Number	Function
X1 to X9	General Use
X11 to X19	No.1 P&C wiring
X21 to X29	No.2 P&C wiring

Each terminal in the terminal block group is to be identified by a number within the terminal block group. The design is to specify the terminal by the concatenation of the terminal “block group number” + “:” + “terminal block number”. Thus X11:1 is terminal 1 in terminal block group X11.

7.4.2 Terminal block wiring convention

All wiring entering the panel is to be connected to one side of the terminals and all internal panel wiring is to be connected to the other side of the terminal.

7.4.3 Bus wiring termination

Two terminals are required for control panel bus wiring termination. The bus wiring terminals are to be adjacent to each other on the terminal rail and bridged with an approved link. The bus wire is to loop in and out of the terminals from the same side.

8 Substation Low Voltage Cables Design

Substation low voltage cables are used for three broad purposes: -

a) Power cables are used to supply 400/ 230Vac for general purpose application such as light and power to motors, battery chargers and building services. Generally power cables will be unscreened, double sheathed, multiphase, orange circular cables.

b) Control cables are multicore screened cables that are designed to interconnect secondary systems that are distributed between control panels and secondary equipment in the primary plant.

c) Communication cables are specialised cables used to connect communication equipment together. These cables may be fibre optic, twisted pairs or special 15kV pilot wire cables that are used between remote sites.

8.1 Low Voltage Power Cable Design

The design and selection of low voltage power cables must comply with AS/NZS 3000:2018 – Electrical Installation “Wiring Rules”, Section 3.1.2. Power cable design must

a) Protect people from physical contact with live parts
b) Be selected for adequate current carrying capacity, adequate voltage drop characteristics and sufficient short circuit rating.
c) Provide reliability of connectivity through approved joints and terminations
d) Provide adequate support, suspension, fixing
e) Be mechanically protected from damage by external influence or the environment using enclosures or other approved means
f) Protected from short circuit or overload by approved protection devices

8.1.1 Power cable types and their wiring systems

The types of wiring system and method of installation shall comply with AS/NZS 3000:2018 – Electrical Installation “Wiring Rules”, Table 3.1. Design consideration shall be given to the influence of ambient temperature, external heat sources, water, humidity, corrosive substances, mechanical damage, vibration, flora, fauna, direct sunlight, hazardous areas and thermal insulation.

8.1.2 Low voltage power cable conductor size

Low voltage power cable conductor size must comply with the requirements of AS/NZS 3000:2018 – Electrical Installation “Wiring Rules”, Section 3.5 including the requirements for the neutral conductor.

8.1.3 Low voltage power cable conductor identification

Low voltage power cable conductors shall be clearly identified to indicate their intended function as an active, neutral, earthing or equipotential bonding conductor as per AS/NZS 3000:2018 – Electrical Installation “Wiring Rules”, Section 3.8.

Table 8.1 – Low Voltage Power Cable Conductor Colours

Type of conductor	Colour code
Three Phase 400Vac (Multiphase Cable)	active - Red, White, Dark Blue (according to phase) neutral – Black earth – Green/ Yellow
Single Phase 230Vac	active – Red or Brown neutral – Black or Light Blue earth – Green/ Yellow

8.2 Control Cable Design

8.2.1 General

Control cable cores shall be uniquely identified by colour, core number or another approved means. Control cables are to be terminated with approved terminals as per Company Standard ETS014 – Control Panel Fabrication and Installation Section 7.

All control cables shall be screened to prevent transient voltages causing interference with microprocessor relays.

All control cable cores shall be connected to the same side of a row of terminals. Cable cores are typically used starting from the highest core number first. Spare cores do not need to be connected to terminals. Each core shall be numbered as per the wiring number rules.

Substation control cables are used for four broad purposes: -

a) Auxiliary DC Supply
b) CT and VT Supply
c) DC Control
d) SCADA Control

8.2.2 Auxiliary DC supply cables

Control cables that are used for dc supply to control panels shall have a minimum cross-sectional area of 2.5mm^2. The cable shall be designed to carry the anticipated future load of the circuit. For long cable routes the volt drop is to be calculated. The volt drop under maximum load conditions shall be less than 10%.

8.2.3 CT and VT supply cables

Control cables are used for the CT and VT supply to control panels shall have a minimum cross-sectional area of 2.5mm^2 for indoor substations and 4.0 mm^2 for outdoor substations.

If the CT cable route length for a 1amp CT secondary, is greater than 60m (indoor substation) or 100m (outdoor substation) then calculations are required to check the burden on the CT.

CT and VT burden calculations are required for revenue metering and 5amp secondary protection CTs.

Separate cables are required for No.1 and No.2 CT and VT cables. Smaller 2.5mm^2 screened cable can be used between the CT/ VT marshalling cubical and the CB, post CT or VT if the overall cable burden is acceptable.

DC control cables shall have a minimum cross-sectional area of 1.5 mm^2 . Separate cables are required for the No.1 protection and control (typically 15 core) and No.2 protection (typically 6 core).

8.2.4 SCADA cables

SCADA analogue and digital input cables shall have a cross-sectional area of 0.5 mm^2 (16/0.2mm stranding). Typically, 4 pair or 8 pairs cables are used. Each pair is numbered and is either a black or a white core, for example, (1Bk,1Wh); (2Bk, 2Wh); (3Bk, 3Wh) etc.

The recommended connection for digital input wiring is to use the highest black core (ie 8Bk or 4Bk) as the DIU negative, skip the associated pair white core (ie 8Wh or 4Wh) then proceed to allocate individual cores for each input.

For digital output and analogue input connections, a pair is used for each channel. The white core is the positive and the black core is its associated negative.

8.2.5 Control cable screens

The screen shall be earthed at one location only, (to prevent circulating earth currents). The preferred earthing location is at the control panel earthing bar using a 50/0.25mm green/yellow conductor soldered or fixed by an approved method to the control cable screen.

8.2.6 Communication cables

A variety of cables are used for communications including

a) Single-mode optical fibre cables between substation (ADSS or OPGW)
b) Multi-mode optical fibre cables within the substation
c) Copper serial communications cables for RS232 & RS485 applications
d) Copper ethernet cables (category 6)

Communication cables shall be protected from mechanical damage using fixed or corrugated white conduits. Optical fibre cables installation shall be designed such the recommended cable bending radius is not exceeded.

The design of copper communication pilots shall consider the possibility of a remote earth causing a voltage rise at the termination end of the cables. Pilots must be terminated in insulated cubicles with 15kV isolation from earth.

Detailed requirements for the installation and application of communication cables are written in Company Standard Automation Design Instruction ADI 0006 – Substation Communication Systems.

8.3 Cable Schedules

A cable schedule shall be produced to list all LV cables installed at a site. Each cable shall be identified with a unique cable number. The cable shall be numbered as per the following rule: -

a) LV power cables
Numeric eg, 1,2,3,4

b) Control cables
Alpha Numeric from the concatenation of the bay number and a cable number
eg for Bay A1; A1-01, A1-02, A1-03 etc

c) Communication cables
Alpha Numeric from the concatenation of CC and cable number
eg CC01, CC02, CC03 etc

A cable number label or tag is to be securely and clearly fixed to both ends of the cable.

A cable schedule shall be used for recording LV power cables and control cables and a separate cable schedule is required for communication cables.

The control cable schedule shall list the:-

a) Cable number
b) Location of the cable run (from Panel and To Panel)
c) Cable function
d) Cable stranding
e) Cable length

8.4 Cable Installation Design

Cable installation design is generally performed as a part of the substation mechanical design and the substation general arrangement design. Electrical designers shall review the design of the cable installation.

8.4.1 Cable routes

Cable routes shall be designed such that cables from different equipment are segregated. For example there should be separate cable routes available for the No.1 transformer and the No.2 transformer cables within the substation.

The cable support systems and conduits have sufficient capacity to enable all the proposed cables to be installed. An allowance shall be made for additional cables in the future.

8.4.2 Separation of services

SCADA and control cables shall not be installed in the same conduits as power cables. Separate conduits shall be nominated in the conduit design.

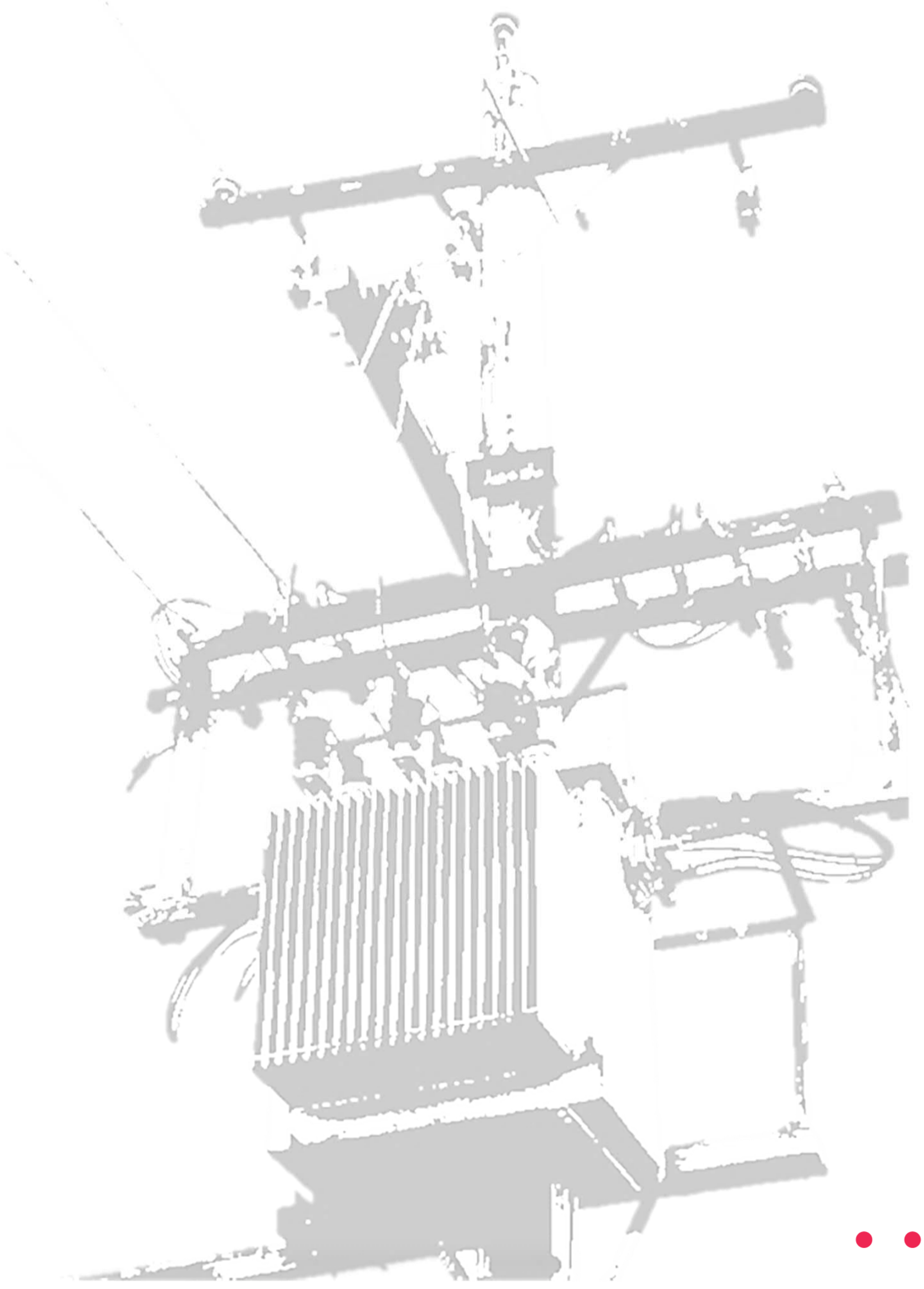
Where ever practical duplicated protection cables and backup communication cables shall be installed in diverse paths.

PART 2 – SYSTEM DESIGN

Control, Protection, SCADA, Communication, Auxiliary Supply, Metering and Load Control System Design

Sections 9 to Section 16

Part 2 of this standard is concerned with the design requirements of specific substation secondary systems. It must read in conjunction with Part 1 which specifies generic design requirements that are common to all secondary system design.



9 Control System Design for Primary Equipment

Control system shall be designed to safely operate substation primary equipment including, circuit breakers, motorised disconnectors and transformers. The principle control of primary equipment shall be via a remote control system, such as the SCADA system. An emergency local control system is required if the remote system fails. The design of the control system shall comply with the following requirements.

9.1 Control System Supplies

Duplicate dc control supplies are not required. The dc control supply shall be protected by fuses or mcb typically at the station dc supply panel, No.1 battery. The bay control protection shall grade with the station dc supply panel protection (1).

Separate dc control supply circuits shall be required when there are large number of circuit breakers. Each control supply circuits shall be bussed together in logical arrangements of circuit breakers; *for example, 11kV Section 1 Control Supply, 11kV Section 2 Control Supply etc.* Ring busses shall not be used.

The control supply bus wiring shall loop in and out of each control panel through two adjacent terminals on the dc supply terminal block, *as per clause 7.4.3, terminal block design.* The bus wiring shall be of a suitable size to carry the load of the circuit (2). A wire size smaller than the bus wiring may be used from the bus "tee" at the control panel dc supply terminals, to the control panel protection, if the tee wire it is adequately protected from short circuits by the station dc supply panel protection.

The health of the control supply is to be supervised at each bay via a fuse supervision circuit or the use of a mcb auxiliary contact. Loss of supply shall raise an alarm via the SCADA.

The control circuit shall be segregated from the protection circuits and the wiring shall not be intermixed. The loss of the control supply shall not affect the functionality of the protection circuitry. Clean contacts from an interposing relay in the control circuit, shall be used by the protection supply to open the circuit breaker (3).

NOTES:

(1) *Typical dc panel, control supply fuse and bay control supply fuse are rated at 32A and 10A.*
(2) *The typical bus wire is 4mm^2.*
(3) *The interposing relays are initiated using the control supply and trip the CB using the protection supply to provide circuit isolation between protection circuits and control circuits.*

9.2 Circuit Breaker Control

Circuit breakers (CB) shall be manually controlled via a CB selector switch and a CB control switch. The CB control selector switch shall select the control system that will operate the circuit breaker. The CB control switch shall open or close the circuit breaker.

9.2.1 CB control switches

The CB control switch shall be a three-position switch that shall spring return on release to the centre or neutral position. The left position is the trip position and the right position is the close position. The handles of CB control switches shall be red.

The CB selector switch shall select the control system that will operate the circuit breaker. The circuit breaker can be operated from either of three systems or control modes: -

a) Supervision control mode (normal inservice control);
b) Panel control mode (backup inservice control); and
c) Maintenance control mode (CB out of service control).

In the supervision control mode, the circuit breaker shall only be opened or closed by the SCADA and all other controls modes shall be disabled. The protection trip shall remain unaffected in this mode. This is the normal inservice control mode.

The panel control mode is a manual backup mode and is designed to be used in the rare event that the SCADA is not operational. In this mode the circuit breaker shall be opened or closed from the panel CB control switch and all other control modes shall be disabled. The protection trip shall remain unaffected in this mode. This is the backup inservice control mode.

In the maintenance control mode, the circuit breaker shall only be opened or closed by the local CB control switch located at the circuit breaker and all other control modes shall be disabled. In this mode all protection trips shall be disabled to prevent the circuit breaker from being unintentionally operated, during circuit breaker maintenance. This is the CB out of service mode.

If the CB selector switch is situated remotely from the CB, then the selector switch shall have a key lock that can lock the selector switch into the maintenance mode. The lock is a safety in design feature preventing unauthorised operation of a CB control selector switch during circuit breaker maintenance.

The CB selector switch shall not be left in the maintenance position when the circuit breaker is inservice, as it disables the protection. The maintenance mode must be alarmed in SCADA as "*CB unavailable*".

The tables below summarise the functionality of control switches.

Table 9.1 –
Functional operation of (panel) SPM switch, (panel) CB control switch & (CB) CB control switch [1]

CB Selector Switch Mode	Protection Trip	SCADA Open	SCADA Close	(Panel) CB Control Open	(Panel) CB Control Close	(CB) CB Control Open	(CB) CB Control Close
Supervisory	yes	yes	yes	no	no	no	no
Panel	yes	no	no	yes	yes	no	no
Maintenance	**no**	no	no	no	no	yes	yes

Table 9.2 – Functional operation of (CB) SPM switch, & (CB) CB control switch [2]

CB Selector Switch Mode	Protection Trip	SCADA Open	SCADA Close	CB Control Open	CB Control Close
Supervisory	yes	yes	yes	no	no
Local	yes	no	no	yes	yes
Maintenance	**no**	no	no	yes	yes

NOTE:

(1) *When the control panel is remote to the circuit breaker (eg for outdoor CBs) there will be two CB control switches; one located on the control room panel and the other at the CB. The panel CB control switch shall remotely operate the circuit breaker when the CB selector switch is in the panel position. The CB control switch shall locally operate the circuit breaker when the CB selector switch is in the maintenance position and if available, the CB local/remote switch is in the local position.*

(2) *On many distribution feeders the control panel is integrated into the switchgear and there will be only one CB control switch. The CB control switch shall operate the circuit breaker when the CB selector switch is in the local position or the maintenance position (protection is disabled in the maintenance position)*

9.2.2 Circuit breaker open circuit

All protection trip and control open contacts shall be wired in series with the circuit breaker auxiliary 52a contact and the CB trip coil [1].

In the supervisory control mode, the SCADA open commands shall operate an interposing relay. The SCADA interpose relay contacts shall be used by the No.1 protection circuit to trip the No.1 trip coil. The interposing relays shall be located in the P&C panel and not the CB.

In the panel or local mode, the CB control switch shall operate the No.1 trip coil.

NOTE:

(1) *The 52a CB pallet is required to prevent damage to relay contacts if they were to directly interrupt the trip coil current. Consideration should be given to the risk of damage to relay contacts during protection testing or circuit breaker failure.*

9.2.3 Circuit breaker close circuit

All control relay close contacts shall be wired in series with the circuit breaker auxiliary 52b contact and the CB closing and anti-pump circuit.

In the supervisory control mode, the SCADA close commands shall operate an interposing relay. The interposing relay contacts shall initiate the CB close circuit. The interposing relays shall be located in the P&C panel and not the CB.

In the panel or local mode, the CB control switch shall operate the CB close circuit.

9.2.4 Synchronisation check

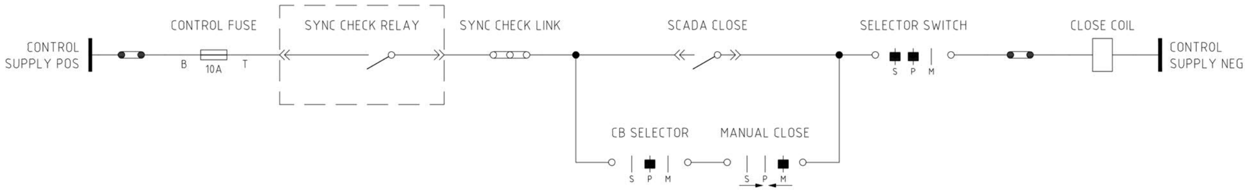
Control systems shall be employed to prevent the closing of a circuit breaker in situations where there may be a difference in the voltage, phase angle or frequency between the load side and bus side of the circuit breaker.

The sync check relay shall source VT supplies from the circuit breaker load and bus side. The VT supplies shall be supervised and alarm via the SCADA when unhealthy.

The sync check relay contact shall be connected to the control supply then in series with the CB closing circuit. A test link shall be connected after sync check contact for testing the sync check operation. Sync check is not required when closing in the maintenance mode. The CB shall close when the:

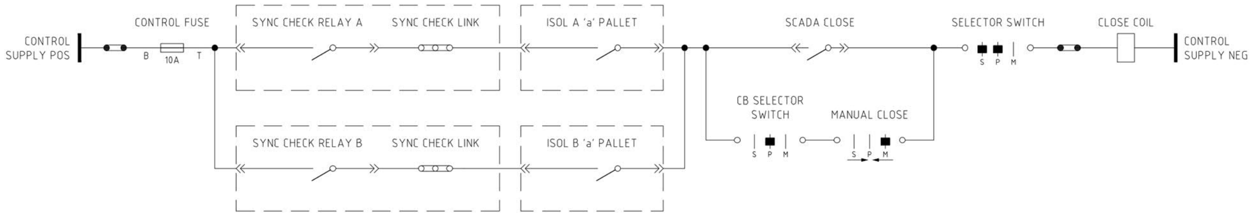
a) Sync check is healthy and a SCADA close is issued
b) Or Sync check is healthy and a panel close is issued

Figure 9.1 – Sync Check Control



When sync checking a double bus arrangement an isolator ‘a’ pallet switch shall be connected in series with the sync check relay contact to confirm that the appropriate sync check relay is used. In these situations, multiple sync check contacts connected in parallel shall be used.

Figure 9.2 Double Bus Sync Check Control



9.2.5 Capacitor bank circuit breaker control

Point of Wave (POW) control may be specified for the control of capacitor bank circuit breakers. The POW relay shall delay the CB close and open commands so that when the circuit breaker operates, it minimises switching transients. The protection trip shall bypass the POW control.

When specified, a capacitor circuit breaker shall be delayed by a predetermined time, after the circuit breaker is opened, to allow the capacitors to discharge. Typically, a discharger time is energised via a CB pallet switch when the capacitor circuit breaker is opened. The discharge timer shall inhibit the closing of the capacitor circuit breaker until the timer has expired, typically 10 minutes. The close inhibit relay shall provide indication via SCADA that the CB is locked out during the discharge time.

In circumstances where 11kV feeder CB is not rated to break the capacitive load to a capacitor bank bay during a fault, then an intertrip shall be sent to the capacitor bank bay, circuit breaker. The protection trip to the 11kV feeder breaker shall be delayed by 100ms. An intertrip is not required for vacuum CB that are a *dedicated* capacitor bank feeder.

For manual or SCADA opening, the capacitor bay circuit breaker shall be opened before the feeder. A caution label shall be fixed adjacent to the feeder CB control switch. Hard wired CB opening interlocking is not required.

9.2.6 SF_6 circuit breaker control

The management of the alarm and tripping of SF_6 gas insulated equipment is discussed in detail in Company Standard SDI 547 – Alarm and Tripping Requirements in SF6 and Dry Air Equipment. The SF_6 gas in this type of equipment is monitored by a gas density monitor installed in each gas compartment.

As the gas density falls to the manufacturers specified level, a Stage 1 alarm shall be initiated in the SCADA, via contacts in the gas density monitor. When the gas density in the CB falls to the minimum Stage 2 functional level, then contacts in the gas density monitor shall operate a gas monitoring relay.

A gas monitoring relay shall be provided for each trip coil in the CB. If the CB has two trip coils, then two separate gas monitoring, normally open contacts, shall independently initiate two separate gas monitoring relays, each supplied from the two independent protection supplies.

The protection supplies to the gas monitoring relay must be supplied via the CB selector switch. The protection supplies must be disconnected when the CB selector switch is locked in the maintenance mode to prevent unintended CB operation during CB maintenance. This is a Safety in Design requirement of the design.

When the gas monitoring relays are initiated, then the CB is at the minimum gas density level permitted and must be disabled from operating. Contacts from the gas monitoring relays shall be wired in series with the trip coils and the closing coil and shall disable the operation of the circuit breaker. Other gas monitoring relay contacts shall initiate a stage 2, or CB lockout alarm via SCADA.

If a circuit breaker has a self-trip option, then it may be selected to open the CB at stage 2 low gas. The CB will trip and be disabled opened. If the CB self-trip option is not selected, then the CB will be disabled and remain in its existing state (ie open or closed). Options for setting the low gas self-trip is discussed in Company Standard SDI 547 – Alarm and Tripping Requirements in SF6 and Dry Air Equipment.

9.3 Control of Motorised Disconnectors

Motorised disconnectors shall be operated using the CB selector switch and a separate disconnector open close switch per disconnector. Electrical interlocks shall be used to prevent motorised disconnectors being operated when under load. The operating of the motorised disconnectors shall have a motor drive retain circuit that prevents the disconnector from stopping midway through an operation. A 52a and 52b pallet is required to determine the disconnector’s status.

10 Protection System Design

Protection systems comprise of protection schemes that monitor the electrical network and isolate parts of the network in the case of electrical faults and other abnormal network conditions. A protection scheme is the arrangement of several protection elements to protect a specific part of the network, known as the protection zone. The design of protection system elements shall comply with the follow requirements.

10.1 General Protection System Design Principles

The design of wiring, links and labelling of protection systems are specified in Part 1 of this standard.

Protection scheme elements shall be designed for high security(1) .

a) The failure of a single protection element shall not leave the network unprotected
b) Protection schemes shall operate independently of each other and the control systems
c) Tripping circuits shall be supervised and where possible, directly trip the circuit breaker without any additional time delay.
d) Well-designed protection interfaces shall be considered, to reduce unintentional tripping of inservice equipment by operators or maintenance personal

NOTE: (1) protection system should operate when required to and not operate when it is not required to.

10.2 Protection Schemes

Protection systems design shall group related protection elements(1) into a protection scheme as specified in the Protection and Indication Equipment Schedules *(PIES).*

Protection schemes shall be either station level such as busbar protection, or bay level such as feeder protection. Each scheme shall be marshalled on its own individual protection and control panel *(refer to 6.2.21 panel functionality and purpose).*

Protection elements associated with the No.1 trip coil shall be called the No.1 protection; and protection elements associated with the No.2 trip coil shall be called the No.2 protection. The No.1 and No.2 protection shall be independent systems.

Duplicate protection schemes shall duplicate every element in the scheme. Single protection schemes with a primary and backup protection relay, may duplicate elements in the scheme where it is practical and economical(2) . The primary protection relay shall trip the No.1 trip coil and the backup protection shall trip the No.2 trip coil.

NOTES:

(1) Protection elements include the equipment that must be connected to form the scheme and includes batteries, dc supplies, CT and VT supplies, relays, links, cables, wiring and trip coils.
(2) Except for the station battery and VTs, many protection elements in a single protection scheme can be duplicated

10.3 Protection System CT supplies

Current Transformers (CT) are a fundamental element of a protection system design[1] and require careful consideration in their application. CT details shall be included on a protection and indication diagram to show the relationship between the CT, VT, relay polarity, CTs physical arrangement and extent of the protection zone[2].

NOTES:

(1) Standard CT rating, class and ratios are specified in Company Standard PDI 1000 – Protection of High Voltage Plant.

(2) A protection zone is the parts of the network that under abnormal or fault conditions will be detected by the protection system

10.3.1 CT primary arrangement

CT specification shall be shown on the single line diagram and the protection and indication diagram. CT shall be arranged so that:

a) where possible, the CT primary polarity *P1,* shall be towards the busbar and CT primary polarity *P2,* shall be away from the busbar

b) where possible, protection CTs shall be located on both sides of circuit breaker with the CT primary polarity *P2,* toward the circuit breaker and the CT primary polarity *P1,* towards the circuit breaker palms.

   In situations where protection CTs are located on one side of the CB then they shall be situated on the circuit breaker side that is away from the busbar.

   In situations where protection CTs are located on one side of a bus section or bus coupler circuit breaker then it is preferred that the CTs are mounted on circuit breaker side associated with the lower bus number. *(For example on a 2-3 bus-section CB, then the CTs shall be mounted on the No.2 bus side of the bus-section circuit breaker.)*

c) Post CT shall be located on the circuit breaker side that is away from the busbar with the CT primary polarity *P1* is towards the bus. For post CTs on a bus section or bus coupler then the CT primary polarity *P1* shall be towards the circuit breaker.

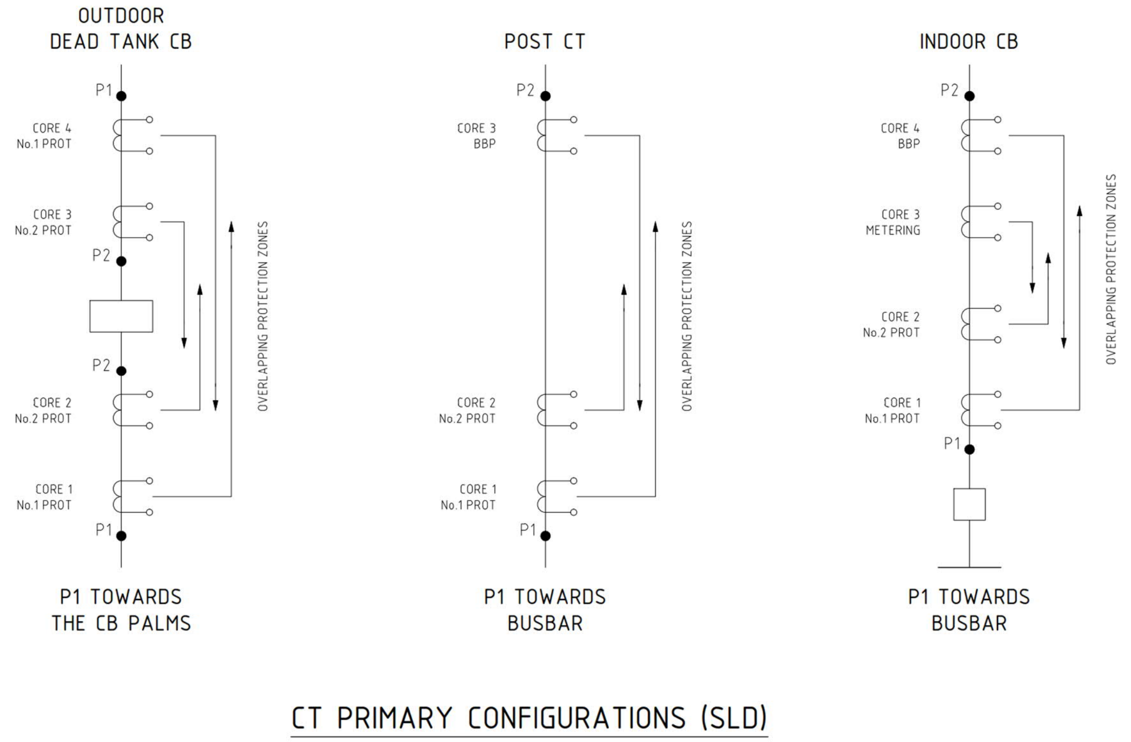
d) where possible, blind spots shall be eliminated by overlapping protection zones

e) separate CTs shall be used for duplicate protection such that the No.1 CT is associated with the No.1 protection relay and the No.1 trip coil.

f) No.2 protection CT shall be overlapped by the zone of No.1 protection CT

g) Instrumentation CT shall be overlapped by the zone of a protection CT

Figure 10.1 – CT Primary Arrangement



10.3.2 CT secondary wiring

CT secondary wiring size, colour and numbering shall conform the requirements of Part 1 of this standard. It is a Safety In Design requirement that CTs are not energised without a secondary burden(1). The CT burden shall be kept to a minimum and the addition unnecessary equipment in the circuit should be avoided.

CT connections shall be robust and secure. Spare CT shall be shorted across the full CT tapping with a 2.5mm^2 wire short and earthed as close as possible to the CT terminals.

NOTES:

(1) *Dangerous secondary voltages are produced when there is no secondary burden on a inservice CT. The secondary burden is to be kept as low as possible. An in service CT must never be opened circuited.*

10.3.3 CT polarity and star point

The CT design shall show the CT primary winding and secondary taps such that the primary *P1* and secondary tap *S1* align. The CT function, class, ratio and connected ratio(1) are to be noted above the CT primary winding.

For protection CTs a fault direction arrow is to be drawn above the set of CTs to indicate the direction of the protected zone. The side of the winding that the fault current will enter is the primary polarity and the side of winding that the fault current exits is the primary non-polarity. The protection relay CT winding polarity shall be shown with a polarity dot adjacent to the winding.

The start point of CT secondaries shall lie inside the protected zone (for example the non polarity side of the CT winding).

EXAMPLES:

- for feeder overcurrent protection, the star point shall be on the line side of the CT secondaries (overcurrent fault direction is towards the line)
- For transformer differential protections, the star point shall be on the CT secondaries nearest the transformer (transformer fault direction is towards the transformer)
- For BBP, the start point shall be on the busbar side of the CT secondaries (busbar fault is towards the busbar)

Some situations a CT may be shared by two protection schemes with conflicting protection zones, for example low impedance BBP and feeder/ transformer protection. In these situations, two fault arrows shall be drawn above the CTs to show the protected zone for each of the two protection zones.

One of the schemes shall be chosen to set the CT polarities[(2)]. An unusual condition icon is to be placed against the CT to nominate which fault direction is being used to set the CT polarities.

For Instrumentation CTs a load direction arrow is to be drawn above the set of CTs to indicate the direction of the nominated normal load flow. The side of the winding that the load current will enter is the primary polarity and the side of winding that the load current exits is the primary non-polarity. The instrumentation winding polarity shall be shown with a polarity dot adjacent to the winding. The instrumentation non-polarity side shall be starred.

NOTES:

(1) The connected tap may be underlined

(2) Due to historical reasons for legacy low impedance BBP schemes, the star point shall be set for the feeder/transformer fault direction ie fault direction is away from the busbar for all CT secondaries including the bus section and bus coupler CB see 11.3.4.

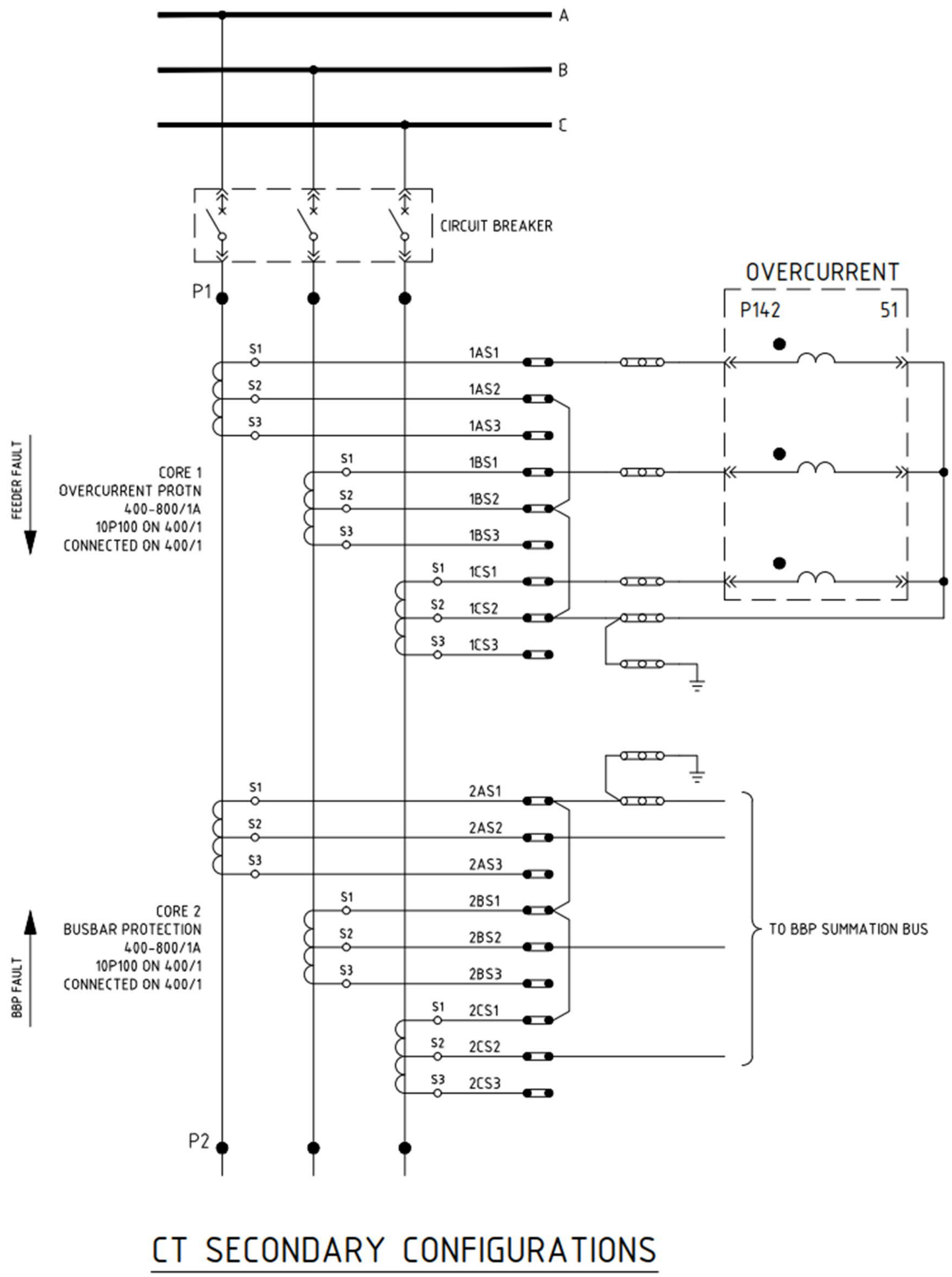
10.3.4 Earthing of CT secondary wiring

All CT secondary circuits shall be earthed with no more than one (1) earth connection to each set of connected current transformers. Except for CTs in equipment under frame leakage protection, all CT earths shall be connected to the station earth. The earth connection shall be made to the following arrangements

a) Star connected secondaries shall be earthed at the star point
b) Delta connected secondaries shall be earthed at white phase
c) Transformer differential protection with star-delta windings shall be earthed at the star point
d) Transformer differential protection with delta-delta windings shall be earthed at white phase of the low voltage CT.
e) High impedance BBP schemes, with star connected CT shall be earthed on the summation busbar neutral
f) CT that are located within the circuit breaker under frame leakage protection shall be earthed to the circuit breaker frame earth (see 11.3.5).
g) Single core CT used for NEF, Frame Leakage Zone, NUB, SEF core balance etc shall be earthed on the non-polarity winding.

Where possible the earth connection shall be made via a dedicated CT earth isolation link that shall be used to isolate the earth connection for CT earth testing and fault finding. For legacy design the CT earth isolation link shall be located with the CT panel termination. For new design the CT earth isolation link shall be located on the front of the panel with the CT test links.

Figure 10.2 – CT Secondary Arrangement



10.4 Protection System VT supplies

Voltage Transformers (VT) are used for a variety of purposes that are essential for the correct functioning of protection systems. VT specifications are detailed in Company Standard PDI 1000 – Protection of high voltage plant. VTs are also used for a variety of control functions, instrumentation and metering. The VT design shall marshal the VT secondary equipment as per the following design requirements.

10.4.1 VT arrangement

VT are generally connected to a busbar, line or transformer via a set of HV fuses. The physical location of VT is important for some control function such as sync check. The design of secondary system shall consider the suitability of the VT location on the secondary system.

The VT primary arrangement shall be shown on the protection and indication diagram and shall detail the phasing, winding connection, polarity and voltage ratio of the VT.

It is a Safety in Design requirement that isolation of the secondary windings be provided in an accessible location to prevent a possible back feed into the primary network during the network outage. The isolation shall have a facility to attach an operating danger tag. There shall be only one isolation point per VT. A set of VT test studs shall be connected either side of the isolation point for phase testing of the VT.

10.4.2 VT secondary wiring and protection

VT secondary wiring size, colour and numbering shall conform the requirements of Part 1 of this standard. Inservice VT secondary windings must not be shorted at the secondary terminals. Protection devices shall be installed as close to the VT secondary terminals as practical to improve the sensitivity required by the primary protection for faults between the VT secondary terminals and the VT secondary protection.

If a VT has dual secondary windings, then the protection schemes shall be dispersed across the two windings; ie No.1 Protection on winding 1 and No.2 Protection on winding 2. If there is only one protection scheme, then the first winding shall be used for protection and the second winding shall be used for metering and indication.

If VT secondary protection is provided by a mcb then the mcb shall be single phase and shall have an auxiliary normal closed contact that provides an alarm to SCADA when the mcb has tripped. Alarms shall be grouped per VT secondary winding.

Separate circuits shall be used for protection and instrumentation. Each VT circuit shall be clearly labelled describing the circuits function.

VT fuses and mcb shall be rated at no more than 6A and shall grade with panel fuses as required.

10.4.3 Earthing of VT secondary winding

The most common voltage transformers used in the network are three phase star-star connected. For new substations the primary and secondary windings shall be earthed at the star points. The secondary VT protection shall use a white Fuse Link to isolate the VT neutral.

It is preferred [(1)] when installing new VTs in existing substations that the current standard be applied.

NOTE:

(1) *In some existing substations where a legacy metering standard exist, it may not be practical or cost effective to convert to the new standard. Some 11kV switchboards for instance, have VT trucks where the neutral has not been bought out. Some 11kV metering may require complete rewiring of VT change over circuits.*

10.4.4 VT change over design

VT Change over schemes shall be designed so that that the VT supply is biased from the normal inservice VT and only changes over to the standby VT supply, on the loss of the normal inservice supply. The change over operation shall initiate a SCADA event. When the normal inservice supply is healthy the VT change over shall return to normal inservice VT supply. A cascading circuit may be used for three or more sources.

10.5 Protection System DC supplies

Two dc protection supplies shall be used for circuit breakers with two trip coils or for protection systems with two protection schemes. The dc protection supply shall be protected by fuses or mcb typically at the station dc supply panel. The bay dc protection supply shall grade with the station dc panel, protection supply(1).

If there are two station batteries, then the No.1 Protection supply shall be taken from the No.1 battery and shall supply the No.1 protection relay and trip the No.1 trip coil. The No.2 Protection supply shall be taken from the No.2 battery and shall supply the No.2 protection relay and trip the No.2 trip coil.

If there is only one battery, then the No.2 Protection supply shall be a separate circuit on the station dc panel.

All protection schemes shall have individually protected supplies, which shall be used exclusively for the scheme. Each scheme shall independently trip associated circuit breakers through their own trip coil, *(that is two protection schemes protecting the same equipment shall not operate the same trip coil).*

Separate dc protection supply circuits shall be required on the station dc supply panel when there are large number of circuit breakers. Each protection supply circuit shall be bussed together in logical arrangements of circuit breakers; *for example, 11kV Section 1; No.1 Protection Supply, 11kV Section 2; No.1 Protection Supply etc.* Ring busses shall not be used.

The protection supply bus wiring shall loop in and out of each control panel through two adjacent terminals on the dc supply terminal block, *as per clause 7.4.3, terminal block design.* The bus wiring shall be of a suitable size to carry the load of the circuit (2). A wire size smaller than the bus wiring may be used from the bus “tee” at the control panel dc supply terminals, to the control panel protection, if it is adequately protected from short circuits by the station dc supply panel protection.

NOTES:

(1) *The bay protection fuse shall typically be a 20A HRC fuse. This fuse provides short circuit protection only. Overload protection is not required as the protect trip circuit is not loaded under normal inservice conditions. A 20A cartridge rating has been specified to minimise the risk of inrush current operating the fuse when it is required to trip equipment that are under fault conditions. The typical dc panel, protection supply fuse is rated at 32A.*

(2) *The typical protection bus wire is 4mm^2.*

10.6 Tripping Circuits

Tripping circuits shall originate from a single protection fuse at the local bay protection panel(1). Tripping circuits shall use *clean contacts* with a supply test link and a trip test link. Multiple trip functions may use a common trip link if there will be no need for inservice isolation of any of the trip functions(2).

It is preferred (3) that multiple local trip functions trip the #1 trip coil. This would include single BBP, UFLS, SCADA open and manual open while only the #2 protection trips the #2 protection coil.

Labelling of trip links shall use the text "*Trip*" in the label inscription.

NOTES:

(1) Some legacy sites use multiple trip positives from various remote panel such BBP, UFLS etc that marshal at the local bay protection panel. Tripping isolation for this legacy arrangement requires the isolation at remote panels which may be inservice. These legacy arrangements can be a network security risk and where project budget and timing are available, may be bought up to the current standard.

(2) Example: Separate intertrip links are required as the intertrip function may need to be isolated in some inservice situations.

(3) The principle is to direct the main protection functions to the trip coil that is exercised the most. In some legacy sites this may not be practical. However, where possible the SCADA and primary protection shall operate the same trip coil.

(4) In some legacy sites there is only one trip coil. In these circumstances the second protection relay is unable to trip the #2 trip coil. The preferred configuration is to use a common negative for both relays and an optional second protection supply for the #2 protection relay. Both supplies must originate from the same battery.

10.7 Trip Circuit Supervision

The health of the protection trip circuit shall be continuously monitored by a Trip Circuit Supervision, TCS circuit. The TCS circuit shall initiate a SCADA alarm[(1)] when

a) Protection supply is lost;
b) CB control selector switch is in Maintenance position *(for example protection disabled);* and
c) The trip coil or wiring from the tripping links[(2)] to the trip coil is open circuit.

For some legacy substations, such as TransGrid (formerly ELCOM) protection panels, TCS is not practical. In these situations, trip fuse supervision shall be used. The trip fuse supervision relay shall initiate a SCADA alarm on the loss of the protection supply.

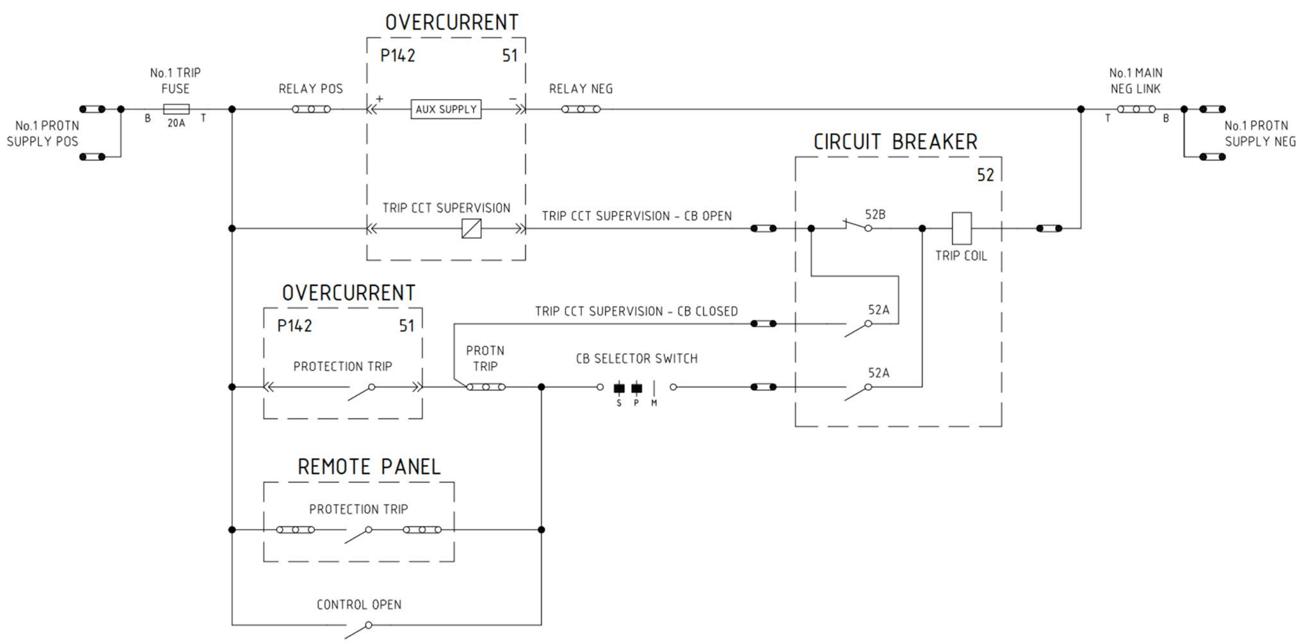
MCB used for protection supplies shall use a normally closed contact to initiate a loss of protection supply.

It is preferred that separate alarms are initiated for No.1 and No.2 TCS circuits. They may be grouped when there are insufficient SCADA inputs available.

NOTES:

(1) The TCR shall be a fail safe circuit
(2) If there is only one trip link then it shall be monitored by the TCS

Figure 10.3 – Tripping Circuits



10.8 Circuit Breaker Fail Protection

Circuit Breaker Fail (CBF) protection is used to trip all sources of supply flowing to a fault on the network when a circuit breaker fails to isolate a faulty circuit, by a set time. The configuration of the CBF relay shall be specified in the PIES.

CBF circuits shall be separated from other circuits, located in a defined area of the terminal block and shall be clearly labelled. The CBF circuit must be supplied from an independent CBF fuse. The CBF positive bus and CBF trip bus shall be formed using bridging links between adjacent terminals. Twin core cables shall be run between the busses to the CBF positive link and CBF trip link on the individual bay panels. The CBF links shall be clearly labelled. Clean contacts shall be used for the CBF output relay.

A very high network security risk is associated with CBF circuits. To reduce the risk of unintentional operation of CBF circuits

a) CBF wiring and circuits shall be identified on schematics by a network security caution icon and a comment added to the network security section of the design cover page.
b) CBF wiring shall be segregated from other wiring
c) A red link shall be used on the outgoing bay protection panel

NOTES on legacy CBF circuits:

(1) *Circuit breaker fail is preferred to the legacy term Local Backup protection (LBU). During the augmentation of legacy sites all labelling may be changed from LBU to CBF if it is within the project budget and timing but only if the labelling of the whole scheme can be changed. The terminology shall be consistent on site.*

(2) *The current CBF standard uses a distributed CBF timer within each bay protection rather than a common scheme CBF timer. The common timer is required on some legacy schemes, as many legacy protection relays do not have internal CBF timers. During the replacement of legacy relays, the common timer shall be retained until all legacy protection relays have been replaced. The removal of the timer is not mandatory unless specified in the PIES.*

(3) *Where practical, legacy sites shall not use a half panel to marshal LBU relays from multiple busses. During relay replacement programs the No.1 and No.2 LBU relay shall be located on a half panel per section of bar. Separate panels will improve network security and reduce issues associated with future panel replacements.*

11 Protection Scheme Design

Protection Scheme for the HV network shall be designed to the specifications provided in company Protection Indication and Equipment Schedules (PIES). The PIES specify the protection equipment and their general hardware configuration. Protection relay software, firmware, settings and configuration files are produced and managed by the Protection Section.

11.1 Transmission Feeder Protection

Transmission feeder protection schemes may use a combination of differential, distance, directional overcurrent or overcurrent protection as specified in Company Standard PDI 1000 – Protection of High Voltage Plant and shall be designed to comply with Section 10 of this standard.

11.1.1 Pilot design

The preferred feeder differential protection schemes use microprocessor based digital relays communicating via optical fibre pilot through the company's communication network. However, there are still many legacy schemes in the network that require analogue relays that communicate via copper pilots.

Optical pilots in the company communication network shall be terminated at the Fibre Termination Points (FTP) within the station main fibre termination cabinet as per the Company Standard ADI 0006 – Substation Communication Systems.

Six core single mode optical fibre cables shall be terminated on feeder protection FTP within the main fibre termination cabinet. The other end shall be terminated in a suitably located FTP enclosure in the HV feeder protection panel.

A separate optical cable is required per relay. Two cores shall be for a direct path between feeder protection relays, two cores shall be for the indirect path and two cores shall be spare. Patch leads shall be used to patch between the FTPs to create the communication path.

Dual channel relays shall patch channel 1 from the relay at the main substation, to channel 2 on the relay at the remote substation. For 132kV Feeders both the direct path and indirect path shall be patched through. It is preferred that at the main substation channel 1 is patched via the direct path and channel 2 is patched via the indirect or alternate path.

For 66kV and 33kV feeders indirect path may be patched through if:

a) There is an available alternate or indirect path
b) The indirect path does not need patching through an impractical number of sites
c) There is sufficient numbers of spare cores available in the fibre ring.

For single channel relays the direct path shall be patched through. In the event of the loss of a pilot then the indirect path shall be manually patched through.

Refer to ADI 0006 for feeder protection communication that interface via muxes to relays at TransGrid substations.

Copper pilots shall be terminated and managed in pilot isolation cubicles. The cubicles shall be designed for 15kV isolation and situated 1.5m from metal or earthed surfaces. An isolation mat of a suitable size shall be situated on the floor adjacent to the door of the cubical. Substation wiring connected to the pilot wiring shall pass through 15kV isolation equipment such as pilot isolation transformers or barrier relays. 15kV isolation jacks shall be used to isolate individual pilot cores.

A high voltage caution sign shall be placed on the cubical door and a remote earth hazard icon shall be included in the drawing.

11.1.1 Feeder VT changeover

VT changeover is not required for feeder protection unless explicitly specified in the PIES. The exception is for some legacy sites with analogue directional overcurrent relays. In these situations, the VT changeover bus wiring supplying the analogue relay shall be retained until the legacy relays are replaced.

11.1.2 Distance protection VT supply

It is preferred that VT supplies for distance protection are sourced from the feeder VT. Network security risks are associated with using VT supplies from bus VTs. If bus VTs are used, then a warning label shall be installed adjacent to the bus VT isolation links and an unusual condition hazard icon added to the drawing.

11.1.3 Feeder No Volt Changeover

Transducers on multidrop serial communication links shall not be used to initiate feeder No Volt Change over schemes. It is preferred that the No Volt Changeover scheme is managed by SCADA a dedicated server terminal or dedicated comms to a protection relay. Legacy relay schemes are removed from service.

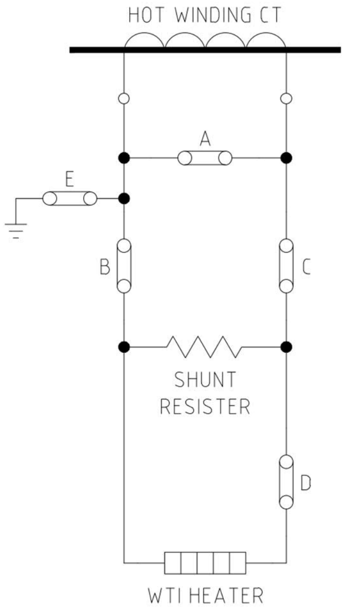
A warning label shall be fixed adjacent to isolation links or fuses used for the sensing of loss of volts. A hazard icon shall be added to the drawing warning that *No Volt Changeover associated with this circuit*.

11.1.1 Feeder intertripping

Feeder intertrips, shall be implemented with clean contacts using the feeder trip supply. If multiple tripping is required, then the trip links shall be grouped with the common feeder trip positive link.

11.2 Transformer Protection

Transformer protection schemes may use a combination of differential, overcurrent, restricted earth fault, neutral earth fault and temperature protection as specified in Company Standard PDI 1000 – Protection of High Voltage Plant and shall be designed to comply with Section 10 of this standard.



11.2.1 Winding temperature indication

Winding Temperature Indicators (WTI) used to model the heat in the transformer winding shall configure the test links as per the adjacent figure:

a) CT secondary winding shorting link (Link A)
b) CT secondary winding earth link (Link E)
c) CT test injection links (Link B & C)
d) WTI test link (Link D)

The shunt resistor used for the setting the WTI heater current, shall be designed such that a suitable shunt resistance will always be connected across the WTI heater, including circuits that will switch staged resistors. The preference is for a WTI that is not switched.

The requirements for the WTI are specified in company transformer Equipment Technical Specifications.

11.2.2 Close interlock

Latched normal closed multitrip contacts shall be wired in series with the close control circuit, to prevent the closing of the transformer circuit breakers, after a transformer fault. After inspecting the transformer for damage, the multitrips must be manually reset before the transformer can be returned to service.

11.3 Busbar Protection

Busbar protection schemes are specified in Company Standard PDI 1000 – Protection of High Voltage Plant and shall be designed to comply with section 10 of this standard. Circuit Breaker Fail (CBF) is often associated with BBP as it convenient to utilises the BBP multitrip relay to *clear* the bar, for failure of a circuit breaker to trip within a designated time after a protection operation.

11.3.1 High impedance BBP schemes

BBP schemes shall be divided into separate bus zones such as bus Zone A, bus Zone B etc. Each bus zone shall be associated with a section of busbar such as Section 1, Section 2 etc and shall be arranged on a BBP panel, (or half panel) per zone.

The BBP zones shall overlap at the bus section or bus coupler circuit breakers connecting the busses together. Bus section circuit breaker require BBP CTs for two BBP zones and the CTs shall be arranged so that there are no *blind spots*. Bus section CBF protection shall be connected in the star point side of the bus section circuit breakers *butterfly* CT connection. The bus section CBF relay shall be located on the bus section circuit breaker protection and control panel.

Bay circuit breakers shall be tripped by the BBP multitrip relay using the individual bay circuit breaker trip supplies(1). Each multitrip must use a contact to initiate a SCADA event to indicate that the summation bus is shorted (2).

NOTES:

(1) *There are many legacy sites that use a common BBP trip positive. It is preferred that the tripping circuits are bought up to the current standard as per the guidelines of Section 4.1.3.*

(2) *Caution if a multitrip is used solely to short the metrosil and is not reset after a bus fault, then the bus may be returned to service with the BBP disabled.*

11.3.2 High impedance summation bus

For outdoor circuit breakers a BBP summation kiosk shall be used to marshal the BBP CTs. Where practical the BBP kiosk shall be located near the busbar in a central location. For indoor circuit breakers the BBP summation shall be located on the BBP panel in the control building.

Each bus zone shall be logically arranged, typically with No1 Protection, bus Zone A, bus Zone B, bus Zone C etc, in the top half of the panel and No.2 Protection, bus Zone A, bus Zone B bus Zone C etc in the bottom half of the panel.

The CT test links shall be arranged in logical groups along the summation bus. Typically, feeders CTs then Trf CT, Bus Section CTs and then the outgoing test links to the BBP relay. In situations where a bus section circuit breaker has not been installed, then the future zone shall be established and the summation bus extended via isolation links to bridge the two zones, creating a single bus zone.

Example:

If bus section 1-2 is not installed, then zone A and zone B summation bus are to be bridged and the BBP zone shall be called zone A/B. When the bus section circuit breaker is installed then the summation bus bridge is to be removed and separate bus zones established (zone A & zone B).

11.3.3 Stub bus protection

Stub bus protection shall be implemented to extending a BBP zone to include sections of busbar that are not connected to an incoming or outgoing source of supply, as in the case of a spare feeder bay or future use bus section CB.

In these situations, the design shall

a) short the out of service bay protection CTs at the bay protection panel
b) short the out of service bay BBP CTs at the BBP panel and open the links to enable the BBP zone to see faults on the stub bus.
c) Add an unusual condition hazard icon to the drawing.

11.3.4 Low impedance busbar protection CT arrangement

A separate panel shall be used for the low impedance protection to marshal CT and tripping wiring to the associated bay protection panels.

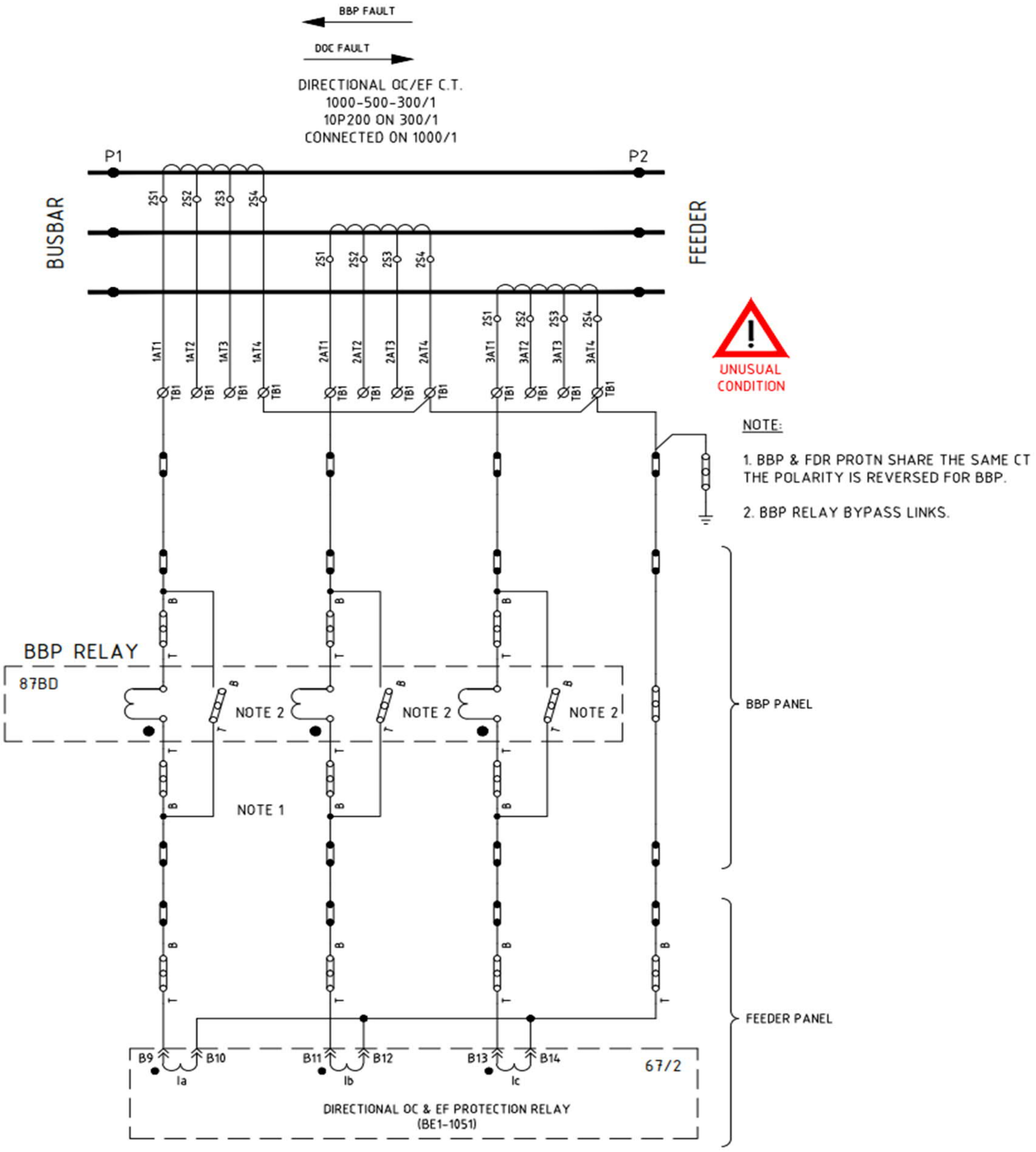
When one set of CTs is shared by the low impedance and bay protection relays, then the protection CT shall be connected firstly to the low impedance relay ac windings which shall then be connected in series with the bay protection relay ac windings. The CT earth link shall be installed on the panel with the CT supply in links. The CT star point shall be made up at the bay protection panel. The CT fault polarity shall be configured for the bay protection.

At the low impedance protection panel the CT links shall be grouped in a standard arrangement

a) CT SUPPLY IN; (5 links A, B, C, N and Earth)
b) CT SUPPLY OUT; (3 links A, B, C)
c) CT SUPPLY BYPASS; (3 links A, B, C)

The CT bypass links shall be connected from the CT side of the *CT SUPPLY IN* links to the outgoing side of the *CT SUPPLY OUT* links as per the diagram below.

Figure 11.2 – Low Impedance BBP standard CT arrangement



11.3.5 Frame leakage protection

Frame Leakage protection is a legacy form of BBP used at some sites in the network on 33kV and 11kV busbars. Frame leakage protection detects earth currents (1) flowing from the metallic structures or enclosures housing the busbar, to the station earth, via a frame earth and frame leakage CT.

The design of the Frame Leakage protection shall arrange the bus into frame zones. All metallic structures within that zone shall be electrically bonded together and insulated from the main substation earth. For outdoor metallic structures, two insulated earthing conductors shall be used to bond each metal structures with the frame zone. Each frame zone shall be bonded to the main substation earth via a single busbar or earth conductor. The Frame CT shall be mounted around the frame earthing conductor to the main earth.

The integrity of the frame zone shall be maintained and shall not be bridged by metallic objects, such as cable ladders or ducts, between frame zones or to the substation earth. Electrical equipment such as heaters and GPOs within the frame zone shall be earthed at the distribution board and not the frame earth.

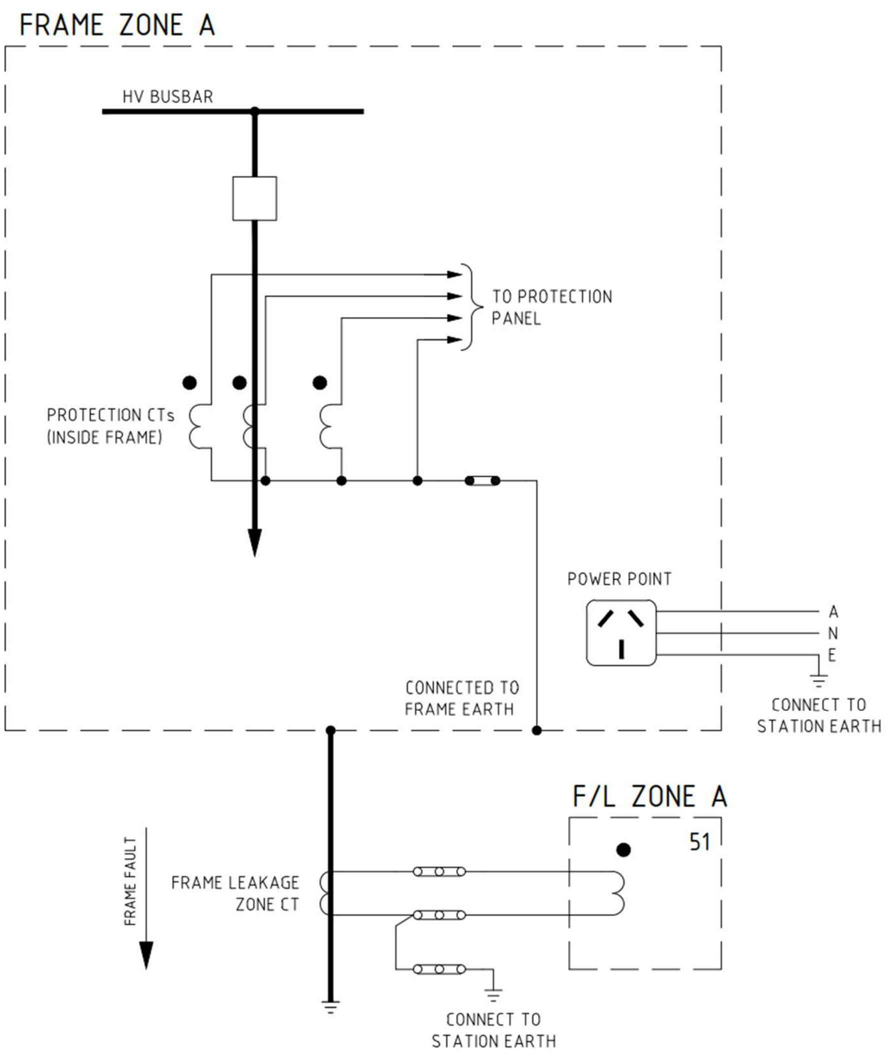
Protection and indication CT and VT star points within the frame zone shall be earthed to the switchgear frame earth. The frame leakage CT secondary winding shall be earthed from the non-polarity tap to the main station earth. Screens from power or control cables shall not be bonded to the frame zone earth.

During the refurbishment of Frame Leakage protection it is preferred that the frame leakage multitrip trip wiring be amended to use clean contacts and trip supplies from the bay protection, subject to the management of legacy design principles in Section 4.1.3.

NOTE

(1) *The Frame Leakage zone CT will detect an earth current flowing through the frame. A frame leakage check must be used to confirm that the protection system has also detected an earth fault. During refurbishment of Frame Leakage protection check circuits it is preferred to use numeric relays to provide the check function and remove the analogue check relay and stabilising resistor in the indication CT circuit.*

Figure 11.3 – Frame Leakage secondary earthing



11.4 Distribution Feeder Protection

Distribution protection schemes are specified in Company Standard PDI 1000 – Protection of High Voltage Plant. The protection schemes typically use a combination of overcurrent, earth fault and sensitive earth fault protection and shall designed to comply with Section 10 of this standard.

11.4.1 Feeder SEF protection

The distribution feeder design shall enable the SEF protection to be made Non-Auto and Auto remotely via SCADA or locally at the substation. The SEF protection must be made non-auto during single phase field switching on distribution feeders, to prevent the out of balance currents from operating the SEF. Generally, SEF check circuits are not used in company substations.

The station SEF control shall toggle the status of all feeder SEF protection between Auto and Non-Auto for the duration of the switching. Station SEF control circuits are discussed in section 12 as part of the SCADA system design.

11.4.2 Circuit breaker racking switches

Rackable distribution circuit breakers shall have a microswitch that operates when the CB is racked into the inservice position. The normally open contact, from the racking switch indicator, shall be wired in series with the CB selector switch in the supervisory position, to indicated that the CB is available for SCADA control.

11.5 Underfrequency Protection

Underfrequency protection schemes are specified in Company Standard PDI 1000 – Protection of High Voltage Plant. The protection schemes shall be designed to comply with Section 10 of this standard.

11.5.1 Frequency sensing

The frequency sensing source shall be taken from an underfrequency circuit, in the AC supply panel, via a 230/110Vac step down transformer (1). The underfrequency check circuit shall be marshalled in the UFLS panel with twin cores cables run to the individual transformer relay underfrequency check output.

NOTE

(1) *Legacy sites which use 230Vac supply for the sensing circuit shall be bought up to the current standard using a 230/110 Vac step down transformer.*

11.5.2 Panel layout

The panel shall be laid out in a logic arrangement with group trip links arranged in sections. The panel shall leave space if required, for future additional feeders. The tripping circuits shall use clean contacts with the trip supply originating from the bay protection supply.

12 SCADA System Design

SCADA system design shall conform to the requirements of Company Standard ADI 0012 – Substation Automation Systems and Part 1 of this standard. SCADA systems enable the remote monitoring and control of network equipment within substations and the distribution network from a central control room. This section specifies the secondary design requirements associated with the implementation of SCADA systems in transmission and zone substations.

The SCADA system within a substation, is known as a Substation Automation System (SAS). The SAS utilises the substation RTU for software control and local automation routines on substation equipment. The SAS design can be organised into three physical parts.

a) SCADA SMU panel
b) SCADA marshalling panel
c) SCADA communication network

12.1 Substation Management Unit (SMU) Panel

The SMU panel is the main interface between operators and the equipment within the substation. It shall be located away from the AC and DC panels and house the main CPU and associated station level RTU.

12.1.1 SCADA DIU design

It is preferred to decentralise the SCADA system with distributed I/O at individual bays via protection relays or I/O interface units in line with the new digital substation strategy (see 4.1.4). Legacy sites may use a centralised SMU panel.

A centralised SMU panel shall be designed to house the SCADA DIUs and CPU which will typically be mounted on a swing frame sub rack. The sub rack shall be designed for four DIUs. A 32amp DC supply typically from the No.1 battery shall be distributed via fuses or mcb within the SMU panel to the DIU power supplies, managed switch, monitor and other SMU equipment including sub circuits to any RTUs on remote panels. DC to DC converters may be used as required for 24Vdc equipment.

Typically, DIU 1 will manage the station level I/O including alarms from the SMU, AC, DC, BBP, UFLS and mux panels. DIU 2, DIU 3 and DIU 4 will typically manage the I/O from P&C panels and switchgear.

DIM, DOM, POM and AIM cards within Logica DIUs are to be arranged so that each type of card is grouped together, and spare slots are left available for future cards, if required. DOMs and POMs are installed beginning from slot 0. AIMs are installed in the centre slots while DIMs are installed beginning from slot 15. The addition of a new card must not relocate existing cards without consultation with Automation design.

12.1.2 SMU cooling

The SMU panel shall be designed for natural ventilation and cooling; the use of fans shall be avoided where appropriate. If fans are required, then they shall be controlled with a thermostat.

12.1.3 HMI Human Machine Interface

The HMI (Human Machine Interface, ie touch screen) and associated PC shall be specified by the automation section. The HMI shall be mounted at eye height on the SMU panel front door or another suitable location in the control room such as the control desk.

12.1.4 Medical emergency control

The medical emergency control circuit is a Safety in Design feature for the substation and shall be designed to the following standard.

A dedicated dc supply (J77, J76) from the No.1 Station battery shall be used for the Medical Emergency siren. The siren shall be mounted in a suitable central location, typically under the eaves of the control building. A red Medical Emergency Push Button (MEPB) shall be located centrally on the SMU panel front door.

The MEPB shall be an Izumi type ABGW-411R, or approved equivalent. A MEPB 25x25mm label shall be fixed adjacent to the push button. The label shall use white 3mm text on a red background with the text “Medical Use Only”.

When the MEPB is activated a station level DIM shall be initiated, via dedicated wire number X931. This input notifies the system operator that there has been a medical incident at the substation.

The system operator will send notification via the SCADA that medical assistance is on the way. A station level DOM shall be used to set the medical emergency control relay 74ME, via dedicated wire number X950ME.

The 74ME shall be a bistable relay with two normally open contacts. One contact will initiate the siren the other contact will activate a station level DIM via dedicated wire number X932 to indicate that the siren is activated. The 74ME and siren shall be reset by the system operator or via SCADA after 30seconds.

12.1.5 Station SEF control circuit

Station SEF control may be implemented using either a hard wired control circuit or via communications. SEF protection is discussed in Section 11.

The station SEF control circuit shall be used to toggle the status of all the Sensitive Earth Fault (SEF) protection relays. The station SEF shall be remotely controlled via SCADA or locally controlled via a manual station SEF auto/ non-auto switch located on the SCADA HMI panel. The status of the station SEF control shall be monitored by SCADA.

A local bay SEF Auto/ Non-Auto switch or link shall be installed at each panel for individual bay SEF control. In the Auto position the SEF switch shall allow remote control of the SEF protection. In the Non-Auto position, the SEF protection will be blocked or disabled. For double cable feeders each feeder leg shall have a separate local SEF Auto/ Non-Auto switch.

When the station SEF is set auto, then the SEF function of all bay feeders selected for SEF auto operation shall be enabled. When the station SEF is set Non-Auto, then all bay feeders selected for SEF auto operation shall be disabled or blocked.

A separate station level SEF control supply shall be bussed to each bay feeder panel for the hard wired SEF control. When the station bus is energised and the bay SEF control switch is selected to Auto, then the SEF function shall be blocked [(1)] .

In situations using dual battery or two SEF relays then, a SEF interposing relay shall be used to separate the No.1 and No.2 SEF blocking supplies to the relays. Each blocking supply shall originate from the associated battery or protection supply.

NOTE

(1) *In some legacy sites the station SEF control bus may be design as an enabled bus. In these situations, when the station bus is energised, and the bay SEF control switch is selected Auto, then the SEF function will be Auto.*

Although a blocking bus is preferred to the enable bus, legacy sites do not need to be reconfigured to the blocking bus standard. Unless specified by the project, the station SEF control bus legacy design shall be maintained throughout the site.

12.2 SCADA Marshalling Panel

SCADA marshalling panels shall only be used when there are insufficient resources to manage I/O at each equipment bay. It is preferred to marshal all SCADA I/O at the individual equipment bays either through protection relays, distributed I/O interfaces or distributed RTUs.

If required, SCADA marshalling panels shall be used to interface SCADA I/O with the substation equipment via an array of termination modules. Termination modules are to be arranged logically within the panel and shall be clearly labelled.

Separate DIM/ POM (or DIU) negative supply shall be distributed by separate circuits to every equipment bay. Each circuit shall be individual protected by a 1A fuse and given a fuse circuit number. The DIU negative supply shall be connected to the bay DIU negative link. All SCADA I/O on the panel shall be supplied by this link.

Bay I/O shall return to the termination modules in the SCADA by a screened SCADA cable. Typically, the SCADA cable will include the DIU negative and all the I/O for a particular bay. Analogues signals shall not be run in the same SCADA cable as digital signals.

12.3 SCADA Communication Network

A Local Area Network (LAN) shall be set up to establish communications between the SCADA and station equipment. A managed switch shall be installed in the SMU panel to distribute communications from the CPU to the individual DIUs, the HMI, outdoor GPS and station communication cubical.

The GPS is typically installed in the SMU and requires a communications cable run to a suitably located outdoor antennae that is within the substation lightning protection sphere.

Separate ethernet cables from the managed switch shall be run to unmanaged switches in the switchgear and HV protection and control panels as required. Individual ethernet cables shall be run from the unmanaged switches to bay relays or RTUs.

The installation of communication cables shall comply with ADI 0006 Substation Communication systems. Only equipment controlled by the SCADA shall be connected to the SCADA LAN. Metering, VOIP and other corporate communication equipment must be physically separated from the LAN and should be connected directly to the station communication MPLS.

13 Communication System Design

The secondary design requirements for substation communication systems is extensively covered in Company Standard ADI 0006 – Substation Automation Systems.

14 Auxiliary Supply System Design

Station auxiliary systems provide ac and dc power to the station protection and control systems. The design of auxiliary systems shall conform to the requirements of Company Standard SDI 511 – Auxiliary AC Supplies and Switchgear, Company Standard SDI 513 – Substation batteries and battery chargers, Part 1 of this standard and AS/NZS 3000:2018 – Electrical Installation “Wiring Rules”.

14.1 Station AC Supply System

Station AC auxiliary supply is provided by station auxiliary transformers or from a street supply from the local distribution feeder network. The ratings and configuration of the ac auxiliary supply systems are specified in Company Standard SDI 511 – Auxiliary AC Supplies and Switchgear. Consideration must be given in the design to arc faults as per 6.2.18.

For zone substations the AC supply system are typically supplied from the station auxiliary transformer via the station LV bar and by a standby street supply. The station main auxiliary transformer distribution board supplies the SFU, control room air conditioning, streamline filter supply, emergency generator incomer and station AC supply panel.

The backup street supply is a limited supply, typically 40kVA, and shall only supply the station AC supply panel. Depending on the earthing system of the distribution network an isolation transformer may be required. The street supply shall be isolated in a suitable location within the substation.

For transmission substations the AC supply system are typically supplied by auxiliary transformers connected to the power transformer’s tertiary winding.

14.1.1 Auto change over design

The station auxiliary supply system shall supply the station AC supply panel via an Auto Change Over (ACO) system. The station AC panel shall be used only to supply essential services within the substation such as Station L&P, DC battery charges, SCADA, transformer cooler control and oil separator circuits and fire and security services.

The ACO shall be in a separate outdoor cubicle located near the station auxiliary transformers (1) and shall supply, via separate sub circuits, L&P distribution boards and the station AC supply panel.

NOTE: In many legacy sites the ACO is installed in the station AC supply panel

14.1.1.1 Zone Substation ACO

The 400Vac supplies from the main supply and the street supply shall supply an ACO system via separate 4 pole (3 phase and neutral) isolation switches or links. The ACO shall use electrically and mechanical interlocked contactors with a break before make operation. A one second delay is required between change over to prevent issues arising from phase shift between supplies.

An ACO selector switch shall be used to select the main supply, street supply or ACO off. Indication shall indicate when the main supply contactor or the street supply contactor is on.

a) Main supply selected: In the event of a loss of main supply the ACO shall automatically switch over to the street supply and initiate an alarm via SCADA. When the main supply is restored the ACO shall automatically switch back to the main supply. (ie the ACO system defaults to the main supply when it is healthy).
b) Street supply selected: In the event of loss of street supply no change over is initiated.

c) ACO selected off: The ACO is turned off and there shall be no supply to the station AC supply panel.

14.1.1.2 Transmission substation ACO

The 430Vac supplies from each auxiliary transformer shall supply an ACO system via separate 4 pole (3 phase and neutral) isolation switches or links. The ACO shall use electrically interlocked contactors with a break before make operation. A one second delay is required between change over to prevent issues arising from phase shift between supplies.

A selector switch shall be used to select the default auxiliary transformer supply. On the loss of the default supply then the ACO shall cascade to the second supply, and on the loss of the second supply then the ACO shall cascade to the third supply. Indication shall indicate when the auxiliary supply contactor is on. A supply fail alarm shall be raised via SCADA when an auxiliary supply is lost. The ACO system shall change back to the default supply on the restoration of the selected auxiliary transformer.

14.1.2 Earthing arrangements

The earthing of the auxiliary, isolation and street supply transformers shall be as Company Standard SDI 511 – Auxiliary AC Supplies and Switchgear and Company Standard EDI 516 – Major substation earthing design, construct and commissioning. A bond shall be made between the neutral and earth bar at the AC supply panel. A 95mm^2 earth cable shall bond the AC supply panel earth link to the station main earth.

14.1.3 AC distribution boards

Suitable sub-circuits shall be run from the station AC supply panel and the light and power distribution boards. The distribution boards shall not be MEN. A fault level and grading study shall be undertaken to determine the mcb ratings and settings.

14.1.4 Emergency DC lighting

At some legacy sites an emergency dc lighting system has been installed in the AC supply panel. On the loss of supply to the ac supply panel the dc emergency lighting is activated for 30mins to allow workers safe access from the control building. Consideration should be given, in line with the objective of 4.1.3, to bringing this old dc lighting standard up to the current lighting standard as per Company Standard SDI 529 – Light and Power.

14.1.5 Streamline supply

A 250A circuit shall be taken from the main auxiliary transformer to the stream line distribution board. The streamline distribution board shall be located near the transformers. The stream line supply shall have suitable terminations for the connecting trailing leads and shall have an isolation switch.

The streamline board may be used as a general use heavy current supply and as a means for connection of the emergency mobile generator if required.

14.1.6 AC system supply study

A study of the station ac system shall examine the expected fault levels, check rating, grading and sensitivity of protection devices, check expected volt drops and calculate the expected standing load. Special consideration shall be given to the protection from arcing faults within the ACO. The findings of the study shall be documented in a report and shall be filed with the substation design documentation.

14.2 Station DC Supply System

The ratings, configuration and isolation of the Station DC auxiliary supply are specified in Company Standard SDI 513 – Substation batteries and battery chargers. The DC auxiliary supply connects to the station DC supply panels. The station DC supply panels shall separately group the dc supplies for each battery. The DC circuits shall be arranged in a logical order with a suitable label. The DC panel shall be designed with a reasonable number of spare circuits.

14.2.1 Battery 70% test point

A battery 70% positive test socket and isolation fuse link shall be installed for each battery. A 70% dc supply fuse is to be mounted as close as possible to the battery. The test socket and fuse link shall be located on the DC supply panel. The 70% supply is used for simulating reduced battery voltage when testing switchgear.

14.2.2 Indication and alarms

A voltage indicator shall be installed on the dc supply panel for each battery. A dc transducer shall be used for SCADA dc supply indication, including under and over voltage alarms.

For single battery sites a failsafe dc monitoring relay shall be connected across the dc bus. The dc monitor relay shall initiate a, *loss of station dc*, alarm via the station radio or WAN communication system.

A battery earth fault detection system (1) shall be installed to detect for earths connected to the positive or negative dc bus wiring.

Battery charger alarms shall be grouped as a single DC abnormal alarm except for the earth fault alarm. The battery charger earth fault alarm shall be a separate alarm. If the alarms are high in the healthy state, then the SCADA input shall be inverted, and a note added to the master I/O list.

DC supply fuse supervision shall be provided at each bay panel for protection and control circuits. Fuse supervision is not required at the DC supply panel.

DC ring busses shall not be used.

NOTE

(1) *Typically, the battery earth detection circuit has used two incandescent lamps in series across the dc bus. The circuit is fused with 4A fuses and the midpoint of the lamps is earthed. An earth on one of the buses will provided an alternate path across the lamp on the faulty bus via the midpoint earth. The lamp on the earthed bus will dim and the lamp on the heathy bus will be brighter.*

14.2.3 Battery parallel switch

Where two batteries are installed at a substation then, the DC supply panel shall have a switch that parallels the No1. And No.2 batteries together.

14.2.4 DC system study

A study of the station dc system shall examine the expected fault levels, check grading and sensitivity of protection devices, check expected volt drops and calculate the expected standing load. The findings of the study shall be documented in a report and shall be filed with the substation design documentation.

15 Metering Design

The specification for substation metering equipment are provided in metering schedules attached to the project definition. The design of the metering system shall conform with part 1 of this standard.

15.1 New Substation

The current standard for new substations will typically specify a power quality meter (PQM) for each transformer. All statistical metering functions shall be obtained through the PQM. Typically, discrete energy meters are not required for new substations.

Where practical a metering panel shall not be used and the PQM shall be installed on the transformer LV circuit breaker. CT and VT wiring shall be marshalled through a metering test block and connected directly to the PQM. The PQM and wiring burden shall be less than the CT and VT burdens. The minimum CT & VT wire size shall be 2.5mm^2. The PQM shall be a 3 phase, 4 wire arrangement. The neutral shall be earthed.

The PQM must be connected to the corporate communication system only. For security reasons the PQM must be physically separated from the station communication LAN systems and SCADA.

15.2 Existing substations

A review of the legacy metering design shall be undertaken during the refurbishment of the substation metering panel. Consideration shall be given to upgrading of the legacy metering panel to the new standard, subject to the objectives of Section 4.1.3, management of legacy design.

Refurbishment considerations

a) Replacing existing metering with a PQM per transformer, removing summation CT and VT change over circuits.
b) Bringing existing 2 phase 3 wire metering system up to 3 phase 4 wire system. Relocating the VT neutral from white phase to neutral.
c) Add *sag ride through* circuit (1) and *hot standby* (2) control to VT change over circuit if supplying single existing PQM.

NOTE

(1) *The sag ride through circuit prevents the VT change over from operating for voltage dips greater than 15% on the network that are longer than 3 secs.*
(2) *A hot standby situation occurs when the transformer is on soak with the HV CB closed and the LV CB open. As the VT is on the transformer side of the open LV CB, it will be energised. The metering voltage supply shall not be supplied from the hot standby VT and shall change over to an inservice transformer.*

15.3 HVC Metering

Metering for HVC shall be arranged through an accredited metering provider.

16 Load Control Design

Load control manages the usage of power by reducing the peak load, reduces the need for higher network capacity. For new substations load control is managed by the energy retailer through smart metering located at the customers metering board.

There are substations with legacy load control equipment which may require refurbishment. The design of these legacy load control system is documented in the Electrical Design Guides and Company Standard ETS 0018 – Audio frequency injection control equipment.

17 Authorities and Responsibilities

Manager Asset Standards & Design has the authority and responsibility for approving this standard including any variations.

Substation Design Manager has the responsibility for:

- reviewing and endorsing this standard in accordance with company policy and procedures
- authorising designs that are compliant with this standard.

Substation Secondary Systems Design Manager has the responsibility for:

- revising and updating this standard in accordance with company policy and procedures.
- overseeing the implementation of this standard within the Substation Secondary Design Section
- approving designs that are compliant to this standard
- approving any deviation to this standard

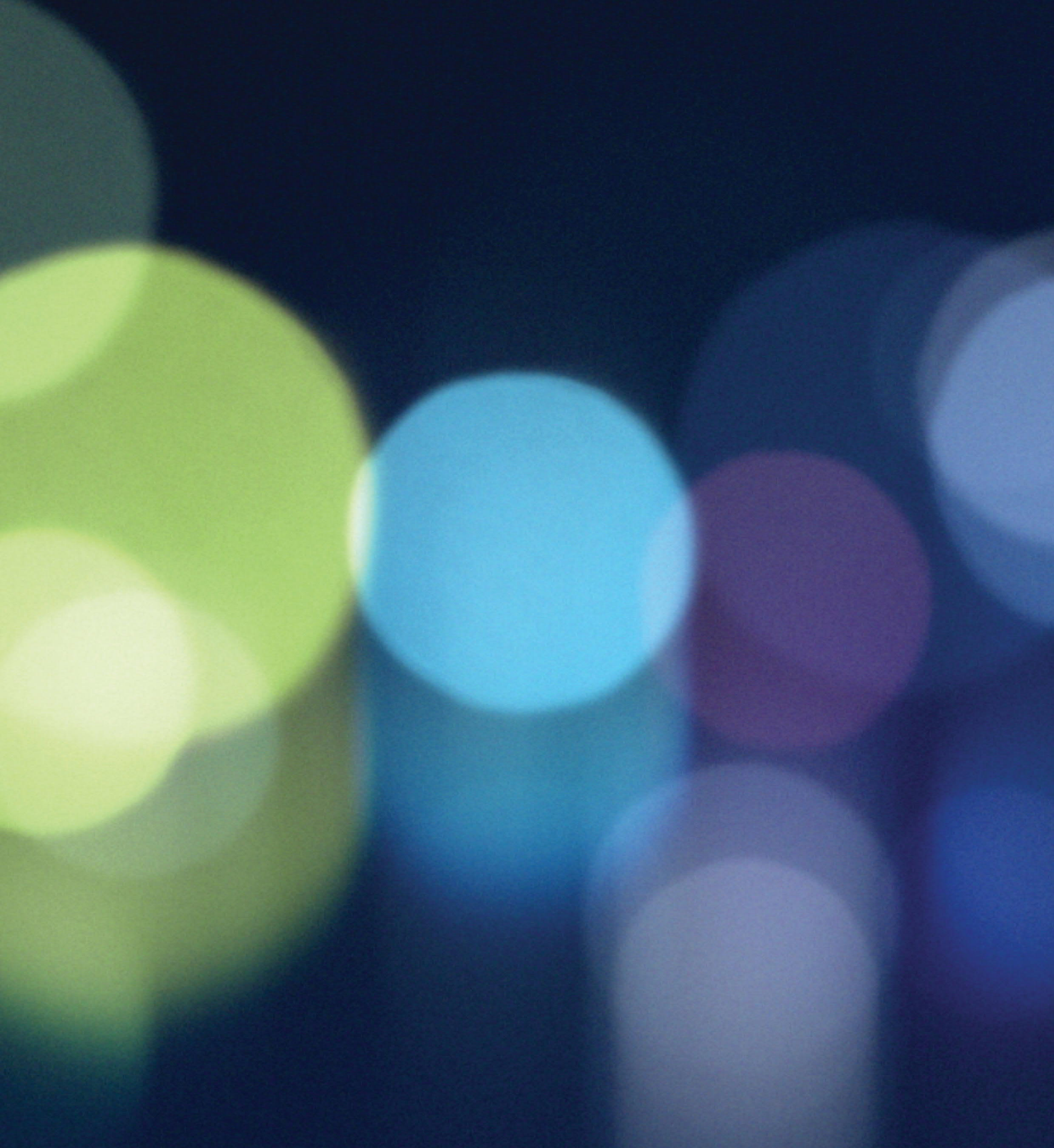
Senior Electrical Designers are responsible for verifying that substation electrical designs are compliant with this standard

Electrical Designers are responsible for producing substation electrical designs that are compliant with this standard.

Regional Managers are responsible for allocating appropriate resources to:

- validate that construction of the substation secondary designs comply to this standard
- seek approval for any changes to the issued substation secondary design

Designer Service Providers are responsible for producing substation electrical designs that are compliant with this standard.



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