Substation Secondary Systems Design

Design Standard

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CONTACT

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Contents

Revision Details

Version	Date	EDM Version	Summary of change
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11	29/2/24	13	Standards Online Updates

1 Introduction

This design instruction documents Western Power's transmission secondary systems design principles.

1.1 Purpose and scope

This design instruction covers the secondary requirements necessary to implement transmission protection systems.

1.2 Acronyms

Acronym	Definition

1.3 Definitions

Term	Definition
Cubicle	An enclosure used to house secondary equipment. Cubicles may be fixed, have a door or have a swing frame door. Racks and panels are types of cubicles.
Single Pole Circuit Breaker	Each pole of the circuit breaker has a separate mechanism and is tripped by a separate trip coil
Three Pole Circuit Breaker	All three poles of the circuit breaker have a common mechanism and are tripped by a single trip coil
Remote Open and Close	The circuit breaker is opened or closed from the control centre or the relay room
Local Open and Close	The circuit breaker is opened or closed by a switch on the circuit breaker
Automation	Refers to the SCADA system
CB	Circuit Breaker
PPR	Protection Planning Report
RRS	Relay Reservation Sheet

1.4 References

References which support implementation of this document

Table 1.1 References

Reference No.	Title

2 Supporting Documentation

3 Compliance

The Engineering Design Instruction should encompass all requirements of the relevant Australian Standards which are current at the time. These relevant Standards and Guidelines are listed in below in Table 3.1. A period will be set when the standard needs to be reviewed. If significant changes occur on an Australian Standard which affects safety, then an out of cycle review can be completed.

Table 3.1: Standards and Guidelines

Standard Number	Standard Title
	AS/NZS 3000:2018, "Electrical installations (known as the Australian/New Zealand Wiring Rules)," in Australian Standards. Australia, 2018.
	AS2067:2016 "Switchgear assemblies and ancillary equipment for alternating voltages above 1 kV," in Australian Standards. Australia, 2016.
48703581	Engineering Design Instruction – Substation Secondary Systems Design – Hazard Management Register
42766841	Engineering Design Instruction, Construction Technical Specification Information & Drawing Issues Register
34258889	Protection Design Guidelines
10897814	*Engineering Design Instruction – AC Auxiliary Systems*
42624040	*Engineering Design Instruction – Drawing Numbers and Titles*
42622268	*Engineering Design Instruction – Electrical and Mechanical Interlocking Requirements*
42766841	*Engineering Design Instruction – Engineering Design Instruction Information & Drawings Issues Register*
48934370	*Engineering Design Instruction – Substation Labelling and Numbering*
34127945	*Engineering Design Instruction – Substation Layout*
48703581	*Engineering Design Instruction – Substation Secondary System Design – Hazard Management Register*
48719723	*Engineering Design Instruction – Substation Secondary System Design – Supporting Documentation Register*
42781004	*Engineering Design Instruction – Substation Secondary Systems Design – Visio Drawings*
8992239	*IEC61850 Reference Designation System*
40638015	*Material List and Label Schedule Examples*

Standard Number	Standard Title
43241023	*Safety in Design*
8974136	*STEP 1 – SS361 Reference Designation Hierarchy*
44880492	*Technical Specification – Cables and Conductors*

4 Functional Requirements

This Engineering Design Instruction is intended to be used by Substation Engineering staff and by companies completing outsourced design work for Western Power, as it outlines the Western Power requirements pertaining to secondary systems design.

5 Safety in Design

5.1 Hazard Management Register (HMR)[1]

Safety in Design (SID) must be considered when completing all substation design work. SID focuses on making the design safer and easier to understand, with the aim to eliminate and mitigate potential hazards during the design phase of a project.

Some examples of Safety in Design are shown below:

5.2 Interlocks

All interlocks provided or recommended by manufacturers are to be operational. Refer to *Engineer Design Instruction – Electrical and Mechanical Interlocking* for interlocking requirements.

5.3 Local Remote Switch

All Local / Remote switches must disable all remote operations when placed in the local position.

5.4 Control Switches

Control switches must be located in the relay room. It is unacceptable to install control switches in field cubicles.

Brownfield circuit breaker controls must be moved from a mimic panel to the protection cubicle when:

1. The protection relays are replaced[2]

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1 See Western Power Internal Document

2 This is to allow the circuit breaker to be opened should an error occur while configuring a test bloxk.

2. The circuit breakers are replaced, and the relays have been recently replaced. When the relays are old and due for replacement in the near future the controls can remain on the mimic until the relays are replaced.

Generally, metering and indication are also moved to the protection cubicle. A label must be placed on the mimic directing people to the protection cubicle.

5.5 Shrouding

There must be at least 1 physical barrier between personnel and live equipment during normal operation and maintenance.

5.5.1 Existing Terminals

Polycarbonate sheets 3 mm thick are acceptable to shroud existing exposed terminals. There must be an item included in the project hazard management register and a comment in the PEA instructing construction to provide this barrier when it is required.

5.5.2 New Terminals

All new terminals and lugs are to be shrouded and, when possible, finger safe. 415V AC terminals must be located separate from other terminals and clearly labelled as dangerous.

5.5.3 Dexion Racks[3]

Dexion racks are open by design and therefore pose a potential hazard of contact with exposed energised equipment. Usually, 3 mm polycarbonate sheets shrouding exposed energised equipment is sufficient to prevent accidental contact. Polycarbonate sheets may be required to be fitted to enclose existing standalone dexion racks if the usual shrouding is insufficient. Refer to Appendix H.

5.5.4 240V AC

All 240V AC supplies must be terminated on a separate terminal strip which is shrouded and clearly labelled.

For greenfields indications, 110V DC must be used for all circuits. In brownfield applications when 240V AC is used for indications, it should be transferred to 110V DC when possible.

5.6 Voltage Isolation

5.6.1 DC Isolation

Disconnect terminals must be provided to allow isolation on the terminal strip of voltages from external cubicles. The disconnect terminals to be used for voltage isolation are to be mounted separate from other terminals.

[3] See Western Power Internal Document

5.6.2 C&H Test Blocks

C&H test blocks were used in the past to isolate CT and VT secondary circuits. Western Power's current test blocks are considered safer to work with than older C&H test blocks. It is therefore preferable to replace C&H Links with current test blocks when it is practical.

In most cases, modern test blocks that replace C&H test blocks cannot be installed in the same location. This requires CT wiring within protection panels to be completely replaced and re-commissioned. C&H test blocks are also often installed in protection schemes that have contributions from multiple CT circuits (e.g., bus zone, interzone, breaker and 1/2). This adds to the complexity associated with accessing the C&H test block wiring and the associated re-commissioning. For these reasons C&H test blocks shall only be replaced when the following criteria is met:

- A protection relay associated with the C&H link is being replaced. An exemption to this is when the protection relay being replaced is located on a separate panel to the C&H link. An example is a circuit breaker fail relay being replaced in a breaker and a half yard with the C&H link(s) located on a line panel that is not being worked on. In this type of scenario, the C&H links must not be replaced.
- No additional outages are required for all wiring attached to the C&H test block to be out of service.
- A C&H test block located inside a CT marshalling box are generally not required and should be removed when the associated CT, CT marshalling box or CT cabling is replaced. When the buszone relay is being replaced, the C&H links in the CT marshalling box should only be replaced if one of the criteria mentioned previously is met
- For existing bus zone schemes that are retained a test block should be added after the CT summation point prior to the bus zone measuring relay.

5.7 Trip – Neutral – Close Switch[4]

Under rated TNC switches must be replaced with switches that are rated to break the CB trip coil current when a panel is worked on. This replacement work includes wiring the CB indication into the new TNC switch when the switch has this capability and auxiliary contacts are available.

If test blocks are not configured properly a commissioning or maintenance person can accidentally open circuit a current transformer. The safest course of action to take should this happen is to open the circuit breaker. TNC switches must therefore be located near the test block for a circuit when possible.

Controls are moved from a mimic panel to the protection panel containing a test block when protection locations are rebuilt.

5.8 150V AC Indication Supply

Some older substations use a 150Vac supply as a source for the circuit breaker indications on the relay cubicles. When the panel is worked on the TNC switch must be changed and the TNC switch circuit breaker indication wired to the 110V DC supply.

5.9 Different Voltages[5]

Generally, different voltages should be shown on different drawings.

[4] See Western Power Internal Document
[5] See Western Power Internal Document

Table 5.1: Voltages per drawing

Voltage	Drawing
System AC voltages and currents	AC drawing
110V DC	DC drawings
50 V DC	Alarms and indication
Auxiliary 240V AC	CB motor supplies

There are some drawings where it is more practical to combine different voltages:

- Motorised disconnector hard wired interlocking drawings have both 240 V AC and 110V DC on the same drawing.
- 330 kV and 220 kV terminal yard circuit breaker auxiliary supply drawings can have 110V DC TCS circuits as well as 240V AC heating and lighting circuits.

New drawings combining voltages must be approved by the Substation Design Principal Electrical Design Engineer.

5.10 Body Fit

The maximum body fit height is 2200 mm. The minimum body fit height is 450 mm (1 RU = 43.6 mm).

Designs must use Safety in Design principles to address body fit issues. If body fit heights cannot be met the following is required:

- Approval from Substation Design Principal Electrical Design Engineer after consultation with construction, commissioning, and maintenance.
- A comment in the substation design report documenting the hazard and outcome.
- Hazard assessed and entered into the Hazard Management Register.

5.10.1 Arrangements - General Guidelines

The protection equipment should be arranged in the cubicles to minimise personnel bending and reaching. It is also important that equipment used during commissioning, maintenance and switching is conveniently located. Leaving space for future expansion is important, however meeting body fit requirements takes priority. Refer to Section 7.3.3 for IEC61850 arrangement guidelines and Section 8.1.1 for DNP arrangement guidelines.

5.10.1.1 Acceptable Strategies to Meet Body Fit

When necessary to meet body fit it is acceptable to:

- Make a plate to fit in a tier rack. Switches and meters can then be mounted on the plate to free up space below.
- Remove a tier rack and mount a test block directly to the plate when there is only one test block in a tier rack. Switches and meters can then be mounted next to the test block.
- Mount fuses and links on the same row (fuses to the left, links to the right). Spare fuse and link holes can be drilled to the entire row.

- If two rows are used for the fuses and links, then both fuses and links should be mounted to the left. Drilling spare holes should be limited to 2 fuses and 4 links to allow room on the right for future expansion.
- Switches and meters can be mounted alongside fuses and links
- Replacing old relays with a single numerical relay will help by creating additional space. If a relay is nearing its obsolete date this may be a viable option.

5.10.2 Egress and Access

The minimum dimension for an aisle is 750 mm[6]. If a door can be opened into an aisle, the 750 mm measurement is from the open door to the other side of the aisle.

Minimum access requirement to equipment is 600 mm.

5.10.2.1 Rear Panel Access

If the minimum aisle dimension of 750 mm behind a panel cannot be met, the following solutions may alleviate the problem:

1. Install a Dexion swing frame unit. This type of unit allows access to the terminal from the front of the panel. Refer to Appendix I for an example.
2. If option 1 is not practical there may be space in the relay room to install as standard swing frame unit. Considerations for this option include:
    a. Cabling – Depending on how the cables come into the relay room it may be possible to run existing cables to the new swing frame. If not, then it may be possible to run cables from the existing terminals to the new swing frame.
    b. There is usually more than one panel with the limited space to the wall problem. If migrating the protection location to a new swing frame unit, allocate space to ultimately move all panels to new swing frame units.

5.11 Non-Standard Designs

Non-standard designs can contribute to human error faults when field personnel are presented with a layout which is different than they expect. When a non-standard design cannot be avoided, the designer must take every step possible to ensure that the design is easy to follow. Refer to the Sections 6.2.3, 7.3.3 and 8.1.1 discussing arrangements.

5.12 Non-Compliant Designs

There are fundamentally two types of non-compliance:

5.12.1 Non-Compliance with this Guideline

New designs must comply with this guideline.

Existing non-compliant designs must be identified at the scoping or preliminary design stage so a decision to correct or leave the design can be made. Non compliant designs found during the design stage of a

[6] AS2067 requires and emergency door width of 750mm. Western Power interprets this to mean that a clearance of 750mm is required for emergency egress.

project must be highlighted to the project engineer via a TQ to ensure a discussion can be made to which standard should be followed.

5.12.2 Non-Compliance with Australian Standards or Government Regulation[7]

Designs that were compliant with the Australian Standards or government regulations of the day may not meet today's standards or regulations. When work is done on these designs, they must comply with today's regulations and standards and if the design will lead to significant cost, a TQ should be raised to obtain a decision on a direction to be taken.

5.13 Circuit Breaker Control and Indication

5.13.1 Remote Open and Close

Remote control of the circuit breaker includes all open and close signals from:

- The Automation system (EPCC or HMI)
- The relay room (TNC switch).

All remote control of circuit breakers must go through the circuit breaker local / remote switch. When a person places the circuit breaker local / remote switch in the local position, all remote open and close commands must be defeated.

Remote closing of a capacitor banks must be delayed ensuring the capacitor bank is discharged before closing.

Remote closing of lines must be conditioned by the check synchronism function in the protection relay when a requirement to check for synchronism exists.

5.13.2 Indication

Circuit breaker indication:

- Green indicates the circuit breaker is open. In three pole circuit breaker applications a normally closed auxiliary contact is used. In single pole applications, three normally closed auxiliary contacts are wired in series (i.e., all three poles must be open to give an open indication).
- Red indicates the circuit breaker is closed. In three pole circuit breaker applications a normally open auxiliary contact is used. In single pole applications, three normally open auxiliary contacts are wired in parallel (i.e., any closed pole will give a closed indication).

The emergency trip push button on P2 of early IEC61850 designs is red. Pushing the red button results in a green indication. The emergency trip push button must be protected by a cover. The emergency push buttons are no longer used because the TNC 'Open' is now hardwired to the circuit breaker. The push button must be removed when the TNC switch is replaced with the 'open' hardwired to the circuit breaker.

[7] See Western Power Internal Document

5.14 Secondary Induction

Secondary induction can occur when primary conductors and secondary copper conductors are run in parallel and located close together.

5.14.1 Dangerous Voltages

As an example, running a secondary cable in the same trench or vicinity as a 132 kV cable could result in dangerous voltages in the secondary cable. Where there is a possibility that dangerous voltages can be induced in the secondary wiring, one of the following steps is required:

- Run the primary conductor and secondary conductor along different paths
- Replace the copper secondary conductor with a fibre cable.
- Demonstrate quantitatively the maximum induced voltage complies with AS3000 and the circulating current would not cause measurement errors. This must be documented in the substation design report and HMR.

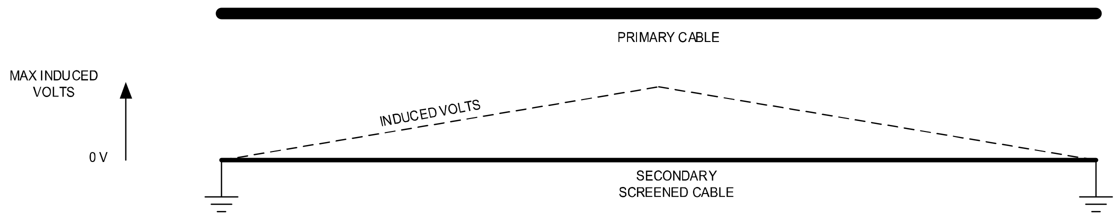

Figure 5.1: Induced voltage profile

5.14.2 Low Frequency Interference

AS2067:2016 gives the following recommendations to reduce low frequency interference:

- When laying cables:
  - Separate control cables from power cables by using spacing or different routes
  - lay power cables in trefoil formation in preference to a flat formation
  - as far as possible, cable routes should not be parallel to busbars or power cables
  - control cables should be laid away from inductances and single – phase transformers
- The circuit arrangement should:
  - avoid loops
  - for d.c. auxiliary supply circuits, prefer a radial configuration to a ring configuration
  - avoid the protection of two different d.c. circuits by the same miniature circuit breaker
  - avoid parallel connection of two coils located in separate cubicles
  - locate all connections of the same circuit in the same cable. When different cables must be used, they should be laid along the same route
- Twisted pairs cables are recommended for low level signals.

In addition, wires carrying analogue signals must be shielded to within 25 mm of the terminals. The pretence is to earth the shield at the source end only.

6 General Design Requirements

6.1 Wiring

6.1.1 Wiring Sizes, Colour and Voltage Grade

All wiring shall be either:

- Paired screened cable for transducer outputs (0-10mA)
- Single core, unsheathed, multi-stranded, PVC flex V105 insulated copper conductor with a voltage grade of 0.6/1kV for all other applications

Table 6.1: Typical cubicle wiring sizes and applications

Application	Wiring Size	Wiring Colouring
CT and VT Secondary	2.5mm^2 (50/0.25)	Phase: Red, White, Blue Neutral: Black
240 V AC (5A)	1.5mm^2 (30/0.25)	Phase: Red, White, Blue Neutral: Black
415 V AC	2.5mm2 (50/0.25)	Phase: Red, White, Blue Neutral: Black
Earthing	2.5mm2 (50/0.25)	Green/Yellow
230, 110 V DC Control	1.5mm2 (30/0.25) (16 A Fuse/MCB)	Grey
32 V DC Control	2.5mm2 (50/0.25) (20 A Fuse/MCB)	Grey
50V DC Alarm and Indication	0.5mm2 (16/0.2)	Grey
DC Battery Supply Note 1	4.0mm2 (50/0.25) (32 A Fuse/MCB)	Positive: Red Negative: Black
Metering and Transducers	0.5mm2	Black / White Screened Twisted Pair –

Notes:

(1) The DC Battery Supply is Red / Black from the distribution board to the relay cubicle terminal strip. DC wiring internal to the cubicle is grey. The DC supply wires from the terminal strip to the fuses are internal to the cubicle and are therefore grey.

(2) These wiring sizes are minimum standard requirements. Some installation may have higher requirements based on load current, secondary burden and voltage drop limitations. This shall be considered and documented during design and shown on the appropriate drawings.

(3) Wiring sizes depend on the fuse protecting the wire. The 110Vdc wiring between the 32A fuse in the distribution board and the protection cubicle is typically 4mm2. The 110Vdc wiring downstream from the 16A fuse in the protection cubicle is typically 1.5mm2. 32 Vdc control wiring it typically 4mm2. Wire sizing must be verified from wire manufacturer specifications.

(4) MCBs are used at Greenfield sites.

6.1.2 Volt Drop

Long cable runs between the relay room and circuit breaker can cause unacceptable volt drop. The following wires are prone to volt drop:

- Wires between the relay room and trip coil. This includes the wire returning from the SF6 +ve supply to the relay room as a part of the TCS circuit for non-fail-safe circuit breakers.
- Wires between the relay room and the remote close
- Wires involved in the local close supply.

If a volt drop is outside acceptable limits then the order of preference of a solution is:

- Including the SF6 supply in the TCS circuit is not necessary if the circuit breaker is fail-safe[8] . This may reduce the volt drop to the close coil to an acceptable level.
- Use a 4mm wire
- Use parallel 4mm wires

Using 6mm wire is not recommended because it is impractical to terminate 6mm wires in the mech box.

If a 4mm cable is required, it is acceptable to use spare cores for other functions.

6.1.3 Wire Colour Abbreviations

Table 6.2 summarises the wire colour abbreviations derived from IEC757.

Table 6.2: Colour abbreviations

Colour	Abbreviations
Black	Bk
Brown	Bn
Red	Rd
Orange	Og
Yellow	Ye
Green	Gn
Blue (including Light Blue)	Bu
Violet (purple)	Vt
Gray (slate)	Gy
White	Wh
Pink	Pk
Gold	Gd
Turquoise	Tq
Silver	Sr
Green and Yellow	GnYe

[8] A fail-safe circuit breaker is one that generates a TCS alarm if the SF6 supply is lost. Refer to SF6 supervision.

6.1.4 CT and VT Wiring

CT and VT wiring shall be continuous, with no intermediate connections between the CT and VT secondary windings and the first terminal strip.

6.1.5 Installation

Wiring shall be installed in ducts with removable covers. Ducting should be placed such that it facilitates easy access to the back of relays and other equipment.

Where wiring is installed in new ducting, a maximum of 50% of the duct volume shall be used. This is to allow for additional future wiring.

All wiring termination including cable core ends shall have no less than 200mm slack, sufficient to permit two re-terminations or reconnection to a nearby terminal.

6.1.6 Wire Identification

All wiring shall be ferruled at both ends.

Ferrules shall be white insulating material with a glossy finish to prevent adhesion of dirt, or other approved method of similar quality. Ferrules and markings shall not be affected by damp or oil and characters shall be clearly and permanently marked in black or with a contrasting colour.

Wire identification shall utilise a prefix letter, a number and then an optional suffix letter.

The AC drawings must also include the wire colour in parenthesis (e.g., E10(Rd), E30(Wh), E50(Bu), E70(Bk)).

Case earths do not require identification (e.g., protection relays).

6.1.6.1 Prefix Lettering

Appendix A summarises prefix letters.

6.1.6.1.1 Rules

- Each branch of any connection shall have the same identification.
- VT wiring can have multiple branches with different functions coming from a common point (e.g., metering and voltage control). Each branch requires separate identification prefixes. The prefix change can occur:
  - Where the circuits split at a separable contact (e.g., fuse, link, switch, relay contact), the prefix should change from the splitting point as required. Note that VT neutral wires must be continuous. The prefix can change at the next continuity terminal.
  - For manufacturer's equipment prefixes can change when the wire leaves the manufacturer's equipment.
- Appendix B.3 demonstrates the prefix changing to identify wires associated with protection and metering (E) and voltage control (F).
- Where more than one function is covered by common wiring (i.e., parallel circuits or multifunction relays), the first appropriate prefix letter should be used.
- The prefix changes across auxiliary, interposing or isolating transformers when the function changes. The prefix does not change when the function does not change. An example of the prefix changing is an interposing metering CT branching off a protection circuit.
- The prefix of the wire associated with an earth point is the same as the neutral wire associated with the earth point.
- The relay with the most functionality takes precedence when different relays from different protection schemes are in series.

An example is the CB Fail relays in series with line protection at some older 1 ½ CB switchyards. In this case the line protection relay results in an 'A' prefix.

- Inter-cubicle wire numbers are determined at the source end.

6.1.6.2 Wire Number Suffix[9]

The following rules apply to suffixes:

- Suffixes are used when:
  - Wire numbers in a cubicle, marshalling box or piece of plant could otherwise be duplicated. Examples include:
    - Inter-cubicle trips and CB fail initiate in a 1.5 CB yard.
    - Busbar, UVLS, synchronising and fault recorder schemes.
  - The suffix allows identification of a specific circuit among many similar circuits. An example is including the suffix on the wires from relay watchdogs originating from a general alarm page.
- The wire number suffix is determined by the end that does not have the common wire number:
  - Contact end. An example is multiple CB Fail trips going to a bus zone trip relay. Each CB Fail trip has a suffix identifying the circuit containing the contact sending the CB Fail signal.
  - Coil end. An example is a trip relay sending a trip to multiple circuit breakers. Each trip signal has a suffix identifying the circuit breaker trip coil receiving the trip.
- Intermediate cubicles or marshalling boxes which the wire may pass through have no effect on the suffix.
- Suffixes appear on the wires in the schematic and termination drawings.

6.1.6.2.1 Zone Substation[10]

6.1.6.2.2 Circuit Breaker and a Half[11]

The first letter of the suffix is derived from the bay number

(e.g., bay 1 = 'A'). The second letter of the suffix is derived from the section number (e.g., centre breaker = 'C'). The suffix of the centre breaker of bay 1 would be 'AC'.

6.1.6.2.3 Non-Circuit Specific Suffixes

- Goose managers are associated with specific busbars. The goose manager suffix is a combination of the busbar suffix + GM. As an example, the suffix for the goose manager associated with the 'W1' busbar would be 'W1GM'.
- Battery 1 logic controllers are named LC1 + a sequential number starting at '1'. Battery 2 logic controllers are named LC2 + a sequential number starting at '1'. As an example, the first battery 1 logic controller is LC1-1. The logic controller suffix is the name.

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9 See Western Power Internal Document
10 See Western Power Internal Document
11 See Western Power Internal Document

6.1.6.3 AC Wire Numbers

Examples of AC wire numbering is shown in Appendix B.

6.1.6.3.1 AC Wire Number Rules

AC wire numbering follows the following general rules of thumb:

- Wire numbers cannot be repeated within a cubicle.
- Wires with the same wire number are at the same potential.

Wire numbers start at the source using the lowest available wire number. The wire numbers increment sequentially following the secondary current flow within the same cubicle.

Note that it is unacceptable to add a '- 1, - 2, …'to an existing wire number to identify a new AC wire. The only time a '-1' is added to an existing wire is with the return wires located in the same cable on DC schematics.

6.1.6.3.2 AC Wire Number Characteristics

- Inter cubicle wiring requires a suffix to identify the source of the wire. Suffixes can be retained in the cubicle to identify separate circuits with the same wire number (e.g., fault recorder).
- Wire numbers are divided into 2 groups depending on the protection system. Protection 1 wires are numbered from 10 – 90. Protection 2 wires are numbered from 310 – 390.
- The wire numbers within each protection system are grouped according to the phase they are associated with. Red phase wires are numbered from 10 – 29 (P1) or 310 – 329 (P2). White phase wires are numbered from 30 – 49 (P1) or 330 – 349 (P2). Blue phase wires are numbered from 50 – 69 (P1) or 350 – 369 (P2). Neutral wires are numbered from 70 – 89 (P1) or 370 – 389 (P2).
- In differential schemes the wire numbers within each phase are grouped according to the current transformers they are associated with. The first 10 numbers are allocated to the HV source. The second 10 numbers are allocated to the LV source.

As an example:

  - The P1 wire numbers from the HV CT in a transformer differential scheme will start with A10, A30 and A50.
  - The P1 wire numbers from the LV CT in a transformer differential scheme will start with A20, A40 and A60.

- The P1 earth wire is numbered 90. The P2 earth wire is numbered 390.

Table 6.3 outlines the AC wire number allocation used in differential schemes.

It is important to note that both primary and secondary earths may be shown on AC schematics. The secondary neutral wire is numbered with respect to the secondary earth, not the primary earth.

Table 6.3: AC wire number allocation (differential schemes)

Battery	Phase	Source	Wire Number
Protection 1	RED	HV	10 – 19
		LV	20 – 29
	WHITE	HV	30 – 39
		LV	40 – 49
	BLUE	HV	50 – 59
		LV	60 – 69
	NEUTRAL	HV	70 – 79
		LV	80 – 89
Protection 2	RED	N/A	90
		HV	310 – 319
	WHITE	LV	320 – 329
		HV	330 – 339
	BLUE	LV	340 – 349
		HV	350 – 359
	NEUTRAL	LV	360 – 369
		HV	370 – 379
	EARTH	HV	10 – 19
		LV	20 – 29

6.1.6.4 DC Wire Numbers[12]

DC wire numbers must match the battery they are connected to. On occasions in the past, a protection circuit has been changed from one battery to the other without changing the wire numbers. This may have been done to balance the battery load. When this situation is found it must be rectified either by:

- Changing the circuit back to the original battery if the battery sizing permits.
- Correct the wire numbers on all drawing affected. This will include inter panel wiring.

With new designs the DC wire number is created from:

- The first four digits corresponding to the line which the wire first appears on. For each circuit there are 1000 line numbers for each type of drawing. This allows all of battery 1 wires to start with a 1 and all of battery 2 wires to start with a 2.
- A final sequential digit to make it odd or even. The final digits are 1,3,5,7 or 9 for the positive supply and 2, 4, 6 or 8 for the negative supply. The change from odd to even numbers occurs at the load (e.g., coil, resistor, lamp, or relay) that is closest to the negative supply.

[12] See Western Power Internal Document

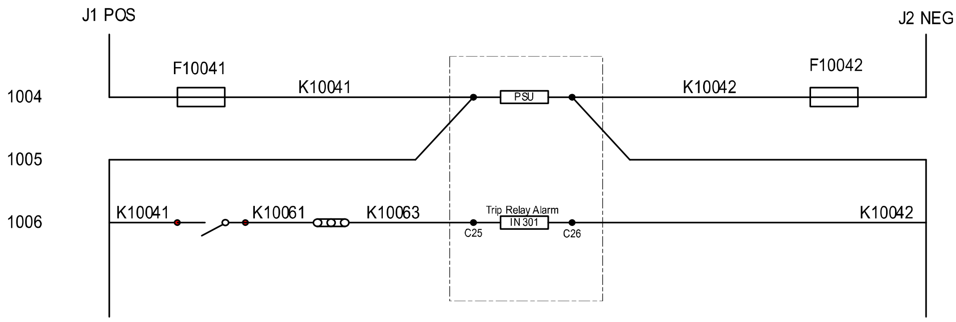


Figure 6.1: Example of DC wire numbering

6.1.6.5 TCS Wire Numbers

TCS wiring to a circuit breaker can result in duplicated wire numbers in the same cable. In order to uniquely identify these wires, the positive and negative TCS wires going to the TCS aux contact are designated with a '-1' suffix. This distinguishes the wire going out to the trip coil from the wire going out to the TCS auxiliary contact. It also distinguishes the wire going out to the positive supply from the wire coming from the TCS auxiliary contact.

Refer to Section 6.6.10 – DC Supervision, for further details regarding Trip Circuit Supervision (TCS).

6.2 Cubicles

Four (/4), fourteen (/14) and thirty four (/34) series drawings are concerned with the design of cubicles. This section includes the mandatory requirements, practical requirements, and the preferred arrangements.

Cubicles do not come with a light or GPO as standard.

6.2.1 Colour

6.2.1.1 New Cubicles and Plates

The colour of new cubicles and plates in the relay room is to be Duralloy 'Classic Cream Satin 50 Gloss', 2722095S.

6.2.1.2 Existing Cubicles and Plates

New plates on existing equipment must match the existing equipment (e.g., the note on the plate drawing does not need to be changed). A drawing superceding an existing drawing must specify the same finish as the original drawing. If the original colour is not available, then use brushed aluminium.

6.2.2 Cubicle Types

There are three basic types of protection cubicles:

- Panels are fixed and have plates that the secondary equipment is mounted on.
- Dexion racks are constructed with L-angle and may or may not have plates mounted. Relays can be mounted on the plates or secured into the L-angle frame.

- Swing frame cubicles have plates and a door that opens.
  - FB0131 - 48 RU, 800W x 600 D, Centred. Used for protection relays in the relay room.
  - FB0130 - 48 RU, 800W x 600 D, Offset. Used for the fault recorder and Automation equipment.

6.2.3 Arrangements

Cubicles are used to house protection equipment, DC chargers, AC supplies, tap change equipment, Protection and Automation equipment. Cubicles are in the main HV relay room, LV relay room or in the yard as a field cubicle.

Arrangements should be designed such that:

- Human error faults are minimised
- Construction and commissioning time is minimised
- Body fit issues such as stretching and bending are minimised
- Drafting and engineering time is minimised by using approved templates

6.2.3.1 Location of Equipment

Consideration must be given to the style of arrangement within the site. New circuits or reworking existing circuits should follow the same style at a site when possible and practical.

Fuses must be mounted such that the source (terminal 1) is at the top and load (terminal 2) is at the bottom.

Links must be mounted such that the positive (terminal 1) is at the top and isolated plant (terminal 2) is at the bottom.

6.2.3.1.1 Single Source Cubicles

Single source cubicles have a single battery supply for all equipment. Single source cubicles are typically used in IEC61850 designs where all equipment is supplied by battery 1 or battery 2. The order of equipment for a Protection 1 cubicle is:

- Protection 1 supply fuses / MCBs for all circuits are located at the top of the cubicle
- Protection 1 relay for circuit 1
- Protection 1 Tier rack for circuit 1
- Protection 1 sub fuses, links, and switches for circuit 1
- Protection 1 relay for circuit 2
- Protection 1 Tier rack for circuit 2
- Protection 1 sub fuses / MCBs, links, and switches for circuit 2

Additional circuits follow the same pattern.

6.2.3.1.2 Combined Cubicles

DNP designs typically use combined cubicles with protection 1 and 2 for a circuit in the same cubicle. Protection 1 is above protection 2. Where space is limited IEC61850 may also use combined cubicles (e.g., switchrooms).

Replacing an obsolete protection relay should prompt a review of the entire protection scheme. It is often the time to base the new designs on the current design templates. There may also be opportunities to replace existing hardwired logic with the logic in the new relay. Replacing many existing electromechanical or electronic relays with a single numerical relay frees up space in the cubicle.

It is not acceptable to have equipment associated with a circuit and its protection in more than one location. All equipment associated with a circuit and its protection must be on the same section of the same cubicle.

The preference for the order of equipment from high to low is:

1. Protection relay
2. Tier rack
3. Fuses / MCBs, links and switches

The protection 1 equipment is mounted above the protection 2 equipment. This results in the protection 1 relay at the top of the cubicle and the protection 2 fuses, links, and switches at the bottom.

6.2.3.2 Segregation

Segregation shall be maintained between:

- Protection system 1 and protection system 2 of the same circuit. This may involve having battery 1 in the top portion and battery 2 in the bottom portion of the cubicle
- The protection systems of different circuits. IEC61850 combines different circuits within the same cubicle which must be carefully separated from each other with adequate spacing and labelling.

6.2.3.3 Terminal Strips

Terminal strips must be placed in locations that are easily accessible.

Ducts may be no closer than 75 mm to terminals.

Terminal strips should be located directly behind their related circuit in cubicles with multiple circuits.

6.2.3.4 Approval

All non-compliant arrangements must be sighted by the AM ED Substation Principal Electrical Design Engineer. Any arrangement not complying with this design instruction must have deviations approved by commissioning prior to detailed design and drafting.

6.2.4 Plate Details

Standard plate details shall be used when possible.

Plates for existing dexion racks and swing frame cubicles are 2.5 mm aluminium. Dexion plates have a sanded finish.

All plates details must show overall and cut out dimensions. Swing frame cubicle plates must also show the drilling details for mounting the plate.

Refer to Section 8.1.2 for Asset Replacement requirements.

6.2.5 Material List and Label Schedule

A new Excel spreadsheet bill of material (BOM) list must be created for a circuit where one does not already exist. New items, including labels, must appear on the new material list. The new material list must reference all existing material lists which also contain items found in the cubicle. Existing material lists must be updated to remove any items that are being removed from the cubicle. Refer to Design Standard –Substation Labelling and Numbering for guidance on secondary labelling.

6.3 Relays

Relays are specified in the Protection Planning Report (PPR) and ordered on Relay Reservation Sheets (RRS).

6.3.1 Trip Relays

Trip relays should be selected so that there are at least 3 spare contacts when the ultimate design is implemented.

6.3.2 Input / Output Allocation

The relay input / output allocation is determined by the Engineering & Design Protection Team.

6.3.2.1 Primary Plant Status

A primary plant status is defined by:

- The input function is related to the type of primary plant (e.g., CB STATUS, DIS STATUS, DES STATUS, E/SW STATUS, and VT MCB STATUS). It is not necessary to define the type of auxiliary contact if the contact is shown on the schematic (i.e., 52A, 52B).
- The circuit number must appear above the equipment box surrounding the auxiliary contacts. It must be clear from the drawing what type of plant is generating the signal (e.g., 502.0, 502.4).

6.3.2.2 Phase and Neutral Elements

Phase and neutral currents should be run through individual AC elements when available. It is preferable to use a measured neutral current to a calculated one.

6.3.3 Relay Case Earthing

The relay case earthing is normally shown on the AC drawing. When the relay is not shown on an AC drawing (e.g., I/O relay in the field cubicle), it is acceptable to show the relay case earth on the DC drawing.

6.4 Drawing Referencing

All schematic and termination drawings must reference the Schedule of Terminal Symbols and Wiring Notes standard drawing.

DM references to ferrules are no longer used and should be removed.

Drawing references can be shown:

- In the drawing references box. This is appropriate when more than 1 item in the drawing references the same drawing. The drawing reference box is also used for standard references.

- Throughout the drawing. This can be used for single item references in the drawing.

Existing drawings do not require all existing referencing to be updated.

Referencing is checked and therefore must be completed before the final detailed design check.

New drawings and new parts of existing drawings must follow the following the minimum referencing required. It should be easy for a design person to navigate through the drawings while doing a detailed check.

6.4.1 Arrangements

Arrangements must reference the following drawings:

- Plate details
- Material list
- AC schematic
- DC protection 1 & 2

6.4.2 Plate Details

Plate details do not require drawing references

6.4.3 Material List and Label Schedule

New material lists must reference existing material lists that contain existing items contained in the cubicle.

6.4.4 AC Schematics

AC schematics must reference the following drawings:

- Arrangement
- Other relevant AC schematics. These can include:
  - Transformer HV and LV
  - Synchronising schematics
  - Voltage selection schematic
  - Circuit AC schematics (in the case of voltage selection or synchronisers)
- DC schematics
- Alarms and control schematics
- Protection 1 & 2 cubicle terminations
- Communications drawing reference

6.4.5 DC Schematics

DC schematics must reference the following drawings:

- AC schematic
- Other relevant DC schematics
- Alarms and control schematics

- Relevant terminations
- Automation drawings
- Manufacturer drawings

6.4.6 Alarm and Control Schematics

Alarm and control schematics must reference the following drawings:

- AC schematic
- Relevant cubicle terminations

6.4.7 Terminations

Terminations must reference the following drawings:

- All schematics which have a terminal shown on the termination
- All cable schedules that have a cable shown on the termination

6.4.8 Cable Schedules

- The fields on the cable schedule referencing the drawings for each cable end must be filled in.

6.5 Drawing Revisions

When drawings are revised the following is required:

- A revision cloud is required outlining the items on the drawing that have been added, deleted or updated.
- The drawing revision field on the drawing must be updated.
- A drawing revision box must be added to the drawing. The drawing revision box must contain the following information:
  - The revision number or letter
  - The date
  - The initials of the person who drafted the drawing
  - The initials of the person who checked the drawing
  - The initials of the person who examined the drawing
  - The initials of the person who approved the drawing
  - A revision note explaining what has changed and why. The revision note must allow the person looking at the revised drawing to understand why the revision is required without having to look at the previous revision. Examples of acceptable revision notes include:
    - CB REPLACED, ASSOCIATED WIRING **UPDATED**
    - CB FAIL AND ASSOCIATED WIRING **ADDED**
    - REF 9 QUANITY **WAS** 2
    - CT REPLACED, CT CORE LOCATIONS **SWAPPED**
    - CVT **REPLACED** WITH VT, WIRING **UDATED**, NOTE 2 **ADDED**

Revision notes containing general words such as ‘revised’, ‘modified’, ‘changed’ are unacceptable as they do not add any useful information (e.g., the revision cloud indicates something has been revised, modified or changed).

An example of an unacceptable drawing note would be:

– CONNECTIONS E630 & E633 **MODIFIED**. How and/or why were the wire numbers modified?

6.6 Schematics

Five (/5), fifteen (/15) and thirty-five (/35) series drawings are schematics which include the following:

- AC schematics
- DC schematics
- Alarms and indication
- Controls
- Auxiliary supplies

6.6.1 Line Referencing

Line referencing is used on schematics for all new circuits. Lines are numbered according to the type of drawing. Earlier versions of line referencing had different ranges which resulted in different wire numbers. The existing drawing style should be retained for existing drawings.

Table 6.4: Line referencing

Drawing Type	Line Number Range
AC schematic	0 – 999
DC Protection 1 schematic	1000 – 1999
DC Protection 2 schematic	2000 – 2999

Note: If additional sheets are required for an older schematic with 100 lines per drawing type, the new sheet can start with the higher number line range.

Example: An existing protection 2 (P2) dc drawing has line referencing from 200 to 299. If additional lines are required, sheet three can start from line 2000.

6.6.2 Item Designators

Item designators are derived from the IEC 61850 letter code and the line that the item first appears on. When two or more of the same type of item appears on a line an additional number is added. For example, two fuses located on line 1004 would be identified as F10041 (positive side) and F10042 (negative side).

Table 6.5: Common item designators

Item Designator	Description
BC	Information Converter (transducer, fault indicator)
BE	Measuring shunt resistor
F	Fuse
FA	Metrosil
FC	MCB
FG	Logic controller
FV	UVLS
GF	Signal generator, transducer, wave generator
KF	Protection Relay
PG	Ammeter, voltmeter, wattmeter, synchroscope
PH	Human machine interface
QG	IP Router, layer 3 switch
QH	Ethernet layer 2 switch
QK	Goose message management system
RA	Flow of electrical energy limiting resistor
RG	IP firewall router, VPN concentrator
RH	Access control system, RADIUS server
SF	Switch
TE	Earthing transformer
TF	Signal converter, media converter, terminal server, proxy server, forwarding server, protocol translator
TG	GPS controlled clock, GPS receiver
TH	Ethernet encryption platform
UK	Virtual Machine Host
WJ	Ethernet LAN
X	White Link
XD	Terminal Strip
XG	Test Block

6.6.2.1 Legacy Drawings

Many legacy drawings do not have line referencing. The order of preference for assigning an item designator is:

- Add line referencing.

  Example:

  A line protection relay is replaced, and the existing AC drawing does not have line referencing. It is usually possible to add line referencing to the existing drawing. The new equipment gets their item designator from the line referencing. The existing equipment retain the existing item designators.

- Match existing system when it is not possible to add line references.

  Example:

  A trip relay is replaced on an old raster / vector hybrid drawing. It is acceptable to give the new trip relay an item designator based on the material list.

An item designator must be based on either line referencing or an existing system. It is not acceptable to copy a relay from a template and put it on an existing drawing without updating the item designator.

6.6.3 Clouds

6.6.3.1 Change Clouds

Change clouds indicate a change in a drawing that the construction and commissioning teams need to be aware of. Typical examples are:

- Something is removed from or added to a drawing
- A relay contact function is changed, and the change requires the relay to be re-tested (e.g., a setting change).

6.6.3.2 Reverse Clouding

Reverse clouds indicate that an item has been retained from a previous design.

6.6.4 Instrument Transformers

6.6.4.1 Current Transformers

The following discussion is applicable to both zone substations and terminal stations.

6.6.4.1.1 Core Utilisation

The key points to consider when determining core utilization are:

- Identify the CT cores which will be used for a protection function (i.e., bus zone, line and transformer). This is done by analysing the winding characteristics and available CT ratios.
- Select the CT cores such that the protection systems overlap.

6.6.4.1.2 Star Point

Current transformers are installed per phase. A star point is formed from the corresponding cores of each phase CT.

CT polarisation refers to the orientation of the star point. In general, the star point of the cores faces the item of plant being protected. Bus zone schemes are an exception. The star point faces away from the busbar with bus zone schemes.

This rule has not always been followed in the past. It is important that with differential schemes, the star points forming the scheme have the same orientation. As an example, during an asset replacement it is noted that the star point of the cores of a transformer differential scheme face away from the transformer. If only one CT is being replaced, then there are two options:

- The star point of the new cores must match the existing cores (i.e., face away from the transformer)
- Re-wire the existing cores to match the current standard (face towards the transformer). This can require significant extra work and generally would be done if the relay was also being replaced.

Star points should be earthed on the CT side of test blocks. This has been done inconsistently in the past. As an example, many sites have the transformer differential schemes earthed on the CT side of the test block. At these same sites the bus zone schemes are earthed on the relay side of the test block with a short across the test block neutral terminals.

When adding a circuit to an existing bus zone the existing method is followed.

6.6.4.1.3 CT Ratios

CTs come with defined ratios across specific terminals. The ratio used is underlined on the schematic. The CT specification is shown at selected ratio. A 1200/800/300/1 CT will come with an S1, S2, S3 and an S4 terminal. The following ratios can be obtained from this CT:

Table 6.6: CT ratios

Ratio	Terminal 1	Terminal 2
1200/1	S1	S4
800/1	S1	S3
300/1	S1	S2
400/1	S3	S4
500/1	S2	S3
900/1	S2	S4

6.6.4.1.4 Unused CT Cores

If a CT is not used it must be shorted and connected directly to earth with the CT specification shown at the maximum ratio.

6.6.4.1.5 P1 / P2 considerations

P1 / P2 is a convention used by the manufactures to mark the CT's primary terminals. As a rule of thumb, P2 faces the busbar. The cores within the CT are arranged so that overlapping of protection systems is ensured. As an example, the core for the bus zone protection is located closer to P1 and the core for the line protection is located closer to P2.

For asset replacements it is acceptable not to follow the P1 / P2 rule of thumb. Selecting the correct CT specification and having the protection systems overlap is the primary consideration. The P1 / P2 orientation will be the outcome of these considerations. However, whenever possible, the rule of thumb should be followed.

6.6.4.1.6 Interposing Current Transformers (IPCT)

IPCTs have several functions in protection designs. One of the more common is to provide a delta winding to filter zero sequence current in older transformer differential schemes.

6.6.4.2 Voltage Transformers (VT)

HV Voltage transformers have 2 secondary windings. Protection 1 AC circuits should be connected to winding 1 and protection 2 AC circuits to winding 2.

The secondary of all voltage transformers is required to have an earth reference to protect equipment and personnel. Refer to IEEE C57.13.3-2005.

The VT secondary is earthed at a single point through a withdrawable link. Having multiple earths can result in circulating currents due to different potentials in the substation earth grid. Circulating currents can cause measurement errors. A withdrawable link is required to allow the insulation between the secondary and earth to be tested without removing wiring (i.e., insulation test).

Current practice is to earth the neutral of the voltage transformers for new installations.

6.6.4.2.1 Voltage Selection Schemes

Voltage selection schemes are typically used for:

- Fault recorder VT input from lines
- Feeder statistical metering from transformer LV VTs
- UVLS schemes with VT inputs from lines
- Synchronising and check synchronising schemes from VT inputs from line and bus VTs

The voltage selection scheme will typically have a voltage sensing component and a changeover component. The voltage sensing component senses voltage on the primary voltage source. If the primary voltage source loses volts, the changeover component switches to the secondary voltage source. When the primary voltage returns, the changeover scheme switches back. Changeover schemes can be cascaded to select from more than 2 voltage sources.

6.6.5 Interlocking[13]

Hardwired interlocks are shown on the schematics. All types of interlocking must be shown on an interlocking diagram. Interlocking diagrams are done in Visio and uploaded to a .dgn file.

6.6.6 Protection Devices[14]

MCBs and fuses are used to protect a circuit from overloads and short circuits and can be an isolation point. Western Power's preference is for MCBs to allow for grading. Grading fuses with MCBs can be difficult and, in some cases, not possible (refer to Appendix J). All new circuits should have MCBs where possible. Existing circuits with fuses must be dealt with on a case-by-case basis with MCBs used where practical.

[13] See Western Power Internal Document
[14] See Western Power Internal Document

6.6.6.1 General Requirements

- AC circuits from VT's are protected by MCBs. All protection and metering MCBs must have their status reported via SCADA.
- MCBs protecting DC supplies on the DC distribution board do not require their status to be reported via SCADA.
- An MCB which is also used for isolation shall be lockable.
- Upstream MCBs on an AC switchboard supplying a battery charger shall have curve D tripping characteristics.
- MCBs and fuses shall have a continuous current rating not less than the full load current of the circuit.
- MCBs and fuses shall be graded to ensure discrimination.
- MCBs and fuses must operate before the thermal rating of downstream equipment is exceeded.
- All MCB and fuse assemblies shall be rated at or above the fault level of the circuit.
- MCBs and fuses shall be logically grouped together by type and purpose. Fuses for AC supplies shall be spaced from those for DC supplies by at least the width of one carrier base.
- DC circuits can be protected by a lockable MCB, pluggable MCB or a withdrawable fuse link. When both fuses and MCBs are used in the same circuit the devices must grade and the downstream device must operate before the upstream device's thermal limit is reached.
- Fuses in critical circuits must be monitored.
- Withdrawable fuse bases and carriers shall be black. Bases and carriers of a different colour painted black will not be accepted.
- All protection circuit fuses shall be HRC type conforming to the requirements of AS 60269. All fuse carriers shall be fitted with the appropriate HRC fuse.
- Non-critical loads such as the circuit breaker closing coil shall be sub fused from the protection supplies.
- Fuses are mounted vertically with the lowest fuse terminal (e.g., '1') towards the voltage source.

6.6.7 Secondary Isolation

Types of secondary isolation include:

- Protection trip

  Protection trip isolation allows commissioning and maintenance to inject a relay without causing the circuit breaker(s) to trip. Protection trips are isolated with withdrawable white links.

  With DNP designs it must be possible to isolate all trips in the cubicle containing the protection relay.

  Two examples are below:

  – A trip relay in a 1.5 CB yard has all of the white links located in the circuit breaker protection cubicle which has the protection relay. This is acceptable because all isolations can be performed at that cubicle.

  – A trip relay in a 1.5 CB yard has the white links distributed in the cubicles of the circuit breakers being tripped. In this case the trip relay requires a withdrawable white link between the protection relay and trip relay. This allows all the trips from the trip relay to be isolated in the cubicle with the protection relay.

A protection relay contact operating a trip relay should have isolation points on both sides of the relay contact. This allows a voltage free relay contact which assists commissioning.

With IEC61850 designs the protection relay is located in a relay or switch room and the white link in the field cubicle.

- CB fail initiate is isolated with a withdrawable white link.
- Voltages from other locations are isolated with disconnect terminals.
- Signals into a relay are isolated with disconnect terminals or test blocks.
- Current transformers are isolated with test blocks.
- Voltage transformers are isolated with test blocks.
- Circuit breaker supplies are isolated with fuses or withdrawable blue maintenance links.

6.6.7.1 Test Blocks

Test blocks can be used to isolate:

- Current Transformers. It is preferable to have the CT earth on the CT side of the test block.

  In the past the CT was often earthed on the relay side of the test block. This required a bridge across the test block neutral terminals to ensure the earth reference was always maintained for the CT.

  Each relay requires a separate test block for CT isolation. More than one test block may be required for a relay.
- Voltage Transformers
- Protection trips
- Primary plant status and alarms wired into a protection relay.

6.6.7.2 Withdrawable Links

6.6.7.2.1 General Requirements

- All withdrawable links shall provide a clear physical break when opened.
- Withdrawable links shall be fitted with tinned copper straps having minimum continuous and short time current ratings equivalent to the fuse carrier rating and equal to or more than 20A continuous.
- Withdrawable links shall be logically grouped in a horizontal arrangement.
- Lowest link terminal faces the source.

6.6.7.2.2 White Isolation Links

White isolation links are used to isolate protection trip signals and CB fail initiate signals. In the past white isolation links were also used to isolate signals into a relay that were used in the protection functions.

- Every relay contact used for tripping and CB Fail initiation shall be connected through a withdrawable white isolation link.
- The relay contact and white isolation link shall be in the same cubicle.

  Two examples are below:

- A trip relay in a 1.5 CB yard has all the white links located in the circuit breaker protection cubicle which has the protection relay. This is acceptable because all isolations can be performed at that cubicle.
- A trip relay in a 1.5 CB yard has the white links distributed in the cubicles of the circuit breakers being tripped. In this case the trip relay requires a withdrawable white link between the protection relay and trip relay. This allows all the trips from the trip relay to be isolated in the cubicle with the protection relay.

An exception to this is IEC61850 designs where the isolation link for the main protection relay is in the field cubicle.

- When the HV protection relay trips and controls the LV circuit breaker the white isolation links are shown on the HV drawing.

6.6.7.2.3 Blue Isolation Links

Blue isolation links are typically used to isolate CB supplies during maintenance. Isolating the CB supply without isolating the relay supply allows the relay to remain in service while the circuit breaker is maintained. The relay can then perform its normal function in 3 ended differential schemes or gather plant status as an Automation device.

Blue isolation links are typically installed in:

- Protection 1 & 2 line DC schematics. This is to cater for possibility of the two ended line being converted to a three ended line in the future. Not including the blue isolation links could cause problems with the DC wire numbers if the blue isolation links are added in the future.
- IEC61850 designs where it is necessary to keep yard indication in the relay for interlocking and remote metering during circuit breaker maintenance.

6.6.7.3 Disconnect Terminals

Disconnect terminals are primarily used:

- To isolate voltages from other locations
- To isolate alarms and indication wired into a relay
- As a test point when a test block is not available
- To isolate CTs when it is not practical to use a test block (e.g., feeder metering)

6.6.7.4 Voltmeters

Voltmeters typically have two white links to isolate them if they need to be replaced.

When voltmeters are included in circuits containing other equipment (e.g., transducer or synchroscope), one link is replaced with a fuse. At white phase earth sites, the link must remain in the white phase.

6.6.8 Point on Wave (POW)

The following discussion relates to the ABB F236 and PWC600 relay requirements. Other relays may have other requirements. If voltage or current are not available or suitable for the adaptative function feedback, circuit breakers with high precision auxiliary contacts must be used.

6.6.8.1 Reactors

6.6.8.1.1 Adaptive Function

Reactors use current for the adaptation function.

Reactors with a dedicated circuit breaker require:

- A single-phase, supply-side reference voltage. In 1.5 CB yards this would be the single-phase line side VT. When the reactor is connected across two bays, a voltage changeover scheme is required.
- Three-phase, load side current for the adaptative function.

6.6.8.2 Lines

6.6.8.2.1 High Speed Single Pole Auto Reclose (HSSPAR)

- Resistors (100kΩ, 1 W) are required to charge the capacitors in the POW relay's electronic close output contacts. Note that shunt resistors are only required when HSSPAR is required.
- HSSPAR dead times must be long enough to allow the line to be fully discharged before closing.

6.6.8.2.2 Adaptive Function

Lines use voltage for the adaptation function.

- Single bus applications with a dedicated circuit breaker require
  - A single POW relay.
  - A single-phase reference voltage from a bus VT.
  - A three-phase voltage from the load side of the circuit breaker for the adaptive function.
- Circuit breaker and a half application
  - Outer circuit breakers require
    - A single POW relay associated with the outer circuit breaker and associated line.
    - A single-phase reference voltage from a bus VT.
    - A three-phase voltage from the associated line for the adaptive function.
  - Middle circuit breaker requires
    - One POW relay for each line being controlled by POW.
    - Each relay requires a reference single-phase voltage from the line it is not controlling.
    - Each relay requires three-phase voltages from the line it is controlling for the adaptive function.

6.6.8.3 Transformers

Point on wave for transformers requires the following:

- Circuit breakers with high precision auxiliary contacts for active feedback.

- Single-phase source VT used as a reference voltage.
- Three-phase load side VTs.
- Three-phase load side CTs.

6.6.9 Circuit Breaker Tripping

6.6.9.1 Automatic Low SF6 Tripping[15]

Some circuit breakers (220kV and 330kV) can be selected to automatically trip or not trip when the SF6 gas gets to the lockout level. The selection is made in the mech box. The options are:

- Automatically trip the faulty circuit breaker. This opens the faulty circuit breaker before it locks out and puts the circuit breaker in a condition to be re-gassed and inspected.
- Not automatically trip the faulty circuit breaker. If the gas reaches the lockout level the controllers will have to open circuit breakers upstream to isolate the faulty circuit breaker. This is the equivalent to a circuit breaker fail scenario. This allows the controllers more flexibility to manage load.

The insulation with SF6 gas is maintained down to a pressure of 1 ATM. The circuit breaker's insulation is not compromised with low gas .

The Network Operator has requested that the 220 kV and 330 kV circuit breakers do not automatically trip when the SF6 gas reaches the lockout level .

6.6.9.2 Pole Discrepancy

Pole discrepancy is a protection function that detects when the three poles of a single pole circuit breaker are not in the same state. If the poles are not in the same state all 3 poles are tripped. It can be performed by the protection relay or, if enabled, by the circuit breaker.

Pole discrepancy is enabled or disabled on the circuit breaker at the direction of the protection team.

6.6.10 DC Supervision

6.6.10.1 Trip Circuit Supervision

Standard trip circuit supervision (TCS) is by a single binary input energised by the battery voltage, via the circuit breaker trip coil and circuit breaker auxiliary contacts. TCS is not intended to monitor the battery system. The output of TCS is an alarm is time delayed by 1000 ms on pickup to allow transient disturbances without alarming. No delay on drop off is required. TCS monitors the trip coil when the circuit breaker is open or closed.

The wires from the trip contact and the TCS element to the circuit breaker are within the same cable. If one of these wires is severed, it is assumed that both wires are severed.

At 110V dc sites it is standard to include the SF6 supply supervision in the trip circuit supervision circuit for both fail-safe and non-fail-safe circuit breakers.

[15] See Western Power Internal Document

6.6.10.1.1 Start and Finish Wires

The TCS circuit loops between terminals in the protection panel before going to the trip coil. This allows the TCS circuit to supervise some of the associated secondary wiring. The TCS loop is defined by a start wire and a finish wire. The start wire is the first wire coming out of the supply fuse. It is standard to terminate the positive and negative start wires on the power supply unit of the main protection relay. The TCS looping then continues to the finish wire. Inter panel wiring is not included in the TCS looping.

Generally, there are two types of finish wire terminations depending on additional supply supervision requirements:

- No additional circuit breaker supply supervision is required:
  - The positive TCS finish wire terminates on the positive TCS input of the relay.
  - The negative TCS finish wire terminates on the negative CB trip coil terminal.
- Additional circuit breaker SF6 supply supervision is required (refer to Section 6.6.10.2.3 - non-fail-safe circuit breakers):
  - The positive TCS finish wire terminates on the protection panel terminal strip. A second TCS wire is run from the circuit breaker SF6 low gas lockout supply terminal to the positive TCS input of the relay.
  - The negative TCS finish wire terminates on the protection panel terminal strip. A second TCS wire is run from the circuit breaker SF6 low gas lockout supply terminal to the negative CB trip coil terminal.

Additional wire supervision may require additional start wire / finish wire designations.

In both cases a wire runs from the negative terminal of the relay TCS input to the circuit breaker TCS terminal. Because this is a single wire with only two terminations, the start wire / finish wire designation is not required.

The order of the wire looping between the start wire and finish wire is determined by construction to minimise the complexity of the wiring.

6.6.10.1.2 LV Switchboards

On LV switchboard feeders, TCS only asserts if the circuit breaker is in the "In Service" position. This ensures an "Out of Service" circuit breaker cannot produce an irrelevant indication. An irrelevant indication may mask a genuine trip circuit fault in an "In Service" circuit breaker.

6.6.10.1.3 Three Pole Circuit Breaker

Current designs use single element TCS schemes. Older designs often use two element TCS schemes.

One Element TCS Scheme

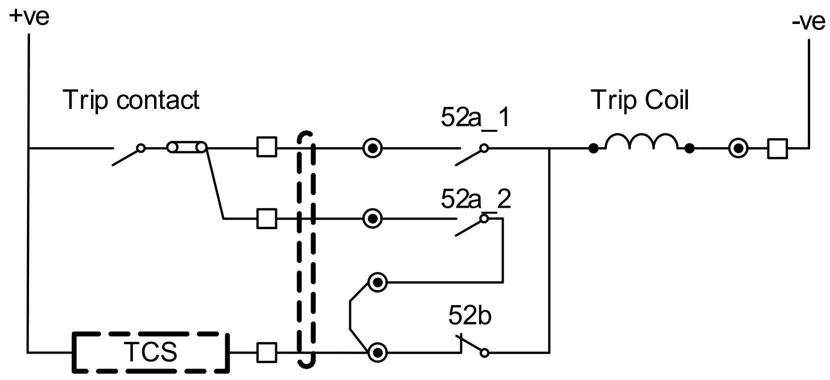


Figure 6.2: One element TCS scheme

A small current passes from the positive rail through the high impedance TCS element and the trip coil to the negative rail. When the current is present, the trip circuit is functional. If the current is absent, the trip circuit is considered faulty.

When the circuit breaker is closed, the TCS current passes through:

- TCS element
- 52a_2 auxiliary contact
- 52a_1 auxiliary contact
- Trip coil

When the circuit breaker is open, the TCS current passes through:

- TCS element
- 52b auxiliary contact
- Trip coil

The normally open auxiliary contact (52a_2) between the TCS element and trip relay contact is included in the design to:

- Break the current drawn by the trip coil when the circuit breaker trips. The trip contact does not have to carry the trip coil current and can reset without breaking this current (refer to Appendix D).
- Without this contact the TCS element is shorted across the positive rail when the trip contact is closed. This will result in a TCS alarm for hand or electric reset trip contacts.

The wire carrying the trip signal is monitored between the relay panel and the trip coil. This is accomplished by bringing the wire connected to the 52a_2 contact back to the relay panel. If the circuit breaker terminals are shorted at the circuit breaker, the wire from the protection panel to the circuit breaker is not monitored (refer to Appendix D).

One Element TCS Scheme with External Trip

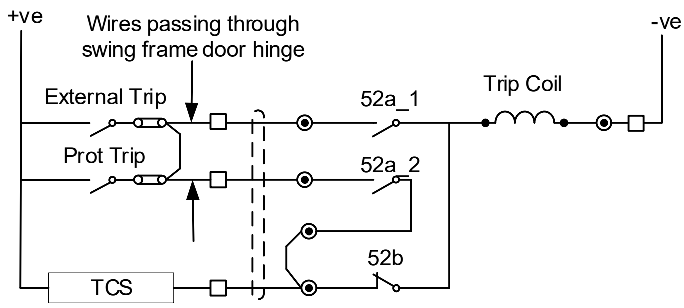


Figure 6.3: One element TCS scheme with external trip

The wire between the isolation links is necessary to include both wires passing through the door hinge in the TCS scheme.

Two Element TCS Scheme

Figure 6.4: Two element TCS scheme

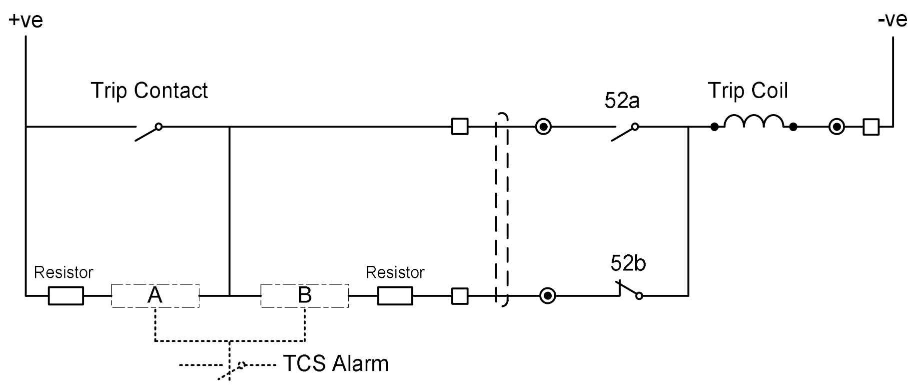


Figure 6.5: Two element TCS scheme

With the circuit breaker closed the TCS current flows through coil A, the 52a auxiliary contact and the trip coil. When the circuit breaker is open the TCS current flows through the A and B coils, the 52b contact and the trip coil. Both coils A and B must be de-energised for an alarm condition.

6.6.10.1.4 Single Pole Circuit Breaker

One Element TCS Scheme

Single pole circuit breakers require a separate TCS circuit for each phase.

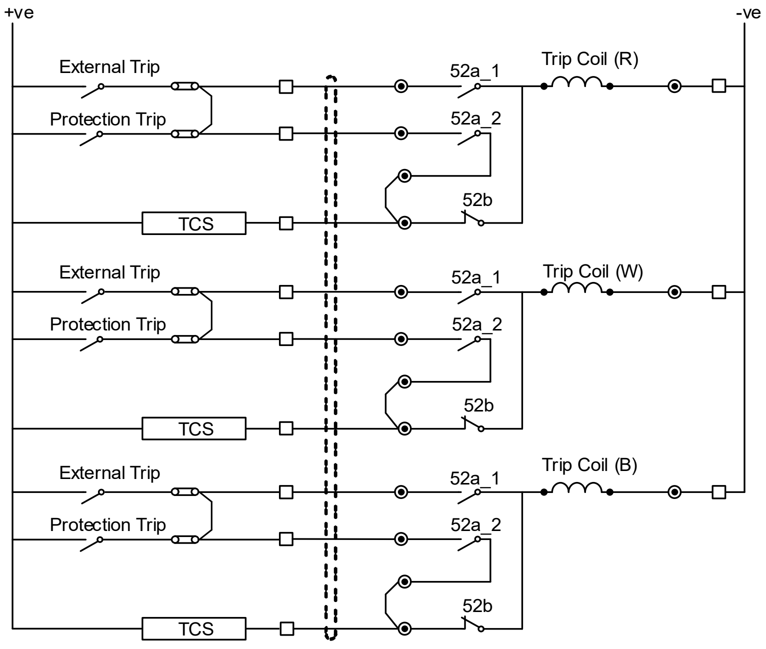


Figure 6.6: **One element TCS scheme**

Refer to Figure D1 in Appendix D which shows the problem with using one trip contact to operate all three poles

6.6.10.1.5 Single Pole CB Wired as a Three Pole CB

The voltage rating of each trip coil is reduced to 1/3 (e.g., 36.7V for a 110V dc system).

One Element TCS Scheme

Figure 6.7: **Single element TCS scheme**

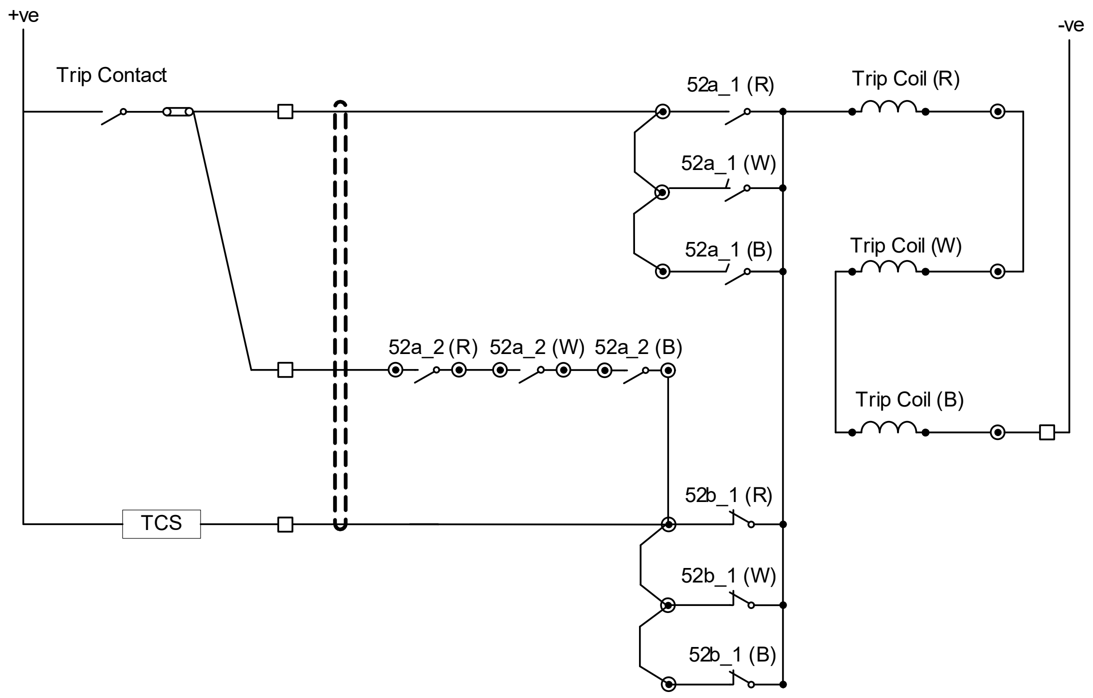


Figure 6.8: Single element TCS scheme

When converting from a two element scheme to a one element scheme it is acceptable to leave the existing 52a_1 and 52b_1 contacts as they are (e.g., some circuit breakers have the 52b_1 contact wired in series). The 52a_2 contacts used to break the trip coil current must be wired in series.

Two Element TCS Scheme

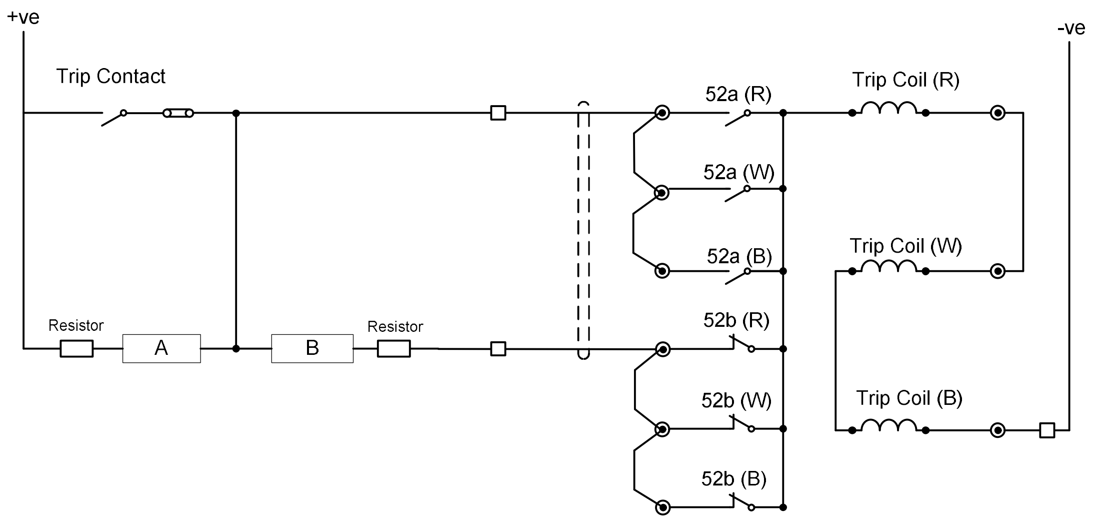


Figure 6.9: Two element TCS scheme

6.6.10.1.6 Circuit Breaker Replacement

Use of a trip relay to segregate the trip signals is acceptable when replacing a 3 pole circuit breaker with a single pole circuit breaker. Using a trip relay reduces the inter-panel wiring and rework required on other panels. The trip relay adds 10 milliseconds so the total fault clearance time must be checked to ensure the clearance time requirement is still met.

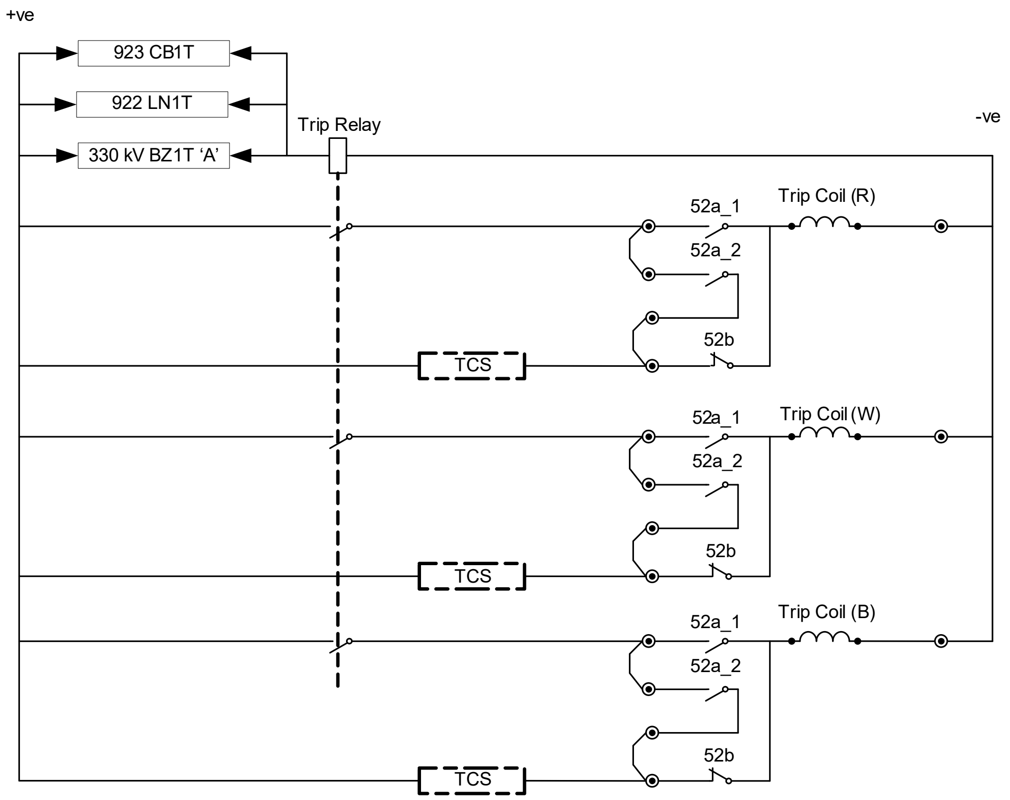


Figure 6.10: Single pole circuit breaker with phase segregating trip relay

6.6.10.2 Supply Supervision

Circuits other than tripping circuits may also require supply supervision to ensure correct operation.

6.6.10.2.1 Trip Supply Supervision

Trip supply supervision is required on protection circuits which do not include a trip coil but are involved in tripping. Examples of these circuits include line protections in 1.5 CB yards and busbar protection schemes.

6.6.10.2.2 Bund Valve Supply Supervision

In some designs a bund valve is required to be closed for a transformer main protection system operation. Older designs used a bund valve operate relay (BVOR) to accomplish this. The supply to the bund valve must be independent from the transformer. Bund valve supply supervision (BVSS) is considered a critical alarm and is required on all transformer circuits.

6.6.10.2.3 SF6 Supply Supervision[16]

SF6 circuit breakers have two possible SF6 lockout configurations:

- SF6 fail-safe supply circuit breakers have a normally open SF6 supervision relay contact in the trip circuit. When the supply is lost the contact is open preventing tripping and generating a TCS alarm.

16 See Western Power Internal Document

- Non-fail-safe supply circuit breakers have a normally closed SF6 supervision relay contact in the trip circuit. When the supply is lost, the contact remains closed and no TCS alarm is generated.

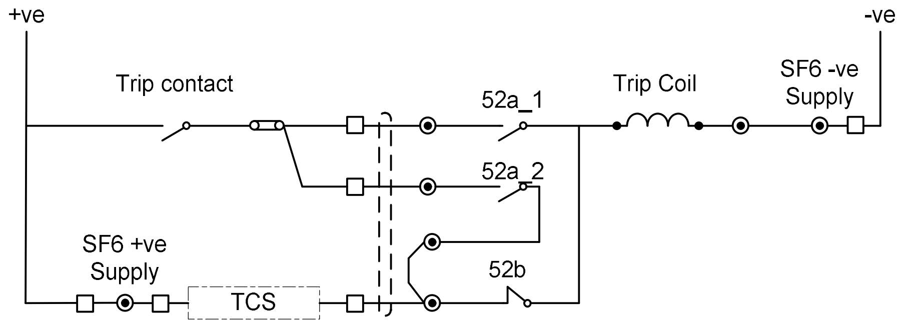


Figure 6.11: SF6 supervision included in one element TCS scheme.

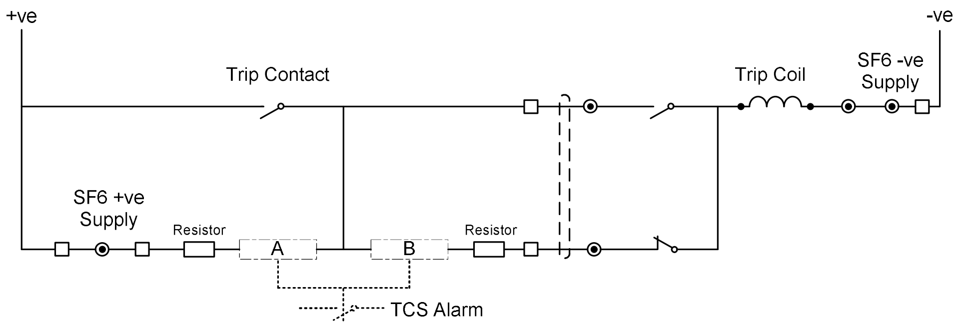


Figure 6.12: SF6 supervision included in two element TCS scheme.

At 32V sites the external looping required to include the SF6 supply in the TCS may cause volt drop problems. In this instance the extra looping can be removed if the circuit breaker is SF6 supply fail-safe. If the circuit breaker is not SF6 supply fail-safe, then it is necessary to either add parallel supply cables or install a separate supply supervision relay across the SF6 alarm and lockout circuit.

6.6.10.2.4 Close Supply Supervision

Close supply supervision (CSS) is required on high-speed single pole automatic reclose (HSSPAR) designs. Close fuse supervision (CFS) is required when a relay input is available.

6.6.10.3 Sub Fusing

The purpose of sub fusing is to prevent faults on non-critical circuits from affecting critical circuits.

6.6.10.3.1 Critical Circuits

Sub fuses in critical circuits must be monitored if there is a chance a goose manager could be lost.

- Tripping Circuit

Cross connections between batteries should be avoided on tripping circuits. New circuit breakers have two trip coils so cross connecting batteries should not occur. Many older circuit breakers have one trip coil so cross connecting batteries may be unavoidable. When cross connecting batteries is unavoidable the following options are available:

- Connect both batteries directly to the trip circuit. This has the small risk that both batteries could be shorted taking out both protection systems. This condition would result in alarms to alert system operations. The circuit would then be taken out of service until the protection systems are restored.
- Insert a sub fuse in one of the protection systems. The benefits must be weighed against risking losing a fuse, and therefore a protection system, until the blown fuse is detected. Sub fuses used in tripping circuits must therefore be monitored. Generally, sub fusing in tripping circuits is not required.

- Goose Managers

Goose managers impact several circuits in a substation. Cross connecting batteries without sub fusing is therefore unacceptable.

6.6.10.3.2 Non-Critical Circuits

- Closing Circuit

All signals involved in the closing circuit must be separated from the tripping circuit with an appropriately graded sub-fuse. This includes delayed auto reclose, high speed single pole auto reclose and point on wave closing. The closing fuse should be monitored when spare relay inputs are available.

- Other Non-Critical Circuits

There may be advantages to sub fusing in other non-critical circuits. An example is the P1 and P2 goose managers sending a 'protection operated' signal to the fault recorder. Sub fusing the P2 signal would prevent taking out both goose managers for the entire site. Because the 'protection operated' signal to the fault recorder is not critical, the sub fuse does not have to be monitored.

6.6.11 Signals

The general format of a signal is:

- Plant
- Relay Name
- Signal Function
- (Qualifier)

The relevant drawing number and line reference will be located below the signal name.

Signals originating or terminating at other sites must include the other site's abbreviation as a part of the plant. Signals originating and terminating at the same site as the drawing do not require the site's abbreviation.

Relays associated with a circuit breaker have a 'CB' as a part of their name. A signal going into a relay associated with a circuit breaker will have the plant in the format 'XXX' (e.g., 911 CB2 CB Fail Initiate).

A signal going into a circuit breaker (trip coil) will have the plant in the format 'XXX.0' (e.g., 911.0 TC1).

6.6.11.1 Signal Input into a Relay (or Trip Coil)

The first part of the signal is the plant associated with the origin of the signal. The second part is the name of the relay from which the signal was sent. The third part (if required) is the signal function. The relay input element should have the input element function written above it so the signal may not always require the signal function. If further information is required a qualifier, included in parenthesis, can be added.

6.6.11.1.1 Examples:

- 911 CB1T – this signal originates from the protection 1 circuit breaker protection trip relay on the 911 circuit.
- 912 LN1T – this signal originates from the protection 1 line protection trip relay on the 912 circuit.

6.6.11.2 Signal Output from a Relay

The first part of the signal name is the plant associated with the destination of the signal. The second part is the name of the relay to which the signal is being sent. The third part (if required) is the signal function. If further information is required a qualifier, included in parenthesis, can be added.

6.6.11.2.1 Examples

- 913.0 TC1(R) – this signal goes to the red phase of the 913.0 trip coil.
- 913 CB1 CB Fail Initiate – this signal goes to the 913 circuit breaker relay and initiates CB Fail.

6.6.11.3 Trip Versus Intertrip

The term 'Trip' is reserved for tripping signals whose destination is within a site.

The term 'Intertrip' is reserved for tripping signals whose destination is another site.

6.6.11.3.1 Examples

- A digital differential line protection relay would send an 'intertrip' to the circuit breaker at the other end of the line.
- A CB fail trip relay would send a 'trip' into a bus zone.
- A transformer HV OC relay sends a 'trip' signal to the LV circuit breaker.
- A CB fail trip relay would send an 'intertrip' to the remote end of a line via the line protection relay.

Normally the terms 'Trip' and 'Intertrip' should be sufficient, however if terms such as 'Direct' or 'Transfer' are required, they can be added as a qualifier.

6.6.11.4 Information Boxes

There are two types of information boxes used in signalling:

- A single information box contains one signal that goes to a specific destination.

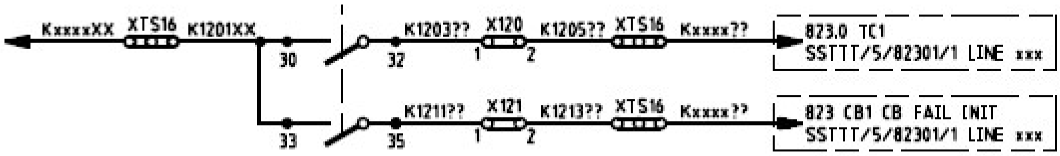


Figure 6.13: Single information box

- A multiple information box is used when a single wire goes to a destination and is then looped at the destination. It is used to show that a single wire is sent rather than two wires.

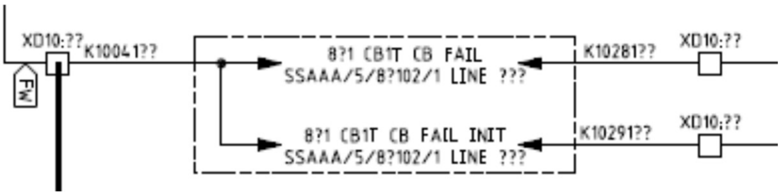


Figure 6.14: Multiple information box

6.7 Terminations

Termination drawings are done for all cubicle and plant terminations. Termination drawings are created as a .dgn file from the appropriate template.

The best fit shall always be considered in determining the correct type of termination for a wire into a terminal block or accessory.

6.7.1 Termination Drawings

Termination drawing must follow the following rules:

- Continuity terminals have the wire number shown on the terminal.
- Wires going to other panels have the suffix shown with the wire numbers on a wire coming out of the terminal. The wire number without the suffix also appears on the terminal.
- Bridged continuity terminals only require a wire number on one terminal.
- Disconnect terminal have wire numbers on wires on both sides of the disconnect terminal.
- Bridged disconnect terminals will have only 1 wire coming out of 1 side. The location of the bridge must match the schematic (i.e., bridge on left or right side of the terminals).
- Wire numbers should increment sequentially.

Terminals added after the drawings are issued (e.g., as constructed or future designs) can be added to the end of the terminal strip. This may result in the wire number not being in the correct sequence so updating the terminal number on the schematic is important.

If a terminal must be inserted in an existing terminal strip, then the terminal numbers must be updated on both the termination drawing and the schematic.

6.7.1.1 Terminal Numbering

Construction of the terminal strip has priority over the terminal numbering on the schematics. The terminal strips are constructed and then the terminal numbers are updated on the schematics. The goal is to have the most efficient terminal strip and a 1:1 relationship with the terminals shown on the schematic. This must be implemented on new designs. On old drawings:

- Consecutive terminal numbering does not necessarily need to be implemented
- The number of terminals on the schematic must match the number of terminals on the termination.

6.7.2 Terminal Cross Connections (Bridges)

The size of the terminal cross connections must match the terminal sizes (e.g., 2.5mm cross connections are not suitable for 4mm terminals and vice versa).

6.7.3 Future and Spare Terminals

The terminal strip should cater for space for future requirements plus space for 3 – 5 spares. The exact number of spares will depend on available space on the terminal strip. Typically, 3 – 5 terminals will be included on the bridged positive rail. Space must also be allowed for to cater for an additional 3 – 5 negative terminals corresponding to the bridged positive terminals.

6.7.4 Primary Plant Mech Box

When possible, it is preferred to bridge wires with the same wire number at the terminal strip in the primary plant mech box. This saves wiring between the mech box and marshalling box and terminals in the marshalling box.

This is not suitable for indication wired to the RTU. The Automation design standard is to have 2 wires for alarms and indication wired to the RTU.

6.7.5 Terminals

All terminals and fuse holder connectors are to be shrouded and, when possible, finger safe. Shrouding of terminals is to be shown on all appropriate drawings.

6.7.5.1 Stud Terminals

Eyelet lugs are required for stud terminals. Locknuts shall be fitted to the stud on the rear face behind where the lug is be fitted. A flat washer shall be fitted on either side of the eyelet lug followed by a spring washer and a full thread nut. Washers shall be:

- Non-corrosive material or
- Equivalent material as the stud.

Flat washers that form part of the conductive path shall be of a high conductive material.

A maximum of three wires using eyelet lugs can be connected to one stud terminal. Any more than this will compromise the clamping pressure across multiple contact surfaces.

6.7.5.2 Vibration Proof Terminals

Vibration proof terminals are spring loaded and require lip blade lugs. Vibration proof terminals are required for:

- Current Transformers
- Voltage Transformers
- 50/110V DC wiring in vibration areas of power transformers.

6.7.5.3 Disconnect Terminals

Disconnect terminals are used to isolate:

- Voltages from other cubicles
- Alarms and indication
- CT earths (for measuring earth resistance)

Table 6.7: Orientation of vertically mounted disconnect terminals

Application	Orientation
CT and VT earth link terminal	Slide up to open
All other slide terminals	Slide down to open
Automation blade terminals	Blade flicks up to open (to allow installation of shorting links to be installed on the field side of the terminals)
All other blade terminals	Blade flicks down to open

6.7.5.4 Krone Terminals

Only one wire shall be terminated at each Krone terminal point.

6.7.6 Lugs

6.7.6.1 Bare Wire Terminations

A bare wire may be terminated in a clamp terminal (excluding screw clamp) provided:

- The wire size is greater than or equal to 1.5mm^2
- The wire is composed of 30 strands or less

6.7.6.2 Eyelet Lugs

Eyelet crimp lugs should be used when a terminal is designed to accept it.

Except for CT circuits, forked/open eyelet lugs may be accepted where ease of connection is a factor.

6.7.6.3 Crimp Lug

It is permissible to terminate 2 wires into a clamp terminal provided they are specifically designed for this purpose. If the terminal is a screw clamp the wire strands shall be protected by using a crimp lug.

In general, crimp lugs shall be used:

- For all flexible wire of 30 strands or more
- If the cross-sectional area of the cable is less than $1.5mm^2$

Where insulated lugs are to be used, these shall be of the “UTILE super grip” style. These lugs require a double crimp rather than a single crimp.

6.7.6.4 Lip Blade Lug

Lip blade lugs should only be used on vibration terminals.

6.7.6.5 Bootlace Lug

Bootlace lugs are commonly supplied on manufacturer’s equipment.

It is acceptable to use bootlace lugs to terminate field data cables which are typically $0.5mm^2$ or less.

The use of bootlace lugs shall be considered for other applications when the crimp lug is considered unsuitable.

6.7.7 Connecting Two or More Wires

The preferred methods for connecting two or more wires are:

- Bridge two terminals

  Disconnect terminals are bridged on the side that does not require isolation. When external plant requires isolation, the disconnect terminals are bridged on the internal side. When internal plant requires isolation, the disconnect terminals are bridged on the external side. Terminals that are bridged on opposite sides can be connected with a wire.

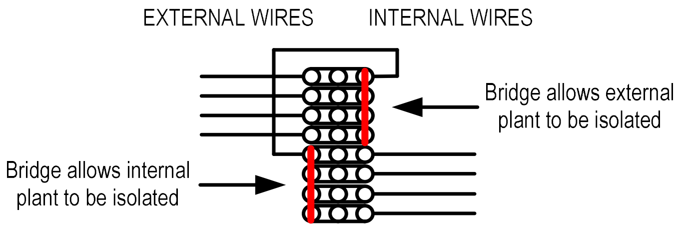


Figure 6.15: Bridged disconnect terminals

- Use a terminal designed to accept multiple wires
- Link two terminals with a wire
- Flat blade lugs shall be used back to back where two wires are required to be terminated in one terminal (e.gg. if terminal space is limited).

6.7.8 Approved Terminals

Approved terminals to be used for all projects are shown in Table 6.8.

Table 6.8: Approved terminals

Terminal	Rating (A)	Type	WP Stock Code
WDU 2.5	24	Continuity	FT0026
WTR 2.5 StB	24	Test disconnect	FT0027
WDU 4/ZR	32	Continuity	FT0020
WDU 4	32	Continuity	FT0021
WTL 4	32	Test disconnect	
WTR 4 StB	32	Test disconnect	FT0024
WTD 6/1	41	Continuity	FT0025
WTD 6/1 EN	41	Continuity	
WTL 6/1 EN	41	Test disconnect	
WTL 6/1 StB	41	Test disconnect	FT0022
WPE 2.5	300 (Short Time)	PE Continuity	FB0102
WPE 4	480 (Short Time)	PE Continuity	FT0023

Notes:

(5) WTD 611 EN can be bridged to WTL6/1 EN. WDU4 cannot be bridged to WTL4.
(6) Krone 6428 5 to be used on all STRs.
(7) Terminal ratings as per IEC 60947-7-1
(8) The above terminals are all approved for use. Equivalent alternatives that are functionally the same and of equal or better quality may be used if approved by the AM ED Substation Design - Standards Group.

6.7.9 Terminal Strip Numbering

The terminal strips are numbered as follows:

Table 6.9: General terminal strips

Name	Description
XD1	VT marshalling box
XD2	CT marshalling box

Table 6.10: P1 & P2 terminal strips

Name		Description
P1	P2	
XD10	XD20	DC Continuity terminals
XD11	XD21	DC Disconnect terminals (alarm and status isolation)
XD12	XD22	DC Disconnect terminals (voltage isolation)
XD13	XD23	DC Disconnect terminals (SCADA 50V isolation)
XD14	XD24	DC Other
XD15	XD25	AC Continuity terminals (CT & VT)
XD16	XD26	AC Continuity and disconnect terminals (current shunts)
XD17	XD27	AC Transducers
XD18	XD28	AC Other
XD19	XD29	AC Other

Note: Watchdog and Protection Healthy alarms on IEC61850 designs are isolated by either an XD12 or XD22 terminal as they are wetted by 110V DC from the Automation cubicle.

XD11 and XD21 terminals isolate alarms and primary plant status signals going into a relay. They are typically found before an input element. XD12 and XD22 terminals isolate voltages from other panels. They are typically found on each side of an output contact. XD13 and XD23 terminals isolate the Automation supply from the protection panel. They are found on the alarm page.

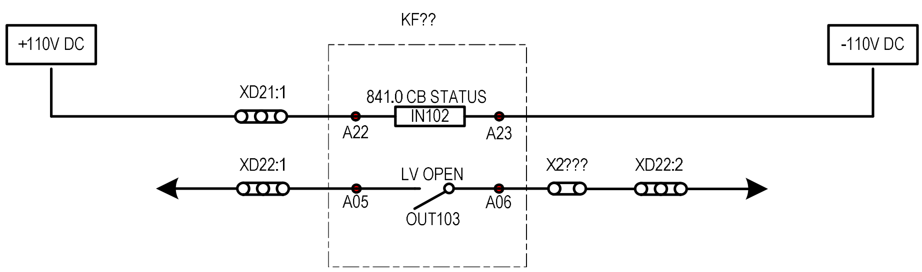


Figure 6.16: Terminal strip numbering

6.8 Alarms and Indication

The preferred contact convention shown on drawings is:

- De-energised
- Not operated
- No operating force applied (not powered, not gassed and no pressure.)

If the contacts are drawn differently the convention used must be stated on the drawing. Refer to AS1103.3 – 1989 clause 11.1 and 11.2.

6.8.1 Auxiliary Contacts

Normally open auxiliary contacts follow the state of the primary plant (e.g., a normally open circuit breaker auxiliary contact is open when the circuit breaker is open).

Normally closed auxiliary contacts are opposite the state of the primary plant (e.g., a normally closed circuit breaker auxiliary contact is closed when the circuit breaker is open).

The sense of primary plant auxiliary contacts is drawn with the primary plant open and de-energised.

Auxiliary contacts are drawn such that when operating, the contact moves clockwise. When resetting it moves clockwise. The hinge is always drawn on the negative side of the contact.

Current practice is to bring both a normally open and a normally closed contact into the protection relay. This allows the relay to do a discrepancy check which improves security and reliability.

Keeping an existing single contact is acceptable if the primary plant is not being replaced and there is no protection requirement for both states. In this case the auxiliary contacts are updated when the primary plant is updated.

6.8.1.1 Historical Contact States

Prior to IEC61850 and DNP3 the plant status was hardwired to the RTU. When primary plant is replaced, it is preferred to wire the status to the protection relay. When it is not practical or when the relays are not capable of accepting the status, it is acceptable to hardwire to the RTU.

6.8.1.1.1 Primary Plant Status Sent to the Control Centre

Table 6.11 summarises the auxiliary contact state for single busbar, double busbar, 1.5 CB (except lines) when the primary plant status is being sent back to EPCC:

Table 6.11: Auxiliary contact state – primary plant status sent to control centre (historical)

Primary Plant	Auxiliary Contact State
Circuit Breaker	Normally Closed
Disconnector	Normally Closed
Motorised Disconnector	Normally Closed and Normally Open
Earth Switch	Normally Open

In the past, single pole circuit breaker status has been sent back as three normally closed contacts wired in series. If any pole is closed, the status sent to the control centre is ‘closed’ (signal inverted). The current standard is to wire a normally closed contact from each pole back separately. When replacing a relay it is acceptable to keep the existing contact wiring unless there is a protection requirement to bring back both states.

6.8.1.1.2 Primary Plant Status Not Sent to the Control Centre

Table 6.12 summarises the auxiliary contact state for 1.5 CB yards when the circuit breaker and isolator auxiliary contacts are in series and the status is not sent back to SOCC:

Table 6.12: Auxiliary contact state – primary plant status not sent to control centre (historical)

Primary Plant	Auxiliary Contact State
Circuit Breaker	Normally OPEN
Disconnector	Normally OPEN
Motorised Disconnector	Normally Closed and Normally Open
Earth Switch	Normally Open

6.8.2 Alarms

Current practice is to use normally open contacts for all alarms.

A normally open relay contact to form a 'Protection Healthy' alarm. The normally open 'Protection Healthy' relay contact is held closed in the settings when the relay is functioning correctly ('1' state = healthy). If the relay is faulty or the relay supply is lost the contact opens resulting in a not healthy alarm ('0' state = not healthy). Losing a wire also results in a '0' state = not healthy alarm.

In many older designs a relay normally closed watchdog contact was used to form a 'Protection Defective' alarm. The contact is held open when the relay is functioning correctly ('0' state = not defective). If the relay is faulty or the relay supply is lost, the watchdog contact closes resulting in a defective alarm ('1' state = defective alarm). This has the disadvantage that the wires to the watchdog are not monitored (losing a wire will result in a '0' state in RTU).

6.8.3 Indication

6.8.3.1 Primary Plant

Current practice is to bring a normally open and a normally closed contact to a protection relay from disconnectors, earth switches and circuit breakers. This allows the relay to perform a discrepancy check.

6.8.3.2 Secondary Auxiliary Contacts

All MCB and fuse contacts are brought back individually to Protection and Automation devices.

6.8.3.3 MCB Indication

- MCB alarming for protection. With the MCB in the off state a normally closed auxiliary contact is required. An example is alarming of a distance protection VT MCB. The wiring is not supervised.
- MCB alarming for control / logic. With the MCB in the off state a normally open auxiliary contact is required. An example is a sync check VT MCB with an existing hardwired alarm. The wiring is supervised.

- When multiple MCBs are supervised by a single relay input, normally open contacts (MCB off) are wired in series.
- MCB supervision is not required for DC supply MCBs on the DC distribution board.

6.8.3.4 Power VT Fuse Indication

- Power VTs have fuses that operate auxiliary contacts when the fuse operates. A normally open auxiliary contact is required (with the fuse not operated). The wiring is not supervised

6.9 Secondary Cables

Alarm and indication wires and protection control wires are always run in separate cables. This allows for loss of the control cable without losing the alarms and indication. Secondary Cables are specified in the Technical Specification – Cables and Conductors.

6.9.1 Cable Schedules

All cables shall be listed in a cable schedule. Each circuit shall have its own cable schedule. Any cables not directly related to a circuit shall be listed on the general cable schedule. New cables should be listed on an Excel spreadsheet cable schedule.

Fibre cable schedules are prepared as an MS Excel spreadsheet by the Automation and control group. Substation Design is responsible for including these schedules in the issued drawing package and registering them in the drawing management system.

6.9.2 Standard Cables

Cable selection shall be chosen from a standard list of unarmoured PVC cables available to be used in Western Power substations. All control, indication and alarm cables are double sheathed and screened. The rating and size of the cables shall be verified by means of volt drop calculation. Black sheath is preferred to orange.

Table 6.13: Standard secondary cables

Power		Control, Indication and Alarms (Protection)		Indication / Alarms (Automation)[17]		SCADA Data (Automation)	
PVC		**PVC&S&S**		**PVC&S&S**		**PVC&S[18]**	
Size	Stock Code	Size	Stock Code	Size	Stock Code	Size	Stock Code
3 ½ c[19] / 35 mm²	EE1644	16c / 2.5 mm²	EE1652	20pr / 0.5 mm²	ED1054	12c / 0.2 mm²	ED1062
4c / 16 mm²	EE1640	12c / 2.5 mm²	EE1653	10pr / 0.5 mm²	ED1056	3pr / 0.2 mm²	ED1063
4c / 6 mm²	EE1641	8c / 2.5 mm²	EE1654	6pr / 0.5 mm²	ED1057	24c / 0.2 mm²	ED1064
4c / 4 mm²	EE1642	4c / 4 mm²	EE1656	1pr / 0.5 mm²	Not Stocked[20]		
2c / 4 mm²	EE1643	4c / 2.5 mm²	EE1651				

[17] External cables must be a minimum of 0.5mm² PVC&S&S. 0.5 mm² alarm and indication conductors can be terminated on the Automation terminal strip.

[18] 12 and 24 cores (ED1062&ED1064) Automation cables are used between the krone block and RTU card (internal use only). The conductors in 3 pair Automation cable (ED1063) are tightly twisted (twisted pairs) and used for the DNP link.

[19] Rd, Wh, Bu, Bk cores

[20] Can be ordered for specific projects if required, min. qty 3000m, lead time > 4 months. Consult Substation Design prior to specify.

Power		Control, Indication and Alarms (Protection)		Indication / Alarms (Automation)[17]		SCADA Data (Automation)	
PVCS V90		2c / 2.5 mm^2	EE1655				
Size	Stock Code	2c / 1.5 mm^2	EE1650				
4c+E / 2.5 mm	Not Stocked						
4c+E / 6 mm	Not Stocked						
2c+E / 2.5 mm	Not Stocked						
2c+E / 6 mm	Not Stocked						

6.9.3 Cable Selection

Spare cores between primary plant, marshalling boxes and relay cubicles should be utilised whenever possible. New cables should only be run when necessary.

Automation cables can be large and running spare cores from one end of the STR to the other can be difficult. In this case it may be better to run a new cable, even though spares are available. Alarms and indication can be run in the same cable however controls must be in a separate cable.

As per AS3008.1.1:2017 cable selection must be based on:

- Current carrying capacity.
- Volt drop
- Short circuit temperature

The smallest cable which satisfies the three criteria is generally the one selected.

Calculations must be included in or referenced in the Substations Design Report.

6.9.3.1 Current Carrying Capacity

The current for which the circuit is designed must be less than or equal to the current carrying capacity of the conductor.

AS3008.1.1:17 tables 22 thru 29 must be used to de-rate the cable being selected. For indoor cables an ambient temperature of 40 $^{\circ}$C is typically used. For outdoor cable trenches an ambient temperature of 60 $^{\circ}$C is typically used.

6.9.3.1.1 Thermoplastic Insulation V90

AS3008.1.1:2017, Table 5, column 8 is considered suitable to determine current carrying capacity of Western Power's thermoplastic V90 cables in trenches. Normally Table 5 is for cross-linked elastomeric and polyolefin (XLPE) insulation, however it is considered acceptable for Western Power V90 installations because:

- Cross-linked elastomeric and polyolefin (XLPE) insulations are used because they maintain their shape at higher temperatures and do not flow under mechanical pressure[21].

[21] AS3008.1.1:2017, Note 4, Table 1.

- V90 cables may be operated to a conductor temperature of 90° C if they are installed in a manner that does not subject them to severe mechanical pressure at temperatures higher than 75° C[22]. Western Power cables are not subjected to severe mechanical pressure.

6.9.3.1.2 R-HF-110

Table 6, column 6 is suitable to determine current carrying capacity of R-HF-110 cables.

6.9.3.2 Volt Drop

- The voltage at the equipment terminals shall not impair the safe functioning of the electrical equipment. This is typically the minimum operating voltage of the circuit breaker trip and close coils for protection circuits. It may also be the spring charge motor requirements for Terminal Yards.
- The source voltage shall be the battery end voltage[23].
  For 110 V dc NiCad batteries this is 88 V dc. Other types of batteries may have a different end voltage.

Refer to Section 6.1.2 Volt Drop for more information.

6.9.3.3 Short Circuit Temperature

AS3000:2007 Section 5.5.3.1 defines the maximum fuse rating.

6.9.3.3.1 Fuse Discrimination:

- Overload Zone. Fuses with the same utilization category and different current rating have parallel characteristics. Selectivity is obtained by comparison of time current characteristics.
- Short Circuit Zone. Fuse discrimination is achieved when the total I^2t of the minor fuse does not exceed the pre-arc I^2t of the major fuse.

6.9.3.3.2 Short Circuit Rating

The short circuit capacity of the cable must not be exceeded.

6.9.4 Test Cables

External trips require timing tests during commissioning and maintenance. This requires four test wires to be run between the HV relay room and the external trip locations. External trips requiring test wires are typically located in field cubicles and switchrooms. The order of preference is:

- Use spare cores in the protection control cable (2.5mm^2 minimum)
- Run a new 4 core 2.5mm^2 protection control cable (EE1651).

Locate the test terminals on the right side of the upper terminal strip if possible.

[22] AS3008.1.1:2017, Note 2, Table 5.
[23] Also known as 'final voltage' and 'end of discharge voltage'.

6.9.5 Spare Cores for New Cables

The number of cores should allow for at least 25% spares. As a rule of thumb:

Table 6.14: Spare cores

Number of Cores Immediately Required	Cable to be Installed
2 Core	4 Core
8 Core	12 Core
10 Core	16 Core

6.9.5.1 Segregation

6.9.5.1.1 Protection Systems

Cores between the protection system 1 and the protection system 2 must be segregated in separate cables. Loss of one cable must not result in loss of both protection systems.

6.9.5.1.2 Disconnectors

Spare cores between existing disconnectors and marshalling boxes may be limited. The following options are available in order of preference:

- Use spare cores in an existing cable that allows segregation of battery 1 and battery 2.
- Wires with the same wire number can be bridged in the mech box.
- Use spare cores in another cable when no spare cores are available in a cable which allows segregation of battery 1 and battery 2[24] .
- If there are insufficient spare cores available, then the order of preference is:
  - Add a new cable. Items to be considered include:
    - Construction costs (direct buried or cable trench).
    - Cable entry and space limitations in the marshalling box
  - Use repeat relays with existing auxiliary.

6.9.6 Cable Installation

AC and DC wires must be run in separate cables

6.9.6.1 Installation Methods

Cables can be installed in:

- Cables trenches (concrete / preformed / brick)
- Ducts
- Cable trays in the relay rooms and switch rooms.

Cables must not be direct buried.

[24] Loss of both a cable and a circuit breaker fail condition is an N-2 condition. Construction and maintenance are expected to 'test before touch' when working on cables.

During the transition from one medium to another, cables shall be mechanically protected to prevent damage to cables.

AS/NZS 2373:2003 Appendix F indicates the minimum bending radius of screened cables.

6.9.6.2 Cable Identification

Each end of a cable shall be identified by the cable number as indicated on the cable schedule drawing.

6.9.6.3 Outdoor Structure Supported Cables

All switchyard primary equipment (e.g., circuit breaker, current transformer) secondary cabling shall be installed on cable trays suitably mounted to the support structure. A suitable means of fixing the cables to the tray shall be used.

6.9.6.4 Joining Cables

CT and control cables must not be joined.

415 Vac and 240 Vac power cables may be joined using the appropriate joint kit.

6.9.7 Cable Earthing

6.9.7.1 Auxiliary Supplies

Refer to Engineering Design Instruction – AC Auxiliary Supplies for earthing of AC auxiliary supplies.

6.9.7.2 Secondary Cables[25]

6.9.7.2.1 DC Cables

Protection secondary cable screens are earthed at both ends.

Metering secondary cables (e.g., transducers) are screened and earthed at the source end only[26] . This earthing is shown on the relevant schematic drawing

Automation alarm and indication cables are earthed in the protection cubicle.

Automation IED serial link data cables are earthed at the RTU.

6.9.7.2.2 Analogue Cables

Fault recorder current shunt cables are earthed in the protection cubicles.

Transformer analogue cables are earthed at the transformer cubicle.

CT and VT cables are earthed at the CT and VT.

6.10 Primary Equipment Control, Indication, Alarms and Statistical Metering

For the purposes of Section 6.10 'local' means at the substation and 'remote' means at the control centre.

[25] See Western Power Internal Document

[26] More than one earth on a cable results in circulating currents which can affect measurements

6.10.1 Introduction

This guideline applies to new circuits and existing circuits when they are upgraded.

The types of control, indication, alarms and metering are generally governed by:

- RTU capabilities. Older RTUs may not be capable of a DNP serial link.
- Presence of a Mimic panel. Human Machine Interfaces, Data Display Units, and Mimic Panels

6.10.1.1 Mimic Panels

Protection panels must meet control and metering requirements independent of the mimic panel. Removal of equipment from an existing mimic panel is a case-by-case decision.

6.10.2 Controls and Indications

6.10.2.1 General Requirements

- The LED and LCD displayed alarms must assert and latch (non-volatile) only if the relay sends a trip signal during a fault. They must not assert and latch for a through fault which is cleared by another protection system.
- Controls shall be available via at least one method that is independent of the RTU or gateway.
- Remote control from EPCC, the Trip-Neutral-Close switch on the control panel or any other switch or push button shall be disabled when the Local – Remote switch on the circuit breaker is in the local position.
- The requirements outlined in Sections 6.10.2.2 – 6.10.2.5 are common for all circuit types.

6.10.2.2 Circuit Breaker Control (Open / Close)

Circuit breaker control for IEC61850 green field sites is on battery 1. Circuit breaker control for brownfield sites must match the existing control schemes.

- Local control shall be provided by:
  - A Trip-N-Close switch on the protection panel.
  - A second Trip-N-Close switch shall also be provided on the circuit breaker mechanism. This shall either be lockable or be contained in a lockable mechanism box[27].
- Local indication must be provided by either:
  - A single device independent from the Automation device (e.g., lamps) or
  - Two independent devices displaying CB Status. The first must be IED LEDs or lamps driven by an IED. The second may be an IED scrolling display[28].
  - A mechanical indicator shall also be provided on the circuit breaker mechanism.
- Remote control is required
- Remote indication is required

[27] A second TNC switch is not required on LV switchboards.

[28] In the event of an IED being out of service, there must be at least 1 local indication of CB status

6.10.2.3 Circuit Breaker Selection (Local / Remote)

- Local control shall be provided by:
  - Two position switch on the circuit breaker.
  - In the case of indoor switchboards, this switch shall be located in the auxiliary compartment.
- The position of the switch provides sufficient local indication
- Remote control of this switch is not permitted
- Remote indication is not required

6.10.2.4 Disconnector Control (Open / Close)

- Local control shall be provided by:
  - Non-motorised disconnectors are mechanically operated only
  - Motorised disconnectors shall have an open-close switch at the disconnector mechanism and on the appropriate protection panel
- Local indication shall consist of the position of the disconnector
- Motorised disconnectors require remote control
- Remote indication is required for voltages at 66 kV and above

6.10.2.5 Earth Switch Control (Open / Close)

- Local control shall be provided by mechanical and, when practical, electrical means.
- Local indication shall consist of the position of the earth switch. When the position of the switch is not visible (e.g., GIS switchgear) then indication lamps are required.
- A means to verify that the circuit to be earthed is voltage free is required. Examples include: voltmeter, relay displaying volts, blocking coil, visibly open disconnectors or circuit breakers.
- The Control Centre does not require remote control. Consideration should be given to have sufficient control circuitry supplied in GIS equipment for possible future changes to this requirement.
- Remote indication is required.

6.10.2.6 Feeder Control and Indication

Refer to Protection Design Guidelines – Feeder Protection for feeder secondary indication requirements.

6.10.2.6.1 Double Cable Terminations

- Local control is not applicable
- Local indication of the faulty cable is required
- Remote control consists of a reset facility
- Remote indication of the faulty cable is required.

6.10.2.7 Capacitor and Reactor Circuit Control and Indication

Refer to Protection Design Guidelines – Capacitor Protection for capacitor secondary indication requirements.

The following requirements are in addition to the general requirements:

- Timed switching of capacitors in zone substations shall be achieved via Automation. Separate capacitor time clocks are not to be installed.
- Switching of capacitors in terminal stations shall be manual only.

Note that transmission planning may request an exemption from this requirement and require over voltage tripping and under voltage closing to be performed by the protection relay.

6.10.2.8 Transformer Circuit Control and Indication

Refer to Protection Design Guidelines – Transformer Protection for transformer secondary indication requirements.

The following requirements are in addition to the general requirements:

6.10.2.8.1 Tap Change Selector (Raise / Lower)

- Local control provided by a raise and lower switch (or two pushbuttons) in the tap-changer control cubicle.
- Local indication by the tap position indicator on the transformer.
- Remote control is required
- Remote indication by the tap change in progress and tap position indicator.

6.10.2.8.2 Tap Changer Mode (Master / Trailer / Independent)

- Local control by a switch or push button in tap-changer control cubicle.
- Local indication by a position switch is sufficient. The switch position may be in discrepancy if remote selection has occurred.
- Remote control is required
- Remote indication is required

6.10.2.8.3 Paralleling Mode (Parallel / Separate / Lockout)

- Local control by a switch or push button in tap-changer control cubicle.
- Local indication by a position switch is sufficient. The switch position may be in discrepancy if remote selection has occurred.
- Remote control is required
- Remote indication is required

6.10.2.8.4 Automatic Voltage Regulator (Auto / Manual)

- Local control by a switch or push button in tap-changer control cubicle.
- Local indication by a position switch is sufficient. The switch position may be in discrepancy if remote selection has occurred.
- Remote control is required
- Remote indication is required

6.10.2.8.5 Tap Changer (Local / Remote)

- Local control by a switch or push button in tap-changer control cubicle.
- Local indication by a position switch is sufficient.
- Remote control is not permitted

- Remote indication is not required

6.10.2.8.6 Fan Selector (Off / Auto / Test)

- Local control by a switch in tap-changer control cubicle. Control of this function is not required on the HMI.
- Local indication by a position switch is sufficient. Cooler fail alarm is to be activated if the fan selector switch is not in the Auto position.
- Remote control is not required
- Remote indication is not required

6.10.2.8.7 Bund Valve (Open/ Close)

- Local control by a Normal / Isolated switch at the valve. Control is not required at the HMI.
- Local indication by a position switch is sufficient.
- Remote control is not required
- Remote indication is not required

6.10.2.9 Bus-Section Circuit Control and Indication (Includes Bus-Couplers)

Refer to Protection Design Guidelines – Bus Section Protection for Bus Section secondary control and indication requirements.

There are no specific standard requirements in addition to the general requirements.

6.10.2.10 Line Circuit Control and Indication

Refer to Protection Design Guidelines – Transmission Line and Cable Protection for line and cable secondary indication requirements.

There are no specific standard requirements in addition to the general requirements.

6.10.2.11 Miscellaneous Control and Indication Requirements

6.10.2.11.1 Supply Voltages

All control and indication on protection panels shall be supplied at 110V DC. For installations in sites where existing panels contain 50V DC indication, the policy of maintaining consistency applies. This includes using 50V DC for all indications.

Interposing relays being driven by the RTU require 50V operating coils to suit the RTU I/O cards.

6.10.2.11.2 Free Wheel Diodes on 50V Interposing Relays

Free wheel diodes are to be installed on any new or replacement 50V DC interposing relays. These are required to stop the dissipation of inductive switching impulses from triggering spurious alarms in the RTU.

Drawings are required to explicitly show these diodes.

6.10.2.11.3 Automatic Voltage Control

All power transformers shall have an automatic voltage regulator (AVR).

Substation power transformers with dual secondary windings shall have a separate AVR relay for each winding. In order to avoid LV over voltage problems, a tap ‘raise’ shall require both AVRs to issue a tap ‘raise’ command. Either AVR may initiate a tap ‘lower’ command.

6.10.2.11.4 Transformer Paralleling Control

Transformer paralleling control is to be performed by a hard-wired scheme or transformer paralleling relays. Use of the RTU is not acceptable.

6.10.2.11.5 Automatic Switching Scheme

Automatic switching schemes (ASS) shall be performed via Automation.

6.10.3 Alarms

6.10.3.1 Local Display of Alarms

Local display of alarms has the following design requirements:

- All alarms in a substation that are sent to EPCC shall be available locally.
- Unless otherwise indicated, substations with HMIs or data display units shall have all alarms available at the HMI or data display unit. Both fleeting and latched alarms shall be displayed in the HMI or data display unit log until reset by a local or remote operator.
- Multiple data display panels shall be in the same location when possible. They shall be in their own cubicle or box which is clearly labelled ‘Alarm Panel’.
- Alarms sent to the RTU via a protection relay shall be available as LEDs or an LCD display on the protection relay. All alarms must be available from the front of the protection relay with no button presses required.
- Trip alarms, including transformer mechanical trips, are required to be accessible in a manner that is independent of Automation. This provides local indication of operation if the Automation system is out of service. This may be via flag relays, relay LCD displays or LEDs.

Alarms utilising a LED bank or lamps for local indication shall be clearly labelled to indicate which LED(s) or lamp(s) refer to which alarm.

6.10.4 Gas Insulated Switchgear

Gas insulated switchgear (GIS) equipment shall have individual gas pressure alarms provided at the GIS switchgear. A low gas pressure alarm for each circuit shall be provided at the substation’s local display and sent to EPCC. Local display can be by a HMI, data display unit or flagging relay.

6.10.5 Metering

Refer to Appendix F for metering examples.

6.10.5.1 General Metering Requirements

If an HMI is installed, all metered values shall be available at the HMI.

The Automation device is typically a protection relay.

6.10.5.1.1 Single Device Independent of the Automation Device

Examples of single devices independent of the Automation device are ammeters, volt meters and ion meters.

6.10.5.1.2 Two Independent Devices

When duplicated local metering is required, the intent is to have at least 1 means of local metering available for the loss of:

- One Automation device or
- The RTU. This is relevant when an HMI is used as an independent device. The HMI is independent from a specific Automation device if the metering is derived independently from the specific Automation device (e.g., a different Automation device or a transducer).

6.10.5.2 Distribution Feeder Circuit Metering

6.10.5.2.1 Current (Amp)

- Local metering:
  - A single device independent of the Automation device or
  - Two independent devices displaying feeder current. These may be driven from a common CT core.

    At least one of these devices shall:

    - Have the current as the default display and
    - Require no user intervention to display the current

On double circuit terminations, local display of both cable currents is required. This may be achieved by ammeters or fault indicators that display load current. In this case, only a single device displaying total feeder current is required.

- Remote metering is required. Only one of the local displays is required to be sent to EPCC.

Remote metering of both cables is required on double circuit terminations.

6.10.5.2.2 Power Factor, MW, MVAR

- Local metering is required if the substation has an HMI
- Remote metering is required

6.10.5.3 Capacitor and Reactor Circuit Metering

6.10.5.3.1 Current (Amp)

- Local metering by a single device displaying capacitor / reactor current is required[29]. This device shall:
  - Have the current as the default display.
  - Require no user intervention to display the current.
- Remote metering is required.

[29] On LV switchboards the designs allow a circuit to be used for either a feeder or capacitor, so switchboard capacitor designs typically have two metering devices.

6.10.5.3.2 MVAR

- Local metering is required if the substation has an HMI.
- Remote metering is required.

6.10.5.3.3 Voltage (if plant is connected to a bus without a remote voltage measurement)

- Local metering is required if the substation has an HMI.
- Remote metering is required.

6.10.5.4 Transformer Circuit Metering

6.10.5.4.1 LV Current (Amp)

- Local metering must be provided by two independent devices displaying LV current.

These may be driven from a common CT core.

One of the devices may be an LV current ammeter in the tap changer control cubicle.

In addition to the ammeter in the tap changer cubicle at least one of the devices shall

  - Have the LV current as the default display.
  - Require no user intervention to display the LV current.

  For transformers with dual LV windings, these requirements apply to each winding.

- Remote metering is required. Only one of the displays is required to be sent to EPCC.

6.10.5.4.2 HV Current (Amp)

- Local metering shall be provided by two independent devices where a transformer has:
  - A load carrying tertiary, other than the station supply, or
  - Dual LV windings.

These devices:

  - May be driven from a common CT core.
  - One of the devices may be an HV current ammeter in the tap changer control cubicle.
  - In addition to the ammeter in the tap changer cubicle at least one of the devices shall
    - Have the HV current as the default display.
- Remote metering is required. Only one of the displays is required to be sent to EPCC.

6.10.5.4.3 TV Current (Amp)

Where a transformer has a load carrying tertiary winding, other than the station supply, the requirements for transformer LV current given above apply. When the only load on the tertiary winding is the station supply one local metering device is sufficient.

6.10.5.4.4 TV Voltage (if plant other than a station supply is connected to the TV winding)

- Local metering is required if the substation has an HMI.
- Remote metering is required.

6.10.5.4.5 LV Voltage (Phase – Phase Volts)

- Local metering shall be provided by two independent devices displaying phase-phase voltage:
  - These may be driven from a common VT.
  - One of the devices may be a voltmeter in the tap changer control cubicle.

  For transformers with dual LV windings, these requirements apply to each winding.

- Remote metering is required. Only one of the displays is required to be sent to EPCC.

6.10.5.4.6 LV MW and MVAR

- Local metering is required for each load carrying LV or TV winding (other than the station supply) if the substation has a HMI.
- Remote metering is required for each load carrying LV or TV winding (other than the station supply).

6.10.5.4.7 Winding and Oil Temperature (°C)

- Local metering shall be provided at the transformer. Only required locally if the substation has a HMI.
- Remote metering of HV winding and oil temperature is required on all transformers. Remote metering of LV winding temperatures is required for dual LV windings.

6.10.5.5 Bus-Section Circuit Metering (Including Bus-Couplers)

6.10.5.5.1 Current (Amp)

- Local metering shall be provided by a single device displaying bus section current. This device shall:
  - Have the current as the default display,
  - Require no user intervention to display the current.
- Remote metering is required.

6.10.5.6 Busbar

6.10.5.6.1 Volts

- Local metering is only required locally if the substation has an HMI.
- Remote metering is required*.

These requirements do not apply to the ‘A3’ bus-sections in the standard LV switchboard ‘5 bus-section’ arrangement.

*Remote metering of busbar volts via the protection relays is acceptable when a bus VT is not available.

6.10.5.7 Line Circuit Metering

6.10.5.7.1 *Current*

- Local metering must be provided by either:
  - A single device independent of the Automation device or
  - Two independent devices displaying current. These may be driven from a common CT core.

    At least one of the devices shall:

- Have the current as the default display.
- Require no user intervention to display the current.

- Remote metering is required. Only one of the displays is required to be sent to EPCC.

6.10.5.7.2 Voltage

Phase - phase voltage is preferred. Single-phase voltage is acceptable if two voltage transformers are not available.

- Local metering must be provided by either:
  - A single device independent of the Automation device or
  - Two independent devices displaying phase-phase volts. These may be driven from a common VT core.

    At least one of the devices shall:

    - Have the voltage as the default display.
    - Require no user intervention to display the voltage.   -
- Remote metering is required. Only one of the displays is required to be sent to EPCC.

6.10.5.7.3 MW and MVAR

- Only required locally if the substation has an HMI.
- Remote metering is required.

6.10.5.8 Gas Insulated Switchgear

Gas Insulated Switchgear shall have individual gas pressure metering for each gas compartment. These are only required at the GIS switchgear.

7 New Circuits (IEC61850)

7.1 Interlocking

All non-mechanical interlocking shall be implemented using the IEC61850 protocol. The interlocking logic is implemented in the IEDs associated with the primary equipment being interlocked.

An interlocking logic diagram showing the functional requirements must be created. The logic diagram will be produced as a .dgn file and issued as part of the drawing package.

7.2 Fault Recorder

7.2.1 Digital Inputs

Output contacts from the HV goose manager 1 and HV goose manager 2 relays are hardwired to individual fault recorder inputs. This puts a mark on the fault recorder recording for any trip by a relay in the IEC61850 system and is used to time circuit breakers.

7.3 Cubicles

The IEC61850 cubicle designation must appear on schematics to allow the field to find the location of relays and other equipment. This is shown in the top right-hand corner for landscape drawings and bottom right hand corner for portrait drawings. Drawings with multiple circuits have equipment enclosure boxes drawn around the equipment with the cubicle IEC61850 cubicle designation in the box.

Each fault recorder requires a separate cubicle.

7.3.1 Cubicle Designation

Cubicles are designated following the IEC61850 naming convention.

7.3.1.1 Zone Substations

Cubicles are designated sequentially starting at UH1. Protection cubicles use the voltage and battery number to uniquely identify cubicles. The designation for the first 132 kV protection 1 cubicle would be E8F1UH1. The first protection 2 cubicle would be E8F2UH1. Marshalling boxes are given a UH number only.

7.3.1.2 Terminal Yards

Cubicles are grouped per bay in a logical sequence. Space should be left to add additional cubicles when a bay is incomplete. Space should also be left to add an additional cubicle to a complete bay if possible.

Cubicles are designated according to what bay the equipment is in. The numbering is demonstrated below:

UH1 to UH49 – General protection equipment such as bus zone, UFLS, Goose Managers.

UH50 to UH99 – General field equipment such as marshalling boxes

UH100 to UH110 – Bay 1 protection equipment

UH111 to UH199 – Bay 1 field equipment such as field cubicles and marshalling boxes.

UH200 to UH210 – Bay 2 protection equipment

UH211 to UH299 – Bay 2 field equipment such as field cubicles and marshalling boxes.

7.3.2 DC Supply

Western Power has a main and a backup protection system. Refer to *Protection Design Guidelines – LV Switchboard Protection,* Section 10.2 for an explanation of how the DC supplies are incorporated in these two systems.

7.3.2.1 Cubicles

- Each cubicle has its own DC supply drawing. A DC supply terminal strip at the top of each cubicle supplies the fuses on the top-front of the swing frame door.
- Individual supplies from the 110V paralleling board supply the following:
- Protection 1 – all cubicles.
- Protection 2 – all cubicles.
- Field cubicles will be supplied from the HV protection cubicle that is associated with its location. The field cubicle will provide the DC supplies for the I/O relays, AVR, MVR and transformer equipment.

7.3.2.2 LV Goose Managers and LV Switchboards

A P1 and a P2 supply from the 110V paralleling board will supply the combined LV goose manager / protection cubicle for each switchroom. The terminal strips supply fuses for:

- P1 goose manager.
- P2 goose manager / busbar protection relay.
- P2 transformer LV protection relay.
- The P1 relays located on the switchboard.

7.3.3 Arrangement

Generally, IEC61850 designs have battery 1 and battery 2 protection relays located in separate cubicles. At least two cubicles are therefore required when circuits require two protection systems.

All equipment associated with a protection scheme must be laid out in a logical manner and in the same cubicle. An exception is where the input/output relay and withdrawable white isolation link are in the field cubicle.

When multiple circuits are in the same cubicle, no more than two circuits may be located per row.

7.3.3.1 Combined Cubicle

Refer to Section 6.2.3.1.2

7.3.3.2 Protection Circuit Assignment

When assessing what protection circuits are assigned to each cubicle it is important to ensure that line circuits are in multiple cubicles. This builds redundancy into the protection cubicles (i.e., if one cubicle fails then the site will still have a line circuit to supply the site).

7.3.3.3 Terminal Strip Configuration

Like the device arrangement, there is a maximum of 2 protection circuits sharing a common DIN rail.

The terminals shall be located such that it is obvious which circuit they belong to. The terminal strip should be positioned at the same level as the protection device it is associated with.

7.3.4 Equipment Location

7.3.4.1 Goose Managers

A goose manager is a device used to communicate between protection IEDs. Generally, there is one goose manager for each busbar.

7.3.4.1.1 HV Goose Managers

The protection 1 HV goose manager is in one of the Protection 1 HV cubicles. Similarly, the protection 2 HV goose manager is in one of the Protection 2 HV cubicles.

7.3.4.1.2 Combined Goose Manager Cubicle

A single combined goose manager cubicle can be installed where space does not permit two cubicles. The combined goose manager cubicle is split into a P1 area and a P2 area.

The LV protection 2 goose manager function is performed by the busbar low impedance protection 2 relay. This relay, the protection 1 goose manager and the transformer LV P1 relay are located in a combined P1 goose manager / P2 bus zone cubicle located in the switchroom.

7.3.5 Field Cubicle

Field cubicles are used to house input / output relays as well as the AVR and MVR relays for transformers.

Field cubicles are located adjacent to secondary cable trenches with the foundation incorporated into the cable trench layout. The distance from the location of the cable in the trench to the field cubicle gland plate must be greater than the bending radius of the copper and fibre cables.

The preferred location of the field cubicle is close to the HV busbar such that it doesn't restrict primary plant maintenance access.

The field cubicle is orientated such that the front door faces southward. The protection relays are located on the front door such that direct sunlight does not heat up this surface.

The field cubicle door must not open onto the secondary cable trenches or any obstruction. The door must be able to open to its fully open position.

A field cubicle will typically have the following circuit configurations:

- Transformer circuit + line circuit
- Line circuit + line circuit (where there are three lines).
- Transformer circuit + transformer circuit (double wound secondary)

Field cubicles and devices are treated as protection 1 equipment.

7.3.6 AVR/MVR relay location

The following order of preference must be adhered to when deciding the best location for the AVR/MVR relays:

- In the marshalling box
- In the field cubicle associated with transformer.
- In the main relay room in the protection cubicle associated with the transformer.
- In a new stand-alone field cubicle.
- The AVR and MVR devices are treated as protection 1 equipment.

7.3.7 Protection Cubicles

There will be a minimum of two Protection cubicles for all IEC61850 applications. One Protection cubicle is assigned to protection 1 and the other to protection 2. This ensures segregation between protection 1 and protection 2.

7.3.8 Finish

- New cubicles and associated plates must be Duralloy 'Classic Cream Satin 50 Gloss', 2722095S
- New plates on existing equipment must match the existing equipment (e.g., the note on the drawing does not need to be changed). If the colour is Cream then Duralloy 'Classic Cream Satin 50 Gloss', 2722095S is acceptable.
- A drawing superseding an existing drawing must specify the same finish as the original drawing.
- If a colour is not available (e.g., Green), then brushed aluminium is acceptable.
- Plates on dexion to be brushed aluminium.
- Dexion colour to be decided by construction.

The 80mm standoff label holder plates (used in the rear terminal strip area) shall have a brush finish. The 80mm offset is so that the label holder plate is flush with the 80mm ducting.

7.3.9 Optic Fibre Management

7.3.9.1 Cubicles

A minimum of one optic fibre cassette is required in the protection cubicles and field cubicles.

All protection IEDs will be connected between the optic fibre cassettes and the IED communication devices via an optic fibre. These optic fibre connections will be defined on the internal fibre connection schedule.

7.4 Room Layout

7.4.1 Main Relay Room

- The following IEC61850 equipment is located in the main relay room:
- Automation cubicles
- Protection cubicles
- Antenna(s) for the IRIG B interface(s)

- Protection 1 cubicles shall be grouped together and P2 cubicles grouped together when possible

8 Asset Replacement

Bringing designs up to current standards is desirable when practical. The following guidelines should be considered when updating designs:

- When replacing relays, it is generally practical to update the designs based on current templates. However, it may not be cost effective to update the primary equipment alarms and indication if re-wiring the primary equipment is required.
- When replacing primary equipment, it is generally practical to update primary plant alarms, control, and indication.

8.1 Cubicles

8.1.1 Arrangements

DNP designs typically use combined cubicles with protection 1 and 2 for a circuit in the same cubicle. Protection 1 is above protection 2. Refer to Section 6.2.3.1.2.

Replacing an obsolete protection relay should prompt a review of the entire protection scheme. It is often the time to base the new designs on the current design template. There may also be opportunities to replace existing hardwired logic with the logic in the new relay. Replacing many existing electromechanical or electronic relays with a single numerical relay frees up space in the cubicle.

It is not acceptable to have equipment associated with a circuit and protection in more than one location. All equipment associated with a circuit and its protection must be on the same section of the same cubicle.

8.1.2 Mounting Plates

8.1.2.1 New Mounting Plates

In general, if there is more than a 50% change with the panel or cubicle it is better to have new mounting plates with new equipment mounted and wired. Under the outage the existing equipment will be removed, and the new plates and terminal strips mounted and wired back. The old equipment is then reused. If there are only a few items, then a modification in situ is required.

Care must be taken to ensure that that the field cables are long enough to re-terminate if new terminal strips are installed. If the field cables are not long enough, then the strategy must be reconsidered as running new field cables is expensive. Refer to Secondary Cables section.

8.1.2.2 Fabricating at Kewdale

It is often more efficient to fabricate dexion plates and mount equipment in workshops rather than fabricate on site. The requirement for these measurements should be noted in the Scope of Design Works. Plate details showing the exact measurements of the existing dexion rack are required. These measurements should be made during the Detailed Design Site Visit.

8.2 Circuit Breaker Replacement

Western Power's standard circuit breaker design for 220 kV and 330 kV requires single pole circuit breakers. Substation Design must be consulted if an asset replacement requires 3 single pole circuit breakers to be wired as a 3-pole circuit breaker.

8.2.1 Cut Throats

In older designs a normally open auxiliary contact cutthroat was placed between the circuit breaker's negative terminal and the negative supply. The purpose of this cutthroat is to break the trip coil current when the circuit breaker is opened because older relays did not have contacts rated to break the current. The auxiliary contact cutthroat should be removed when replacing the circuit breaker. New circuit breakers have an auxiliary contact incorporated in the trip circuit. New protection relays have rated contacts.

8.2.2 Trip Circuit Supervision

Some older designs did not have a TCS scheme or had one that consisted of a push button. The push button only monitored the trip coil while it was pushed. In these cases, a TCS scheme must be implemented with:

- A single element scheme when the protection relay can provide this or when the protection relay is replaced.
- A two-element scheme. The test lab should have spares of the older two element relays. If none are available, then a new numerical relay is required.

It is unacceptable to work on a circuit that contains a trip coil and does not include a single or two element TCS scheme.

8.3 Relay Replacement

Refer to Section 7 covering New Circuits (IEC61850) when DNP relays are replaced with IEC61850 relays.

8.3.1 Trip Relays

8.3.1.1 Parallel Trip Relays

Trip relays should not be wired in parallel. When parallel trip relays are found in existing drawings a calculation must be made demonstrating that the relay contact is rated to make and break both trip relays. This must be documented in the substation design report.

When a trip contact is required and there are no spares on the existing trip relay the following options are available:

1. Add another trip relay driven by a dedicated contact on the protection relay.
2. Replace the trip relay with one that has enough trip contacts.

The choice between option 1 and 2 will depend on the cost of revising the settings versus the cost of recommissioning the existing trip relay wires.

8.3.1.2 Dedicated Contacts

A trip relay contact cannot be sent to two destinations.

8.3.1.3 *Parallel Contacts*

An output from a trip relay must not be paralleled to different destinations.

8.3.2 Use of Templates

Replacing the protection relay triggers a decision to modify existing drawings or produce new drawings based on current templates. Older designs often have multiple relays performing single functions. Replacing these relays with a single numerical relay often leads to new drawings based on current templates.

8.3.3 VT Wiring

Three-phase voltage must be wired to new numerical relays when available. The VT connections to the relay will depend on the type of relay when only one or two phases are available. The Protection engineer is responsible for determining the VT connections to the relay when all three-phases are not available.

8.3.4 Wire Numbers

Wire numbers should remain the same when relays are replaced when possible. This reduces the need to re-ferrule and revising other drawings. This requires transferring the wire number on the existing drawing to the new drawing.

8.3.4.1 *Continuity Terminals*

It is acceptable to have a wire number change at a continuity terminal when:

- There is inter-cubicle wiring going to other locations.
- Changing the wire numbers on existing wires to other locations results in significant work or costs.

When a protection scheme is replaced, it is preferred to re-ferrule the wires going to the circuit breaker to match the new schematic.

If changing a wire number does not cause additional outages, it must be updated.

Changing a wire number across a continuity terminal must be approved by Substation Design.

8.3.4.1.1 Examples

A feeder DC protection scheme is changed from battery 1 to battery 2. Changing the wire numbers on the wires going to the bus zone scheme requires an outage of the bus zone, therefore it may be acceptable to have the wire numbers change across the continuity terminal.

Changing alarm and indication wire numbers would not normally require an outage, therefore they must be updated.

8.3.4.2 *Change in Protection System*

It may be necessary to change wire numbers when protection schemes are altered. Below are some examples:

- When moving a protection scheme from one battery to another.
- When the function changes the prefix changes (e.g., if an auxiliary contact changes from an indication function to an interlocking function, the prefix changes from L to K).

8.3.4.3 Update to Current Standard

Wire numbers must be updated to current standards when:

- A wire will need to be recommissioned. Common sense needs to prevail with this direction. If only a few wires at a substation are recommissioned, then it is better to keep the wire numbers consistent at that substation.
- At older sites with a mimic panel, the wire number often indicates it is going to the mimic. If the mimic is removed, then the wire number needs to be updated.

8.4 Terminals

Existing bakelite terminals must be replaced when a cubicle or dexion rack is rebuilt if their replacement does not require an additional outage.

8.5 Secondary Cables

Generally, new secondary cables being run to primary plant are first terminated in a marshalling box. Brown field sites may have cables run directly to the primary plant. When additional cables are required for these circuits, it is acceptable to run them directly to the primary plant (i.e., we don't add a marshalling box).

8.5.1 Field Wiring

Replacing field wiring is expensive and should be avoided whenever possible. A common problem encountered at older sites is field wiring being terminated at the floor level of cubicles. An acceptable solution is to:

- Replace the existing bakelite terminals at the bottom of the cubicle with new continuity terminals and terminal strips.
- Install new terminals in the respective area of the cubicle or rack and wire from these terminals to the new terminals at the bottom of the cubicle or rack, basically treating the new terminal strip at the bottom as a marshalling point. This has the following advantages:
  - Field wiring does not have to be replaced
  - The new terminals and wiring is segregated
  - New terminal types and terminal strips meet current standards of labelling and function.

When replacing field wiring is required and involves civil work the project manager must be notified.

8.5.2 Cable Replacement

The following general statements can be made about cable replacement:

- Secondary cables between the CTs or VTs and the marshalling box are replaced when the CT or VT is replaced.
- Secondary cables are replaced between the CTs or VTs and the relay room if the CTs or VTs and the marshalling box are replaced.

8.6 Metering

In the past, metering equipment was sometimes included in the protection circuit. When this occurs:

- Ammeters and transducers should never be wired in series with the protection relay. It is acceptable to isolate these from the protection circuit with a metering interposing CT. The IPCT will also saturate, thus protect the ammeter and other metering equipment from damage caused by fault current.
- When replacing the CT with a CT that includes a metering core, the existing metering equipment is not necessarily removed from the protection circuit. The metering equipment is moved to the new metering core if the protection relays are replaced or a metering IPCT is required.

Metering equipment should always be connected to a metering class CT. If a replacement CT does not contain a metering core, the metering circuit must include a metering class IPCT. This protects downstream metering equipment from damage caused by fault current.

8.6.1 Ammeters

Refer to Appendix G for specification examples.

8.6.1.1 Over Scaling

Ammeters connected directly to a current transformer are specified 25% over scale. Ammeter connected to a transducer are typically not specified over scale.

8.6.1.2 Dual Scale

Dual scale ammeters are used on some country feeder circuits where the load is significantly lower than the CT ratio.

8.6.1.3 Maximum Demand

Maximum demand ammeters were installed before remote metering was performed by Automation. Maximum demand ammeters and the associated selector switch must be removed when remote metering is performed by Automation.

8.6.2 Voltmeters

Refer to Appendix G for specification examples.

8.6.2.1 Scaling

Voltmeters connected directly to a voltage transformer are scaled +/- 20%.

8.6.3 Statistical Metering

Brownfield sites may have older statistical metering equipment. This equipment requires paper replacement and on-site personnel to read the graphs. This function is now done by numerical relays so the older equipment can be removed.

8.7 Fault Recorders

8.7.1 Cubicles

Fault recorders require an offset swing frame (S/N FB 0130) when installed in swing frame cubicles. The fault recorders are too large for the swing frame door to open when centred.

Each fault recorder requires a separate cubicle.

Fault recorder designs communicating with a modem require a power supply. Power supplies may be hardwired and mounted on a DIN rail. Fault recorder designs communicating via the LAN do not require a power supply.

8.7.2 AC Current Measurement

Two different types of devices are used to measure currents in fault recorder designs. Current shunts are used on new circuits and CICTs are used on existing circuits. CICTs are slightly more expensive but do not require disturbing the secondary wiring.

The following are standard currents required by the fault recorder:

- Line phase currents
- Transformer HV restricted earth fault current (REF)
- Transformer LV standby earth fault current (SBEF)
- Transformer LV phase currents

8.7.2.1 CICT Orientation

The red wire on a current shunt is equivalent to the dot point on a CICT. The following convention is used to orientate current shunts and CICTs:

- HV Line and LV transformer phase currents – dot point faces the phase wire.
- HV REF and LV SBEF –dot point faces the wire closest to the primary system earth

8.7.2.2 Fault Recorder Current Polarity

A positive secondary current flowing into a current shunt or a CICT will produce a positive current flowing out of the current shunt or CICT.

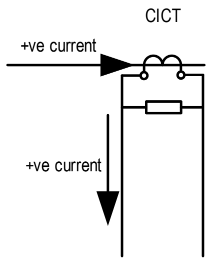


Figure 8.1: CICT current flow

The polarity of the currents at the fault recorder will determine if the current is displayed as a positive graph or a negative graph. A positive current flowing into a fault recorder positive terminal will result in the current being displayed as positive. A positive current flowing into a fault recorder negative terminal will result in the current being displayed as negative. Generally, Investigations require that the LV SBEF current be displayed as negative and the LV phase currents as positive. The following rules ensure the fault recorder displays the correct graphs to meet investigation's requirements:

- HV currents (including line phase currents, transformer REF and autotransformer HV/LV REF). Current from the dot point flows into the positive terminal of the fault recorder channel.
- LV currents (including transformer LV SBEF and phase currents). Current from the dot point flows into the negative terminal of the fault recorder channel.

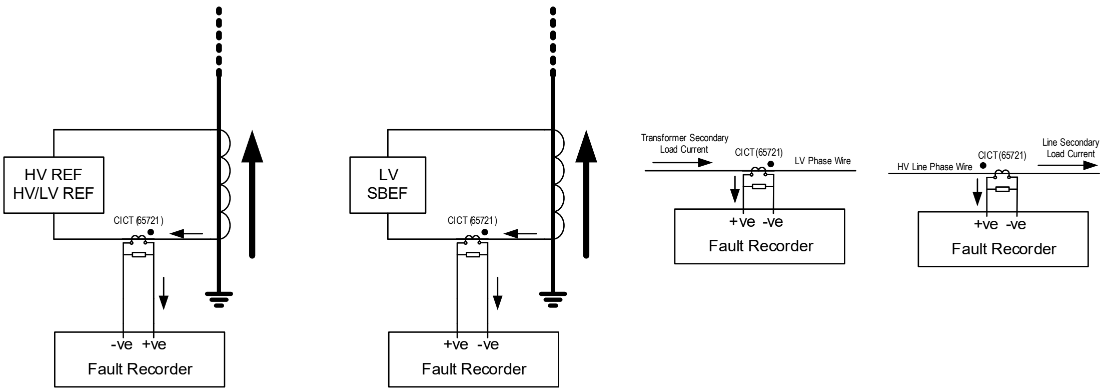


Figure 8.2: Fault recorder polarity

8.7.2.3 *CICT Location*[30]

Current shunts are physically located to minimise disturbing secondary wiring and minimise running cables.

- Transformer HV REF CICT is located on the HV REF secondary circuit.
- Transformer LV SBEF CICT is located in the LV SBEF secondary circuit.
- Transformer LV phase CICT's are located in the differential circuit. The differential circuit is preferable to the LV overcurrent because it provides information on the currents the main protection relay detects.

When the transformer LV differential CT is delta connected it is necessary to locate the LV CICTs in the star connected LV overcurrent circuit[31].

When there is a star / delta IPCT in the transformer LV differential circuit, the CICTs must be located on the star side.

8.7.3 Fault Recorder Cables

Cables used for Fault Recorders applications shall have twisted pairs, and overall screen. (e.g., ED1057)

The following practices shall be followed for cable allocations:

- Multiple CT analogue signals can be run on the same multi pair cable (typical would be 3 or 4)
- AC and DC cables need to be routed in separate ducts on separate side of the rack
- Cable sheath should be run as close as practical to termination point. Maximum distance of unsheathed pairs is 500 mm (typically this would be the run from the duct to the terminals at the back of the FR)
- When unsheathed, pairs shall remain twisted.

8.7.4 Fault Recorder Cross Triggering

Trip relays used for fault recorder cross triggering require MOD A by Western Power (e.g., 65983 MOD A).

[30] See Western Power Internal Document

[31] This is because the output of a delta connected system is a combination of the phase currents and the fault recorder requires the individual phase currents.

8.8 DC Drawings

8.8.1 Digital Inputs

Digital inputs from individual protection systems are often specified. The following is the order of preference:

1. Normally open contact from the trip relay
2. Normally closed contact from the trip relay (Investigations must be notified so they can configure the fault recorder appropriately).
3. Normally open contact from the protection relay
4. Normally closed contact from the protection relay (Investigations must be notified so they can configure the fault recorder appropriately).
5. Additional trip relays or difficult cable runs must be justified. Investigations must be contacted when a digital input from existing equipment is not available.

8.8.2 Disconnect Terminals

It must be possible to isolate voltages from the fault recorder on existing cubicles. This is usually done with disconnect terminals.

8.8.3 LV Overcurrent

Transformer LV overcurrent is often specified on older I/O allocations. Newer transformer designs incorporate the LV overcurrent function in an HV differential relay therefore this digital input is not required. The I/O allocation should be updated to reflect this.

8.9 Earthing

New designs have neutral earthing on all VT secondary wiring. At older sites there may be white phase earthing. There is also the possibility that the HV may be white phase earthed and the LV neutral earthed.

The fault recorder inputs are independently earthed. Supplying HV volts from a white phase earthing system and the LV volts from a neutral earthing system is therefore acceptable.

Supplying white phase and neutral earthed voltage sources into a changeover scheme is unacceptable. Refer to Section 8.17 on white phase earthing for more information.

8.10 Modem Antenna[32]

A modem is required if the site is not connected to the LAN. The bracket to hold the modem antenna must be included in the PEA.

8.11 Under Frequency Load Shedding

AC reference voltages from the AC distribution board must change to a VT on site when the Under Frequency Load Shedding (UFLS) relay is replaced or when there is significant work being carried out on the UFLS panel.

[32] See Western Power Internal Document

8.12 Protection Operate Recorder Panels

When a protection operate recorder (POR) exists many of the digital inputs required for the fault recorder may already be wired to the cubicle. Therefore, replacing the POR with the fault recorder, rather than building a new cubicle, should be considered.

The POR cubicle may also have a significant amount of obsolete equipment and wiring that also must be considered.

Because POR cubicles are obsolete, they do not require updating during asset replacements.

8.13 LV Switchboard Inboard Current Transformers[33]

Some older LV switchboards have the CT on the busbar side of the bus section circuit breaker (i.e., inboard CT). Inboard CTs cannot easily be accessed on live switchboards and therefore cannot be tested. When a design involves this type of switchboard a cautionary note must be included in the project erection authority.

8.14 Local Close Interlock

The disconnectors on both sides of a circuit breaker must be open before the circuit breaker's local close supply is energised. This is normally done with a hardwired interlock utilising normally closed disconnector auxiliary switches. Older circuits may not have this interlock. When doing asset replacements, this interlock must be added to the designs.

8.15 ION Meters[34]

ION meters are not required when a fault recorder is present.

ION meters are installed on circuits to measure power quality. Typically, they are installed on public transport authority (PTA) circuits or other large customer installations. ION meters are usually installed temporarily but may be long term.

New circuits may be designed with the facility to fit an ION meter. This will require the CT to be specified with a metering class core.

Existing circuits may require a prefabricated unit.

8.16 Synchroscopes

Synchroscopes are used at sites where system synchronising is required. Standard designs include a voltmeter on each side of the synchroscope and a switch to isolate the synchroscope. A fuse and link are required to isolate the voltmeter and synchroscope.

[33] See Western Power Internal Document

[34] See Western Power Internal Document

8.17 White Phase Earthing

Some brown field sites have white phase earthing. IEEE C57.13.3-2005 lists white phase earthing as an alternative to neutral earthing. Refer to Appendix C for the history of white phase earthing.

Neutral earthing is our current standard and preferred, however combining neutral earthing with white phase earthing can cause confusion for commissioning. Therefore, when adding new circuits to brownfield sites with white phase earthing it is important to follow the following rules:

- Generally, when installing new circuits or replacing VTs, the existing VT earthing convention is maintained.
- When adding a new transformer and switchboard to a white phase earthing site, it is acceptable for the switchboard VTs to be neutral earthed. This is acceptable because:
  - The switchboard is in a switch room which is physically isolated from the rest of the yard. Labels are required to indicate the VTs within the switchboard are neutral earthed.
  - Present transformer designs do not require an HV VT. There is therefore no mixture of VT earthing in the HV VT marshalling box.

8.17.1 VT Fuses[35]

VTs may have a secondary fuse protecting the white phase secondary winding. These fuses must be replaced with a link when the scheme is white phase earthed. Blowing the fuse will result in loss of the earth reference. Losing the earth reference can result in voltages dangerous to both personnel and secondary equipment.

8.17.2 Secondary Protection Wiring

White phase earthing requires the white phase to bypass the VT MCB and the neutral to pass through the VT MCB.

Many older sites have a link in the white phase (e.g., UFLS schemes). These links must be removed when the VT marshalling box is replaced (refer to Appendix C.2).

8.18 Insufficient Auxiliary Contacts

When there are an insufficient number of auxiliary contacts the following may be done in order of preference:

- Add additional auxiliary contacts to the existing mech box. This will depend on availability of additional auxiliary contacts from manufacturers and space in the mech box. This is usually not a viable solution for circuit breaker auxiliary contacts.
- Use a repeat relay. Repeat relays are acceptable under the following conditions:
  - Self-resetting relays are used as the repeat relay.
  - Both a normally open and a normally closed auxiliary contact must be brought into a numerical relay directly or via a repeat relay. The numerical relay must do a discrepancy check. In a discrepancy condition the numerical relay must:

[35] See Western Power Internal Document

- – Generate a local and remote alarm.
- – Block functions relying on the state of the auxiliary contacts.
- – It is preferred to avoid using repeat relay contacts in Protection functions. The order of preference for contacts taken from a repeat relay is:
  - – Local status and indication
  - – Automation indication. This indication can then be sent to the control centre via hard wire, DNP or IEC61850 from the relay doing a discrepancy check.
  - – CB status in relay (used for aux contact check CB Fail).
  - – Trip Circuit Supervision (and other Protection functions).
- – Repeat relay contacts must be rated to break currents they are carrying. Repeat relay contacts must be rated to break the trip coil current if used in a TCS circuit.
  - – Relay description 65138 MOD LZ by the Test Lab is fitted with magnetic blow outs across output terminals 2-4 and 6-8 (4 & 8 positive).
  - – When wired in series terminal 8 is positive, terminal 2 is negative and terminals 4-6 form the common. Wiring in series achieves a rating of approximately 4 amps. Refer to Appendix E.2.
- – Repeat contacts are to be shown on the drawings in the de-energised state (normally open). The following note is required on the drawing where repeat contacts are used: "REPEAT RELAY CONTACTS ARE SHOWN NORMALLY OPEN. CONTACT STATUS IS AS PER THE AUX CONTACT DRIVING THE REPEAT RELAY".

Repeat relay logic is outlined in Appendix E.

- Provide an additional mech box and auxiliary contacts mechanically connected to the existing equipment. This is typically done with manually operated disconnectors in outdoor switchgear which do not have auxiliary contacts.

  Status indication alone is generally not a valid reason to add a mechanical device. Valid reasons include:

  - – Interlocking – An example is the transformer HV circuit breaker interlocking with an LV switchboard.
  - – If it is required by a protection system. An example is directing a feeder circuit breaker fail trip and initiate to the appropriate transformer LV circuit breaker.

8.19 TPS Equipment

There are two types of signals coming from Teleprotection Signalling Equipment to the protection relay:

- A 'TPS In Service' signal which comes from a normally open contact on the TPS equipment. If the contact is closed the relay input is high which is interpreted as the TPS system is in service. If the contact is open the relay interprets that the TPS system is out of service. If the TPS system is out of service, the relay reverts to a time stepped distance scheme.
- A 'Received' signal which is associated with the type of teleprotection scheme (e.g., 'Permissive', 'Direct Intertrip' and 'Blocking'). When a permissive or direct intertrip signal is received, the relay can trip. When a blocking signal is received, the relay is prevented from tripping.

Blocking schemes were first used for long lines without dedicated communications schemes. The only way to send a signal was via power line carrier. If a block signal was not able to get through the faulted line, the remote end would be allowed to trip. Today blocking schemes are also used to prevent remote zone 2 tripping for zone 3 (reverse) faults. Under this condition, the block signal is sent to the remote end for a zone 3 fault.

Table 8.1 summarises the state of the TPS received contact and relay input element when TPS is in service.

Table 8.1: Teleprotection / relay state when TPS in service

Protection System	TPS Contact State / Relay Input Element State	
	Received Present	Received not Present
Permissive	Closed / High	Permissive
Direct Intertrip	Closed / High	Direct Intertrip
Blocking	Open / Low	Blocking
Blocking (zone 3)	Closed / High	Blocking (zone 3)

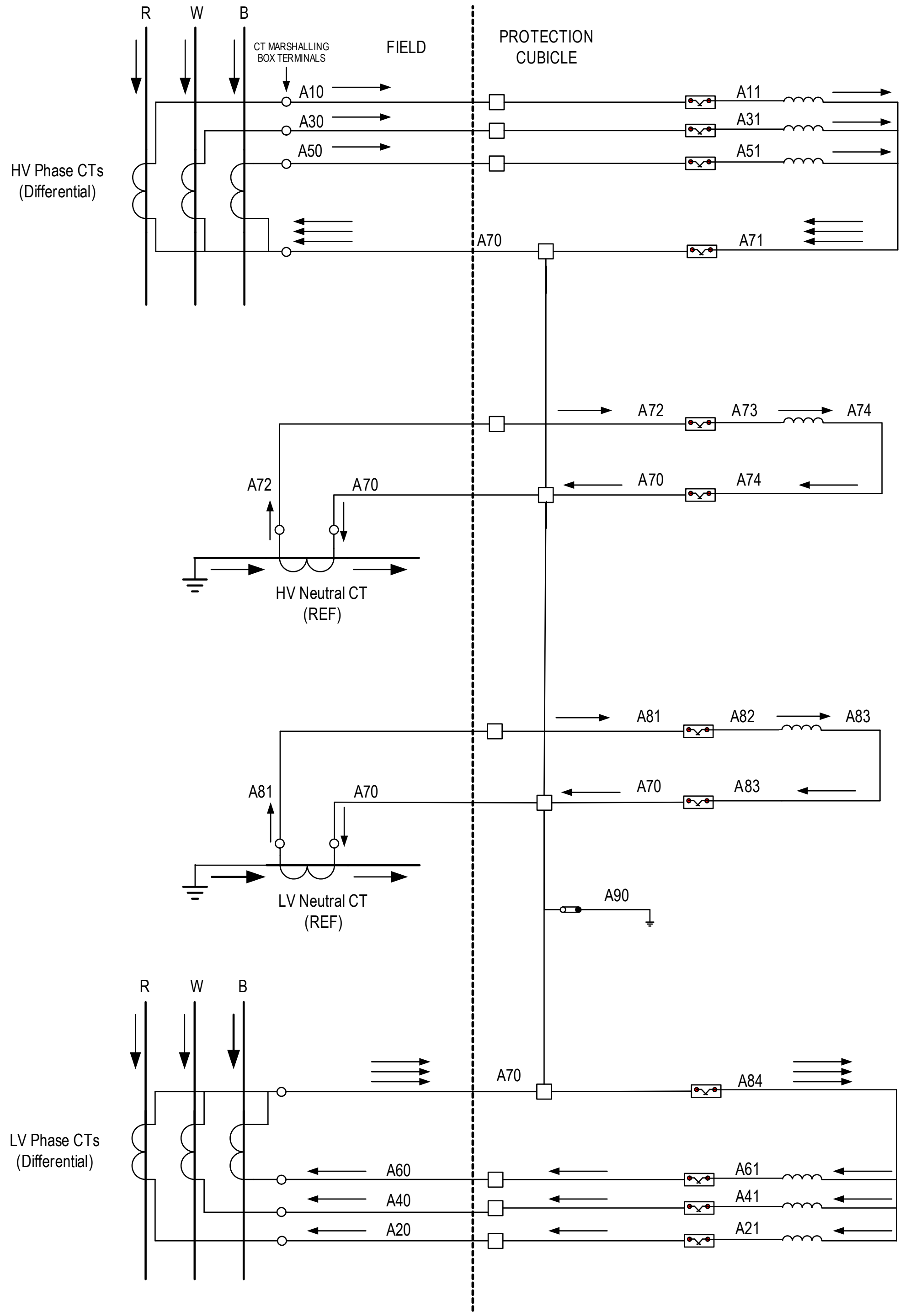
Appendix A: Wire Identification

A.1 Prefix lettering

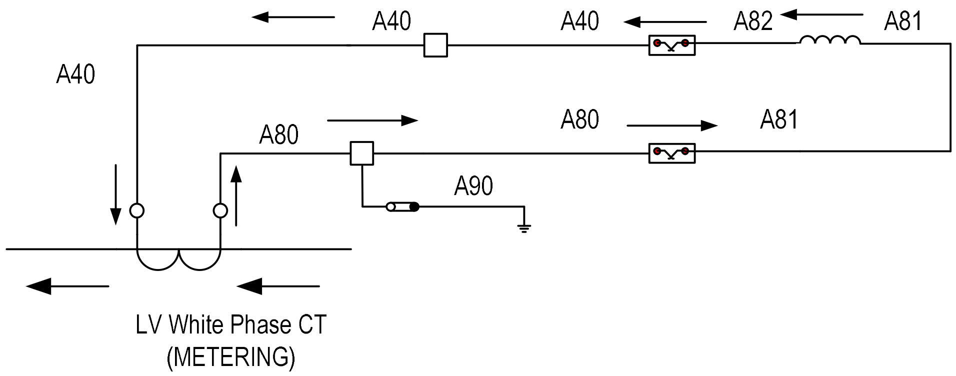
Prefix Letter	Circuit Function	Wire Numbers
A	Current transformers for protection (excluding over current and bus-zone protection).	Protection Number 1 (10-29) Red Phase (30-49) White Phase (50-69) Blue Phase (70-89) Residual circuits and neutral current transformers (90) Earth wires connected directly to the earth bar Protection Number 2 (310-329) Red Phase (330-349) White Phase (350-369) Blue Phase (370-389) Residual circuits and neutral current transformers (390) Earth wires connected directly to the earth bar
B	Current transformers for bus-zone protection.	
C	Current transformers for over current protection (including combined protection devices such as OC/EF relays and protection/ Automation	
D	Current transformers for instruments, metering and voltage control.	
E	Reference voltage for instruments, metering and protection.	
F	Reference voltage for voltage control. This includes automatic voltage control.	
G	Reference voltage for synchronising.	
DD	Output side of current metering transducers.	Any number from 1 upward
DE	Output side of voltage metering transducers.	
DF	Output side of frequency transducers.	
DP	Output side of power factor transducers.	
DR	Output side of reactive power (MVAr) metering transducers.	
DT	Output side of temperature and condition monitoring metering transducers.	
DW	Output side of power (MW) metering transducers.	
H	AC Supplies	240V and 415V AC (410-429) Red Phase
J	DC Supplies.	(3,4) 50V DC Supplies (1,2) DC Battery Number 1 or 2 (32V, 110V or 230V)*
K	Closing, tripping, opening, alarm and indication circuits associated with the protection relay logic. Wire numbers are derived from line referencing	(1000-1999) Circuits supplied from DC Battery Number 1, (1-300 Legacy) (2000-2999) Circuits supplied from DC Battery Number 2 (301-600 Legacy)
L	Alarm and indication circuits initiated by auxiliary switches and relay contacts, excluding those for Automation light current indication and	As for K
M	Motor control circuits e.g., spring charge, transformer cooler and disconnector motors	Any number from 1 upward
N	Tap-changer control, including automatic voltage control, tap position and progress indications	Any number from 1 upward
0	An indication that the ferruling is not in accordance with this general scheme and that if it is not altered; double ferruling will be required for	Any number from 1 upward
P	DC tripping circuits used solely for busbar protection	As for K
R	Interlocking circuits	As for K
S	DC instruments and relays (with the exception of outputs from transducers covered above)	As for K
T	Pilot conductors and their connections to associated protection equipment	As for K
U	Spare cores and connections to spare contacts	Any number from 1 upward
V	Automatic switching circuits not integral to circuit breaker control schemes i.e., separately supplied or isolable from the circuit breaker control	As for K
W	Automation control connections (Legacy)	Any number from 1 upward
X	Automation control connections	As for K
Y	Telephones	Any number from 1 upward

Appendix B: AC Wire Numbers

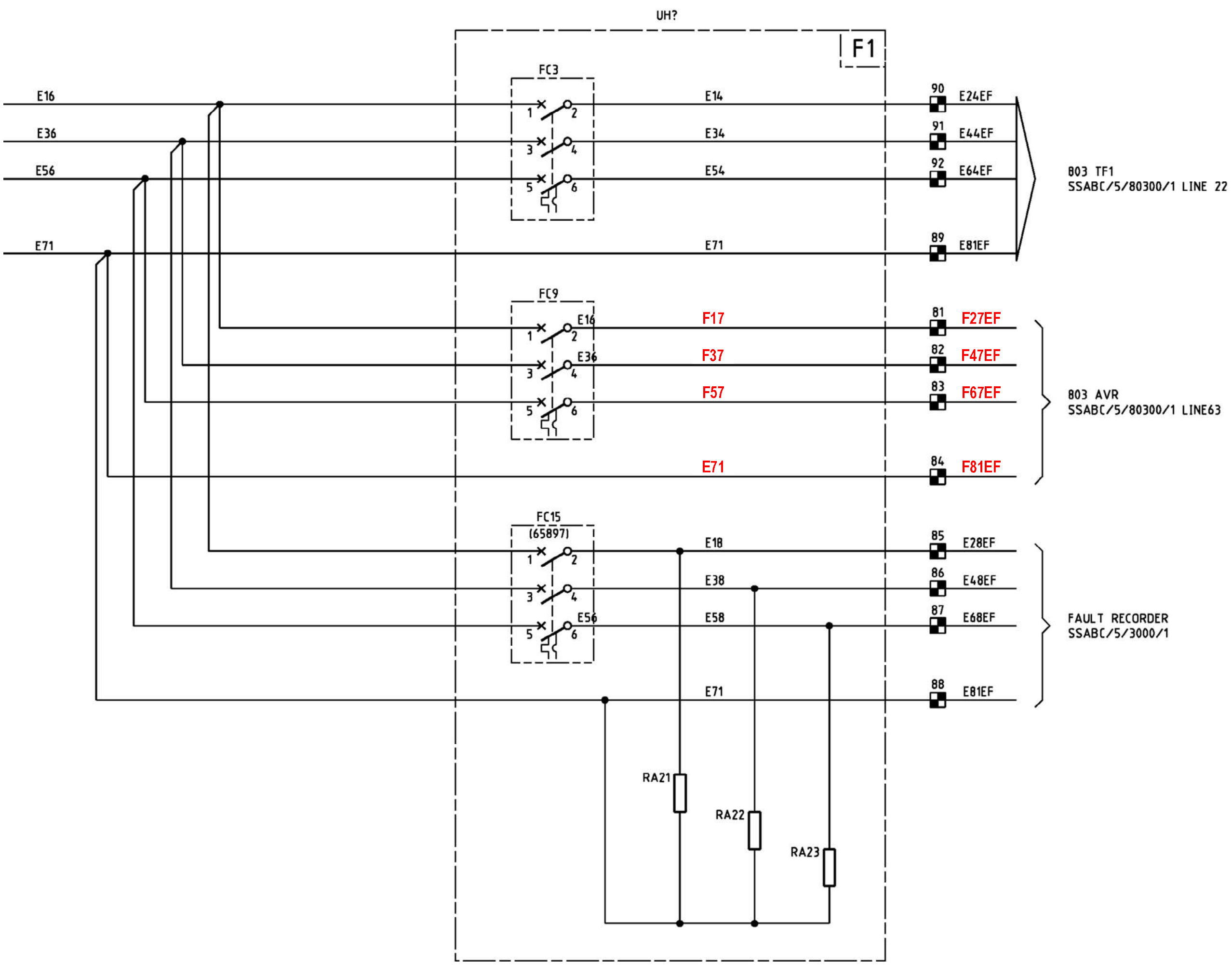
B.1 Transformer Differential Scheme



B.2 White Phase Metering

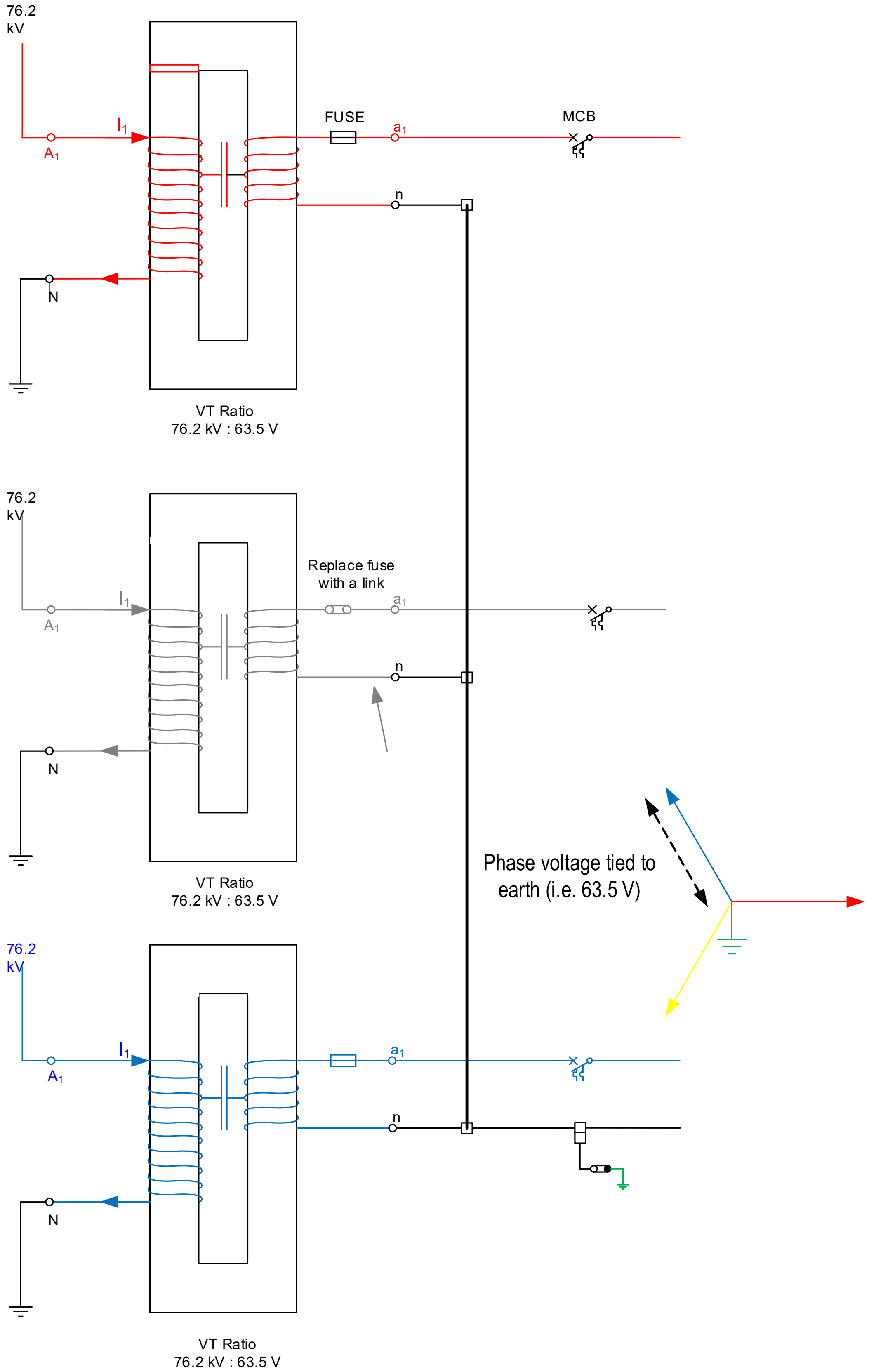


B.3 Prefix Change

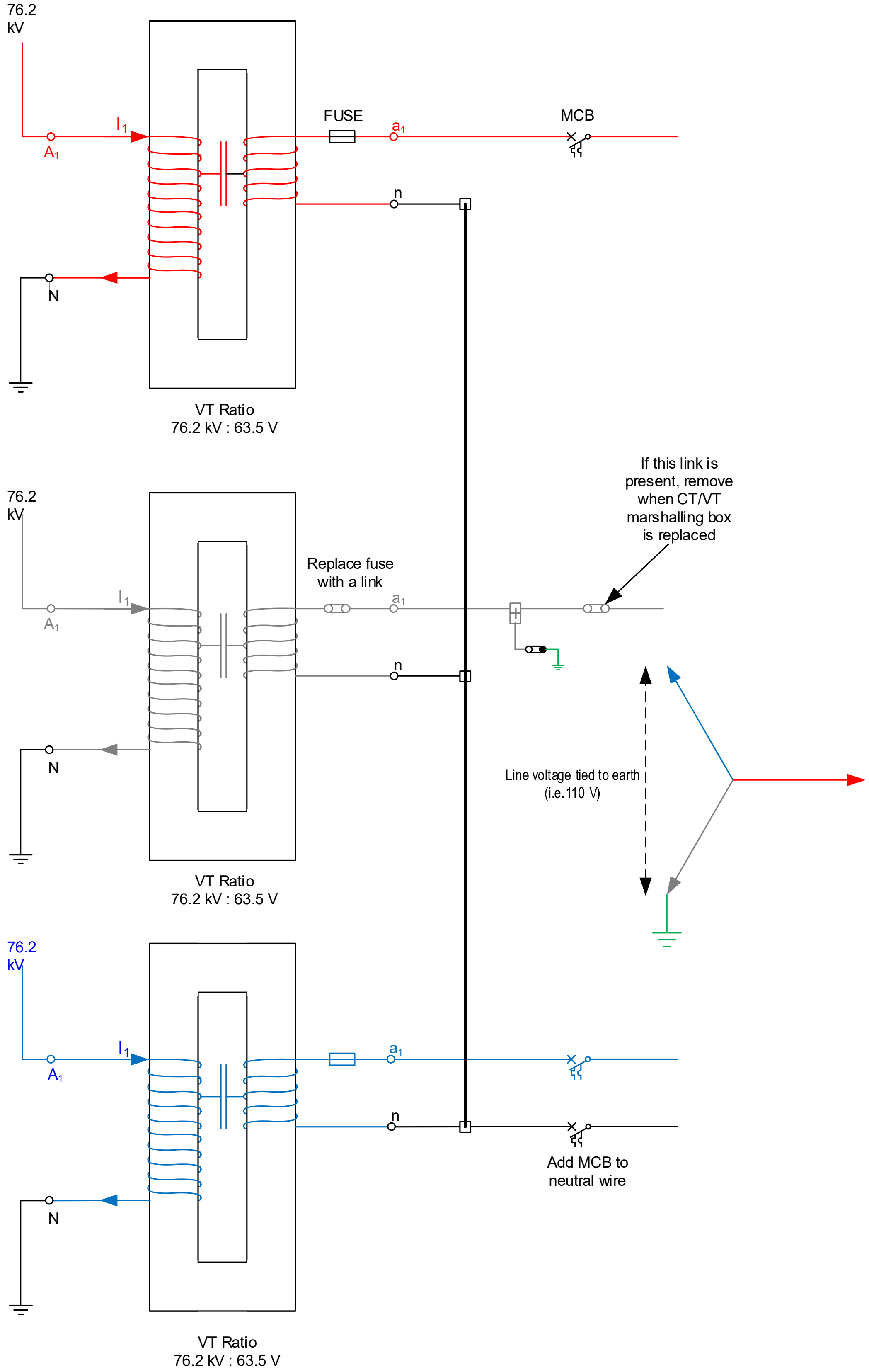


Appendix C: VT Earthing

C.1 Neutral Earthing

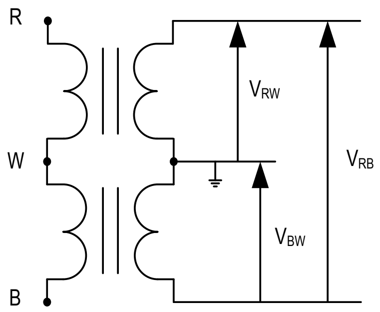


C.2 White Phase Earthing



Originally white phase earthing and the two wattmeter method was used to measure the total power in a 3-phase 3-wire system. The R-W and B-W voltages together with the R and B phase currents provide the information necessary to measure unbalanced 3-phase loads for tariff purposes. All analogue 3-phase kWh and kVArh meters use this principle. By connecting the meter case, the CT star point and the VT white phase to earth, all earth loops, with the errors they can introduce, are eliminated. The white phase is selected because it ties both VT voltages to earth.

White phase earthing was also used to obtain three-phase volts when only two VTs were available:



The advent of distance protection required three star connected VTs. The primary windings are wound phase to earth and one end of the secondary windings is earthed. This reproduces zero-sequence voltages. By this time (the mid-1930s) the white phase earth was the industry standard and was retained. It had been shown that distance protection worked equally well with either the VT secondary star point or the white phase earthed.

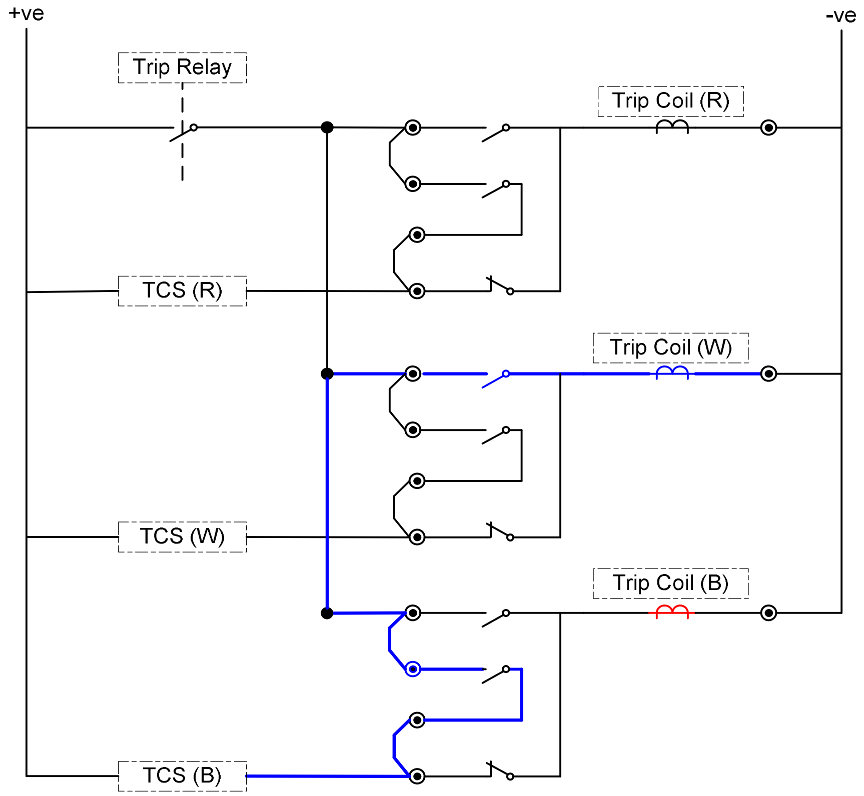
By the 1960s, industry practice was to have separate VT windings for measurement and protection[36]. The white phase earth policy was only retained for measurement VTs. The industry practice for protection VTs became star connected with their neutral points earthed.

On our present system, tariff metering is usually measuring zone transformer secondary voltages. If the tariff metering is numerical, it can easily sum the three Vph-E×Iph×Cosφ quantities – a feat that was impractical in analogue meters.

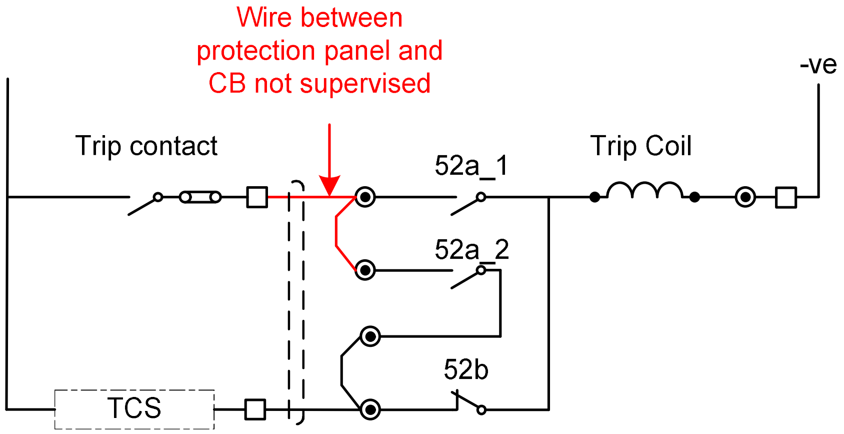
[36] Protection windings require a much higher overvoltage factor to deal with fault transients and are therefore more expensive. The overvoltage factor for measurement windings is less because they deal with the steady state domain of load

Appendix D: Unacceptable TCS Schemes

D.1 Single Pole Non Phase Segregated Tripping Example



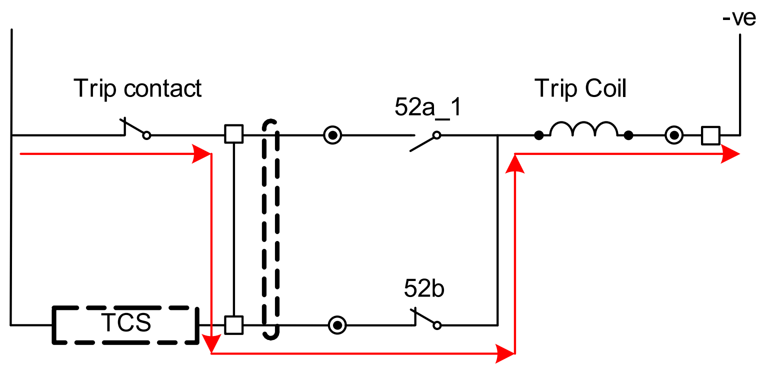
D.2 Circuit Breaker Terminals Shorted



D.3 Single Element TCS without Intermediate NO Contact

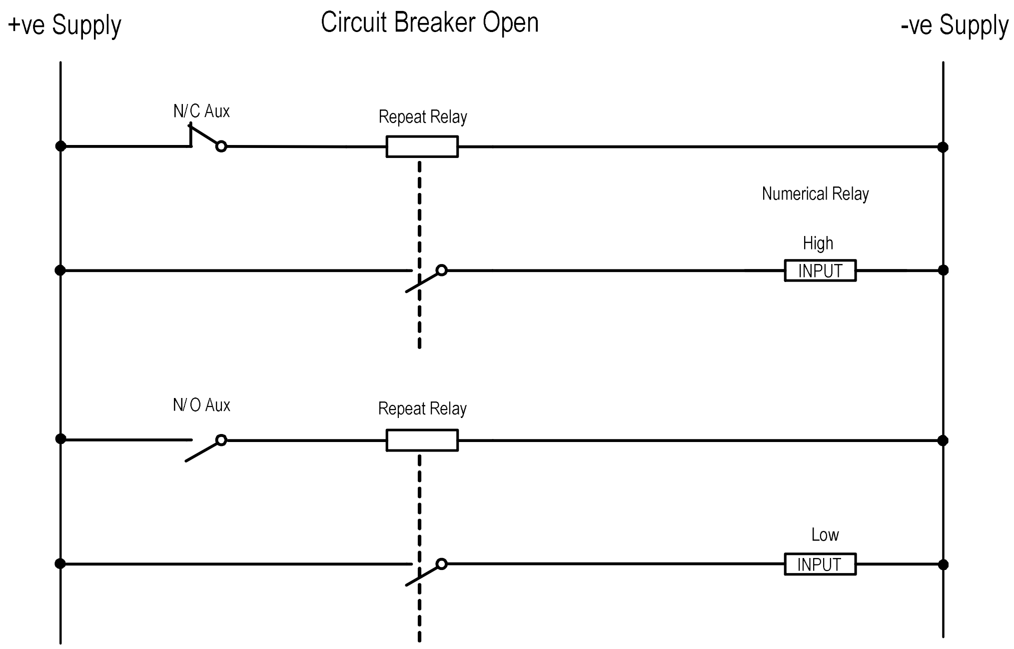
The trip contact and auxiliary contacts are shown in the CB tripped state in the circuit below. The problems with this design are:

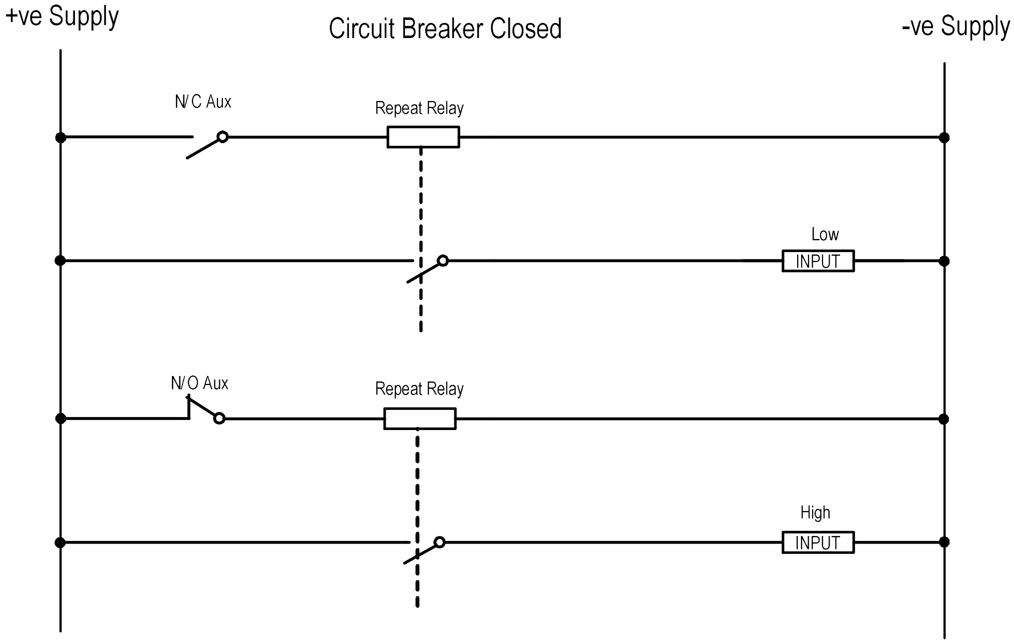
- The trip contact must break the trip coil current when resetting.
- A TCS alarm will be generated if the trip relay is hand reset because the TCS element is short circuited.



Appendix E: Repeat Contact Examples

E.1 Repeat Relay Logic





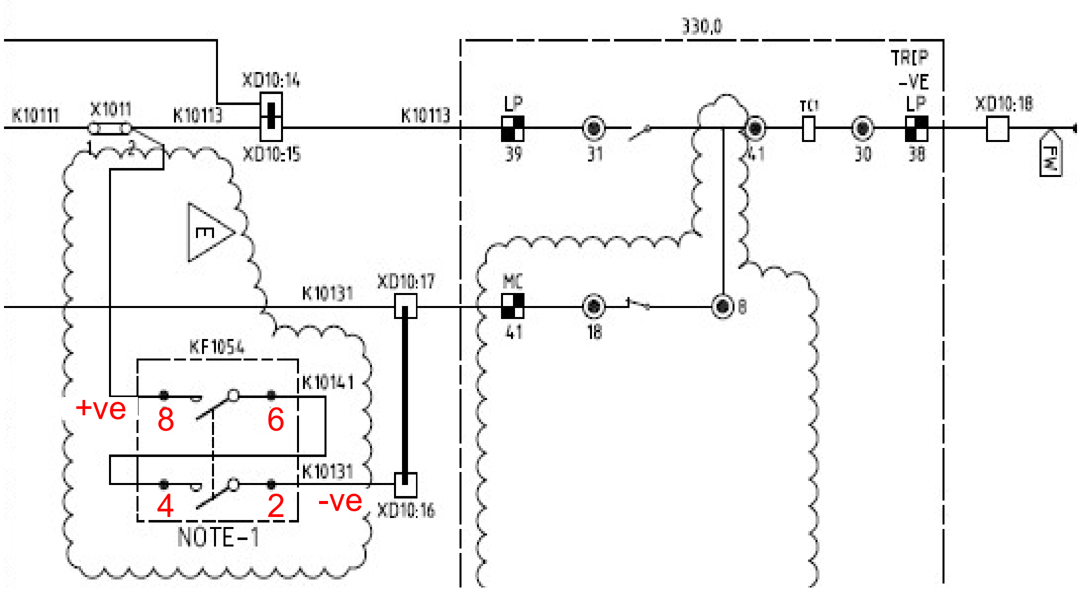
If the de-energised coil fails (auxiliary contact open) the repeat contact is also open

If the energised coil fails (auxiliary contact closed) the repeat contact opens and there is a discrepancy alarm.

If a single N/C auxiliary contact is used for circuit breaker indication and the coil fails the indication will be 'closed'.

E.2 Repeat Relay Contacts used in a TCS Circuit

Relay 65138 MOD LZ



Appendix F: Repeat Contact Examples

F.1 Feeder Metering

Table F.1: Examples of feeder metering

Metering	Local		Remote
Current	Relay[1]	Double Cable Ammeters / Fault Indicators[2]	Relay[1] Transducer[2]
	Relay	Ammeter	Relay
	Relay*	Relay*	Relay
	Relay	HMI**	Relay
PF, MW, MVAR	HMI		Transducer or Relay

1. For total feeder current
2. For double cable terminations. If fault indicators are used, they must be able to display load current.

F.2 Capacitor Metering

Table F.2: Examples of capacitor metering

Metering	Local		Remote
Current	Ammeter		Current
	Relay (default display)		Relay
MVAR	HMI		Transducer or Relay

F.3 Bus Section / Bus Coupler Metering

Table F.3: Examples of bus section / bus coupler metering

Metering	Local		Remote
Current	Ammeter		Transducer
	Relay (default display)		Relay
Busbar Volts	HMI		Transducer or Relay***

F.4 Line Metering

Table F.4: Examples of line metering

Metering	Local		Remote
Current	Ammeter		Transducer
	Ammeter		Relay
	Relay*	Relay*	Relay
	Relay	HMI**	Relay
Volts	Voltmeter		Transducer
	Voltmeter		Relay
	Relay*	Relay*	Relay
	Relay	HMI**	Relay
PF, MW, MVAR	HMI		Transducer or Relay

F.5 Transformer Metering

Table F.5: Examples of transformer metering

Metering	Local		Remote
LV Current	LV Ammeter	Ammeter	Transducer
	Ammeter (tap changer)	Relay	Relay
	Relay*	Relay*	Relay
HV Current	HV Ammeter (control cubicle)	Ammeter	Transducer
	Ammeter (tap changer)	Relay	Relay
	Relay*	Relay*	Relay
LV Volts	LV Voltmeter (tap changer)	Voltmeter	Transducer
	LV Voltmeter (tap changer)	Relay	Relay
	Relay*	Relay*	Relay
LV MW, MVAR	HMI		Transducer or Relay
WTI, OTI	HMI		Transducer or Relay

Notes:

* One of these devices must have the metering set as a default display with no user intervention required.

** The HMI must get the metering from a source other than the local metering relay.

***Remote metering of busbar volts via the feeder circuits is acceptable if a busbar voltage transformer is not available.

Appendix G: Ammeter / Voltmeter Specification

Transducers: MWatt / MVar Dewar 689 (RN 60057)

G.1 Ammeters

G1.1 Ammeter Supplied by a Current Transformer

Table G.1: Ammeter supplied by a current transformer

System Information	Ammeter Specification
Current Transformer Ratio: 400/1	Scale: 0 to 500 A. The scale may be increased if the load is expected to be larger than the CT ratio (i.e., the CT secondary thermal rating is typically 2 A so a 400/1 CT could carry 800 A).
	1 A secondary = 400 A primary

G1.2 Ammeter Supplied by a Current Transducer

Table G.2: Ammeter supplied by a current transducer

System Information	Transducer Information (Crompton 253-TAA)	Ammeter Specification
Current Transformer Ratio: 800/1	Input: 0 – 1 A	Scale: 0 – 800 A
	Output: 0 – 10mA	Calibration: 10mA = 800 A

G.2 Voltmeters

G2.1 Voltmeters Supplied by a Voltage Transformer

Table G.3: 66 kV

System Information	Voltmeter Specification
66 kV / 110 V	Input: 88 V – 110 V – 132 kV
Phase - Phase voltage measured	Scale: 52.8 kV – 66 kV – 79.2kV

Table G.4: 66 kV

System Information	Voltmeter Specification
66 kV / 110 V	Input: 50.8 V – 63.5 V – 132 V

System Information	Voltmeter Specification
Single-phase voltage measured	Scale: 105.6 kV – 132 kV – 158.4 kV

Table G.5: 132 kV

System Information	Voltmeter Specification
132 kV / 110 V	Input: 88 V – 110 V – 132 kV
Phase - Phase voltage measured	Scale: 118.8 kV – 132 kV – 145.2 kV

G2.2 Voltmeter Supplied by a Linear Transducer

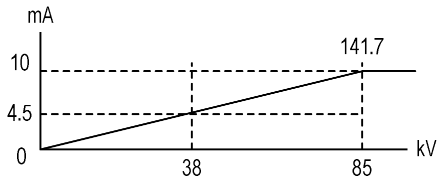
When removing voltmeters from a mimic panel it is often desirable to move the voltmeter to the VT side of the transducer. This reduces the risk of losing both the local and remote voltage metering for the loss of the voltmeter.

Table G.6: 66 kV linear transducer

System Information	Transducer Information (type AV)	Voltmeter Specification
66 kV / 110V	Input: 0 – 141.7 (Vac)	Movement: 4.5 – 10 (mA)
Phase - Phase voltage measured	Output: 0 – 10 (mA)	Scale: 38 kV – 85 kV (1)
		Calibration: 10 mA = 85 kV

Notes:

(1) (4.5/10)*(141.7/110)*(66kV) = 38.26 kV, (141.7 / 110)*(66 kV) = 85.02 kV



G2.3 Voltmeter Supplied by an Offset Transducer

Table G.7: 66 kV offset transducer

System Information	Transducer Information (Dewar 679)	Voltmeter Specification
66 kV / 110 V	Input: 82.5 – 133.1 (Vac)	Movement: 0 – 10 mA
	Output: 0 – 10 (mA)	Scale: 49.5 KV – 79.9 kV (1)
		Calibration: 10 mA = 30 kV (2)

Notes:

(2) (82.5/110)*(66kV) = 49.5 kV, (133.1/110)*(66kV) = 79.9
(3) 133.3 – 82.5 = 50.6, (50.6/110)*(66kV) = 30.36 kV

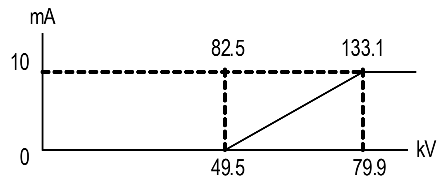
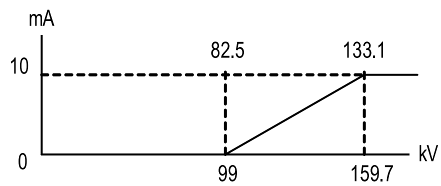


Table G.8: 132 kV offset transducer

System Information	Transducer Information (Dewar 679)	Voltmeter Specification
132 kV / 110 V	Input: 82.5 – 133.1 (Vac)	Movement: 0 – 10 mA
	Output: 0 – 10 (mA)	Scale: 99 kV – 159.7 kV (1)
		Calibration: 10 mA = 61 kV(2)

Notes:

(1) (82.5/110)*(132kV) = 99 kV, (133.1/110)*(132kV) = 159.72kV
(2) 133.1 – 82.5 = 50.6, (50.6/110)*(132kV) = 60.72 kV.



Appendix H: Safety Screens for Dexion Racks

Safety screens must be installed to mitigate the hazard of exposed equipment in dexion racks when required by the field. Clear polycarbonate sheets (Grade S) and general-purpose (GP) types as per AS4256.5 are suitable and preferred for this application.

The equipment in dexion racks is generally located between 500 mm and 2000 mm from the floor. The design outlined below therefore allows for two 1000 mm sheets. If exposed terminals are found above 2000 mm then the size of the polycarbonate sheets must be increased to cover them.

H.1 Design

The following design is suitable for various dexion relay rack structures in different substations.

- No fan cooling or water proofing is required for indoor installations.
- Each open side of the dexion relay rack shall be covered by two 6mm sheet of polycarbonate. Each sheet will have a maximum dimension of 800 x 1000 mm. The lower sheet will extend from the floor. Extra support must be added to the dexion rack if the 800 mm dimension is exceeded.
- Each polycarbonate sheet shall be fastened at the corners using an M8 nylon wing nuts and bolts. Nylon wing nuts are used to distribute pressure and avoid flexible washers. Holes at the top corners shall allow the bolts to pass through. 'U' shaped slots at the bottom shall fit over the bolts at the bottom.
- Finger holes shall be drilled in the polycarbonate sheet to allow placement.
- An expansion allowance of 5mm is required per sheet

H.2 Installation procedure

- Identify the required size of each polycarbonate sheet.
- Identify any required extra support.
- Identify the location of the corner support holes and 'U' shaped slots. This must be done on site to ensure that holes are drilled correctly for the corner supports.
- Use four bolts and nylon wing nuts to secure the safety screen. The bolts must not protrude more than 3mm from the wing nuts.

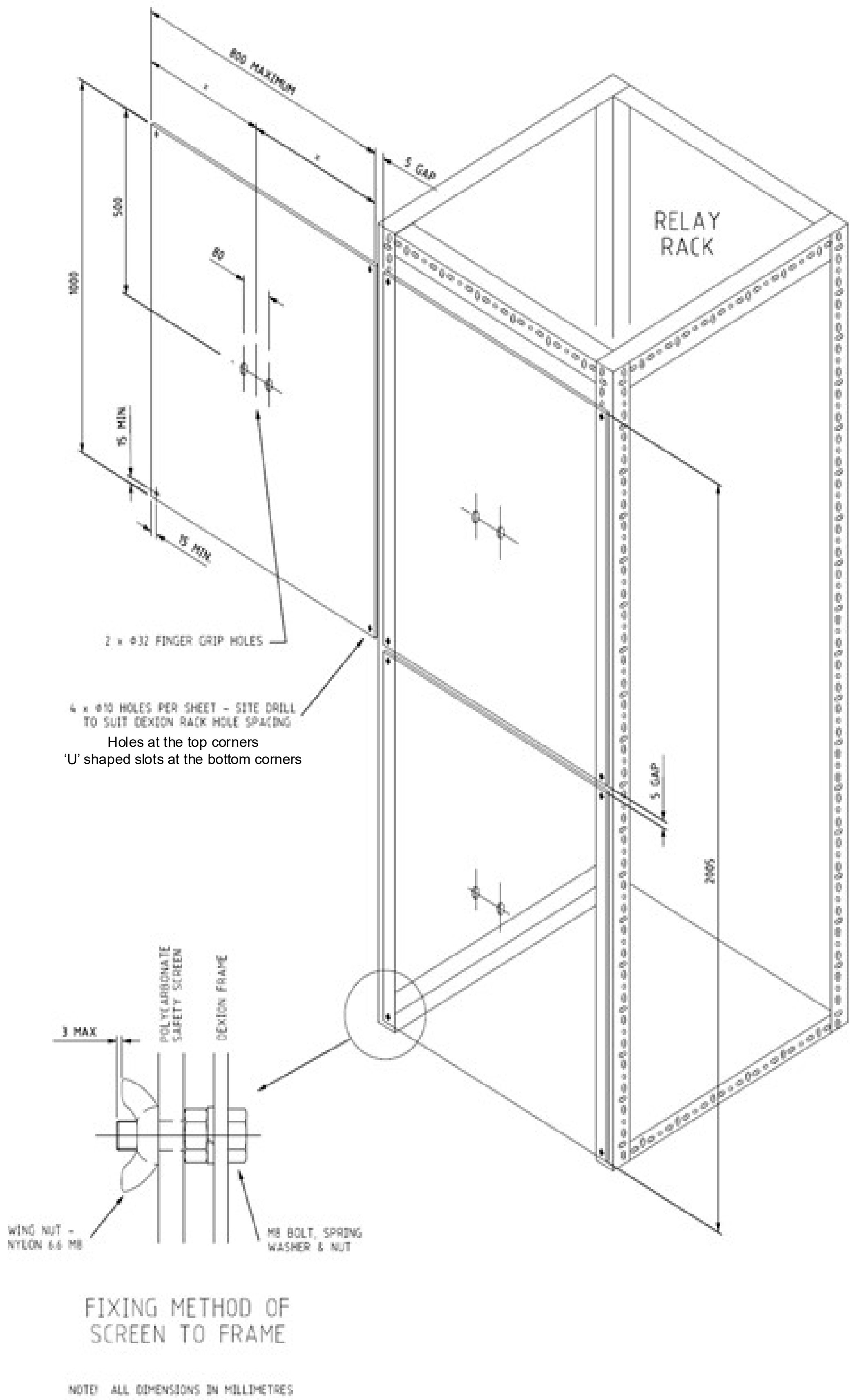


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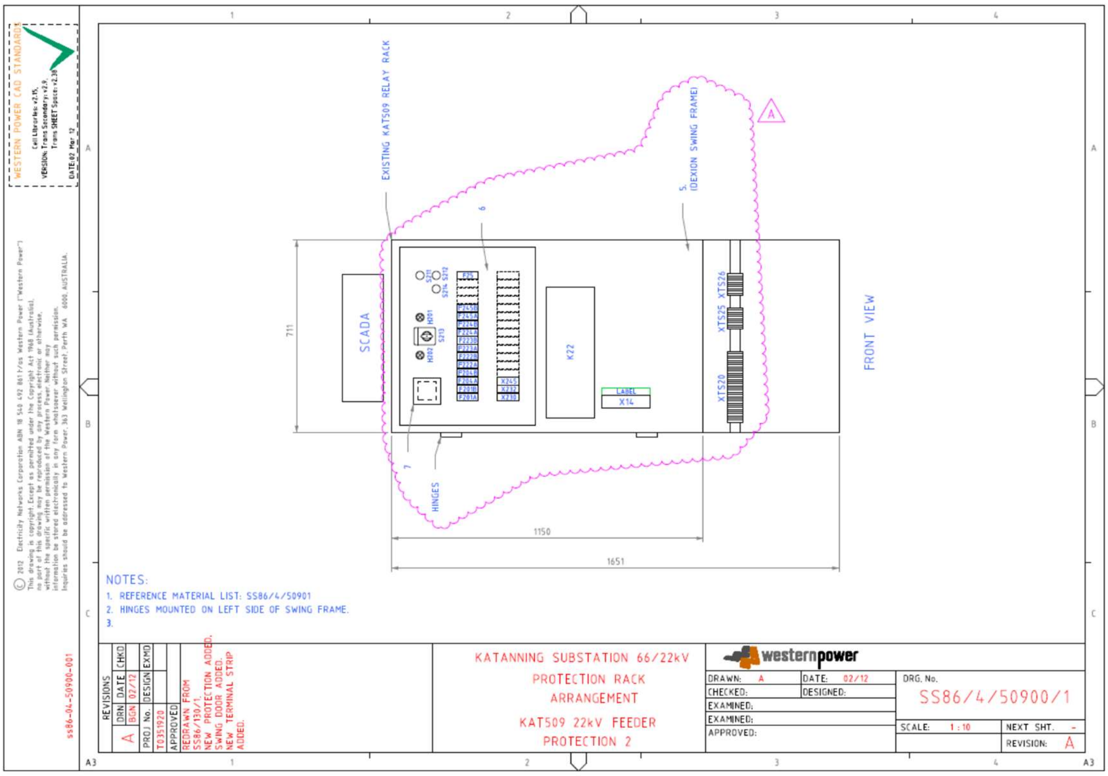
Figure H.1: Layout for polycarbonate safety screen for dexion rack

Figure H.2: Prototype safety screen for dexion rack

Appendix I: Swing Frame for Rear Panel Access

I.1 KAT 509



I.2 BSN 711

Appendix J: MCB / Fuse Grading

Two considerations must be checked when grading an upstream supply fuse with a downstream MCB:

- The downstream MCB must operate before the upstream fuse operates. This is checked by examining the operating curves of the fuse and MCB at the short circuit current of the downstream MCB.
- The MCB must operate before MCB thru energy exceeds the pre-arc rating of the upstream fuse. From the graphs in J.2 and J.3 the let thru energy for the 6 A MCB is less than the pre-arcing I^2t of the 32 A fuse but exceeds the pre-arcing I^2t of the 16 A fuse.

J.1 Short Circuit Current (I_{SC})

DC Charger (XA1313): I_{SC}= 6kA (for 0.1 seconds)
Z_{SC}= 120V/6000 = 0.02

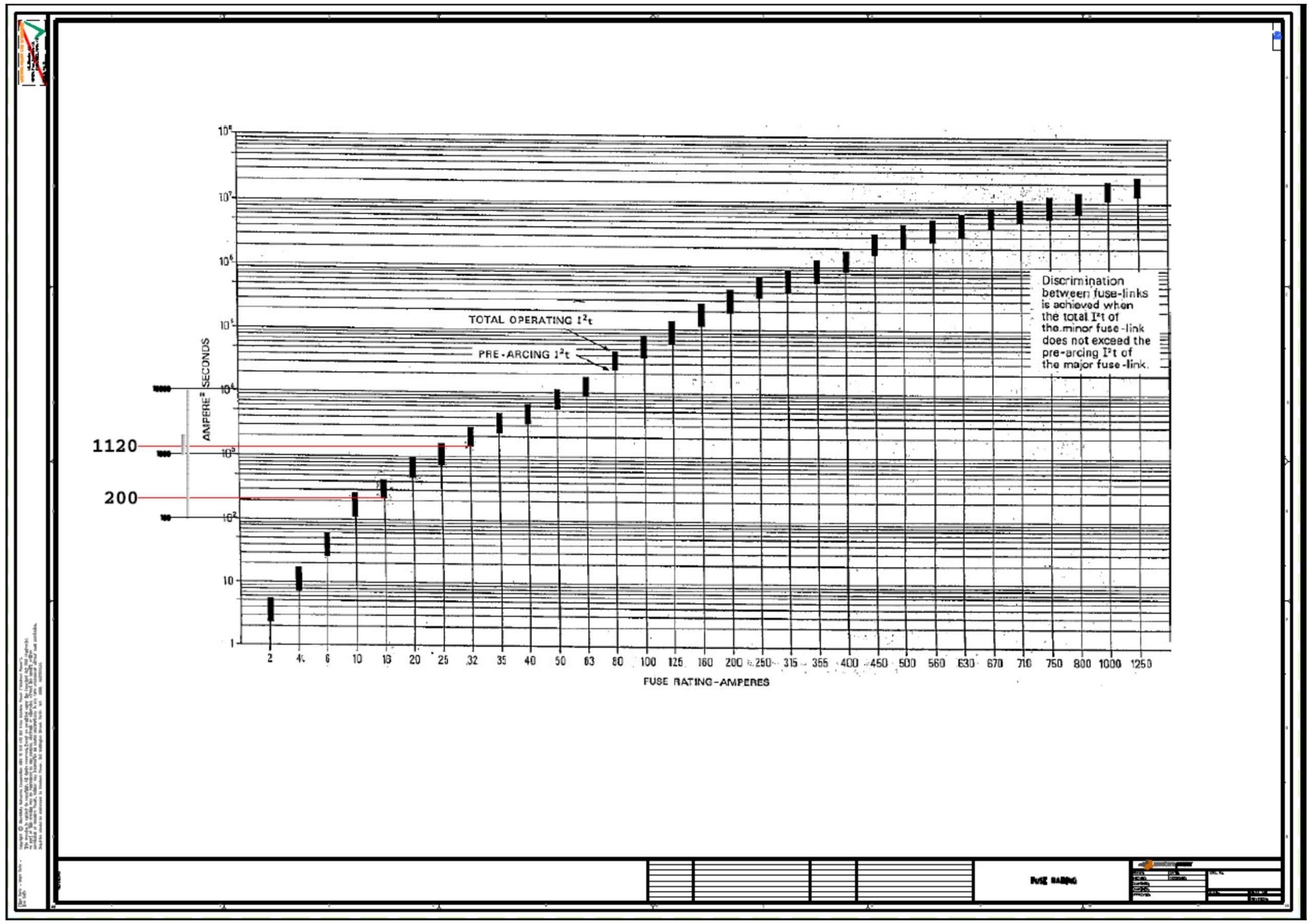
Battery (XA1345): I_{SC}= 6.375 kA
Z_{SC}= 120V/6357 = 0.01897

$Z_{SC,SOURCE}$= 0.2 II 0.01897 ≈ 0.01

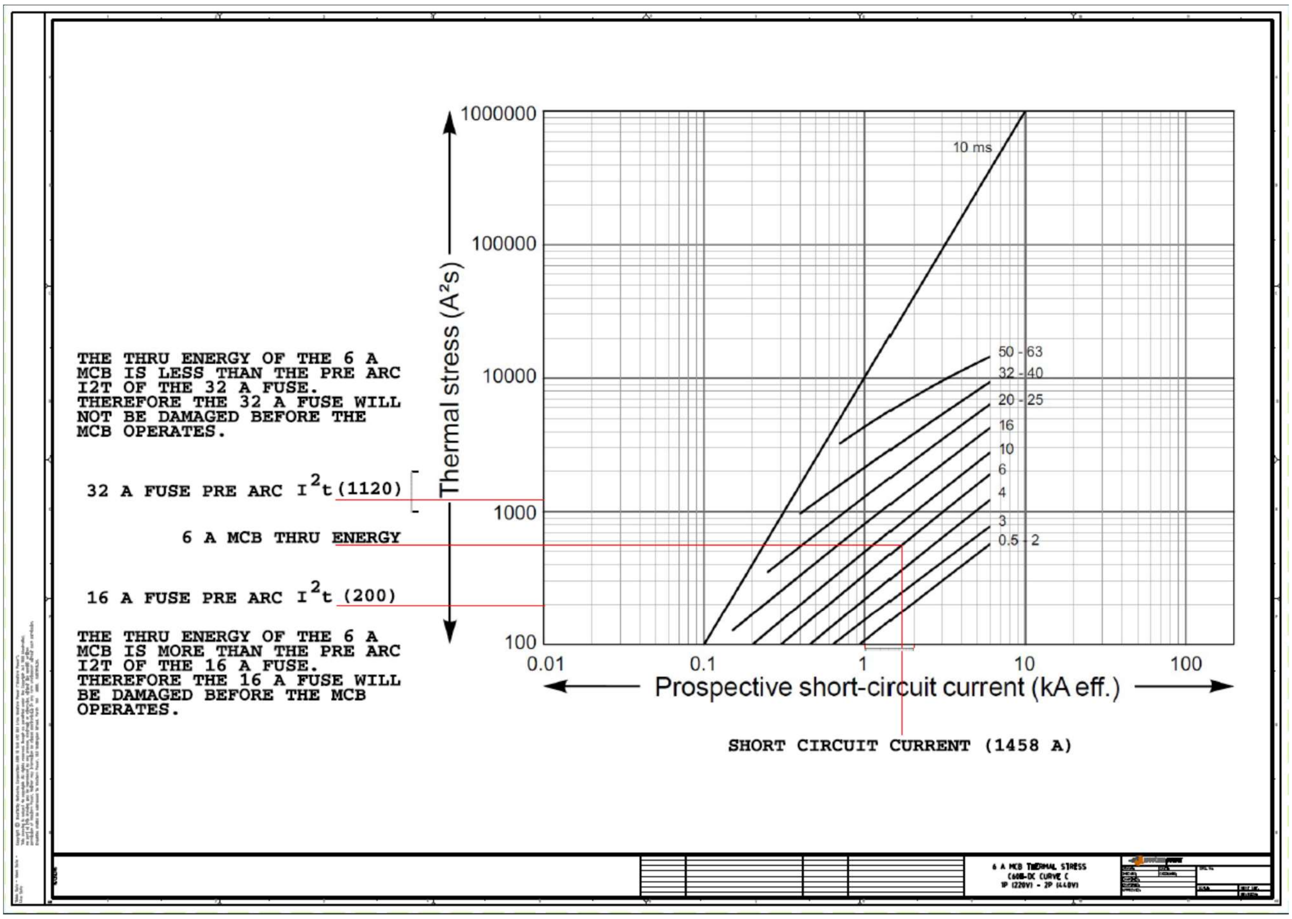
Z_{CABLE}= 71.2 mΩ

I_{SC}= 120V/(0.01+0.0712) = 1478 A

J.2 Fuse Pre-Arc Rating



J.3 MCB Thru Energy



Appendix K: Approval Record and Document Control[37]

37 See Western Power Internal Document