Substation AC Auxiliary Systems

Design Standard

DOCUMENT HIERARCHY

This document resides within the Planning component of Western Power's Asset Management System (AMS).

DOCUMENT DATE

This document was last updated July 2023

IMPLEMENTATION DATE

This document came into service July 2023

DOCUMENT CONTROL

Record of endorsement, approval, stakeholders, and notification list is provided in EDM# 34129744 appendix

RESPONSIBILITIES

Western Power's Engineering & Design Function is responsible for this document

CONTACT

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Contents

Revision Details

Version	Date	EDM Version	Summary of change
0	14/06/2013	0	First Issue
1	26/06/2017	1	Updated with new AS3000 and AS2067 requirements
2	28/03/2021	2	Changed to AMS format. Items 6 – 12 of issues register (EDM42766841) addressed. N-E connections and 4 pole changeover switching added to Section 11. Section 7 on AC supplies, section 8 on phase failure relay and load meters updated. Requirement of RCBOs updated.
3	Jan 2023	3	*Items 13 – 16 of Register – Engineering Design Instruction, Construction Technical Specification Information and Drawing Issues Register (EDM#42766841) addressed.*
4	Oct 2023	4	Standard Online Update

1 Introduction

AC systems are an important part of the substation infrastructure. The 415V AC system in a substation supplies loads such as battery chargers, motors, transformer cooling fans, GPOs, lights and air conditioners.

This design instruction outlines the requirements of a substation AC system and guides engineers on how to design them in accordance with Western Power and Australian Standard requirements.

1.1 Purpose and scope

The objective of this design instruction is to ensure that Western Power and contractors working for Western Power produce safe, functional and economic designs which meet the requirements of Western Power and Australian Standards.

This design instruction covers all aspects of a substation AC system, including supplies, loads, distribution boards, cables and protective devices. It discusses the application of the requirements to both zone and terminal yards and greenfield and brownfield sites

1.2 Acronyms

Acronym	Definition

1.3 Definitions

Term	Definition
kVA	kiloVoltAmp
LED	Light emitting diode
LV	Low voltage (less than 1kV)
LV Kiosk	Housing for combined fuse switches
MCB	Miniature circuit breaker
MDB	Main distribution board
MEN	Multiple earth neutral
MPS	Modular packaged substation (Distribution transformer, LV isolator and 5 x CFS in a ground mounted cubicle.)
MSB	Main switchboard (Another name for MDB)

MV	Medium voltage (n this document 6.6, 11, 22 and 33kV.)
PEN	Protective Earth Neutral
PENDA	Public Electricity Network Distribution Assembly
PILS	Paper insulated lead sheaved (Cable insulation)
PLC	Programmable logic controller
PVC	Polyvinyl chloride
RCBO	Residual current circuit breaker with overcurrent protection
RCD	Residual current device (“Safety switch” or earth leakage circuit breaker, ELCB.)
RPS	Manufacturer of switchgear (Used to be Reyrolle Pacific)
RRST	Rapid response standby transformer
SCADA	System control and data acquisition
SLD	Single line diagram
SVC	Static Var Compensator
TN-C-S	Part of the system uses a combined PEN conductor, which is at some point split up into separate PE and N lines.
TN-S	PE and N are separate conductors that are connected together only near the power source.
TPS	Thermoplastic sheaved (Cable insulation)
Tx	Transformer
UPVC	Unplasticized polyvinyl chloride
UV	Ultraviolet
V	Volts
VESDA	Very early smoke detection alarm
XLPE	Cross-Linked Polyethylene (Cable insulation)

1.4 References

References which support implementation of this document

Table 1.1 References

Reference No.	Title

2 Supporting Documentation[1]

3 Compliance

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

The Design Instruction must comply with higher level Western Power technical documents such as relevant Network Standards and Functional Specifications. The relevant Network Standards and other relevant documentation are listed in Table 3.1.

Table 3.1: Relevant documentation

Document Title
Network Standard – Substation Auxiliary Supply and Electrical Services
Network Standard – Customer Connection Requirements
Substation Design – Execution Process and Quality Plan
Design Instruction – Substation Layout, Labelling and Numbering
AS 3000 Checklist
Cable burial depth – Compliance with AS/NZS 3000

There are also several applicable Australian Standards. These relevant Australian Standards are listed below in Table 3.2.

Table 3.2: Australian Standards

Standard Number	Standard Title
AS/NZS 3000	*Electrical installations. (The Wiring Rules)*
AS 2067	*Substations and high voltage installations exceeding 1kV a.c.*
AS/NZS 3008	*Electrical installations – Selection of cables*
AS 60269.1	*Low-voltage fuses*
AS 60529	*Degrees of protection provided by enclosures (IP Code)*
AS1939 Supp1 and 2	*Degrees of protection provided by enclosures for electrical equipment (IP code)*
AS 60947	*Low-voltage switchgear and controlgear – Circuit-breakers*
AS/NZS 4836	*Safe working on or near low-voltage electrical installations and equipment.*

[1] See Western Power Internal Document

Standard Number	Standard Title
AS/NZS 61009	*Residual current operated circuit-breakers with integral overcurrent protection*
AS/NZS 60898.1	*Electrical accessories – Circuit breakers for overcurrent protection for household and similar installations. Part 1: Circuit Breakers for AC operation*
AS/NZS 3010	*Electrical Installations – Generating sets*
AS 61439	*Low-voltage switchgear and controlgear assemblies*

4 Safety in Design[2]

AC system design is one of the critical Safety in Design areas to be considered when completing substation design work. This document outlines the fundamental principles to be followed to ensure a safe design. The *Engineering Design Instruction – AC Auxiliary Supplies – Hazard Management Register,* shall include evidence of all measures implemented to eliminate or reduce risks. As per the SiD basic principles, the key focus shall be on hazard elimination and on engineering mitigation. The following prompt questions can facilitate the hazard identification process:

1. Has the design been done in accordance to AS3000? Has the AS3000 checklist been completed?
2. Is the AC board labelling and layout legible and easy to understand?
3. Do all new or modified lighting, power and air-conditioning circuits have RCBOs installed?
4. Has the CB or fuse and cable been checked for correct sizing and coordination? Use Powercad to check new circuits.
5. Have the AC and DC systems been totally segregated?
6. Is the layout and design of the AC system logical?
7. Can the use of AC within a panel be avoided entirely?

The following points shall be considered during the design process:

1. Existing cables on site shall be located using dial before you dig (DBYD). If there is any doubt about cables or services location, an on-site survey shall be carried out.
8. Enough access around switchboards shall be provided.
9. The working height for switchboards shall meet body fit requirements (see Section 11 for body fit requirements).
10. There shall be easy and enough access to cable glands for terminating cables. Outdoor switchboards shall be mounted on stands for easier cable gland access, to meet working height requirements and to allow enough bending radii for cables.
11. Local and upstream isolation points shall be clearly labelled.
12. Controls and indications shall be accessible (see Section 11 for body fit requirements).
13. Wiring ducts shall be easy to access

[2] See Western Power Internal Document

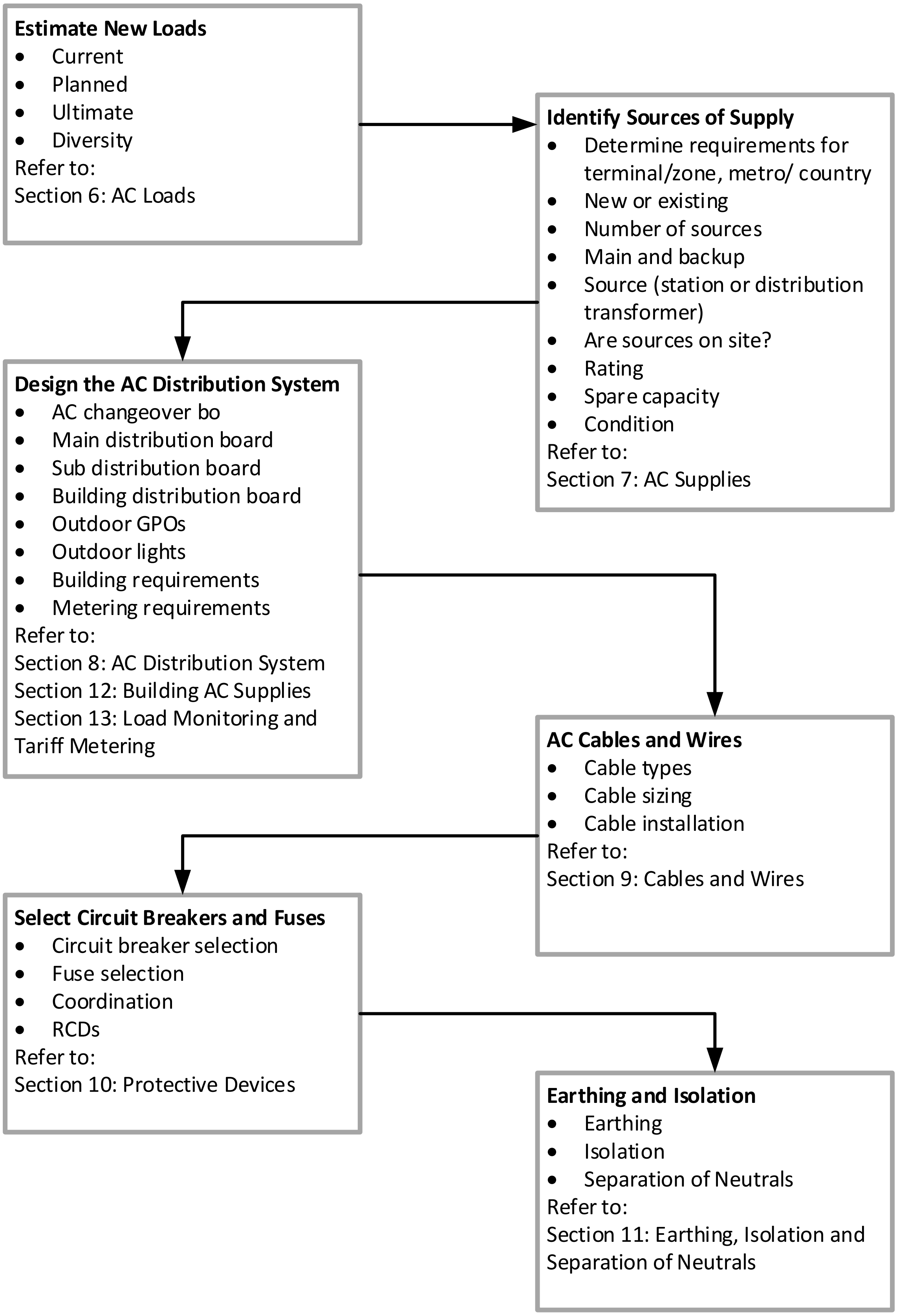
14. Swing out panels to be used where possible to provide better access
15. Lifting eyes shall be provided on heavy cubicles
16. Door props on outdoor equipment shall be adequate for wind loading
17. Solar shields on top and sides of outdoor cubicles to be installed where required
18. Sharp edges and trip hazards shall be identified and removed.
19. All live parts shall be shrouded and insulated.
20. Spare capacity which is easily assessable shall be available for future expansion.
21. Provision shall be made for tagging padlocks on isolation devices.
22. Cantilevered supports for cable trays are preferred wherever possible (to avoid having to thread cables through supports).
23. Pulling points shall be provided for cable duct direction changes on long runs
24. Cable markers shall be installed for buried cable

5 Overview of the Main Design Elements

The purpose of a substation AC system is to supply all the AC loads within the substation in a safe and reliable way. To achieve this, the designer should follow the outlined design process in Figure 5.1. The designer must assess the relevant substation AC loads and then calculate the required size of main and backup supply. The designer should then design the substation AC system, including sizing and coordinating the circuit breaker, fuse and cable sizes.

The following sections describe the considerations and design methods that should be included in the substation AC system design. The appendices contain application information, including photos and information on new and old styles of AC equipment.

Figure 5.1: Overview of AC Design Process



6 AC Loads

6.1 Substation AC Loads

The AC supplies in a substation are required to power many different loads in a substation. These include power for heaters, motors, control, operation and monitoring of substation equipment, lighting and general power outlets in the yard and buildings, air conditioning, battery chargers, pumps and others.

The typical AC loads found within a substation are listed in Appendix A.

6.2 Maximum Loads

New AC supplies shall be designed to meet the maximum continuous load requirements for load combinations using the ultimate substation configuration, with no diversity factor. Below is a guide to substation total load, however detailed calculations are to be completed for each site factoring in all the loads. Allow enough capacity for intermittent and short duration loads such as circuit breaker AC spring charge motors, test equipment and GPOs.

The greater of the worst case day and worst case night scenarios below should be used for sizing.

Worst Case Day Loads

1. Outdoor ambient conditions of 45^{O}C
25. Duty air conditioners at full load in all buildings
26. All internal lighting on in all buildings
27. All transformer fans and pumps running
28. One battery charger of each voltage on boost (if applicable), the others on normal charge.
29. 1 GPO in each building loaded

Worst Case Night Loads

1. Outdoor ambient conditions of 40^{O}C
30. Duty air conditioners at 80% load in all buildings
31. All internal lighting on in all buildings
32. All transformer fans and pumps running
33. One battery charger of each voltage on boost (if applicable), the others on normal charge.
34. 1 GPO in each building loaded
35. All outdoor lighting on

The maximum load required for a substation shall be calculated (for example using Powercad).

6.3 Level of redundancy

Although the DC system provides short term back up, for control and protection, the AC system is a vital component to the long term capacity and operation of a substation and therefore it is important to have a high level of redundancy in the design.

The following important functions are lost with loss of AC supply:

1. On line tap changers: restricting voltage and Var control.
36. Transformer cooling fans: limits transformer capacity or reduces insulation life once the thermal inertia of the transformer has been used up. Tap changes can be done manually.
37. Transformer oil circulation pumps: limits transformer capacity or reduces insulation life once the thermal inertia of the transformer has been used up.
38. Battery chargers: cannot recharge batteries so AC restoration is required within the DC storage design capacity (8hrs for new zones, 24hrs for terminals and possibly less for brown field sites).
39. Air-conditioning: some switchgear and communications equipment could be vulnerable in transportable buildings with low thermal inertia.
40. Battery room extraction fans
41. Zone Substation circuit breaker energy storage systems: once the open – close – open (O-C-O) cycle has been used operators will have to resort to hand charging.
42. Motor drive disconnectors / earth switches: will require operators to hand operate all disconnectors and earth switches.
43. Confined space ventilation: unless natural ventilation is present these would be 'no go' areas. (For example, Cook St tunnels and cable hall).
44. Outdoor lighting: temporary lighting will be required at night.
45. Water pumps: loss of supply until power restored
46. Drainage pumps: not available until power restored or temporary pumps brought in. There is generally some buffer storage.
47. SVC cooling system: SVC auxiliary AC supplies generally have a high level of redundancy and are primarily sourced from the SVC transformers that in themselves are critical to the SVC functioning, so they shouldn't be adversely affected by a substation AC loss.

6.4 Brownfield Upgrades

Existing AC supplies being modified should consider the above loads but only be applied to all installed and planned equipment rather than the ultimate configuration. Should switchboards, conductors and the like must be replaced they should be designed for the ultimate configuration.

7 AC Supplies

The size of the AC supply required for a substation shall always be calculated based on the ultimate arrangement for that site, using the loads calculated in Section 6, AC Loads and applying a diversification factor.

7.1 AC Sources

An AC supply can be supplied from different sources. For zone substations, the most common application is for the main supply to be sourced from a station transformer off the MV busbar. For terminals yards, the most common application is for the main supply to be sourced from a winding in the auto transformer's earthing transformer. Other sources are a power VT, or a generator. In the past, a transformer or pillar supplied from the distribution system were also used as AC sources, but this should not be used for new installations.

7.1.1 Zone Substations – 33/22/11kV/415V Station Transformer

In a standard zone substation, the standard arrangement is to have two AC supplies from two pad mount station transformers, one supplied from the Transformer 1 switchboard, A1 bus section and the second from the Transformer 3 switchboard, A5 bus section, via a combined fuse switch unit or circuit breaker panel.

In all new installations, station transformers shall be ground mounted with cable connections on both the HV and LV sides. They shall be protected on the HV side by fuses, a combined fuse switch unit or a circuit breaker.

The cables between the station transformers and the AC changeover board shall be protected by 415V combined fuse switch units or circuit breakers located as close as possible to the transformers' terminals.

The standard size for 33, 22 or 11kV to 415V pad mount station transformers is 315kVA. However, since the substations are becoming less standard in their configuration, it is important to size the transformer based on the loading calculations outlined in Section 7.

The transformers are available as stock items referred to as MPS (Modular Packaged Substations) which assist in quick replacement under urgent conditions. A modular package substation comes complete with a single transformer and 415V switch/fuse gear. It is housed in a self-contained metal enclosure and is installed, with the cable access overhanging, on an inverted, buried concrete deep culvert. The largest size transformer that can be used with an MPS configuration is 630kVA

See Table 10.1 for stock codes and more information on MPSs and standard transformer sizing.

7.1.1.1 22kV/415V Station Transformer Sizing

The standard size for a zone substation 33, 22 or 11kV to 415V pad mount station transformer is 315kVA.

7.1.2 Terminal Substations – 22kV/415V Earthing Transformer

In terminal substations, two AC supplies from earthing transformers connected to the tertiary of two 490MVA power transformers have typically been used. However, this arrangement introduces issues and alternative options are being considered by Substation Design. Cable access is via an 800A/450A CFS unit mounted by the supplier on the earthing transformer. When using this supply arrangement, loads should be balanced across the phases.

7.1.2.1 22kV/415V Earthing Transformer Sizing

The size of the standard terminal substation 22kV/415V earthing transformer is 500kVA. This size may not be required at many of the smaller terminal sites however to avoid the costs associated with carrying two different transformer sizes, this 500kVA unit shall be used for all terminal sites. As discussed in section 7.1.2, alternative options are being considered by Substation Design.

7.1.3 Distribution supply

415V supplies and transformers supplied from the nearby distribution network are commonly called street supplies. These types of AC supplies are not recommended and should not be used for new installations as they can transfer dangerous voltages to the distribution network. Their reliability is also impacted by external factors such as the changes to the configuration of the distribution network and bush fires. A 415V supply from the distribution network will transfer the earth potential rise (EPR) to other customers on the feeder.

Many older zone substations rely on two LV street supplies and have no station transformer. As switchboards are added or replaced at these sites, the AC supply should be replaced with an MPS supplied from the switchboard.

7.1.4 Power VT

A power VT can be used when no transformers or switchboards are installed on site. The power VT is connected directly to a high voltage line and can supply low voltage power to a 240/415V system.

Power VTs are connected to the system via a disconnector. If the disconnector is rated to break the load current, interlocking is not required. If interlocking is required, the disconnector should be interlocked with the AC paralleling board, not the power system circuit breakers.

7.1.5 Generator

Generators are mainly used as a backup supply when:

1. There are no or only 1 power transformer
2. When a power VT is not practical

Emergency backup generators are to be connected to the standby supply connection on the changeover board.

Generators can be portable or permanently located at the substation. For a portable generator, a provision for generator connection which allows for a generator inlet and a manual changeover switch shall be installed at the substation.

For a permanently located generator, starting shall be automatically initiated by the mains failure sensing in the changeover board.

For the restoration of mains supply, the standby generator is to be disconnected and then the mains supply restored (break before make). The generator supply must not be paralleled with the grid.

The installation shall comply with the requirements of AS/NZS 3010.

7.1.5.1 Generator Sizing

Standby generators should be sized taking the following parameters into account:

1. Operational load,
48. Accepting the connected load in one step,
49. Fuel storage for 24 hrs of operation,
50. Noise emissions,
51. Environmental factors. Refer to *Network Standard – Standard Site Conditions for Primary Plant.*
52. Generators have minimum load requirements. In the past the outdoor halogen lighting has been used to meet this requirement. The lights must be on when the generator is operating. When lights are changed to LED, the decreased load may pose a problem for the generator minimum load requirement. Dedicated resistor load banks may be required.

7.1.6 Brownfield Arrangements

In outdoor MV substations the station transformer is typically supplied from the outdoor busbar and is normally mounted on the busbar support structure. Supplies are typically via drop out fuses and the transformers are normally open bushing HV type.

Note, for some older installations, open bushing type transformers were occasionally ground mounted inside a compound. These installations are dangerous and should have all been removed. If an installation of this type is discovered, it must be replaced by a padmount transformer.

At brownfield sites, when doing significant work on an outdoor MV busbar or replacing the station's supply transformer, the installation should be upgraded to meet the following requirements:

1. Both station transformers should be supplied from the busbar, one connected to the T1 section and one to the T3 section to ensure security of supply when a section of busbar is taken out of service.
53. The transformers shall be the standard padmount type described in section 7.1.1, with a cable connection from the substation MV busbar.
54. The cable will be protected by appropriate drop out fuses mounted close to the busbar.

Note, if it is physically difficult to provide a suitable connection point on the busbar, a station transformer may be "piggybacked" onto a feeder circuit. Fuses are still required for this design to protect the transformer and ensure it can be isolated without interfering with the performance of the feeder. When this arrangement is used, this transformer will be the standby station transformer. Permission to use this arrangement must be granted by the Substation Design Standards Team.

7.1.7 Non-standard AC Sources

There can be situations where the AC supply sources will have to be non-standard. The most common circumstance is when at least one supply is provided by a customer or when Western Power provides an AC supply to a customer. There are several variations possible under such arrangements and each variation is to be considered on its merits. However, the requirements of this standard should be adhered to wherever possible.

7.2 Number of AC Sources

7.2.1 Required Restoration Time

The minimum required restoration time is 8 hours for zone substations and 24 hours for terminal yards in the metropolitan region. Country sites shall be assessed on a case by case basis in the emergency response plan (see Appendix F) and the time may need to be increased based on how quickly a crew can attend to the site.

7.2.2 Zone Substations

In standard zone substations, ultimately two separate 415/240V AC auxiliary supplies are required to provide adequate reliability of supply. Each auxiliary supply is supplied from a separate transformer installed within the substation from differing MV sources, typically Transformer 1 and Transformer 3. The only exception to this is for sites which are only partly developed and only one transformer is currently installed – see section 7.2.2.1 below.

7.2.2.1 Single Transformer sites

If a zone substation is built in different stages and only one power transformer is installed initially, an option exists to install only a single AC auxiliary supply in the form of the station transformer supplied from the MV busbar. A standby supply may not be justifiable depending on several issues that will vary between substations.

Stakeholders must be consulted in the decision to install only one AC supply at a new substation at the concept design phase of a project. There must also be an emergency response plan in place to ensure that an AC outage would be appropriately handled.

Consideration should also be given to how long the substation will be in service until the second power transformer is installed.

Backup supply options available for single power transformer sites include a provision for a generator connection.

7.2.2.2 Second Transformer Installation

When a second transformer is installed at a site the following requirements must be met:

1. For a site with only one auxiliary supply, a second auxiliary supply must be installed, fed from the new transformer and switchboard.
55. If a second transformer is installed at a site with a portable generator as the backup supply, the arrangement should be changed so that the backup supply is from the new transformer and switchboard, except for the following case:

    In the case where Transformer 2 (and a type 2 board) is installed as the second transformer, the portable generator can remain as the backup until the third transformer is installed.

7.2.2.3 Rural Sites

Rural sites require special consideration with respect to the number of AC supplies. If the remoteness of the substation is such that the single AC supply cannot be restored within the required timeframe stated in Section 7.2.1, then it may be necessary to install two AC supplies.

For sites with only one power transformer, it is recommended that a permanent diesel generator or power VT be considered, until a second power transformer is installed.

7.2.3 Terminal Substations

Terminal Yards may have either two or three sources of supply depending on the development and importance of the yard. The standard terminal yard changeover board is designed for three supplies.

The AC supplies consists of the following alternatives whose availability will depend on the substation location:

1. A 500kVA winding on the tertiary earthing transformer of each power transformer. Cable access is via an 800A/450A fuse switch unit mounted by the supplier on the earthing transformer. Typically, this arrangement is used at terminal substations, but it has caused issues and alternative options are being considered by Substation Design.

56. A power VT.
57. A diesel generator which will start automatically when the main AC supply fails.
58. An SPS system subject to approval by Substation Design

In Terminal Yards, the circuit breaker operating mechanisms are DC operated and supplied from the protection batteries. Full operability of the circuit breakers will therefore be available if the assigned capability of the batteries is not exceeded before the AC supply is restored. Regardless of the extent of development of a terminal substation, at least two AC auxiliary supplies are always required.

Three supplies should be used for a Terminal that is greater than 4 bays and/or has very high network importance.

In a terminal with more than one power transformer, an auxiliary supply has typically been sourced from the earthing transformer of each power transformer however alternative options are currently being considered.

If there is only one power transformer, one auxiliary supply has typically been provided from the earthing transformer of that transformer (alternatives options are being considered) and the other shall be from a power VT or diesel generator.

Where there are no transformers in a Terminal Yard, one supply shall be provided by a power VT and the other by a:

1. diesel generator
59. power VT
60. SPS.

7.2.4 Terminals with multiple relay rooms

Generally terminal yards have two separate yards (330kV and 132kV) with separate relay rooms for each voltage. In this case, separate dual supplies are required for each building. This is commonly achieved by taking supplies to both buildings from separate circuits on the station transformer CFS units. This is the standard and preferred arrangement. However, in non-standards installations there may be more efficient ways of providing these supplies such as from the AC distribution board of the higher voltage yard. Any non-standard supply arrangement must be approved by the Substation's Principal Electrical Design Engineer.

7.2.5 Switching Stations and Customer Supply Substations

Switching stations and customer supply substations have no transformers installed, hence it can be difficult to find cost effective AC supplies. For these scenarios, power VTs should be considered for the main supply. A generator or supply from the customer can be used as the backup supply. The use of supply from customer would be subject to the arrangement being reviewed by Substation Design.

7.3 Nomination of Main and Standby Supplies

7.3.1 Zone Substations

In zone substations, one supply is nominated as the main supply and the other as a backup. Under normal conditions, the AC system runs on the main supply, and is only supplied from the backup supply in the event of a loss of the main supply.

If possible, the AC supply from Transformer Number 1 should always be the main supply. This is to ensure consistency across all sites. For new sites, the only case where this can be deviated from is when only Transformer 3 is installed initially.

Where the local distribution system provides one of the auxiliary supplies (not for new installations) and the other is from a switchboard, the internal switchboard supply shall be the main supply and the distribution supply shall be the standby.

Where the distribution system provides one auxiliary supply and the other is from a diesel generator within the substation, then the distribution supply shall be the main supply (not for new installations) and the diesel supply shall be the standby.

7.3.2 Terminal Substations

Terminal substation AC changeover boards have three circuits for incoming local supplies.

1. Where all the auxiliary supplies are sourced from the power transformer tertiary winding earthing transformers, the main supply shall be from the lowest numbered transformer and the standby shall be from the highest numbered transformer. Where a second yard (i.e. 132kV yard at a 330/132kV terminal site) is supplied from the same earthing transformers, the second board shall use the highest number transformer as the main supply and the lowest as the standby, to balance the load across both transformers.
61. Where the local distribution system provides one of the auxiliary supplies (not for new installations) and the other is internal from a power transformer tertiary, the internal supply shall be the main supply and the distribution supply shall be the standby.
62. Where the distribution system provides one auxiliary supply (not for new installations) and the other is from a diesel generator within the substation, then the distribution supply shall be the main supply and the diesel supply shall be the standby.

7.4 Phase rotation[3]

When choosing AC supply sources for a substation, consideration must be given to the phase rotation of the supplies. Different points in the network have a different phase rotation based on the transformer phase displacement. If a backup supply is taken from a substation with a different phase angle from the substation it is supplying, then the main and standby/backup supplies will be out of phase. In most cases this should not be a problem as the changeover board is break before make, meaning that the supplies cannot be paralleled. However clear and

[3] See Western Power Internal Document

visible signs must be installed on the changeover board to make personnel aware of this situation.

8 AC Distribution System

The following general requirements must be considered for the design of all AC design components.

1. Segregation of AC and DC systems. All AC and DC must be totally segregated from each other. Where both AC and DC supply voltages must exist in the same panel, they must be physically separated from each other and clearly labelled.
63. Body fit must be considered in the design of all AC and DC components. The maximum body fit height is 2200 mm. The minimum body fit height is 450 mm. When it is not practical to meet the body fit limits, the following is required:
    a. Approval from the construction, commissioning and maintenance groups.
    b. A comment in the substation design report documenting the problem and resolution.
64. All hazards assessed and entered into the hazard and risk assessment spreadsheet.
65. Each GPO and light switch shall be clearly labelled to show the pole number and phase from which it is supplied. If the location of the GPO or light is such that it is not clear which switchboard it is supplied from (i.e. switchyard GPOs or lights), then it shall also be labelled with the relevant switchboard number.

8.1 AC Changeover Board

8.1.1 Design

The AC changeover board will accommodate the incoming auxiliary supply circuits and the single outgoing circuit that supplies the AC distribution board(s) and equipment. It will also automatically change the auxiliary supply source from one to another under the following conditions:

1. Failure of any one or more phases of the selected supply, or incorrect phase sequence and
66. All three phases of the alternate supply are healthy and have the correct phase sequence

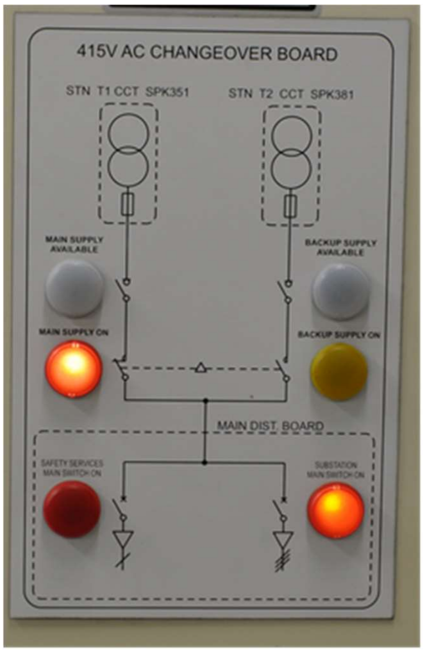
The phase failure relay shall include the following functions as a minimum:

1. Phase rotation check
67. Failure of any one or more phases
68. Adjustable time delayed undervoltage detection
69. Adjustable time delayed overvoltage detection

New changeover boards will have separate compartments for the changeover and distribution board compartments. This is to allow enough isolation during maintenance or construction, reducing the maintenance costs and therefore reducing the whole of life cycle costing. The incoming section must be segregated from the distribution section such that when the incoming circuit isolator is open, the distribution compartment has no live components. The incomer and the DB section must have separate doors. There is to be no opening between the compartments.

New boards may also have a separate safety services board which supplies the VESDA system and any other supplies to safety services. This safety services board shall be fed from the changeover board before the distribution board main switch. See Figure 8.1 for an example general single line diagram.

Figure 8.1: Example of single line diagram required for new changeover boards



8.1.2 Standard Rating and Requirements

The standard rating and design requirements of the AC changeover and distribution boards shall be as follows:

1. Zone Substation
    a. Current Rating: 200A
    b. Fault Rating: 10kA (this rating is based on a 315kVA transformer)
70. Terminal Yard
    a. Current Rating: 400A
    b. Fault Rating: 35kA
71. Common Requirements (Zone and Terminal)
    a. Minimum cable size is 2.5 mm^2
    b. Colours: Red, White, Blue and Black (Neutral)
    c. Degree of ingress protection rating of IP43 for indoor and IP55 for outdoor to AS 60529
    d. Insulated busbars

e. Ambient conditions 0 – 45^{0}C outdoors

f. Humidity, anti-condensation heaters to be fitted for outdoor boards

g. Top or bottom entry as required

h. Dimensions max height 2.5m unless approved by Substation Design Area.

i. Displays and controls to be between 400mm and 1,950mm from floor level

j. Colour (inside and out) shall be orange in accordance with AS2700 for indoor and outdoor switchboards

k. Holding down bolts to consider seismic forces and toppling when doors and swing panels are open

l. Adequate hinges on doors and swing panels to support door mounted equipment

m. Outdoor boards shall be fitted with a padlock facility

n. Indoor boards shall not have locks installed.

The ratings and size of the board must cater for the ultimate arrangement of the substation. The ratings of the boards may differ from those stated above if necessary, to cater for specific substation requirements.

8.1.3 Control, Indication, Alarms and Labelling

The indication and labelling of the board must be clear and legible to ensure that the configuration of the board is easy to understand. The door of the board shall contain a simple single line diagram representation of the AC supply system, showing the location of the sources, changeover component, supply to safety services, and distribution boards.

See Figure 8.1 for a typical changeover board label.

Table 4: Control, Indication and Alarm Requirements

	Zone Substation	**Terminal Yard**
Controls:		
		Selector switch to select manually between main and standby supplies
Indication:		
	Main Supply Available	Main Supply Available
	Main Supply On	Main Supply On
	Backup Supply Available	Backup Supply Available
	Backup Supply On	Backup Supply On
	Indicator lamps to include test function	Indicator lamps to include test function
	Current and Voltage indication – typically with a multifunction meter	Current and Voltage indication – typically with a multifunction meter

Alarms:		
	Main supply fail	Main supply fail
	Standby supply fail	Standby 1 supply fail
		Standby 2 supply fail
	Total supply fail	Total supply fail

8.1.3.1 Load Monitoring

Load monitoring of the 415V AC supply shall be done for all new AC systems. Monitoring the load allows accurate load data to be recorded, allowing expected load values to be confirmed, and assists in the design for future additions to the substation. The meter shall be installed on the input to the main distribution board.

The meter shall be connected to the Automation System via an Ethernet cable to allow remote connectivity for data retrieval.

The meter shall have the following capabilities:

1. Power/current average and peak demand available
72. Power and energy data logging
73. Enough memory for energy logging at 10, 15, 20, 30 or 60 minute intervals for a minimum period of 1 year
74. Ability to download data at site
75. Modbus compatible
76. Remotely accessible via Ethernet/IP communications

8.1.4 Single Supply

At sites where only one AC supply is present the second input into the AC changeover board shall have a 63A generator plug installed. This should allow the generator to be easily connected. This generator plug can be removed when the second supply is installed in the future.

8.2 AC Main Distribution Board

The main AC distribution board is fed from the AC changeover board. Supplies to the various loads within a substation are via appropriately rated MCB's located on the AC distribution board. In previous zone substation designs, the changeover board and the main distribution board are housed in the same cubicle. New substations will have separate compartments for the changeover and distribution boards, see Section 11.1.1 for more information. For terminal yards, the changeover board and main distribution board are in separate cubicles which are located adjacent to each other.

8.2.1 Board Location

AS/NZS 3000 and AS2067 require passageways and aisles to be at least 750mm wide and maintenance access points be at least 600mm wide with the doors open. Note as shown in Figure 8.2 below, 600mm clearance is required throughout the swing of the door so there is no benefit in using 170º opening doors.

Figure 8.2: Access to switchboards (from AS/NZS 3000, Fig 2.17)

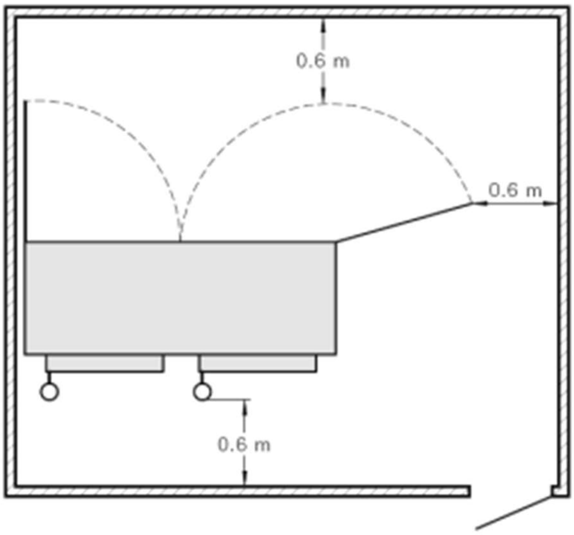


Figure 3: Access to Switchboards (From AS/NZS 3000 Fig 2.17)

8.2.2 Size

The number of ways in in the AC distribution boards should be maximised to allow for future development. The additional cost of spare ways is insignificant compared to the cost of adding an additional board should there be no available spares. Typically, new zone substation boards would have 48 ways and new terminal yard boards 72 ways. Space limitations in brownfield sites may reduce these numbers, however the number of ways should still be the maximum for a given space.

8.2.3 Brownfield applications

Many older substations have fuse holders mounted on an asbestos board for the distribution board. These must not be drilled and where there are no spare circuits a sub board may be required.

In terminal substations, it may be necessary to install a sub-distribution board in the same building as the main AC distribution board due to the number of AC circuits required.

8.2.4 Labelling

Distribution boards are identified using a combination of function and (if required) location. The Changeover and Main distribution board shall be labelled:

'415V Changeover and Main Distribution Board'

The label shall be located on the front door of the panel. Each circuit shall be clearly labelled in a permanent manner to show which equipment or sub boards it supplies. For more information on labelling see the Engineering Design Instruction – Substation Labelling and Numbering.

8.2.5 Busbar Identification on Drawings

The phase, neutral and earth bars shall be distinguished by the colours or by the corresponding alphanumeric notation detailed in Table 8.1 below.

Table 8.1: Busbar phasing identification and conductor colours

DESIGNATION OF CONDUCTORS		ALPHANUMERIC NOTATION	COLOUR
Alternating Current (A.C.) 3 phase system:			
415V Supply	Phase 1	L1 or R	Red
	Phase 2	L2 or W	White
	Phase 3	L3 or B	Blue
Neutral		N	Black
Earth		E	Green/Yellow

The order of the phase connections shall be Red-White-Blue and the phase orientation shall be as follows:

1. When the run of the conductors is horizontal, the red phase shall be (a) the top, or (b) the left or (c) farthest away, as viewed from the front.

77. When the run of conductors is vertical, the red phase shall be (a) the left or (b) farthest away, as viewed from the front.

When the AC system has a neutral connection in the same plane as the phase connections, the neutral shall occupy an outer position. Unless the neutral connection can be readily distinguished from phase connections, the order shall be Red, White, Blue, and Black.

8.3 Building Power Supplies

8.3.1 Sub Distribution Boards

In addition to the changeover board and the main AC board, a terminal yard relay room also houses a small power distribution board. This board supplies the power for the relay room itself (i.e., lights, power).

In zone substations, there is a sub board in the relay room and in each of the switchrooms, each fed from the main distribution board in the relay room. Where there is a separate room to house the protection relays, the sub board should be installed in this room.

There will be no other 415V AC supplies into a building other than from its own AC sub board(s).

8.3.2 General Power Outlets (GPOs)

In all buildings (zone and terminal substations), 10A single phase GPOs shall be installed in sufficient numbers and locations to permit two 20m extension leads from different GPOs to reach any point in the room. These are for general use (such as to supply power tools) and shall be installed with RCBOs. GPOs are not required to be installed in any new cubicles. New cubicles also do not need lighting to be installed within the cubicle, saving the need to bring 240V AC into the cubicle.

For zone substations, a single three phase 5 pin, 20A GPO, is required in the relay building and in each switchroom (or in the partitioned room containing the protection relays). These are required for injection testing of protection equipment and shall be installed such that all relevant equipment can be reached via a single 25m extension.

Terminal substation relay buildings shall be fitted with 20A three phase GPOs for injection testing of protection equipment. These shall be installed in sufficient numbers such that all protection equipment can be reached via 25m extension leads.

In RRST zone substations, a 40A three phase unit to supply the RRST is to be provided inside the relay building. There shall be no RCBOs installed on these circuits.

For all outlets where RCDs are not installed, clear signage must be provided to state the requirement for portable RCD use.

8.3.3 Air Conditioning Supplies

Air conditioning units within substation relay rooms/switchrooms are to be connected to the AC distribution board via a lockable switch located adjacent to the compressor. Three phase motors are preferable to ensure even loading across the phases. RCBOs are required on all air conditioning circuits.

8.3.4 Drawings

A lighting and power layout (detailing the type of lights and power points required) for each building must be prepared and issued along with the sub board and civil drawings to the building construction contractor. This drawing must be developed in conjunction with the building equipment, VESDA and air conditioning drawings and the following points must be checked:

1. Lights shall be placed between rows of equipment to ensure the light is not blocked by any equipment.

78. Access to GPOs must not be restricted by any equipment

8.4 Outdoor Power Supplies

8.4.1 Single phase GPOs

Single phase 10A GPOs shall be installed in suitable locations (e.g. on lightning masts with flood lights or low level lighting posts for new sites) within the switchyard for general use. The locations shall ensure that any point in the switchyard can be reached with a single 25m extension cord. These circuits shall be protected with RCBOs.

8.4.2 Three phase GPOs

Three phase GPOs are required near capacitor banks and transformers.

8.4.3 Capacitor Banks

One 35A GPO is required to be located near each group of capacitor banks mainly for protection testing. This GPO can also be used to supply maintenance equipment such as steam cleaners and SF6 gas reclaiming units. There shall be no RCBOs installed on these circuits.

8.4.4 Oil Treatment 100A Supply

8.4.4.1 Greenfield Substations

The 100A oil treatment supply is no longer required and shall not be installed for any new sites.

8.4.4.2 Brownfield Sites

Previously in brownfield zone and terminal substations, one three phase 100 amp AC outlet has been installed near the power transformers to supply oil filtration equipment, protection testing and commissioning.

There have been corrosion and reliability issues with these outlets due to their exposure to the elements and infrequent use. Mobile generators are generally used nowadays for streamline filtering so there is no need to install these outlets anymore.

There are no changes required at brownfield sites which have these outlets installed. However, if the outlet is damaged and could become a hazard, then it should be removed. In this case, if the outlet is fed from a distribution board, the supply cable shall be removed, and the circuit marked as spare.

This 100A supply can also be removed if capacity is an issue or space is required on a distribution board. If this is the case, then the supply outlet and support post must also be removed.

8.4.4.3 Historical information[4]

8.4.5 Power Distribution cubicle

Power distribution cubicles are installed one per bay in terminal yards only. They are supply points for AC and DC circuits required within the bay. They provide AC supplies to the disconnectors, circuit breakers, marshalling box and lightning mast GPOs and outdoor lighting.

8.4.6 Lighting Circuits

In zone substations, switchyard lighting is supplied from the main distribution board in the relay room, via a lighting contactor located in this main board. In terminal yards, the lighting is supplied via a lighting contactor from the nearest bay power distribution cubicle. The switchyard lighting shall be supplied with single poles so that a fault on one phase does not trip all the outdoor lights. The number of lights on each phase shall be balanced as closely as possible. These circuits shall be protected with RCBOs.

A point of isolation is required for each light in the light pole base.

8.5 Labelling

All cubicles or cabinets where 415V is present must be labelled on the outside with 'DANGER 415/250VAC" labels as per *Engineering Design Instruction - Substation Labelling and Numbering.*

For all outlets where RCDs are not installed, clear signage must be provided to state the requirement for portable RCD use.

All GPOs to have label with the phase and the pole on the DB where they are fed from.

[4] See Western Power Internal Document

9 Cables and Wires

9.1 General Requirements

Cable selection can be done manually or using software such as PowerCad 5 to select minimum cables sizes and circuit breaker ratings based on the requirements of AS/NZS 3000 and AS/NZS 3008. Standard drawings and calculation templates must be used, and Substation Principal Electrical Design Engineer must approve alternate calculation methods.

Cables must meet the requirements in *Engineering Design Instruction – Substation Secondary Systems Design*). Conduit for secondary cables must be at least 100mm in diameter.

All AC supply cables shall be 4 cores plus earth flexible cable.

9.2 Sizing

The sizing of the cable needs to take the following parameters into account:

1. Current rating,
79. Fault current rating,
80. Cable lengths (the maximum allowable cable length depends on the protective device and cable size used, see Table 6 below),
81. Installation (whether the cable is direct buried, in conduit or in a trench will affect its rating),
82. Voltage drop (typically use 2% from the transformer terminals to the distribution board, and 5% from the distribution board to the load. See AS/NZS 3000, Clause 3.6.2 for more information)
83. Protection of equipment and personnel,
84. Protective device used (fuse or circuit breaker type B, C or D)

Table 9.1 provides the typical maximum circuit route lengths above which the magnitude of the short-circuit current may not be sufficient to operate the protective devices within the required time. The lengths are calculated using Equation 1 (Equation B7 from AS/NZS 3000).

Equation 1

$$L_{max} = \frac{0.8 U_o S_{ph} S_{pe}}{I_a \rho (S_{ph} + S_{pe})} \quad \ldots \text{B7}$$

where

L_{max} = maximum route length, in metres (see Table B1)

U_o = nominal phase volts (230 V)

ρ = resistivity at normal working temperature, in Ω-mm^2/m

= 22.5×10^{-3} for copper

= 36×10^{-3} for aluminium

I_a = trip current setting for the instantaneous operation of a circuit-breaker

or

= the current that assures operation of the protective fuse concerned, in the specified time

S_{ph} = cross-sectional area of the active conductor of the circuit concerned, in mm^2

S_{pe} = cross-sectional area of the protective earthing conductor concerned, in mm^2

Table 9.1: Maximum route lengths for different conductors and protective devices (from AS/NZS3000:2018 Amd 1:2020, Table B1.) See Section 10.1.1 for more information on circuit breaker type.

TABLE B1

MAXIMUM ROUTE LENGTHS FOR DIFFERENT SIZES OF CONDUCTORS AND PROTECTIVE DEVICES USING APPROPRIATE MEAN TRIPPING CURRENTS (I_a)*

Conductor size		Protective device rating	Circuit-breaker (see Note 1)			Fuses (see Note 2)
Active	Earth		Type B	Type C	Type D	
mm²	mm²	A	Maximum route length (L_{max}), m			
1	1	6	170	91	55	204
1	1	10	102	55	33	114
1.5	1.5	10	153	82	49	170
1.5	1.5	16	96	51	31	82
2.5	2.5	16	160	85	51	136
2.5	2.5	20	128	68	41	93
4	2.5	25	126	67	40	90
4	2.5	32	98	52	31	70
6	2.5	40	90	48	29	60
10	4	50	117	62	37	73
16	6	63	142	76	45	85
16	6	80	112	59	36	59
25	6	80	124	66	40	66
25	6	100	99	53	32	47
35	10	100	159	85	51	75
35	10	125	127	68	41	58
50	16	125	198	106	63	90
50	16	160	155	83	50	71
70	25	160	235	126	75	108
70	25	200	188	100	60	84

* See Clause B4.5 for values of I_a.

NOTES TO TABLE B1:

1 The types of circuit-breakers (Type B, C or D) are based on the types described in AS/NZS 60898 series.

2 Fuses based on IEC 60269-1 are also known as BS 88 type fuses.

3 The maximum route lengths are the length of the phase conductor from the point of connection to the point of use and are related to a disconnection time of 0.4 s.

4 When the nominal phase voltage of the electrical installation is not 230 V, the maximum length may be determined by multiplying by a factor of U_o/230. For a nominal phase voltage of 240 V, the factor would be ~1.04.

5 Lengths of circuits may also be limited by voltage drop, particularly for single-phase arrangements.

6 The maximum length obtained only satisfies the fault protection requirements of Clause 1.5.5.3. The overload, short-circuit and voltage drop requirements will need to be considered independently.

Standard size cables should be used wherever possible since these cables are in stock and readily available. When non-standard items are requested, they are time consuming and often expensive to procure, since a whole drum of cable will have to be purchased.

9.3 Cable Support

Cable installation shall comply with the requirements stated in *Engineering Design Instruction – Substation Secondary Systems Design*.

Four core cables are preferred for three phase supplies. When single core cable is required, provide force calculations for cables under fault and bundle the cables in R, W, B & N groups using cable clamps or cable ties if justified by the force calculations.

9.4 Mechanical Protection[5]

All outdoor AC cables shall be buried in conduit or run in cable trenches.

AS/NZS 3000 Part 2 requires 415V AC cables to be installed at a depth of 500mm. The current substation control cable conduit at a nominal 300mm burial depth is therefore not compliant with the specific requirements of this part of the standard. However, extensive internal and external reviews and risk management workshops have demonstrated compliance with Part 1 of the standard and hence compliance overall with AS/NZS 3000.

AC cables may only be installed above ground in a temporary situation where risk of damage to the cables and associated risk to personnel is assessed as low. In this situation the cables shall be mechanically protected in accordance with AS/NZS 3000.

9.5 415V Cable Identification and Colouring

Cables shall be identified by their cable number at each end with stainless steel embossed tags.

Cable colouring shall be as prescribed in AS3000. If two core cables are used, then the active and neutral shall be red and black respectively, no matter what phase (red, white or blue) is being represented. This is allowed under AS3000 as the cables are numbered which clearly identifies each cable. Cable sleeving is not required in this case.

9.6 Wire Numbering

All AC wiring shall be numbered as per the *Engineering Design Instruction – Substation Secondary Systems Design*.

[5] See Western Power Internal Document

9.7 Terminations

AC power terminal strips are to be segregated from other wire terminations on a separate terminal strip, which may be mounted on a common rail with other circuits but segregated with a partition.

AC power terminals shall be shrouded and clearly labelled “415V/240V AC Supply”

Weidmuller WDU series terminals are to be employed as per *Engineering Design Instruction – Substation Secondary Systems Design*.

10 Protective devices

For general requirements of circuit breakers and fuses, see *Engineering Design Instruction – Substation Secondary Systems Design*.

10.1 MCB, MCCB & ACB Selection

Circuit breakers are selected based on the following parameters:

1. Rating,
85. Type of load (e.g. resistive, inrush etc.),
86. Fault current,
87. Tripping characteristic (See Section 13.1.1below), and
88. Protection grading

10.1.1 Tripping Characteristic

The tripping current required, is a function of the circuit breaker type and rating. See Table 10.1 for the standard ranges for B, C and D circuit breaker types.

Table 10.1: Standard ranges for instantaneous tripping (from *AS/NZS 60898* Table 2)

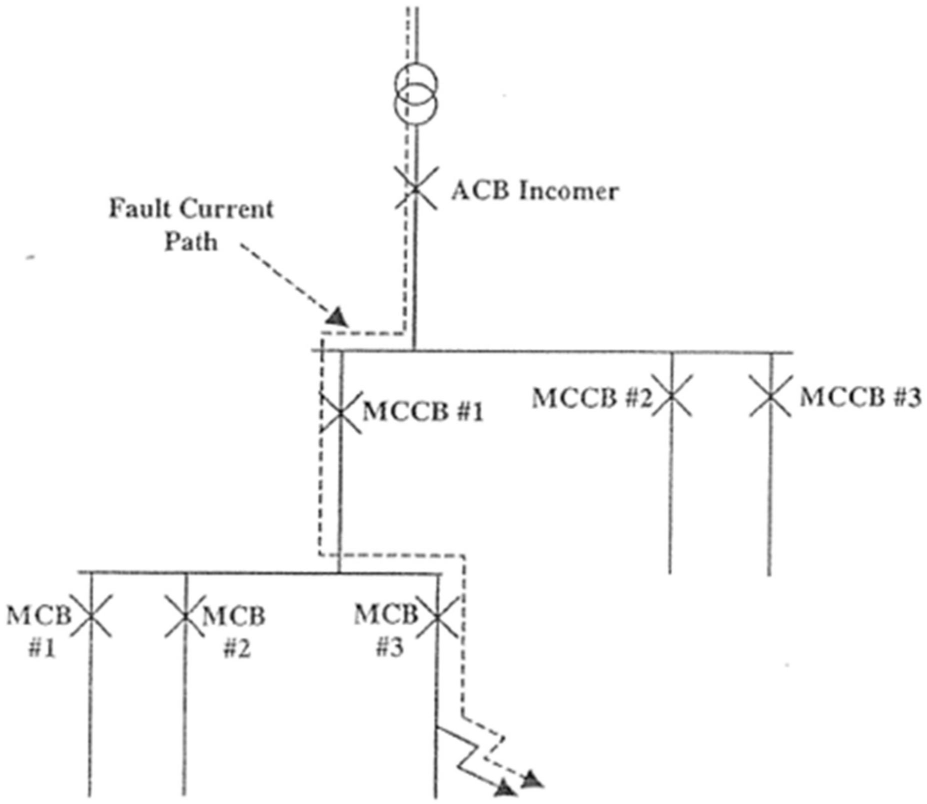
Type	Range
B	Above 3 I_n up to and including 5 I_n
C	Above 5 I_n up to and including 10 I_n
D	Above 10 I_n up to and including 20 I_n [a]
[a] For special cases values up to 50 I_n may also be used.	

10.2 Circuit Breaker Coordination

When MCBs are used in series, they must be graded to ensure that only the MCB supplying the faulted part of the 415V network is disconnected. For example, Figure 10.1 shows fault current flow in the event of a phase to earth fault downstream of MCB#3. In this example, if the MCBs are graded correctly, only MCB#3 should operate to isolate the fault.

MCB coordination can be done by hand using time current curves or using software such as Powercad.

Figure 10.1: Network example of discrimination



10.3 Residual Current Circuit Breakers with Overcurrent Protection (RCBO) [6]

Western Power uses RCDs with an overcurrent protection in substations. These RCDs are called residual current circuit breakers with overcurrent protection (RCBO).

RCBOs shall be installed in all new substations in accordance with AS/NZS 3000. However, RCBOs are not to be installed on certain circuits within the substation since it is important that vital loads are not tripped for faults on low level equipment. RCBOs should be installed on any

6 See Western Power Internal Document

circuit that can be accessed by personnel in accordance with the *Network Standard – Substation Auxiliary Supply and Electrical Services*.

RCBOs shall be installed the following circuits:

Circuits requiring RCBOs	Notes
Airconditioning	
Lighting	Yard lighting should not be installed all on the same circuit, such that a single RCBO trip will trip off all the outdoor lights.
GPOs (refer to notes for exclusions)	All GPOs shall have RCBOs installed with the following exclusions: Three phase GPO for RRST GPO for capacitor bank

There are many Western Power brownfield sites which do not have RCDs installed. This is due to a dispensation formally held by Western Power to not install RCDs. This dispensation no longer stands. There is currently no requirement to retrofit RCDs in brownfield sites, however when new work is done in brownfield sites, RCDs shall be installed on any new or modified circuits.

10.4 Fuses

Fuses are used in the following locations:

1. On the Station Transformer LV
89. In the AC distribution kiosk (for backup supplies from the distribution network)
90. LV kiosk may be required for fuses in terminal yards.

10.5 Station Transformers and LV Kiosk (PENDA)[7]

The available station transformers and their stock codes are shown in Table 10.2 below.

[7] See Western Power Internal Document

Table 10.2: Station transformer stock codes

Transformer Size (kVA)	**Voltage** (kV)	Notes	MPS/NON MPS	Stock Code
315 kVA	11 kV		MPS	XA2414
315 kVA	22 kV		MPS	XA2420
315 kVA	33 kV		MPS	XA2424
630 kVA	11 kV	Subject to approval by Western Power	MPS	XA2416
630 kVA	22 kV	Subject to approval by Western Power	MPS	XA2422
630 kVA	33 kV	Subject to approval by Western Power	MPS	XA2425
500kVA	22 kV	Auxiliary winding of earthing transformer		

Stock codes for the components making up Penda units can be found in the EDM reference in table 10.3.

Table 10.3: LV Kiosks, Public Electricity Network Distribution Assembly (PENDA)

Type	**Rating**
PENDA Type 2.2	1400 A

11 Earthing, Isolation and Separation of Neutrals

11.1 Neutral to Earth Configuration[8]

This section outlines the required Neutral to Earth (N-E) configuration for AC sources used at a substation. The N-E configuration includes the location of N-E links and MEN links, and neutral switching. TN-S system of earthing is used where the neutral conductor is only connected to the substation earth grid at a single location at any one time. This arrangement avoids parallel paths which allow stray neutral current to flow through the earth grid. AS3000 Clause 5.5.2.1. states that “Protective earthing conductors shall not normally carry load current”.

These requirements apply to greenfield applications and brownfield applications. Where an existing system is being modified and it is practicable, the earthing arrangement should also be modified to meet the requirements specified in this section.

[8] See Western Power Internal Document

11.1.1 Greenfield application

11.1.1.1 Station transformers, earthing transformers with an auxiliary power winding and generators (located in substation)

For station transformers, earthing transformers and generators, the N-E link is located at the source. A dedicated earthing conductor is required between the N-E link and the AC distribution board, in addition to the earth connection to the local earth grid. Four pole changeover switches shall be used so that only one N-E link is connected at any one time.

Figure 11.1 shows the N-E configuration for station transformers, earthing transformers and generators.

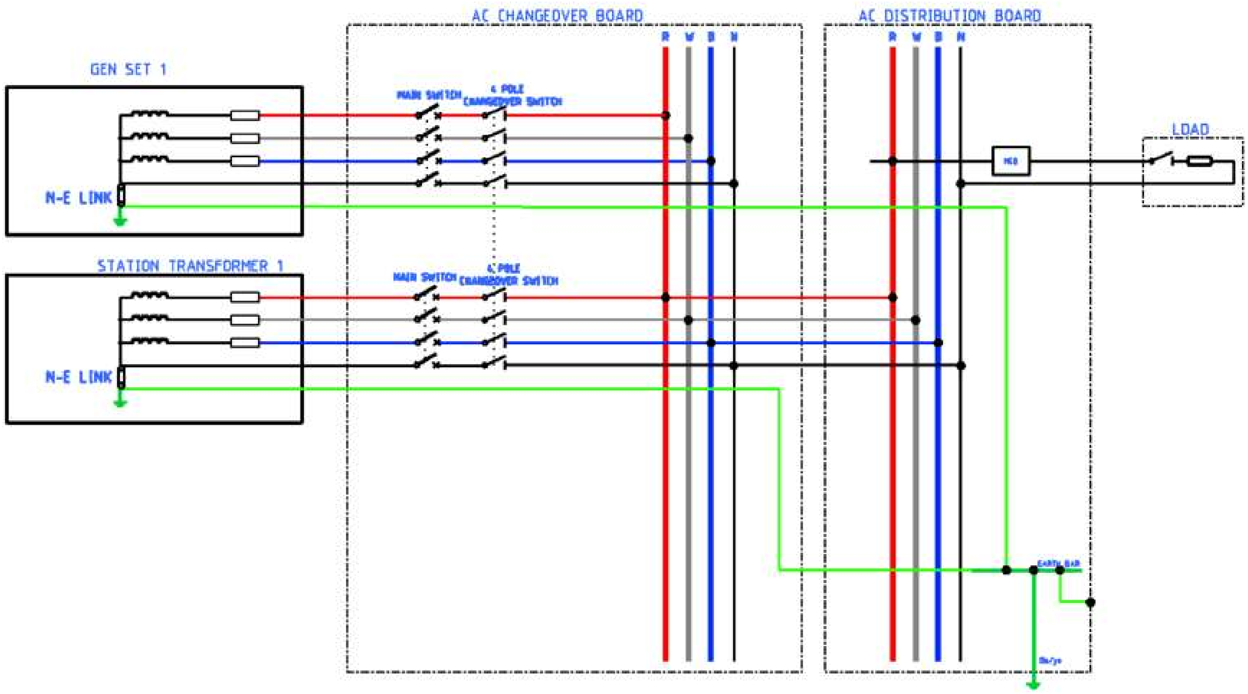


Figure 11.1: N-E configuration for station transformers, earthing transformers and generators

11.1.2 Brownfield application

11.1.2.1 Station transformers, earthing transformers with an auxiliary power winding and generators (located in substation)

When N-E connections are installed at each of these AC sources and the neutral conductor is not switched (i.e. 3-pole change-over device is used), parallel paths between AC sources are present.

4-pole change over devices shall be used to switch the neutral to prevent these parallel paths.

Figure 11.2 shows an existing installation with 3-pole change over switches and stray currents flowing in the earthing conductor/earth grid.

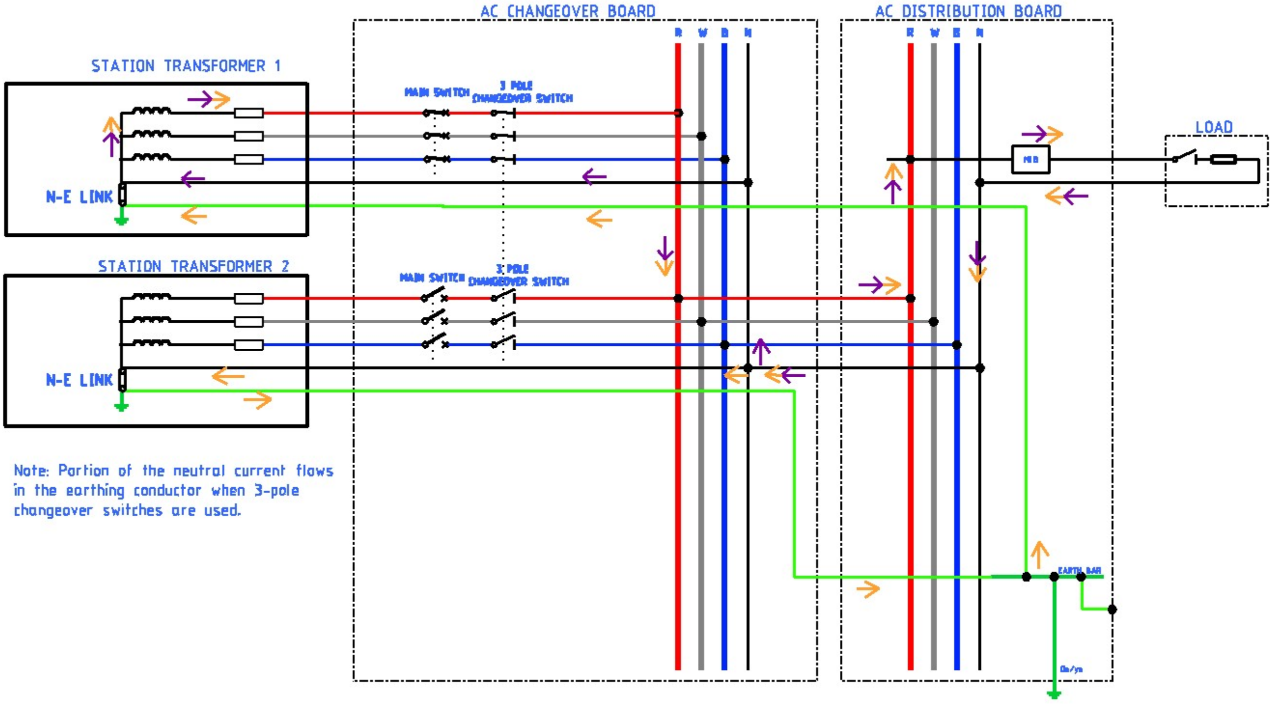


Figure 11.2: Existing installation with 3-pole changeover switches and parallel paths between neutral and earth grid.

In brownfield sites where it is not practicable to change to 4-pole changeover devices, calculations must be carried out to verify that[9]:

1. conductors are not overloaded by current sharing
2. conductors are suitable for the maximum calculated fault current
3. the nominal size of copper earthing conductors complies with the requirements of AS3000 Clause 5.3.3; and
4. the current carrying capacity of neutral conductors shall be not less than that of their associated active conductor.

11.1.2.2 415V Distribution network/street supply (transformer located outside substation)

415V street supplies are no longer installed but will be discussed to cover brownfield scenarios where the system is being modified.

In cases where the AC supply is from the 415V street supply, the TN-C-S system used in the distribution network is converted to a TN-S system in the substation. The combined protective earth neutral (PEN) conductor is brought into the substation and connected to the neutral and earth bar through a MEN link at the AC distribution board and a N-E link at the station transformer.

[9] AS3000 clause 7.3.8.1.1

For the purpose of clarity, the terminology MEN link should only be used for true MEN configurations where the PEN from the distribution network is used.

Existing installations may have the MEN connection installed on the load side of the main switch and changeover device. If there are other types of AC sources connected with their own N-E links, the neutral and earth grid will be connected in parallel. Where practicable, the MEN connection should be moved to the source side of the main switch and changeover device and N-E links should be installed in the other connected AC sources. 4 pole changeover switches are also required in this arrangement. Refer to Section 11.3 for more information.

Figure 11.43 shows an example of an existing installation where stray currents flow earth grid. Figure 11.4 shows the N-E configuration modified as described above.

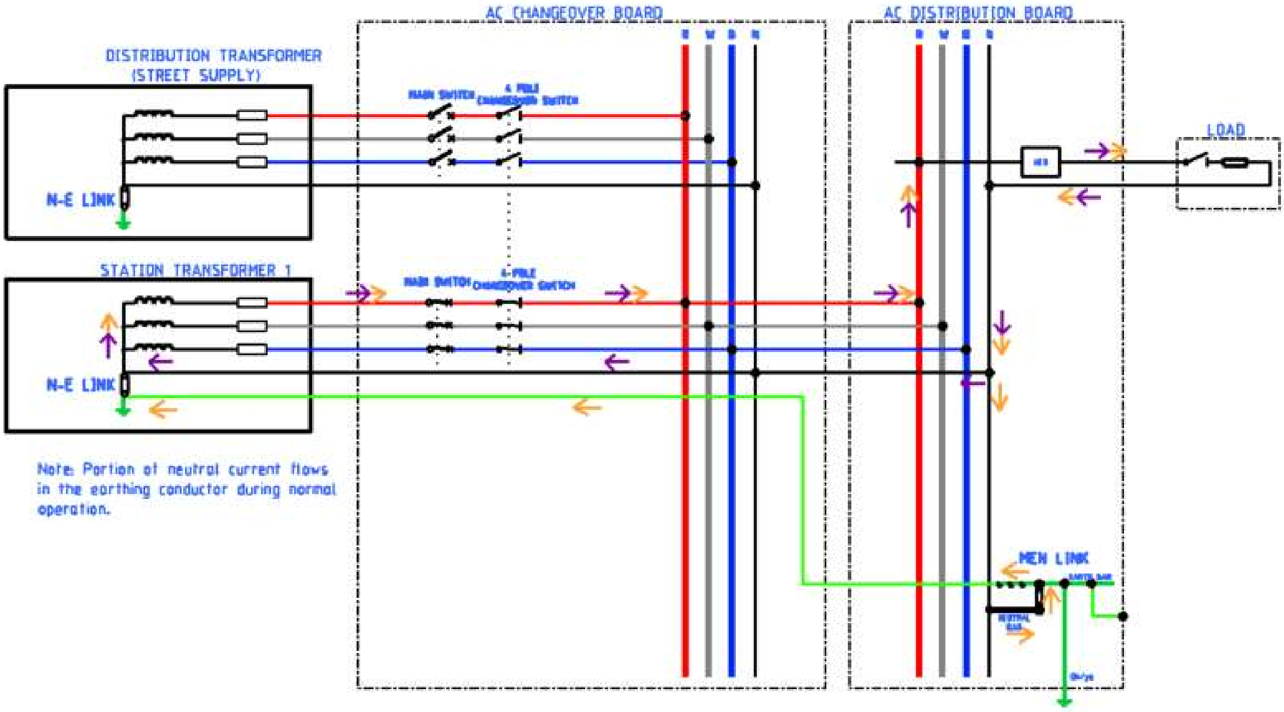


Figure 11.3: Existing installation for 415V street supply with neutral and earth grid connected in parallel.

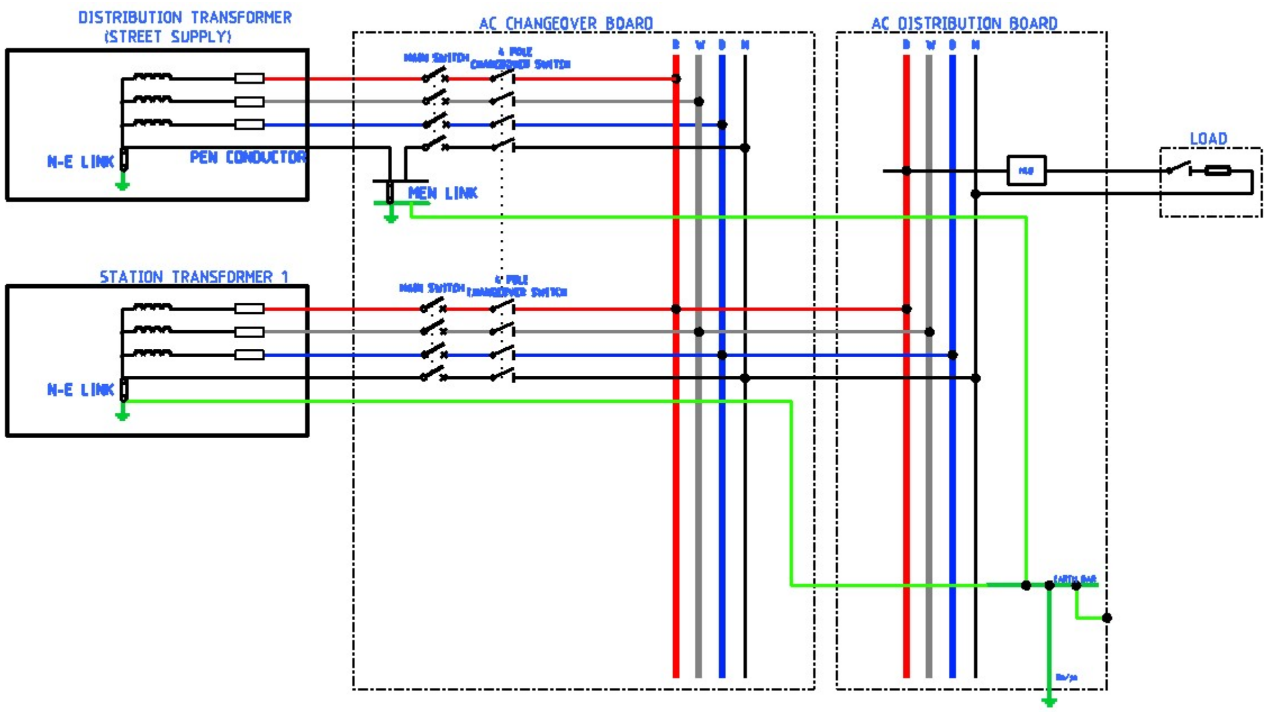


Figure 11.4: Modified N-E configuration for 415V street supply

If it is not practicable to make these modifications, calculations in accordance to AS3000 clause 7.3.8.1.1, must be carried out.

11.1.3 Summary

For any AC source, there should be only one N-E link or MEN link connected at any one time which is either at the AC source (station transformers, earthing transformers, generators) or at the supply side of the main switch and changeover device (415V distribution network). 4 pole changeover switches shall be used.

A N-E connection at the load side of the main switch and changeover device should be avoided. This arrangement could result in multiple N-E links connected at the same time.

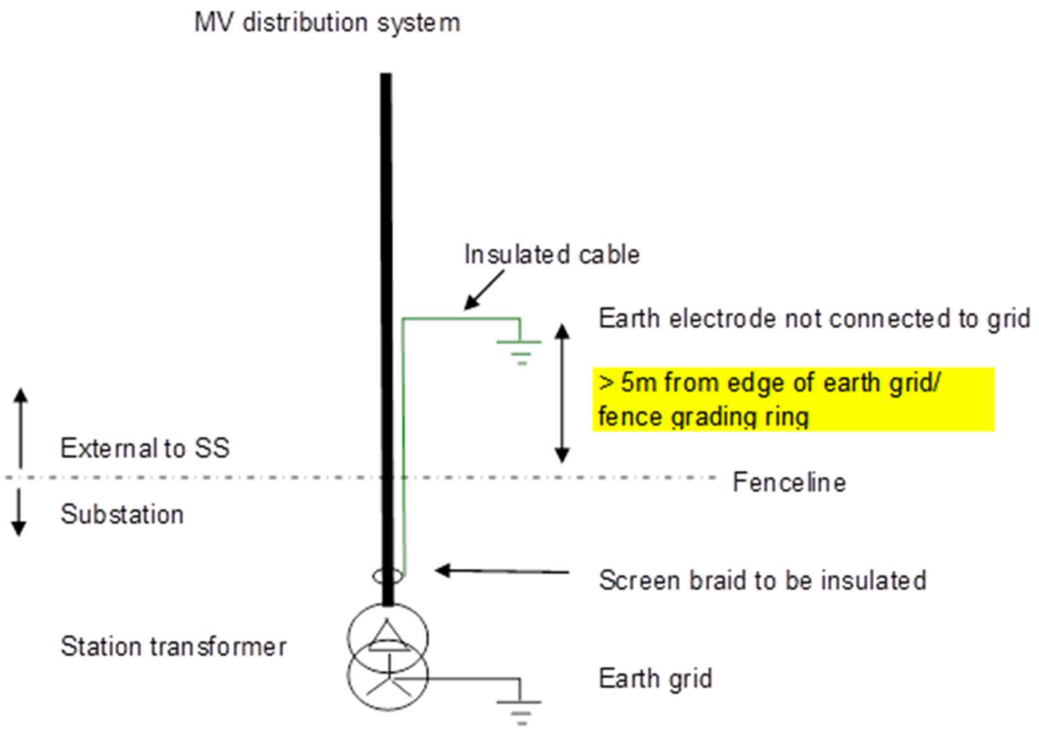
11.2 Connection of substation earth grid and distribution system

11.2.1 Terminal Yards

The following applies for terminal yards where the backup supply is a dedicated transformer supplied from the distribution network. The connection between the distribution system and the station transformer shall be by standard screened cable. To avoid transfer of earth potential rise (EPR) from the substation earth grid to the distribution system, the screen shall not be connected to the substation earth grid. It shall be connected to a separate earth electrode outside the substation boundary via a dedicated earthing cable run from the station transformer to the electrode. See Figure 11.1 below.

By dedicating the transformer to the substation there will be no transfer of EPR to the distribution system via the neutral.

Figure 11.5: Dedicated transformer supplied from distribution system.



11.2.2 Zone Substations

Zone substations already have an interconnection with the distribution system via the earthing of the feeder cable screens at each end, hence there is no point isolating the dedicated distribution transformer earth grid from the substation earth grid.

11.3 Electrical Isolation between Auxiliary Sources

11.3.1 Different AC supplies shall not be able to be operated in parallel

The AC auxiliary supplies must not be able to be operated in parallel for the following reasons:

1. Fault levels become excessive.
2. It is important to prevent back feeding a transformer from the 415V changeover board.
3. Prevents paralleling of 415V AC supplies with different phase angles.

Prevention of paralleling AC auxiliary supplies is achieved by designing the changeover arrangement to interlock all incoming supplies so that only one can supply the AC distribution board at any one time. To avoid even short term paralleling, the changeover switches shall operate on a break before make basis.

11.3.2 Four - pole changeover switches[10]

When N-E connections are installed at each source or at the supply side of the main switch and change over device (415V distribution network), four-point changeover switches are required. This prevents multiple N-E links or MEN links to be the connected at the same time which can cause stray neutral currents to flow through the earth conductor during normal operation.

Switching the neutral via the fourth pole also provides the electrical isolation necessary to ensure there cannot be any back feeds from faults on an in-service supply to any that are out of service.

The use of portable generators also requires the neutral conductor to be switched. This is to ensure that the neutral pin in the inlet socket does not become live when the generator is not connected.

11.3.2.1 Brownfield applications

In brownfield sites where 3 pole change over devices are installed and the AC system is being modified but it is not practicable to change to 4 pole changeover devices, in accordance to AS3000 clause 7.3.8.1.1, calculations must be carried out.

11.3.3 Three - pole changeover switches

Three-pole changeover switches can be found in existing installations. They may be found in brownfield applications where the N-E link is only at the load side of the main switch and changeover device. In this arrangement, there may not be N-E links at the sources and there is a risk of the source becoming unearthed.

Where it is practicable, the AC system should be modified to meet the requirements specified in section 11.1.2.2. N-E links should be installed at each source and the N-E link at the load side of the main switch and changeover device should be removed. If the AC source is from the 415V distribution network, a N-E link should be installed at the source side of the main switch and changeover device. Each supply must then be connected to the AC changeover board through a four-pole changeover switch.

If it is not practicable to make these modifications, in accordance to AS3000 clause 7.3.8.1.1, calculations must be carried out as per Section 11.1.2.1 (i)-(iv).

10 See Western Power Internal Document

11.4 Separation on Neutrals of Multiple AC Supplies

Except for AC sources from the 415V distribution network, each N-E link shall be installed as close to its source transformer as possible, for example, in the local supply transformer LV terminal box.

A label shall be installed adjacent to the location of the link stating that the N-E link for the relevant auxiliary supply system is located at that point. Figure 11.1 below contains the wording for this label.

Figure 11.6 Label for Neutral Earth Link

THE NEUTRAL EARTH LINK FOR THE No 1 AUXILIARY SUPPLY SYSTEM IS INSTALLED IN THIS TERMINAL BOX AND MUST NOT BE DISCONNECTED – REFER TO DRAWINGS FOR DETAILS

A label shall also be installed on the 415 V AC changeover board stating that each incoming supply system has a single N-E link installed and the location shall be stated. Figure 11.2 below contains the wording for this label.

Figure 11.7 Label for 415V changeover board with regards to Neutral Earth Link

THERE ARE NO N-E LINKS IN THIS SWITCHBOARD. THE N-E LINKS FOR THESE INCOMING SUPPLIES ARE LOCATED IN THE RELEVANT LOCAL SUPPLY TRANSFORMER TERMINAL BOXES – REFER TO DRAWING XXX FOR DETAILS

When the 415V distribution network provides the auxiliary supply to the substation, the MEN link for this supply shall be located in the changeover board on the source side of the main switch and changeover device. Figure 11.4 below contains the wording for this label.

Figure 11.4 Label for 415V changeover board with regards to MEN Link

THE MEN LINK FOR THE AUXILIARY SUPPLY FROM THE LOCAL DISTRIBUTION SYSTEM IS LOCATED IN THIS SWITCHBOARD AND MUST NOT BE DISCONNECTED – REFER TO DRAWING XXX FOR DETAILS

11.5 Segregation

Power cables of separate voltages shall be segregated.

Each load centre (e.g. a line circuit, transformer, building) is to be separately supplied from the AC distribution board apart from area lighting which can be daisy chained.

The following items should be considered when designing the supply points from the distribution boards:

1. Battery charger 1 and battery charger 2 supplies should not be adjacent to each other on the switchboard and cables should be segregated wherever possible.
5. Battery charger 1 and 2 should not be adjacent to each other.

6. Switchrooms 1, 2 and 3 supplies should not be adjacent to each other on the switchboard and cables should be segregated wherever possible.

See *Engineering Design Instruction - Substation HV Power Cables and Terminations* for more information on segregation from HV cables.

12 Building AC Supplies

AC supplies for the building are sourced from the relevant sub distribution board within that building.

All wiring within the building shall conform to AS/NZS 3000. Wherever possible, wiring shall be installed in wall cavities.

Any externally mounted switched or control devices shall have a minimum protection rating of IP55.

All indoor and outdoor light switches and power points shall be labelled appropriately.

13 Tariff Metering

13.1 Brownfield Sites[11]

In the past, meters were installed in some substations and hence some substations have accounts with Synergy. Many substations do not have any kind of metering installed.

The requirement of metering street supply is no longer a current practice. A street supply is necessary to run the substation and is deemed a direct cost of running the system network.

When meters are removed from existing substations, the Finance and Metering Area must be notified to update their meter database to reflect that the site is now unmetered.

13.2 Third parties

Where substation AC supplies are shared with third parties, kWh tariff metering is required to measure the power exported to the third party. Tariff metering requirements shall be in line with *Network Standard – Customer Connection Requirements* and the *Western Australian Distribution Connections Manual WADCM 2015* requirements.

[11] See Western Power Internal Document

14 Documentation[12]

To ensure and demonstrate that the AC design meets the requirements of AS3000 and this design instruction, it is important that the appropriate documentation and checklists are completed for every project.

A PowerCad model shall be completed for all greenfield sites and for significant extensions or changes to the AC system in brownfield sites.

15 Drawings[13]

16 Typical AC Loads[14]

17 Emergency Response Plan[15]

Appendix A: Approval Record and Document Control[16]

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12 See Western Power Internal Document
13 See Western Power Internal Document
14 See Western Power Internal Document
15 See Western Power Internal Document
16 See Western Power Internal Document