Part of Energy Queensland

Substation Standard

Standard for Substation Design Requirements

These standards created and made available are for the construction of Energy Queensland infrastructure. These standards ensure meeting of Energy Queensland's requirements. External companies should not use these standards to construct non-Energy Queensland assets.

If this standard is a printed version, to ensure compliance, reference must be made to the Energy Queensland internet site www.energyq.com.au to obtain the latest version.

<table>
<tr><td>Approver</td><td colspan="2">Carmelo Noel
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<tr><td colspan="3">If RPEQ Sign-off required insert details below.</td></tr>
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Abstract: This document covers criteria and considerations needed in the design of a substation to meet the performance expected by Energy Queensland. This document covers all aspects of substation design such as safety, environment, system security and reliability, switchyard layout, plant, equipment, protection, control, metering, communications, auxiliary supplies, cabling, earthing, surge and lightning protection, oil containment, fire protection, security, etc. This document also points to related documents in a series of substation standards with detailed requirements.

Keywords: Civil, Control, Design, Earthing, Environmental responsibility, Fire protection, Guide, Metering, Layout, Oil containment, Protection, Safety, SCADA, Standards. Structures, Switchyard

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1 Overview

1.1 Purpose

This document is designed to communicate requirements in designing and augmenting substations, in Ergon Energy (EE) and Energex (EGX) distribution networks.

This document also serves as a pointer guiding to relevant detailed documents, design standards and guidelines in Energy Queensland's substation standard series.

1.2 Scope

The document is intended to apply to transmission substations, switching stations and zone substations in the networks owned and operated by Ergon Energy and Energex.

The designer is expected to be familiar with, and have access to the rules, regulations and standards listed throughout the document and standard detailed design drawings.

Should there be a difference between the general wording of this document and the precise interpretation of any relevant legislation, then that legislation shall apply.

Customer and industrial substations or other distribution level substations are outside the scope of this document.

2 References

2.1 Legislation, Regulations, Rules, and Codes

Electrical Safety Code of Practice – Works, 2020 (Queensland Government)

Environmental Protection Act, 1994 (Queensland Government)

Queensland Electricity Act, 1994 (Queensland Government)

Queensland Electricity Regulation, 2006 (Queensland Government)

Queensland Electrical Safety Act, 2002 (Queensland Government)

Queensland Electrical Safety Regulation, 2013 (Queensland Government)

Queensland Work Health and Safety Act, 2011 (Queensland Government)

Queensland Work Health and Safety Regulation, 2011 (Queensland Government)

National Construction Code. (ABCB)

Mitigating the Adverse Impacts of Flood, Bushfire and Landslide. State Planning Policy. Queensland Government. June 2003

2.2 Controlled Documents

DR E3 Transformer Manager Application and Settings Guide for Ergon Energy - 12993358

Electrical Safety Rules - 6503074

Environmental Assessment Guide R242 - 691328

Guide for Reactive Plant in Substations (STNW3048) - 3059908

Hazard and Risk Management R209 - 690531

HSE Management System R206 - 690989

Network Physical Security - Design Reference - 13158190

Power Quality Planning Guideline - 3046919

Standard for Busbar Conductor Selection (STNW3014) - 3062690

Standard for Cables and Cable Installation (STNW3018) - 12737281

Standard for Clearance in Air (STNW3013) - 3054141

Standard for Climate and Natural Hazard Resilience (STNW3007) - 3057510

Standard for CVT Monitoring (STNW3049) - 8332893

Standard for DC Supplies (STNW3022) - 3062917

Standard for Electric and Magnetic Field Design (STNW3042) - 3060782

Standard for Insulation Co-ordination (STNW3034) - 3058912

Standard for Interlocking (STNW3046) - 3060386

Standard for GIS Application (STNW3045) - 3053734

Standard for Network Performance - 9997336

Standard for Oil Containment (STNW3036) - 3062359

Standard for Panel Wiring (STNW3024) - 2938164

Standard for Selection of Surge Arresters (STNW3033) - 3055929

Standard for Substation Direct Lightning Strike Shielding (STNW3032) - 20389422

Standard for Substation Earthing Devices (STNW3029) - 3057007

Standard for Substation Equipment Identification (STNW3001) - 2947172

Standard for Substation Fire and Explosion Protection (STNW3035) - 3058013

Standard for Substation Lighting (STNW3040) - 2949685

Standard for Substation Metering (STNW3114) - 3061818

Standard for Substation Signage (STNW3037) - 2941554

Standard for Switchgear Selection (STNW3051) - 12743722

Standard for Transmission and Distribution Planning - 11539388

Standard for Ventilation and Air Conditioning (STNW3047) - 3055324

2.3 Other Documents

Reliability Planning Guideline

RED364 Energex Substation Design Standard

SS-2-3.12 – OLTC AVR (Ergon Standard)

STNW3015 Primary Plant Ratings

STNW3023 Substation AC Supplies

STNW3028 Substation Earthing

STNW3041 Audible Noise

STNW3106 SCADA Standard Point List

STNW3107 SCADA Standard Point Naming Standard

2.4 Other Sources

AS/NZS 1170 (all parts)	Structural design actions
AS/NZS 1768:2021	Lightning protection
AS 2067:2016	Substations and high voltage installations exceeding 1 kV a.c
AS/NZS 3000:2018	Wiring rules
AS/NZS 3835 (all parts)	Earth potential rise – Protection of telecommunications network users, personnel and plant (all parts)
AS/ISO 14001:2015	Environmental Management Systems
AS/ISO 31000:2018	Risk management
AS/ISO 45001:2018	Occupational health and safety management systems – Specification with guidance for use
AS/ISO 55000:2014	Asset management – Overview, principles and terminology
AS/NZS 4804:2001	Occupational health and safety management systems – General guidelines on principles, systems and supporting techniques
AS/NZS 4853:2012	Electrical hazards on metallic pipelines
CJC 4 (HB 100) - 2000	Coordination of power and telecommunications
CJC 6 (HB102) - 1997	Coordination of power and telecommunications – Low frequency induction (LFI)
HB 203:2012	Environmental risk management – Principals and process
HB 219:2006	Earth potential rise – Protection of telecommunications network users, personnel and plant – worked examples for application guide.
HB 436.1:2020	Risk management guidelines — Companion to AS ISO 31000:2018, Part 1: Boards and executives
IEC 61936-1:2021	Power installation exceeding 1 kV a.c
IEEE 80.2013	IEEE Guide for Safety in AC Substation Grounding
NER	National Electricity Rules
	ENA Doc series, EG series and NENS series
	Queensland Electricity Entity Standard for Safe Access to High Voltage Electrical Apparatus

3 Definitions and Abbreviations

3.1 Definitions

For the purposes of this standard, the following definitions apply.

Term	Definition
Voltage Definitions	References to voltage level in this document are in accordance with AS/NZS 3000 Wiring Rules and are defined as follows:
Extra low voltage (ELV)	Not exceeding 50 V a.c or 120 V ripple free d.c
Low voltage (LV)	Exceeding ELV, but not exceeding 1000 V a.c or 1500 V d.c
High voltage	Exceeding LV
Circuit definitions	
Transmission feeder	Any feeder with a voltage of 110 kV or above, supplying either a transmission substation, a switching station, a zone substation or a single customer taking supply at that voltage
Sub-transmission feeder	Any feeder with a voltage of 66 kV or 33 kV, supplying either a zone substation or a single customer taking supply at that voltage
Distribution feeder	Any feeder emanating from a zone substation and supplying one or more distribution transformers, generally at 11 kV, 22 kV but not precluding 33 kV
Open point	A normally open switch connecting between two feeders, enabling them to be paralleled
Low voltage distribution	Lines or cables distributing 230/400 V supply from a distribution transformer to loads
Network element definitions	
Point of supply or bulk supply point	The physical connection point between the Ergon Energy or Energex network and an incoming supply of electricity. This may be a Powerlink substation, an Ergon Energy generation facility, or an interconnection with another network
Transmission substation	A substation connecting between transmission circuits or between sub-transmission circuits and distribution feeders including transformers, circuit breakers and associated equipment
Switching station	A station connecting between transmission circuits or sub-transmission circuits or distribution circuits including switchgear and associated equipment
Zone substation	A substation connecting between sub-transmission circuits or between sub-transmission circuits and distribution feeders including transformers, circuit breakers and associated equipment

Commercial & industrial (C&I) substation	A substation on the distribution network that is either a switching station or has transformers with 400/230V secondaries to feed commercial or industrial customers directly. Not covered by this standard.
Other Definitions	
Earth potential rise (EPR)	The potential difference between the local earth and remote earth due to the flow of electric current from the line to the earthing system (AS/NZS 3835.1)
EPR hazard zone	The area around an earthing system within a contour joining all points of EPR equal to the maximum permissible EPR hazard voltage, outside which zone no special precaution need to be taken to protect telecommunication plant or personnel (AS/NZS 3835.1)
Greenhouse gas	Industrial gases emissions, principally carbon dioxide, sulphur hexafluoride, chloro-fluorocarbons, nitrous oxide and methane, which contribute to the amplifying of the earth's natural warming processes
PCB	Polychlorinated biphenyl
Power quality	The quality of electricity supply in regard to such things as waveform quality, frequency, voltage levels and rate of change of voltage. The term is interchangeable with the term "Quality of Supply"
Reliability	The continuity of the electricity supply
Lightning shielding	A system of lightning masts, overhead earth wires and other components used to reduce the injurious and damaging effects of lightning
Surge	A transient overvoltage caused by lightning or switching or other causes
Voltage sag	A temporary reduction of the voltage at a point in the electrical system below 90% of the nominal. Sags are described not only by retained voltage but also duration. They may last from half a cycle to one minute

3.2 Abbreviations

This list does not include well-known unambiguous abbreviations, or abbreviations defined at their first occurrence within the text.

Abbreviation	Definition
AC	Alternating current (or a.c.)
ACWV	Power frequency withstand voltage
AIS	Air insulated switchgear
ALARP	As low as reasonably practicable
AVR	Automatic voltage regulation
BOM	Bureau of Meteorology
CB	Circuit breaker

Abbreviation	Definition
CT	Current transformer
CVT	Capacitor voltage transformer (or CCVT – Capacitor coupling voltage transformer)
DC	Direct current (or d.c.)
DIS	Disconnector (disconnecting switch / isolator)
EE	Ergon Energy
EGX	Energex
EMF	Electromagnetic field
EMC	Electromagnetic compatibility
EQL	Energy Queensland
EPR	Earth potential rise
ES	Earth switch
GIS	Gas insulated switchgear
GPO	General purpose outlet
GWP	Global warming potential
HIS	Highly integrated switchgear
HV	High voltage
IED	Intelligent electronic device
JW	Joint workings between Ergon Energy and Energex
LCF	Local control facility
LIWV	Lightning impulse withstand voltage
LV	Low voltage
MUX	Multiplexer
OCN	Operational Communication Network
OLTC	On load tap charger
OPGW	Optical ground wire
OTE	Operational Technology Environment
PCB	Polychlorinated biphenyl
PF	Power factor
RFL	Recommended floor level
RL	Relative level
RTU	Remote terminal unit

Abbreviation	Definition
SA	Surge arrestor (or SD – serge diverter)
SAIDI	System average interruption duration index
SAIFI	System average interruption frequency index
SCADA	Supervision control and data acquisition
SFAIRP	So Far As Is Reasonably Practical
SIWV	Switching impulse withstand voltage
SPO	Special purpose outlet
Std	Standard
VCR	Value of customer reliability
VT	Voltage transformer
ZSS	Zone substation standards

4 Actions and Responsibilities

All relevant Substation Design personnel and consultants either working on behalf of Energy Queensland, or constructing substation assets that will be gifted back to Energy Queensland, shall carry out works in accordance with this guide, Energy Queensland policies and standards, any interrelated Australian Standards or relevant international standards and Technical Guides.

The overall design philosophy is to ensure substations are:

- Safe for the public,
- Safe for operation and maintenance personnel,
- Suitably rated plant and equipment,
- Consideration of environmental factors,
- Consideration of operational and maintenance requirements
- Consideration of aesthetic quality,
- Connecting customers and market participants with acceptable levels of quality and reliability.
- Satisfying minimum standards for transmission substation, switching stations and zone substation designs.
- Meeting the requirements for forseeable future development.
- Financially sustainable investment considering whole of life costs.

5 Safety Considerations

5.1 Safety of the Public and Staff

Safety of the public, staff and all workers inside and around the substation is a major factor in substation design. Safety hazards shall be managed so far as is reasonably practical.

Substations shall be designed to provide protection for public and workers from a minimum of:

- direct contact during normal operation and maintenance by ensuring adequate clearances, or having exposed conductors behind enclosures, barriers or permanent obstacles,
- indirect contact such as step and touch voltages due to Earth potential rise (EPR),
- arc flash hazards
- electromagnetic fields (EMF)
- equipment failures
- possible fires
- exposure to hazardous chemicals either in normal operation or as a result of a fault.

Substations shall be designed so that approved 'safe' working procedures and conditions as defined documents such as the Energy Queensland Electrical Safety Rules and internal work practices, as well as relevant State Acts and Regulations, Australian Standards, Industry Standards and EQL publications can be readily followed.

The following safety related publications are applicable, and shall be taken into account in substation design.

- Electrical Safety Act 2002, and associated Guides and Codes of Practice. Queensland Government.
- Electrical Safety Regulation 2002. Queensland Government.
- Work Health and Safety Act 2011. Queensland Government.
- Work Health and Safety Regulation 2011. Queensland Government.
- Work Health and Safety. Advisory Standards. Queensland Government.
- Queensland Electricity Entity Standard for Safe Access to High Voltage Electrical Apparatus
- National Construction Code, Australian Building Codes Board
- AS 2067: Substations and high voltage installations exceeding 1 kV a.c.

Refer also to substation standards:

- STNW3013 – Clearances in air.
- STNW3028 – Substation Earthing.
- STNW3029 – Safety Earthing.

Australian and international standards and related references are listed in these documents.

5.2 Safety of Plant/Equipment

Plant/equipment shall be designed and laid out to ensure safety during operation, inspection and maintenance. The substation plant shall be positioned to minimise the risk of fire arising or spreading. Plant/equipment shall have adequate attributes during normal operation and under fault conditions.

The following shall be addressed:

- Suitable for the application,
- Adequately rated: such as rated current, short time current, rated voltage, insulation level, transient over-voltages.
- Adequate mechanical strength,
- Pressure relief in the event of an internal fault,
- Non shattering materials,
- Provision for condition monitoring,
- Protection against over-voltage surges and over-current.
- Adequate clearances,
- Suitable pollution level for the site conditions,
- Safe access,
- Operability,
- Maintainability,
- Preventative interlocks,
- Earthing of metalwork.
- Protection against spread of fires.
- Protection against vermin,
- Signage and labelling,
- Locking & security.

Refer also to the following substation standards:

- Technical specifications for period contract plant and equipment
- STNW1002 – Substation standard protection.
- STNW3013 – Clearances in air.
- STNW3015 – Substation plant ratings
- STNW3028 – Substation earthing.
- STNW3032 – Substation direct lightning strike shielding,
- STNW3033 – Surge arrester selection.
- STNW3035 – Substation fire protection.

In the above documents Australian and international standards and related references are listed.

6 Design Criteria

6.1 Service Conditions

6.1.1 Environmental Conditions

Plant / equipment shall be suitable for normal service conditions stipulated in relevant Australian Standards and the following:

- STNW3007 Substation Standard for Climate and Natural Hazard Resilience
- AS2067 Substations and high voltage installations exceeding 1 kV a.c.
- AS1170.2 Structural design actions wind actions
- Other relevant Australian Standards

6.1.2 System Conditions

Table 1: Plant Ratings

Attribute	Units	Recommended Value						
Frequency	Hz	50						
Number of phases		3						
Nominal system voltage	kV	11	22	33	66	110	132	220
Highest system voltage	kV	12	24	36	72.5	123	145	245
Lightning impulse withstand voltage (LIWV)	kVpk	95	150	200	325	550	650 550*	1050 950*
Power frequency withstand voltage (ACWV)	kV	28	50	70	140	230	275	460
System symmetrical fault level**	kA (s)	25 (3)	25 (3)	31 (3)	25 (3)	40 (1)	40 (1)	40 (1)
System neutral earthing **E = effectively earthed** **NE – not effectively earthed**	E or NE#	E or NE#	E or NE#	E or NE#	E or NE#	E or NE#	E or NE#	E or NE#

*. Applicable for transformers only provided insulation coordination studies have proved that these LIWV are safe.

**. The fault ratings of any network equipment should be designed to exceed the maximum fault current they may experience at any time. The values given are for typical equipment ratings for new installations. (Table 6 Standard for Transmission and Distribution Planning, Version 1). For 11 &, 22 kV systems fault level may exceed 25 kA.

#. Equipment such as VT and CB must be suitable for non-effectively earthed systems.

7 Environmental Responsibility

Energy Queensland is committed to responsible environmental management, ensuring all business activities associated with the supply of electricity are carried out with as little adverse impact on the environment as possible in line with ISO 14001 requirements.

7.1 Electric and Magnetic Fields (EMF)

Electric and magnetic fields (EMF) influence selection and management of substation sites and strategies relate to health and safety concerns of staff and the public. Energy Queensland has a policy of “prudent avoidance” in relation to EMF when designing or undertaking major upgrades of network assets such as substations.

7.1.1 Planning

- Subject to the principle of prudent avoidance, locate facilities to minimise public exposure to EMF.
- Consult affected communities as an integral part of site selection.

7.1.2 Implementation

- Subject to the principles of prudent avoidance, design and layout the substation to minimise public exposure to electric and magnetic fields.
- Ensure substation design meets occupational exposure limits for electric and magnetic fields
- Acquire sufficient land area/easement width to ensure acceptably low field strengths at boundaries and emanating from incoming and outgoing feeders.
- When required carry out an EMF Assessment study to submit with any development application to local government.

Refer to STNW3042 – Electric & Magnetic Field Design, and ENA resources on EMF for further information.

7.2 Oil Containment

Substations with plant containing more than 1000 litres of oil shall have oil containment and separation systems to prevent oily discharge in the event of equipment failure, an oil spill incident or run off of oily water during high rainfall events. Oil containment systems must:

- minimise the potential for oil to move off-site,
- protect the environment, and
- satisfy environmental legislative obligations.

7.2.1 Planning

- Review of legislative and other requirements, including internal risk management, insurance and environmental policies, relevant to the management of the oil containment issue.

- Environmental risk assessment of plant, location and site to determine the consequence in the event of an oil spill.

7.2.2 Implementation

- Engineering design practices and policies to AS 1940 for oil containment related to risk assessment.
- Design and installation of suitable oil containment and separator systems for sites that adequately manages the consequences identified above.

Refer to Substation Standard STNW3036– Oil containment for detailed requirements.

7.3 Greenhouse Gas Emission

Burning fossil fuels and release of synthetic gases such as sulphur hexafluoride (SF_6) are contributing to global warming, due to increasing concentrations of these gases in the atmosphere.

7.3.1 Planning

To reduce the impact of greenhouse gases the following shall be considered.

- Site selection and design that minimises bulk earth works (ie less diesel burnt during site preparation)
- Plant selection and substation design that allows for future replacement of assets without major site re-build.
- Reduction in power losses by utilising transformers which meet minimum efficiency standards.
- Managing energy usage in the substation.
- Minimising sulphur hexafluoride emissions to atmosphere.

7.3.2 Implementation

- All new switchgear will have vacuum interrupters for voltages up to 36 kV unless design criteria such as fault level rating cannot be met.
- All new switchgear at 12kV to be air insulated. Indoor switchgear at 24 and 36kV may have low pressure SF6 in combination with vacuum interrupters to reduce footprint.
- For voltages of 66kV and over, switchgear with a minimal volume of SF6 and best practice leakage rates may be used, i.e. 0.5%/year or less, if there is no other equivalent with comparable performance and cost characteristics.

7.4 Soil

Virtually all construction activity that requires the disturbance of the soil surface and the existing vegetation predisposes a construction site to erosion. This in turn leads to land degradation and sediment loss in resultant run-off water, which may impact the surrounding environment.

7.4.1 Planning

- Soil type and erosion potential shall be identified.

- Appropriate techniques and minimisation of excavation shall be adopted.
- Consideration shall be given to land contouring.
- Clearance of land shall be minimised.
- Water pollution potential shall be minimised.
- Soil samples taken for contaminated soil or acidic soil.

7.4.2 Implementation

- Use sediment barriers, check dams, straw bales during earthworks.
- Use approved techniques for clearing the site.
- Retain topsoil.
- Dust minimisation.
- Speedy site stabilisation.
- Safe disposal of contaminated or acid sulfate soil.

7.5 Flora and Fauna

Vegetation Management is necessary to ensure public safety and reliability of electricity supply, mitigate fire risk and reduce asset damage. In achieving this, the requirement for clearing of vegetation is to be reduced to a minimum and *impacts* on sensitive and significant areas avoided. Careful consultation with land and other stakeholders is an essential part of any *vegetation management* program.

In general all native fauna are protected by a variety of state, federal and local government legislation and regulations. However there may be exceptions to this under particular circumstances. Further, their *habitat* and certain areas of native vegetation may also be registered or protected. Care needs to be taken to ensure compliance with all legislation and regulations in this area.

While most animals will move away as a result of the presence of people or equipment in the area, native animals such as koalas and some nesting birds may remain and are protected. There are two potential impacts that substations may have on fauna:

- disturbance of habitat; and
- access of fauna to live electrical plant and equipment.

7.5.1 Planning

- Identify areas of protected flora, fauna and significant habitat by considering local, state, federal government instruments, as well as local signage
- Conduct flora and fauna surveys to identify species present
- Permissions / permits required
- Community sensitivity
- Identify the potential to fragment habitats
- Integrate into planning and assessment process
- Use existing corridors for incoming and outgoing feeders where possible / feasible

- Minimise clearing
- Avoid electric fences and razor wire that may kill local wildlife.

7.5.2 Implementation

- Areas inspected for fauna before work begins
- Works in accordance with permits / planning controls
- Auditing
- Disposal of materials
- Relocation / management plans for identified fauna

7.6 Noise and Vibration

Excessive noise can injure health of workers and cause nuisance to neighbours to the activity. Care needs to be exercised to ensure that regulatory standards are complied with excessive noise is transmitted away from sensitive receptors. Sensitive receptors include residential properties, health facilities, motels, aged care, schools and child care centres.

Similarly vibration may occur during construction for certain activities (eg. piling). A vibration assessment may be required depending on soil type, activity and location of neighbouring properties.

7.6.1 Planning

- Determine what environmental and health and safety noise standards need to be complied with for the activity
- Determine noise sources – transformers, reactors, Statcoms, AFLC, air conditioning plant.
- Determine sensitive receptors and measure distance to noise source.
- If an acoustic study is required, measure background noise levels
- Calculate effects of noise sources at sensitive receptor taking distance into account.
- Consider specific noise reduction measures such as low-noise transformers, noise barriers, buffer zones, etc

7.6.2 Implementation

- Ensure suitable selection of plant
- Where necessary employ noise reduction controls
- Ensure equipment is correctly operated and maintained to minimise noise generation.

Refer to STNW3041 - Substation Noise for the limits of noise level, methods of noise calculation at a location and measures of noise mitigation

7.7 Aesthetic

Care shall be taken to ensure that substations are designed to be compatible with their surroundings and that the stakeholders' requests are complied with where practical. Landscaping of substations should be considered to minimise visual *impact*. However this should not compromise the security of the site or the safety or reliability of the supply of electricity.

7.7.1 Planning

- Ensure that planning adequately considers sympathy with the visual environment, for example buffer zones
- All landscaping to comply with this standard, local authority requirements and Development Application conditions.
- Consider potential future land uses in areas being considered for substation sites
- Minimal possibility of debris/vegetation from landscaping being blown into the substation.
- Include landscaping and revegetation with appropriate non-invasive species in architectural plans for site development for significant construction works
- Wherever possible, use native plants suitable for soil and climate conditions
- Selected trees and shrubs shall be of the type that do not support climbing, particularly where planted within 3m of the fenceline.
- Where required, shrubs and trees to be planted under powerlines shall be of the type that will not grow into the line.
- Avoid planting trees and shrubs over power cables to avoid dryout of native soil or roots getting into conduits.
- For planting near boundaries, avoid species that will overhang neighbours' properties or drop leaves on their roofs.

7.7.2 Implementation

- Design works to take account of visual effects
- Inspect site to ensure that all visual issues have been included in plans
- Audit works design to ensure visual effects are fully incorporated

7.8 Cultural Heritage

Non-indigenous heritage consists of buildings, works, relics, trees or places of historical, scientific, cultural, social, archaeological, architectural, natural or aesthetic significance. This can include historical electrical infrastructure, particularly buildings.

An aboriginal site is any place that has the remains of a prehistoric or historic occupation, or is of contemporary significance to the aboriginal community.

7.8.1 Planning

- Carry out suitable searches for heritage items
- Where possible, avoid works in archaeologically significant areas
- Obtain permits and carry out site surveys where necessary
- Design and locate facilities in sympathy to local heritage issues

7.8.2 Implementation

- Adopt appropriate site controls, including staff awareness, wherever there is the potential for interference with heritage items in accordance with a Cultural Heritage Management Plan.

8 Security of Supply and Network Performance

8.1 Security of Supply

Security of supply is the level of capacity and inbuilt redundancy that a power system will have in order to meet various levels of demand and balance risk, cost and customer requirements [4]. Normally the number of transformers, transformer capacity and the numbers of HV & LV feeders are determined by Network Planning according to their required security criteria, or where the customer requests and pays for a level of redundancy on customer driven works.

Substation design shall also cater for normal operational and maintenance requirements for taking equipment out of service. This may require mobile substation connection points, having adequate transfer capability to shift load, or accept customer outages whilst maintenance is completed.

However, other lower level equipment/services essential to substations that needs redundancy for high security such as DC and AC auxiliary supplies and protection shall also be taken into account.

8.2 Reliability

Substation outages contribute overall to SAIFI and SAIDI indices over a five year period from 2018/19 to 2022/23 as per the following table [5]. These results reflect the less disperse nature of the Energex network and also reflect the quicker time to site to restore defects.

Table 2: Substation outages as a percentage of all outage data

	SAIDI (% OF TOTAL)	SAIFI (% OF TOTAL)
ENERGEX	0.88	3.27
ERGON ENERGY	2.24	4.11

Normally substation topology is determined by Network Planning. Considerations that affect reliability should also be taken into account in the design such as:

- selection of appropriate plant for intended current, voltage, operating environment
- clearances
- application of protection, SCADA, fire protection
- surge protection, lightning protection, earthing and electromagnetic compatability
- testing and commissioning
- isolation requirements for maintenance
- wildlife and vandal proofing

8.3 Operability and Maintainability

Substation designs shall consider Energy Queensland processes and policies regarding operating and maintaining the installation as required to provide a secure and reliable supply. This includes aspects such as:

- the ability to isolate, prove de-energised and earth primary equipment.
- the ability to perform secondary isolation on auxiliary protection and control equipment
- the ability to complete routine and condition based maintenance
- the ability to maintain supply during operation and maintenance activities

8.4 Power Quality

Electric power quality is the degree to which the voltage, frequency, and waveform of a power supply system conform to established specifications. Substations have limited influence on frequency, voltage unbalance and harmonic distortion. Consider the following factors.

8.4.1 Voltage Control

Substation design shall allow for voltage control at a substation via the ability to control OLTC, switched capacitors or reactors, SVC's or Statcoms. Line drop compensation (LDC) shall be able to be implemented to limit voltage regulation on the sub-transmission and distribution networks. Transformer impedance and OLTC range shall be coordinated to meet the voltage regulation requirements in worst case conditions

For very small substations, fixed tap or DETC transformers may be used if voltage regulation is provided by pole mounted regulators outside the substation fence.

8.4.2 Voltage Sags and Surges

Besides disturbances in the system, sags and surges could be contributed by the operation of transformers' on load tap changer (OLTC) and capacitor bank switching. The larger the tap changer step, or capacitor bank output relative to the fault level, the higher the voltage step change. The transformer tap changer step is standardised; therefore considerations should be given when determining the capacitor bank size.

Transformers impedance and OLTC range shall be coordinated to ensure that the transformer meets regulation requirements in worst case conditions. Where reverse power flow may occur through network resistances, or leading power factor loads are expected, check there are enough buck taps to maintain control voltage. Alternatives to changing transformers include static compensators and BESSs. These inverter-based systems can also mitigate transient sags and surges.

8.5 Ratings of Plant and Equipment

Plant/equipment (except surge arresters) shall have rated voltages at least equal to the system highest voltage and insulation levels in Table 1: Plant Ratings. For some switching applications such as switching reactors reference shall be made to STNW 3051 Switchgear selection standard for suitable ratings.

In assessing current or load rating, due regard should be paid to emergency loading, ultimate development and future load growth. However, where appropriate, allowance may be made for the cyclical nature of any load.

Some types of plant such as switchgear, CT, busbars, conductors and cables shall be selected to meet the expected short circuit currents. In some instances where the X/R ratio of short circuit impedance is high, picking a larger size circuit breaker to cater for DC offset may also need to be considered.

The performance of some types of plant such as circuit breakers, voltage transformers and surge arresters may be affected by system earthing.

Refer to:

STNW3015 – Primary Plant Ratings for standardised plant.

STNW3051 – Switchgear selection standard

9 Equipment

9.1 General

All substation primary plant and equipment shall be purchased in accordance with the relevant technical specifications available from the Substations Standards department. These specifications ensure:

- Bult and tested to applicable Australian Standards or IEC standards.
- That the plant is fit for purpose for the intended environment in Queensland.
- Aligns with EQL's policies and procedures such as the Electrical Safety Rules, operational and maintenance practices.

9.2 Major Plant Items

Energy Queensland holds standing order agreements for the following substation plant and equipment:

- High voltage circuit breakers
- Instrument transformers
- Disconnectors
- Surge arresters
- Power transformers
- HV gas insulated switchgear
- MV switchgear
- Audio frequency load control generation plant
- DC auxiliary systems
- AC auxiliary systems
- Protection cubicles

Designs shall utilise these items where possible. Information is contained in the Substation Standards SharePoint site under Consolidated Plant Listing. Standard drawings for these items are available in the Vault. Project specific drawings (e.g. switchgear, new design power transformer) will generally be available between 8-16 weeks after placement of order, so where possible utilising standard plant is recommended.

10 Civil Works

10.1 Switchyard Layout

The following considerations shall be given in layout of the switchyard:

- Bus arrangement – mesh, tee, single bus, sectionalised bus, breaker and a half, double bus.
- Access to plant/equipment for installation and maintenance
- Adequate safe horizontal and vertical working distances
- Adequate clearance for servicing vehicles
- Separation distance between fire origin plant/equipment to buildings and fire victims
- Suitable for Mobile Substation (particularly where design not N-1 or load transfer capacity)
- Suitable for future extension
- Meet aesthetic requirements

10.1.1 Clearances

Standard clearances for uniformity of design and safety to personnel are listed in Tables 1 and 2 of STNW3013 – Clearances in air.

Any type tested equipment designed and built to appropriate Australian Standards and installed as per manufacturer instructions is not required to comply with the minimum clearances as dielectric type tests are used to confirm sufficient insulation.

Separation between possible sources of fire such as oil-filled plant and equipment to control buildings, combustible surfaces and other equipment shall be in accordance with AS 2067.

10.1.2 Access Roads and Pathways

The substation access road shall be designed to allow for easy access for construction and maintenance vehicles at all time and should be designed to approved local parameters and guidelines set out below.

Suitable pathways shall be designed to allow easy of access of mobile plant and equipment such as elevated work platforms within the substation as required for all installation, operation and maintenance requirements. Access from at least one side of a bay should be provided to mobile plant and equipment. Any conduits or cable pits shall be of sufficient strength to allow typical mobile plant to traverse over.

10.1.2.1 Main Access Road Minimum Requirements

Load to be supported	100 tonnes in general (except for transformers 80MVA or greater)
Access road width	5 metres

Cross fall	2%
Surface	25 mm thick dense grade asphalt DC10 in accordance with Main Roads specification MRS 11.30
Base gravel	125 mm Type 2.2 (CBR 60)
Sub base gravel	125 mm Type 2.3 (CBR 45)
Kerb and gutter width	600 mm (semi-mountable to be used on the lower side of road edges throughout)
Concrete edging (bitumen road)	300 mm wide x 275 mm deep (semi mountable to be used on the higher side of road edges throughout)
Maximum access road gradient	1.15 or 3.9 degrees
Minimum access road turning	5 metres inside radius
Minimum turning circle for:	
- Construction trucks	5 metres inside radius
- Low loaders	15 metres inside radius
	20 metres outside radius
Maximum deviation of concrete	10 mm over 3 metres
Storm water drainage	Slots to be left in kerbing in accordance with the site specific storm water design details

10.1.2.2 Finished Levels

The level of the finished access road shall be as close to the level of the transformer footing as possible to enable easy unloading of transformers. Special attention must be paid to the interface between the council layback and the access road to ensure low loaders do not have trouble in gaining access.

10.1.3 Conduits

Cable and drainage conduits shall be installed prior to construction of access roads

Cable conduits shall be buried at depth and with nominated backfill in accordance with STNW3018– Substation Cables and Cabling. Note that low thermal resistivity bedding sand or flowable fill may be required.

For underground cable circuits consideration is to be given to the need for cable re-terminations or replacements. One option is leaving excess cable buried below ground or in basements to allow for slack to be used in re-terminating cables. Alternatively underground design shall allow replacement cables to be pulled in through conduits.

Lay out paralleled cable circuits from a transformer to its switchgear so that the route lengths to the busbar are near equal. (This requirement does not apply to cables connected to different dual-LV windings, as their parallel includes the high transformer impedances.)

10.2 Steel Structures and Fasteners

Outdoor structures for supports shall be galvanised steel, and designed and manufactured to withstand the expected environmental conditions. All fasteners to be used shall be ISO metric. Refer to substation design standard drawings for quality assurance details.

10.3 Switchyard Surfacing

Where necessary the switchyard shall be treated with soil stabilisation chemicals and all bogs shall be removed and replaced with clean fill.

The switchyard shall be contoured to prevent water ponding and subsurface drainage be installed.

Before installing the final covering of crushed rock the switchyard shall be treated to prevent the growth of weeds, the earth grid and all conduits and drainage shall be installed.

The switchyard shall have a covering of a depth of 100 mm of 20 mm - 30 mm crushed rock, generally the crushed rock shall be blue metal but in some environmental sensitive areas rock shall be sourced from local quarries. Ensure that the resistivity of the water saturated rock is consistent with the value used in the earthing system design.

10.4 Switchyard Lighting

The horizontal plane at ground level around equipment and structures in the outdoor structure areas and at the security fence shall be illuminated at a level not less than that indicated in STNW3040 – Substation Lighting.

Lighting fitting shall be placed to overcome shadows, limit glare and avoid spill to the neighbourhood.

A lighting study may be required to ensure sufficient illumination allowed for in the design.

10.5 Design Life

All works must be designed for maintenance free lives as detailed in the below table:

Table 3: Design life for civil works

Structures	50 Years
Concrete Works	50 Years
Drainage works (occasional clean out of gully pits, traps, and Oil Separator excepted)	50 Years
Pavement Works	25 Years
Bitumen Seal	15 Years
Fencing	25 Years
Stairs, Ladders, Pit/Duct Lids	25 Years

10.6 References

Refer to the following documents:

- STNW 3013– Clearances in Air, for the requirements of minimum electrical clearances, safety clearances, clearances to walls and fences, clearances to vehicle access, bay widths, bus height and spacing between busbars
- STNW 3014 – Busbar Design, for standard sizes, current carrying capacity, and permissible maximum spans in various (wind loading) regions
- STNW 3015 – Primary Plant Ratings, for standard ratings of plants in the switchyard and indoor switchgear.
- STNW3032 – Substation Lightning Strike Shielding
- STNW3035 – Substation Fire and Explosion Protection
- STNW3036 – Oil Containment
- STNW3040 – Substation Lighting
- Substation standard general arrangement and civil drawings (Energex & Ergon Energy)

Australian Standards, International Standards, Industrial Guidelines and references are listed in the above documents.

11 Site Services

Site services such as water, sewerage, stormwater and fire services shall be in accordance with the project specification. Considerations for site services shall include:

- 1 x male and 1 x female toilet facilities either on site or within 5 minutes travel time from the substation.
- Sufficient water for site amenities. Potable water preferable however non-potable may be accepted in some circumstances
- Provision for lunchroom during construction.
- Provision for future electric vehicle charging points.

12 Protection

The requirements for protection shall be as per STNW1002 – Substation Standard Protection.

Relays used in protection schemes will be selected from the current period contract. Application guides for these relay applications are available from Protection Standards.

Remote engineering access to all relays shall have DNP-3.00 communications capability.

Refer to the following documents:

- STNW1002– Substation Standard Protection, for common requirements, specific protection systems/schemes for various types of plant in the substation and network components such as transmission/sub-transmission feeders, distribution feeders connected to the substation

- STNW3001 – Substation Standard Equipment Identification, for component identification, item identification, device function numbers, relay codes, wire numbering, indicator light colours and related subjects
- STNW3022– Substation DC Supplies, for nominal rating of CB on protection circuits and trip circuits
- Substation standard circuitry drawings including relay wiring and case drawings
- Protection relay application standards available from the Protection Standards team.

Australian Standards, International Standards, Industrial Guidelines and references are listed in the above documents.

Where practical, protection relays should assist with control, indication and alarming.

13 Substation Circuitry

13.1 Trip Circuits

Protection relay contacts used for tripping, indication, or alarm must be of robust and reliable construction. All contacts must be clean and have appropriate current ratings to match the required duty. All primary switchgear shall have two independent tripping circuits. The preferred method is to initiate CB control via the protection relays.

Where relays/systems do not provide adequate facilities or ratings to trip all required devices, tripping must be achieved by high speed auxiliary/tripping relays initiated from the individual protection relays/systems. The total trip time shall not exceed allowable total trip lengths due to additional auxiliary relays.

Separate tripping relays must be provided for transformer protection schemes and bus protection schemes. These relays must have latching contacts that can be reset locally and remotely via SCADA.

All other tripping relays must have self-reset contacts and continuously rated operating coils.

Operation indicators must be provided on the transformer and bus protection systems trip relays but are not required on trip relays used for contact reproduction. Flags or LEDs are equally acceptable and must be reset by the same system that resets the contacts.

The design of the operation and isolation of trip circuits for all new circuit breakers, and where available on existing brownfield circuit breakers, must ensure the following:

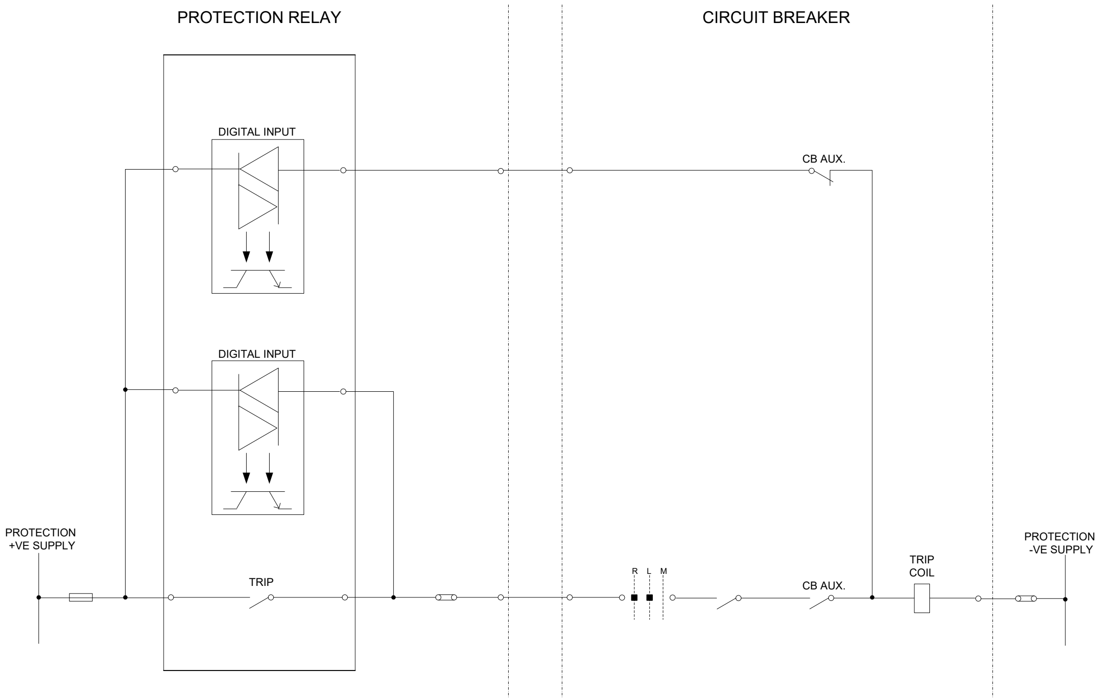
Table 4: Trip circuit

Trip Function	Circuit Breaker REMOTE/LOCAL/MAINTENANCE Switch Position
Protection 1	REMOTE and LOCAL
Protection 2	REMOTE and LOCAL
SCADA Trip	REMOTE
Circuit Breaker Local Trip	LOCAL
All trip circuits to the trip coil must be disconnected when switch is in MAINTENANCE position	

Trip Circuit Supervision (TCS) circuitry must be designed and included for all circuit breakers in new Greenfield Substations. Both trip coils must be monitored in the circuit breaker closed and open states. TCS is implemented in both protection relays in accordance with the Standard Template Drawings and Protection Application Guides. There is no requirement to install additional relays for the purpose of providing trip circuit supervision functions.

A simplified representation of the TCS circuitry is as follows:

Figure 1: Trip circuit supervision



13.2 Close Circuits

Protection relay contacts used for circuit breaker closing must be of robust and reliable construction. All contacts must be clean and have appropriate current ratings to match the required duty. The preferred method is to initiate CB control via the protection relays.

Where relays/systems do not provide adequate facilities or ratings to close all required devices, closing must be achieved by auxiliary close relays.

All closing relays must have self-reset contacts and continuously rated operating coils.

The design of the operation and isolation of close circuits for all new circuit breakers, and where available on existing brownfield circuit breakers, must ensure the following:

Table 5: Close circuit

Close Function	Circuit Breaker REMOTE/LOCAL/MAINTENANCE Switch Position
Auto Reclose from Protection Relay	REMOTE
Auto Reclose from SCADA	REMOTE
SCADA Close	REMOTE
Initiate Close via Protection	REMOTE and LOCAL
Circuit Breaker Local Close	LOCAL
All close circuits to the close coil must be disconnected when switch is in MAINTENANCE position	

There is no requirement to provide supervision of the close coil circuits.

Capacitor bank circuit breakers must have a close inhibit to allow for capacitor bank discharge. This scheme is best implemented by utilising the capacitor bank protection relay to perform the timing function which is initiated from the CB status. The protection relay is required to have a close inhibit output contact placed in the signal path to the circuit breaker close coil and is best positioned in the close coil negative to ensure all sources of the closing signal are inhibited, i.e. from SCADA, control panel, and local at circuit breaker.

13.3 Auto Reclosing

The preferred method for the design and implementation of auto-reclosing (A/R) of substation circuit breakers is to utilise the protection relay logic. If the protection relays are not capable of providing an auto-reclose function, then an alternative is to use the substation SCADA system. The installation of dedicated auto-reclose relays is **not** permitted.

Auto-reclosing is prohibited for bus protection and transformer faults. Application of the standard relay circuitry will ensure an auto-reclose initiate signal is not present for these faults.

Refer to STNW1004 Auto-reclose standard for further information.

13.4 Circuit Breaker Fail Protection

Circuit breaker fail (CBF) protection schemes must be designed to isolate a fault that has been detected by other protection but has not cleared. This other protection is said to initiate the CB fail scheme. The basic philosophy for the implementation of CBF protection is a timer and an overcurrent element, with the timer being initiated by the protection initiating the protection operation. After a time dependant on the expected switch clearing time, (not usually exceeding 200ms), the timer must cause a trip to all other circuit breakers necessary to isolate the fault, only if the overcurrent relay detects fault current still flowing. Isolation of the fault may include a requirement to send an inter-trip signal to a remote end substation.

Refer to STNW1002 – Standard for Substation Protection for further details on CBF schemes.

13.5 Sensitive Earth Fault Protection

Distribution feeder protection schemes shall include Sensitive Earth Fault (SEF) protection. For all new protection installations and any upgrades to existing protection, SEF protection is to be implemented in the new protection relay, hence removing the requirement for a dedicated SEF protection relay.

The SEF scheme must include a transformer neutral check which will inhibit the feeder SEF trip unless transformer neutral current is present. An additional trip output for the purposes of an SEF trip is not required, with the protection relay utilising the main protection trip output contact for this function. As there is no delineation in relay trip output between a protection trip and an SEF trip, the neutral check function is to be provided from a non-latching Multi-trip relay as a digital input to the protection relay performing the SEF, and not as a hard-wired inhibit contact in the tripping circuit.

SEF protection schemes must include control and indication for both remote and local enable/disable of the scheme. Local control will be in the form of a panel pushbutton wired to the protection relay digital input with a corresponding lamp driven from a relay output, or via the HMI interface to the relay. Remote control is implemented through the communication port from SCADA to the relay.

SEF protection may be required to be implemented on transmission and sub-transmission feeders which supply or traverse mining sites, or any other sites considered a mining installation, eg coal handling plants etc. This requirement must be outlined in the Project Scope Statement for the project. This scheme will be implemented in the backup protection relay with the same functionality as the distribution feeder.

13.6 Underfrequency Protection

Under frequency protection is implemented at the distribution feeder level. For all new protection installations and any upgrades to existing protection, underfrequency protection is to be implemented in the new protection relay, hence removing the requirement for a dedicated underfrequency protection relay.

An additional trip output for the purposes of an underfrequency trip is not required, with the protection relay utilising the main protection trip output contact for this function.

Underfrequency protection schemes must include control and indication for both remote and local enable/disable of the scheme. There is no requirement to provide local control of underfrequency protection at the relay panel, and remote control is implemented through the serial communications from the SCADA to the relay.

13.7 Voltage Unbalance and CVT Monitoring

Voltage unbalance supervision shall be conducted via SCADA to detect abnormal voltage conditions, typically arising from a voltage transformer fault, that may impact voltage regulation.

CVT monitoring shall be installed on all capacitive voltage transformers. Routine condition assessment testing of Capacitive Voltage Transformers in the form of oil dissolved gas analysis cannot be undertaken due to the hermetically sealed capacitor stacks, and therefore CVT's require additional on-line condition monitoring.

There is a hierarchy of design options for CVT monitoring. Refer to STNW3049 Standard for CVT monitoring for further information.

14 Control and SCADA

RTUs and a Local Control Facility (LCF) via HMI (Human-Machine Interface) shall be installed at all new substations. AFLC may also be required.

14.1 General Philosophy

The general design philosophy is to use protection relays for integrated protection and control (IPAC) of both indoor and outdoor circuit breakers. Protection Standards will cover relay configurations for IPAC designs. Where there are insufficient inputs/outputs on the relay to cover the application, then an additional SCADA Intelligent Electronic Device (IED) will be required, and there will be an IED configuration for this application.

In addition, there may be other applications without a protection relay, such as transformer management, DC auxiliary systems and AFLC, where an IED may be required for control and indication, and these will also have a standard configuration.

14.2 Circuit Breaker Controls

On new projects control shall be via a HMI interface through the protection relays. Panel switches are not required in new control panels. As an alternative method of control for indoor circuit breakers, a plug interface shall be provided to an extension lead to operate the breaker away from the equipment in the event the HMI interface is not working.

14.3 RTU Requirements

The required substation controls, alarms and analogues for each item of substation equipment is specified in the standards STNW3106– SCADA Standard Point List and STNW3107 – SCADA Standard Point Naming.

The control system and associated communications links shall provide sufficient capacity to meet the scan times specified in STNW3106.

The number and type of RTUs installed depends on the substation configuration. There may be distributed RTUs across the substation, connected onto a LAN. The RTUs shall provide SCADA for HV bays, transformers including OLTC control and AVR, LV bays, capacitor bank control, AC & DC alarms and any other miscellaneous indications. The RTUs shall also interface to the HMI and SCADA Master Station.

The RTUs shall be rack mounted within the protection and control cabinets and shall have a separately fused DC supply for:

- Microprocessor power supply
- Field Input/Output Card supply

The Open/Close controls for HV and LV circuit breakers (CB) shall be provided via the protection relays. These controls shall be performed by utilising momentary action voltage-free trip close contacts.

The OLTC AVR control shall be provided by the RTU and is required to regulate the LV system. The AVR control routine shall be as per the EE standard SS-2-3.12 – OLTC AVR Control or Energex VVR. Accuracy class 0.5M VT sources are required for voltage regulation. A ±20% suppressed zero voltage transducer connected to the VT shall be used for the AVR reference voltage.

The Capacitor Bank control, where required, shall be provided by the RTU and shall be as per the Ergon Energy standard – Capacitor Automatic Control or VVR5.

All configuration settings and programming of the RTU is to be included. Where possible all data and controls will be provided by DNP-3.00 over ethernet to protection relays, metering and other substation equipment.

The communications to the SCADA Master Station shall be DNP-3.00 to the appropriate Remote Data Acquisition Server (RDAS).

14.4 AFLC Requirements (where required)

The AFLC equipment shall comprise of a local controller, a single static frequency transmitter and 1-2 associated coupling cells. The transmitter and coupling cell shall be suitably rated for the network as determined by network studies/sizing calculations prior to ordering. The controller and transmitter shall be located within the control building with the coupling cell located outdoors. The AFLC frequency shall be as per the existing regional frequency.

The controller shall provide for local program operation and remote SCADA program operation with direct communications to the appropriate RDAS via DNP-3.00. It shall also allow for local manual operation. The controller shall transmit the regional protocol and provide GPS time pulse and phase synchronisation when required.

The coupling cell connection to the substation shall depend on the voltage. At 66kV the AFLC shall be connected via a dedicated circuit breaker bay with the coupling cell located outdoors in a fenced off enclosure. At lower voltages the AFLC shall be connected to a feeder on each bus section via an RMU. At lower voltages it is recommended the coupling cell be located indoors. Noise attenuation shall be a consideration for the design of the coupling cell with the possibility of sound barriers.

14.5 Master Station Requirements

Picture creation and database configuration is required on the EQL Operational Control System for all controlled plant and equipment. Configuration of master station communications equipment shall be provided.

14.6 Local Control Facility (LCF) Requirements

A LCF such as panel touch screen required for local control of the substation equipment shall be installed. All picture creation and configuration is required. The LCF shall be installed in a location allowing access to telephones, radio communications equipment and a work area suitable for performing switching operations.

14.7 Communications Links

The communications link to the Operational Control System shall be via DNP3.00-SA.

Communications to the substation IEDs (Protection Relays, Meters) shall be via DNP3.00.

Where communications cabling remains within the same suite of panels it may be performed using twisted pair copper cable, otherwise it will be performed over fibre optics. All communications interfaces will be suitable for use in a high electrical noise environment.

14.8 Remote Engineering Interfaces

A remote engineering interface into all IEDs equipped with such facilities shall be provided and shall utilise the provided communications interface.

14.9 Curtailment Schemes

For some sites, particularly those in the connection path for large embedded generators, loss of a transmission line, transformer, Statcom/SVC or another substation bay may lead to a thermal overload situation for the remaining assets in service. In these situations, rather than a complete interruption of supply to the generator, a run back scheme may be initiated to reduce power generation to within the thermal limits of the connected assets.

The run back scheme needs to be initiated and actioned before any protection operations for thermal overload will occur. The reduction in power over a short duration will need to be assessed that it does not produce any instability in the network from this action.

Contingency constraints are managed by the status of the affected circuit breakers. High speed signalling channels shall be used to send status back to the generator to initiate the appropriate ramp down response.

Curtailment shall be unaffected by a successful reclose of a line. Ramp up can occur 15 minutes after a successful reclose or change of breaker status.

A failsafe system where loss of communications results in ramp down of generation to the lowest contingency limit can be used in lieu of duplication of the curtailment scheme.

Drawings shall include:

- A curtailment single line diagram at all affected substations, highlighting circuit breakers, analogs, RTU’s, DC supplies and communications devices that are part of the curtailment scheme.
- Operational labels at these devices.

14.10 References

For detailed requirements refer to documents:

- STNW3001 – Substation Standard Equipment Identification, for component identification, item identification, device function numbers, relay codes, wire numbering, indicator light colours and related subjects
- STNW3022 – Substation DC supplies
- STNW3023 – Substation AC Supplies
- STNW1002 – Substation Standard Protection, for common requirements, specific protection systems/schemes for various types of plant in the substation and network components such as transmission/sub-transmission feeders, distribution feeders connected to the substation
- STNW1004 – Auto-reclosing in Substations
- STNW3106 – SCADA Standard Point List
- STNW3107 – SCADA Standard Point Naming
- Capacitor Automatic Control

- OLTC AVR Control
- Energex VVR for SACS Version 5
- STNW3114 - Substation Metering

Australian Standards, International Standards, Industrial Guidelines and references are listed in the above documents.

15 Metering

15.1 Energy Queensland Substation Standard

The installation of all new works shall be in accordance with the relevant substation standard STNW3114 – Substation Metering.

15.2 Statistical Metering

Statistical Metering on transformers shall be installed on the transformer LV incoming supply, and included in a metering panel in the new control room as well as additional statistical metering installed in accordance with substation Standard STNW3114.

The metering for statistical purposes is not required to comply with Australian Energy Market Operator (AEMO) requirements.

CT and VTs may be included as part of other primary plant, such as switchboards, GIS, dead tank breakers and power transformers. The requirements for CT and VT accuracy class shall be in accordance with STNW3114.

15.3 Customer Revenue Metering

Customers directly supplied from a dedicated distribution feeder shall be metered.

The meter shall be installed at the customer's meter panel, preferably in an accessible location outside the EE/EGX substation fence.

The requirements for meter, CT and VT accuracy class shall be in accordance with STNW3114.

15.4 Wholesale Metering

Supply to or generation from a wholesale customer shall be metered directly from a substation feeder. Revenue class VT and CT shall be the customer's responsibility, and are generally not provided in our connection assets.

The requirements for check metering, VT, CT and meter accuracy and communications shall be in accordance with STNW3114.

15.5 Panel and SCADA Metering

SCADA Metering shall be provided as per the requirement of STNW3114. Metered quantities to be on Substation HMI in lieu of traditional panel meters.

15.6 Meters

- Meters shall be accuracy class as required
- All statistical meters shall be connected in a fibre communications loop

- Aux DC Supply (e.g. 110V DC) to be wired to the meter panel for meters and 230 V for Modem

15.7 Associated Communications Equipment

Meters will require the following communications equipment.

- IP interface for EQL internal access for Statistical Metering (GSM/5G if not available)
- GSM / 5G mobile for MDP access to local supply metering
- Suitable Mounting and cabling from the GSM/5G Modem to an externally mounted antenna to be provided if required

15.8 Power Quality Metering

Allowances are to be made for the installation of power quality meters where required by the business. These are generally required where embedded generation is connected or the system is experiencing poor power quality.

15.9 References

For detailed requirements refer to documents:

- STNW1175 – Standard for High Voltage Embedded Connections
- STNW3114 - Substation Metering
- ZSS templates

16 Communications

16.1 Requirements

The requirements for the substation communications consist of protection, control systems, engineering access, telephony and environmental monitoring systems.

Communication details will be stipulated in the Project Definition and could include (Telstra) landlines, fibre optic cables, microwave links or radio equipment.

16.2 Protection Communications

The protection requirements are duplicated and diverse communications where communication paths form part of the protection system. Four Operational E1 services (OES) are required to provide communications for these schemes.

Table 6: Protection communications

Service ID	Interface	Feeder	Protection scheme	Comment
PRO-1	64k G.703	HV (eg = EA02)	Protection 1	Protection 1 relay
PRO-2	64k G.703	HV (eg = EA05)	Protection 1	Protection 1 relay
PRO-3	64k G.703	HV (eg = EA02)	Protection 2	Protection 2 relay
PRO-4	64k G.703	HV (eg = EA05)	Protection 2	Protection 2 relay

The protection communication services shall be designed to meet the availability and performance criteria as per the following references:

- Ergon Energy Communications Requirements v0.5.
- National Electricity Rules (NER)

16.3 SCADA Communications

The SCADA communications will be DNP-3.00, connecting the IED's and RTU's to the OTE. SCADA communications shall be designed to meet the availability and performance criteria as per the following references:

- Ergon Energy Communications Requirements v0.5.
- National Electricity Rules

16.3.1 Engineering Access

A communication service will be provided for remote engineering access to IEDs. This connection will be provided via OTE access to the substation. Such access will be protected by firewalls and jump boxes to prevent unauthorised access.

16.3.2 Telephony

Where required a Substation Control Room telephone is to be provided. Exceptions are sites with no hard wired or mobile communications options to site.

16.3.3 Monitoring Systems

Environmental monitoring systems and management interfaces shall be provided to enable CNOC management visibility of the following systems:

- Temperature and humidity inside buildings..
- Distributed temperature sensing and real time ratings (where required)
- Communications 50V Rack Power Systems status
- MSP and PDH multiplexers
- Routing and Switching equipment
- Other communications equipment alarms as required

16.4 Communications Transmission

Communications to the substation will be provided via fibre optic or microwave radio transmission or a combination of both. The choice of transmission medium and capacity will depend on the location of the substation and the existing local communications infrastructure.

Where dual fibre optic transmission is provided physical cable route diversity is to be maintained for connections to and from the substation. SDH Network

16.5 Communications Design

Communications design shall be in accordance with Ergon Energy STNW3393 – Telecommunications Design Guide, and Energex -18388-A3 drawing series.

16.6 DC Supply

The communications active equipment shall be powered from a high reliability 48V power supply which can be a separate supply from the substation auxiliary batteries. If the DC supply is from the substation auxiliary battery system the design shall be as per STNW3022 – Standard for DC Supplies.

16.7 Isolation

RS232 metallic cables greater than 4 metres must not be used. Any RS232 and G.703 protection circuits are to be optically isolated with a fibre optic cable installed between the protection panels and communications equipment.

Any G.703 and RS232 optical converters are to be mounted in the communications cubicles and powered to facilitate suitable diversity for maintenance and power failure contingencies.

16.8 Drawings and Documentation

The following documents are required:

- System Diagrams

- Cubicle Layouts
- Schematic Diagrams
- Wiring Diagrams
- Cable Schedules

The following documents and files will be stored on the communications network data store:

- Completed Inspection and Test Plan
- Equipment Configuration Files

17 AC Auxiliary Supplies

The AC supply system shall be designed in accordance with STNW3023 – AC Supplies, AS/NZS3000 and substation standard drawings.

The AC supply shall be provided from substation services transformers having 230/400 V secondary. The primary voltage is determined by the distribution busbar voltage. Depend upon the requirements of loads and Audio Frequency Load Control (AFLC) plant the power rating shall be determined from standard ratings for distribution transformers.

Local services transformers shall be of pad-mounted, ground mounted or structure mounted (not timber pole) type and their HV and LV connection shall be via underground cables.

AC boards shall be designed and tested in accordance with AS61439.

Design to consider risks associated with an internal arc flash, and implement practical controls to eliminate or mitigate the consequence.

18 DC Auxiliary Supplies

The DC supply system shall be designed in accordance with STNW3022 - Substation DC Supplies and substation standard drawings. Aspects regarding redundancy, autonomy times, ventilation, temperature ranges and compensation are included in this standard.

19 Cables and Cabling

Cables systems in substations shall be designed, installed and protected with the objective of minimising cable failures and their consequences.

The following considerations shall be taken into account:

- Cables life shall be at least equal to the design life of the substation
- Cables shall have the following characteristics: thermal stability, moisture resistance, chemical resistance, flame propagation resistance, reduced hazard emission and insect (termite) resistance
- Cables laid wholly within a building are exempt from needing DBT screen
- Cables within a building should have a low smoke zero halogen insulation and sheath.
- Suitable voltage rating, current carrying capacity and acceptable voltage drop.

- Segregation between power cable systems having voltage ≥ 1 kV and LV power, control and instrumentation cables
- Segregation of redundant cable systems, i.e. two or more systems serving the same objective e.g. primary and backup protection
- Ease of replacement
- Shielding from noises and transients caused by HV switching, capacitive switching, transmission line switching, resonance of capacitor voltage transformers (CVT), earth potential rise (EPR)
- Cable screen earthing
- Bending radius
- Cable penetration fire stops, fire break, preventing spread of fire.
- Conduit, tray and trench systems
- Protection and securing of cables to avoid damage from short circuit forces and other mechanical or electrical causes
- Cable configurations to reduce magnetic fields and voltage drop

Refer to the following documents for detailed requirements:

- STNW3015 – Primary Plant Ratings
- STNW3018 – Substation Cables and Cabling
- STNW3028 – Substation earthing

Australian Standards, International Standards, Industrial Guidelines and references are listed in the above documents.

20 Earthing System

20.1 General

The fundamental requirements of an earthing system can be collected into three categories:

- Safety of people – under all reasonably foreseeable conditions the earthing system shall not impose on any person or group of persons an intolerable risk.
- Protection of equipment – under all reasonably foreseeable conditions the earthing system should provide for the expected operation without damage to any component.
- Support operational security – under all reasonably foreseeable conditions shall not, by action or inaction negatively impact the operation of the power system other than where intended to for the safety of people or protection of equipment.

Earthing systems in substations are to ensure the following:

- Compliance with the requirement of relevant legislation and standards
- A system of equipotential bonding is provided for protection of personnel
- Step and touch voltages are limited to safe levels
- Effective operation of protection equipment in earth fault conditions

- Interference to telecommunication system is controlled
- Energy from lightning strikes is safely dissipated to the earth mass
- The transfer of dangerous voltage out of the substation site is controlled

Due to hazardous earth potential rise (EPR) and associated step and touch voltages the earthing system of a substation poses risks to people working inside the substation, telecommunication or pipeline personnel and the public. Safety for personnel and the public shall be considered both inside and external to the substation. Risk assessment shall be carried out if certain safety criteria are not met.

20.2 Transformer Neutral Earthing

Transformer neutrals may be:

- Solidly bonded to earth
- Solidly bonded to earth, but due to upstream impedances may appear to be non-effectively earthed
- Non-effectively earthed through impedance earthing.
- For delta connected windings, impedance earthing may be achieved by installation of a zig-zag connected earthing transformer off this winding.
- The method of neutral earthing is important with regards to:
- Selection of insulation level
- Surge arrester selection
- Selecting protection relays and instrument transformers
- Design of the earthing system

The location of the substation, the downstream equipment at the distribution level will play an important role in determining whether a location is impedance earthed. Most parts of the Energex network and parts of the south-west network have historically been impedance earthed.

20.3 Planning

AS/NZS 3835.1 requires that where either telecommunication or power utility plans to construct new plant (i.e. substations, lines for power utilities) or change the operating conditions of their plant in a way which may create new (EPR) hazard zones or change the nature of existing hazard zones shall endeavour to coordinate. Limit of planning is from five to 10 years ahead.

AS/NZS 4853 specifies voltage limits and corresponding time constraint acceptable for both underground and above-ground pipelines that may be subject to power system influences.

The following works would be required

- Obtain data related to EPR calculations: earth fault currents, fault clearing time, expected area of the substation
- Carry out soil resistivity tests at the expected substation site
- Estimate earth grid resistance, then EPR
- Investigate EPR hazards to telecommunications plant and pipelines
- Investigate possible EPR hazards to sensitive neighbouring locations.

- Obtain agreement on solutions to negate EPR hazard with telecommunications utility

20.4 Implementation

The design of the substation earthing system shall be based on criteria set by STNW 3028 – Substation Earthing, procedure and risk assessment provided in ENA EG-0 and methodology in ENA EG-1 or IEEE Std 80. The following are steps usually taken in the earthing system design and commissioning process:

- Step1: Data gathering and Project integration include data such as fault levels, protection clearing time, soil resistivity, site layout, primary and secondary power line/conductor details (e.g. OHEW, cable sheath, etc.), data concerning existing earthing systems, points of exposure (e.g. services search, neighbouring infrastructure), Project management plan, overall electrical system design process integration.

Step 2-7: Power frequency design.

- Step 2: Initial concept design to include conductor placement to manage voltage gradient and conductor sizing
- Step 3: Determine design EPR. The expected EPR is calculated for each of the key fault cases identified
- Step 4: Detailed Earthing layout, which includes conductor material, size, layout practicality, identification of shock hazard location and magnitude (EPR, step voltage, touch voltage and transferred voltage, magnetic field induction, electric field coupling)
- Step 5: Safety criteria selection or Standard Voltage-time Criteria chosen (from case studies)
- Step 6: Do "Direct Probabilistic" if the design in Step 4 or redesign in Step 7 does not meet safety criteria, or the design does not match the case study circumstances in Step 5. Quantify the risk to ensure the probability of fatality, which is the product of Probability of Coincidence and Probability of fibrillation, below the acceptable limit. The fatality risk is to be assessed for both individual and societal scenarios. The subsequent steps are calculating Probability of coincidence, Probability of fibrillation, fatality risk and redesign to SFAIRP principle
- Step 7: Mitigation or design improvements. Risk treatment methods include reduction of earthing system impedance, earth fault current and fault clearing time; use of surface insulating layer, gradient control conductors, isolation, barrier and signs
- Step 8: Lightning and transient design, which includes assessing electromagnetic interference (EMI) sources, correct earthing of secondary systems (protection, a.c and d.c auxiliary power and control wiring).
- Step 9: Construction support. Ensuring physical implementation of the design is compliant and installation is to appropriate quality/standard. Refer to detailed earthing drawings.
- Step 10: Commissioning program and Safety compliance review. Which include visual inspection, continuity testing, injection testing, EPR, step and touch voltage measurements, telecommunications coordination and pipeline interference/coordination
- Step 11: Documentation

Refer to the following Standards, Guidelines and EE documents for detailed requirements:

- AS 33835 (all parts) and associated Handbooks HB 100, 102 and 219 for coordination with telecommunications utility
- AS/NZS 4853 for coordination with metallic pipelines in the substation vicinity, permissible touch voltage limits and other requirements
- ENA EG0 – Power System Earthing Guide
- ENA EG1 – Substation Earthing Guide
- STNW3028 – Substation Earthing, for criteria to be used in design of a safe earthing system and method of earthing of plant, equipment, structures, buildings, fences and certain circuits to safeguard personnel and the public from injury that may be caused by electrical potential
- STNW3029 – Safety Earthing, for provision of safety earthing to protect personnel during maintenance of equipment in the switchyard
- STNW3030 – Soil Resistivity Testing, for checking consistency of the results of soil resistivity tests in the field and calculating soil resistivity from the test results obtained
- Detailed Earthing drawings

Australian Standards, International Standards, Industrial Guidelines and references are listed in the above documents.

21 Lightning Shielding and Surge Protection

Plant/equipment is designed to standard insulation levels, which, for economic reasons, are well below the over-voltage surges that plant/equipment, may be subject to. Over-voltage surges can cause equipment damage, system malfunction or power interruption if measures to minimise their effects are not taken.

Direct lightning strike shielding shall be provided. Criteria for designing the shielding system shall be in accordance with STNW3032 – Substation Direct Lightning Strike Shielding. Using overhead earth wires above switchyard busbars and plant/equipment for shielding shall be avoided.

Surge protection shall be incorporated in the substation design and installation to ensure that plant/equipment, control and communication systems in substations are protected and interference reduced from the following:

- Direct lightning strike
- Incoming surges from transmission and distribution lines
- Surge generated internally
- Surge generated by switching
- Earth potential rise (EPR)

Refer to the following documents for detailed requirements:

- STNW3032 – Substation Direct Lightning Strike Shielding, for criteria and methods of design a direct lightning strike shielding system

- STNW3033 – Selection of Surge Arresters, for selecting surge arresters (SA) suitable for applications
- STNW3034 – Insulation Coordination, for information on various types surges, temporary over-voltages (TOV) and guidance on placement of SA

Australian Standards, International Standards, Industrial Guidelines and references are listed in related documents.

22 Fire Protection

In substations equipment containing flammable materials is a potential fire risk as well as the possible cause of risk to human life, loss/damage of equipment and properties in the vicinity, loss of continuity of power supply, and financial losses.

Measures to reduce fire hazard and fire risk include preventions, precautions, containment and extinguishment.

22.1 Planning

When selecting the site for a proposed substation considerations shall be given to:

- The possibility that a substation fire could endanger neighbouring buildings or vegetation
- The risk of fire on neighbouring property damaging the substation
- The supply of water for firefighting requirement
- The availability of Fire Brigade Services in the event of fire

For high risk sites, or sites where fire clearances to AS2067 cannot be maintained, a semi-quantitative fire risk assessment shall be undertaken to determine if additional controls are required.

22.2 Implementation

- Firebreak around the perimeter fence line
- Multiple vehicular entrances
- Provisions for firefighting in the switchyard
- Active fire suppression systems in high risk sites
- Installation of portable firefighting equipment in the control building
- Installation of fire detection and alarm system in the control building, switch room
- Control building construction with fire resistive or non-combustible materials, segregation of rooms, at least two exits, adequately vented battery room, sealed cable conduits, minimisation of storage of combustible materials
- Switch room with overpressure relief facility, high fire rating
- Adequate separation distances between transformers or oil-filled equipment to buildings and other plant/equipment
- Oil containment as required by AS 2067 and other standards
- Fire barriers if separation distances are not adequate

- Incorporate in the design good cabling practice such as loading, separation, sealed penetrations of wall and floors, segregation of control from power cables, use of low smoke and fire retardant cables, use of fire stops between main trenches and branches
- Where power cables cross in the basement with no separation, use ablative coating to prevent fire propagation.

Refer to the following documents

- STNW3035 – Substation Fire and Explosion Protection, for: the required separation between possible fire sources and buildings and other plant/equipment, fire rating of walls and building adjacent to fire sources and design practice to minimise the risks of fire and mitigate the effects of fire
- STNW3036 – Oil Containment
- TSD0171 – Guide to Passive Fire Protection in Substations

Australian Standards, International Standards, Industrial Guidelines and references are listed in related documents.

23 Security

Unauthorised access to substations may result in death, theft, damage and mis-operation of equipment and facilities, and may create potential safety and environmental liabilities.

Risk assessment shall be carried out to determine level of risks that the substation imposes on the vicinity and vice versa. Security systems shall be designed accordingly to the requirements of STNW3039 – Substation Security, to ensure

- Plant and equipment are adequately protected from theft and vandalism
- Safety of the public by restricting access to the substation environment

24 Control and Switchgear Building

The control and switchgear building shall be either a pre-fabricated (modular) design or a specific (masonry) design. The following considerations shall be given in the control building design:

- Operational life shall be equal or longer than 50 years without major refurbishing
- Conforming to relevant building codes and local regulation
- Suitable fire rating
- Suitable for future substation extension
- Pressure relief facility
- Ventilation and air conditioning
- Meet aesthetic requirements

Detailed requirements such as floor, floor covering, surface treatment, external and internal colour/finish shall be in accordance with the specification.

24.1 Control Building Layout

The following considerations shall be given in layout of the control and switchgear building:

- Areas for distribution indoor switchgear, control/SCADA/protection panels, AC auxiliary supply panels, DC auxiliary supply panels, communications panels, batteries and chargers, control interfaces, all wall mounted operating equipment such as portable earthing devices (PED)
- Areas for additional switchgear and control/protection panels required by future substation extension
- Provision of toilet facilities as per Section 11 either in this building or a separate amenities building.
- Accessibility and emergency exit facilities as per clause 2.9, AS/NZS 3000-2018
- Adequate clearances around indoor switchgear as per AS2067 and the switchgear manufacturer.
- Adequate ceiling height to the switchgear as required by the switchgear manufacturer and for cable bending radius.

24.2 MV Switchgear/Switchboard Area

In addition to the above requirements the switchboard area shall meet the following requirements:

- A means of routing the power cables from transformers and to distribution feeders from the switchboard into underground trenches without exceeding the limit of bending radius specified by the cable manufacturer
- Room venting facilities to relieve pressure from a switchboard explosion
- Floor capable of carrying the switchboard weight without undue deflection, high degree of flatness as required by the switchboard manufacturer
- Unrestricted working access to the interior of the switchboard panels
- Sufficient space around switchboard for venting of arc gases to maintain internal arc fault classification.

24.3 Fire Protection

Fire protection facilities such as portable fire extinguishers, smoke detectors, fire alarms and fire suppression systems (where required) shall be in accordance with STNW3035 – Substation Fire and Explosion Protection.

24.4 Air Conditioning

The air condition equipment shall be sized and rated to maintain the interior temperature of the control building in the range of five to 30°C for an exterior temperature anywhere in the specified range taking into account heat losses from equipment housed in the building and also external solar radiation.

The system shall be automatically regulated by an adjustable controller fitted with an on/off override.

An independent adjustable temperature alarm switch shall be mounted adjacent to the protection and control cubicles. This device shall be wired to the SCADA RTU as an alarm input.

24.5 Lighting and Power

Illumination level shall be as per STNW3040 – Substation Lighting. LED lights shall be used.

Adequate general purposed outlets (GPO) and special purpose outlets (SPO) shall be located in the Control room and Switchgear room and any other room where portable testing and maintenance may take place. The minimum is as follows:

- Control room: six single-phase double 10 A GPO's and two three-phase 20 A SPO's
- Switch room: four single-phase double 10 A GPO's and two three-phase 20 A SPO's

24.6 Earthing

Earthing of foundation, metallic walls and roof shall be in accordance with STNW3028 – Substation Earthing.

25 Electromagnetic Compatibility of Control Systems

25.1 General

Interferences may be transmitted into high voltage installations by means of conduction, capacitive coupling, induction or radiation. The following two general principles apply for protection against interference:

- Reduction of penetration of magnetic fields int equipment
- Establishment of equal potentials between all equipment and the earthing system.

Refer to AS2067:2018 Section 7.6 for further information on measures to reduce the effects.

26 Nameplates, Signage, Labelling

26.1 General

Rating plates, nameplates, signs and labels must be located such that they can be easily and safely read from normal operating positions and access ways around the equipment, at ground or floor level.

Full details of all signs, labels, etc. required, including content, sizes and details of lettering, in accordance with the respective template drawings must be provided in the project design, for ordering purposes.

Rating plates, nameplates, signs and labels installed on outdoor equipment must be of stainless steel or non-ferrous metal, with etched or engraved lettering and fixed with stainless steel screws or monel rivets. Indoor labels must be engraved traffolyte or other approved material.

26.1.1 Rating Plates, Nameplates and Operational Signs

Switchyard Operational Number signs are required on each HV operational point only. i.e. circuit breakers, disconnectors, earthing switches, voltage transformers, power transformers (all ratings), HV fuses, disconnectors and earth switches in RMU's and HV switchboards. Current transformers and surge diverters are not operating points and therefore must not be allocated operating numbers, although they may be shown on the Single Line Diagram Operating for information.

All switchyard operational signs must align with the approved Single Line Diagram Operating and all labels and signs must be clearly specified on appropriate drawings.

All CT and VT marshalling boxes must incorporate rating plates showing all relevant rating data of the associated HV plant. A second set of rating plates is usually sourced from the CT or VT manufacturer for installation on the appropriate marshalling box.

26.1.2 Labels

All equipment, operating devices, relays, etc. must be suitably labelled such that they can be readily identified from drawings. Circuit breaker and transformer control cubicles, control panels and relay panels must also be labelled. Cubicles and switchboard panels with rear access must also be labelled on the rear of the panel.

On manufactured equipment, most labels should be supplied and installed by the Equipment Manufacturer, however, it is the responsibility of the Substation Project Designer to check and provide any additional labelling needed to match the requirements of the project drawings. e.g. bay numbering, device identification, etc.

All labels, and in particular those supplied on equipment of overseas origin, must be submitted for approval prior to shipment of the equipment. All labels must be in the English language.

26.1.3 Safety Signs

Warning and safety signs must be installed around and within the substation to warn personnel of dangerous voltage levels, correct operating procedures and safety requirements within a substation. Warning signs must conform to the relevant Australian Standard and Work Health & Safety Act 2011. The design, manufacture, and placement of the signs required for HV substations are specified in STNW3037 Standard for Substation Signage, or on Energex standard drawings.

27 Engineering Reports

The following reports may be required on completion of substation design. Notes on when these reports are required are given in the tables below:

Table 7: Primary Plant Selection

Study	Ref Standard	Comment
Switchgear selection study	STNW3051	For sites where standard plant ratings in Section X may not apply
Surge arrester selection study	STNW3033	For sites where standard plant ratings in Section X may not apply
Earthing transformer study		Sizing for new application
Capacitor bank sizing study		To check voltage step

Load control study		Generally for systems connected to sub-transmission network

Table 8: Site Studies – Civil/Environmental

Study	Ref Standard	Comment
Resolver security risk assessment	STNW3039	New sites, upgrades to existing
Site fire risk assessment	STNW3035	For high risk sites, and sites that do not comply with AS2067 fire clearances.
Geotechnical and acid sulfate soil studies		As directed by civil engineering team
Environmental management plan		
Cultural heritage management plan		
Noise assessment	STNW3041	Depending on separation to sensitive receptors
Crane lift study		Large transformers, difficult sites.

Table 9: Site Studies – Electrical

Study	Ref Standard	Comment
Switchyard life cycle cost estimation tool		New transmission substations during concept design stage
Soil resistivity studies	STNW3028	New sites
Earth grid study	STNW3028	New sites, changed conditions at site (eg fault level)
Busbar design calculator	STNW3014	For non-standard busbar config/lengths between supports
Lightning protection study	STNW3032	New sites, outdoor yards
Insulation co-ordination	STNW3034	For sites where standard plant ratings in Section X may not apply, or other aspects STNW3034 standard checklist not met
Cable rating studies	STNW3018	Large number of cables in common trench, standard separations can't be maintained.
EMF studies	STNW3042	Sensitive areas, required under development application

Arc flash hazard study		High current switchboards >800A
Lighting study	STNW3040	AGI-32 study or equivalent

Table 10: Secondary system studies

Study	Ref Standard	Comment
Battery sizing calculator	STNW3022	Non standard design
Battery ventilation calculation	STNW3022	Non standard design
LV co-ordination study	STNW3023	NHP Temcurve report preferred.

28 Drawings

Substation Project Design Drawings include Single Line Diagrams (SLD’s) General Arrangements (GA’s) in plans and elevations, material lists, earthing, conduit, foundations and steelwork details, panel layouts, schematics, connection diagrams and cable schedules, as per Annex C.

In accordance with the requirements of the Professional Engineers Act 2002 (Qld), it is mandatory that all design be either carried out by an appropriately qualified and experienced Registered Professional Engineer of Queensland (RPEQ), or be directly supervised by the RPEQ.

Appendix A

(Informative)

Brownfield Site Considerations – Primary Plant

A.1 Power Transformers

When replacing power transformers in existing substations, the Designer shall take into account the following design considerations:

- Footing must be assessed as sufficient and in suitable condition.
- The oil containment must be assessed as sufficient and in suitable condition.
- The existing lightning protection scheme shall be checked against dimensions of replacement transformer to ensure adequate coverage. Consideration should be given to the replacement of any existing overhead earth wires above transformer with a lightning mast if economical and in consultation with the project sponsor.
- If the replacement transformer is required to operate in parallel with an existing transformer which has a different electrical specification, then the Designer must consider any differences in tapping steps and transformer impedances to ensure appropriate sharing of connected loads and minimisation of transformer circulating currents. It is permissible to design the parallel operation of transformers to run at different tap steps with the control algorithm in the RTU/AVR relay adjusted accordingly. The Designer must calculate the optimum tap difference over the full tapping range, and advise the SCADA Designer in consultation with Operations Control group and Protection group. An appropriate notation must be included on the Substation Single Line Diagram Operating in this instance.
- Any existing dedicated AVR relays shall be replaced with transformer tapchanger control implemented in the substation SCADA system.
- Where appropriate fire and explosion clearances cannot be maintained between mineral oil filled transformers or to combustible surfaces in accordance with AS2067 and STNW3035, then consideration may be given to using transformers filled with K class fluids such as natural or synthetic esters. Note however that mineral oil and esters cannot share the same oil/water separation systems due to the different physical properties such as density and viscosity.
- Fully enclosed transformers shall be designed with suitable ventilation to cater for transformer losses in accordance with STNW3047. A water mist system may also be required for fire suppression in accordance with STNW3035.

- Control cables between the transformer control box and the substation protection and control panels should be replaced in accordance with current template drawings. The exception to this is if existing control cables are in accordance with the current control cable standard and have sufficient length to terminate in new transformer control box without intermediate junction boxes, or substantial construction work would be required to replace the control cables.

A.2 HV Circuit Breakers (Outdoors)

When replacing high voltage circuit breakers in existing substations, the Designer shall take into account the following design considerations:

- Footing and structure must be assessed as sufficient and in suitable condition.
- If the circuit breaker to be replaced has separate high voltage CTs mounted on the same CB structure, then the replacement circuit breaker design shall include design for a new high voltage CT installation including footings or the use of a dead tank breaker. It is not permissible to retrofit high voltage CTs to new circuit breaker structures.
- Low gas alarms shall be in two stages – first stage is alarm and second stage locks breaker in current position and prevents operation.

Control cables between the circuit breaker control box and the substation protection and control panels should be replaced in accordance with the template drawings. The exception to this is if existing control cables are in accordance with the current control cable standard and have sufficient length to terminate in new control box, or substantial construction work would be required to replace the control cables.

A.3 Current Transformers, including Marshalling Boxes

When replacing high voltage current transformers in existing substations, the Designer must take into account the following design considerations:

(a) Replacing Three Phases of a CT Installation

- It is often more economical to replace the support structure with a new standard structure, rather than carrying out modifications to the existing structure.
- Footing and structure must be assessed
- A new CT marshalling box in accordance with the current ZSS Drawings must be installed. The exceptions to this replacement are:
    - if the physical condition of the existing box is still satisfactory and internal space permits, then a new fit-out can be undertaken. The marshalling box fit-out must be in accordance with the current ZSS Drawings.
    - if the existing marshalling box is used for the marshalling of other related bay circuitry and considerable design and construction would be required.
- Control cables between the current transformer and the current transformer marshalling box must be replaced in accordance with the ZSS Template Drawings.

- Control cables between the current transformer marshalling box and the substation protection and control panels should be replaced in accordance with the ZSS Template Drawings. The exception to this is if existing control cables are in accordance with the current Control Cable Standard and have sufficient length to terminate in new control box without intermediate junction boxes, or substantial construction work would be required to replace the control cables.

(b) Replacing two phases of a CT Installation

If the project scope is requiring only two phases of a CT Installation to be replaced, then the Designer should question the validity of this scope with the Project Manager, Project Sponsor and Asset Manager as it can be more economical and prudent to replace all three phases.

(c) Replacing only one phase of a CT Installation

- Footing and structure must be assessed
- The existing marshalling box may be re-used. There must be adequate space in the existing marshalling box to ensure the termination of all new CT secondary cores. There is no requirement to upgrade the existing CT cores secondary wiring, including the installation of CT links to current standards.
- Control cables between the current transformer and the current transformer marshalling box must be replaced in accordance with the ZSS Template Drawings.

(d) Relay compensation

When retro fitting transformer differential protection relays that were externally compensated (e.g. delta connected line CT's), the CT circuits must be reconfigured to Star connected and compensation undertaken in the differential relay. This includes the removal of interposing CT’s required for the compensation.

A.4 Voltage Transformers, including Marshalling Boxes

When replacing voltage transformers in existing substations, the Designer must take into account the following design considerations:

(a) Replacing Three Phases of a VT Installation

- It is often more economical to replace the support structure with a new standard structure, rather than carrying out modifications to the existing structure.
- Footing and structure must be assessed
- A new VT marshalling box in accordance with the current ZSS Drawings must be installed. The exceptions to this replacement are:
  - if the physical condition of the existing box is still satisfactory and internal space permits, then a new fit-out can be undertaken. The marshalling box fit-out must be in accordance with the current ZSS Drawings.
  - if the existing marshalling box is used for the marshalling of other related bay circuitry and considerable design and construction would be required.
- Control cables between the voltage transformer and the voltage transformer marshalling box must be replaced in accordance with the ZSS Template Drawings.

- Control cables between the voltage transformer marshalling box and the substation protection and control panels should be replaced in accordance with the ZSS Template Drawings. The exception to this is if existing control cables are in accordance with the current Control Cable Standard and have sufficient length to terminate in new control box without intermediate junction boxes, or substantial construction work would be required to replace the control cables.

(b) Replacing Two Phases of a VT Installation

If the project scope is requiring only two phases of a VT Installation to be replaced, then the Designer should question the validity of this scope with the Project Manager, Project Sponsor and Asset Manager as it can be more economical and prudent to replace all three phases.

(c) Replacing Only One Phase of a VT Installation

- Footing and structure must be assessed
- The existing marshalling box may be re-used. There must be adequate space in the existing marshalling box to ensure the termination of all new VT secondary cores. There is no requirement to upgrade the existing VT cores, including the installation of secondary VT fuses to current Standards.

Control cables between the voltage transformer and the voltage transformer marshalling box must be replaced in accordance with the ZSS Template Drawings

A.5 HV Switchboards

When an extension is required to an existing switchboard, it is recommended that baseline electrical testing in the form of partial discharge testing and insulation resistance is undertaken prior to any construction work.

Switchboard busbar extensions generally involve the design, manufacture and installation of a suitable “joggle” (adaptor) panel to match the existing busbar height and position to the new circuit breaker cubicle, and as such it is recommended that this design and supply is undertaken by a switchboard manufacturer.

The switchgear building must be structurally assessed for the new installation, including the footprint and weight of the new cubicles, additional floor and/or wall penetrations for HV and control cabling, and installation of arc venting as required.

Protection and control panels for new circuit breaker extensions to existing switchboards may be installed in the instrument chambers on the switchboard extension, provided such equipment is arc fault tested to vent away from an operator at the front, and that the extension is part of a high speed bus protection scheme. Test terminals shall be brought to the front to allow relay testing with the instrument panel door closed.

A.6 Busbars and Conductors

When extensions are required to existing rigid busbars, the preference is to extend using the tubes as specified in the Standard, unless it is impractical due to excessive on-site fabrication of adaptor flanges etc. If the existing tube size is to be used, then the Designer must ensure that it meets all of the current ratings and mechanical limits in accordance with the Standard.

When adding busbar extensions, and the existing busbar height and phase spacings are not in accordance with the current Standard, then it is permissible to maintain the existing heights and phase spacing so long as the required clearances to the current Standards are maintained, refer Section 13.11. It is preferred that no modifications to standard plant are undertaken to fit the existing busbar installation.

It is permissible to re-use existing flexible conductors and fittings so long as an assessment of the current rating and mechanical condition to satisfy the new installation has been undertaken.

A.7 Clearances

When retro-fitting new substation plant into Brownfield substations, it may not be possible to maintain the switchyard clearances as specified in the Energy Queensland Standard or the Queensland Electrical Safety Act.

The minimum distances that shall be maintained are the section, horizontal, and vertical clearances, as specified in AS2067.

The Qld Electrical Safety Act provides additional clearance above the non-flashover distance as specified in AS2067, and is known as the Exclusion Zone. If the design cannot meet the required clearances using the exclusion zone, then it must meet the requirements of AS2067. In this instance a risk assessment must be undertaken and documented as part of the Safety in Design process.

Example: An 11kV switchyard originally designed to AS2067 will have section clearance of 2615mm (Ground 2440mm +Non-flashover 175mm). Designing new plant in accordance with the Safety Act will require a section clearance of 3140mm, an increase of 525mm. If the switchgear cannot be practically installed to meet this increased clearance, then it is acceptable to use the 2615mm clearance and undertake an appropriate risk assessment. Additional controls may include signage identifying the area as complying with exclusion zones of AS2067 but not clearances defined by the Electrical Safety Act.

Appendix B

(Informative)

Brownfield Site Considerations – Secondary

B.1 Protection and Control Panels

The following guidelines should be used when replacing protection relays in existing substations.

- If a single relay is to be replaced on an existing panel, the new installation should as a minimum include the new relay and a standard test link rack. Consideration should also be given to installing a new fuse/link rack. New AC and DC schematics must be produced in accordance with the latest template drawings.
- If a protection upgrade is required on an existing panel which requires both main and backup protection to be replaced, then consideration should be given to either "re-skinning" the panel with a 19" rack frame, or where possible a new protection panel installed.
- For existing substation installations it may be necessary to alter the standard relay configuration to match existing protection philosophy and circuitry. These alterations may include but are not limited to, the use of additional I/O, using the standard I/O for a different function, and changes to the AC connections. If an alteration is required to the standard protection application, the Designer must consult with the Protection Group.

B.2 Remote Terminal Unit (RTU)

Existing commissioned RTU points must not be rewired to alternate RTU points unless absolutely necessary due to the extra control system design and extra commissioning work that would result from this change.

B.3 Trip Coil Supervision (TCS)

TCS circuitry for brownfield applications must be included as part of protection upgrade works, provided the existing circuit breaker has the required circuitry, or can easily be modified to include the required TCS circuitry for each trip coil. If the circuit breaker cannot be wired to provide the required TCS circuits, then the TCS circuits must be wired from the protection relay to the protection panel terminal blocks for future installation.

Appendix C

(Informative)

Substation Drawing List

The following table lists the drawings typically required for a substation. The required quantity of each drawing type, any additional drawings and drawing sheets required for a specific project must be determined by the designer.

Electrical Drawings	Drawing
Single Line Diagrams	Single Line Diagram Plant
	Single Line Diagram Operating
	Single Line Diagram Protection and Metering
	Single Line Diagram Communications and SCADA
	Single Line Diagram Revenue Metering
	Curtailment Scheme Single Line Diagram
Switchyard Layout	General Arrangement Plan
	General Arrangement Ultimate Plan
	General Arrangement Elevations
	Earth Grid Layout
Equipment	Material List Major Plant HV
	Material List Major Plant LV
	Material List Structures and Poles
	Material List Busbar, Conductors and Fittings
	Material List Miscellaneous
	Material List Buildings
	Material List Earthing
DC Systems	DC Supply System Single Line Diagram
	DC Supply System DC Wiring Schematic
	DC Supply System DC Distribution Board Wiring Schematic
AC Systems	AC Distribution Supply Single Line Diagram
	AC Distribution Supply Main Switchboard General Arrangement
	AC Distribution Supply Wiring Schematic
	AC Distribution Supply Essential Supplies Board Wiring Schematic
	AC Distribution Supply Non-Essential Supplies Board Wiring Schematic

Electrical Drawings	Drawing
	AC Distribution Supply Essential Supplies Sub-Board Wiring Schematic and Layout
	AC Distribution Supply Non-Essential Supplies Sub-Board Wiring Schematic and Layout
Transmission / Sub-Transmission Feeder	Feeder Panel Equipment Layout
	Feeder Panel Equipment Identification
	Feeder AC Wiring Schematic
	Feeder CB Protection & Control DC Wiring Schematic
	Feeder Main Protection DC Wiring Schematic
	Feeder Backup Protection DC Wiring Schematic
	Feeder Panel Connection Diagram
	Feeder Yard Equipment Connection Diagram
Distribution Feeder	Feeder Panel Equipment Layout
	Feeder Panel Equipment Identification
	Feeder AC Wiring Schematic
	Feeder CB Protection & Control DC Wiring Schematic
	Feeder Protection DC Wiring Schematic
	Feeder Panel Connection Diagram
	Feeder Switchgear Panel Connection Diagram
Transformer	Transformer Panel Equipment Layout
	Transformer Panel Equipment Identification
	Transformer 66kV AC Wiring Schematic
	Transformer 11kV AC Wiring Schematic
	Transformer Main Protection AC Wiring Schematic
	Transformer Backup Protection AC Wiring Schematic
	Transformer 66kV CB Protection & Control DC Wiring Schematic
	Transformer 11kV CB Protection & Control DC Wiring Schematic
	Transformer Main Protection DC Wiring Schematic
	Transformer Backup Protection DC Wiring Schematic
	Transformer Inputs To RTU DC Wiring Schematic
	Transformer Panel Connection Diagram
	Transformer Control Cubicle Connection Diagram
	Transformer Yard Equipment Connection Diagram

Electrical Drawings	Drawing
	Transformer Switchgear Panel Connection Diagram
Bus Protection	Bus Zone & Bus Section CB Panel Equipment Layout
	Bus Zone & Bus Section CB Panel Equipment Identification
	Bus Section AC Wiring Schematic
	Bus Zone & Bus Section CB Main Protection AC Wiring Schematic
	Bus Zone & Bus Section CB Backup Protection AC Wiring Schematic
	Bus Section CB Protection & Control DC Wiring Schematic
	Bus Zone Main Protection DC Wiring Schematic
	Bus Section Main CB Fail Protection DC Wiring Schematic
	Bus Zone Backup Protection DC Wiring Schematic
	Bus Section Backup CB Fail Protection DC Wiring Schematic
	Bus Zone Panel Connection Diagram
	Bus Section Yard Equipment Connection Diagram
Switchboard Bus Protection	Bus Zone & Bus Section Panel Equipment Layout
	Bus Zone & Bus Section Panel Equipment Identification
	Bus Zone & Bus Section Main Protection - AC Wiring Schematic
	Bus Zone & Bus Section Backup Protection - AC Wiring Schematic
	Bus Section CB Protection & Control - Wiring Schematic
	Bus Zone Main Protection DC Wiring Schematic
	Bus Zone Backup Protection DC Wiring Schematic
	Bus Zone CB Fail Protection DC Wiring Schematic
	Bus Zone & Bus Section Panel Connection Diagram
	Bus Section Switchgear Panels Connection Diagram
SEF Check and Switchboard Bus Volts	SEF Check Protection DC Wiring Schematic
	Bus Volts Selection AC & DC Wiring Schematic
	Bus Zone & SEF Check Protection & Volts Selection Panel Connection Diagram
Metering Panel	Statistical Metering Panel Equipment Layout
	Statistical Metering Panel Equipment Identification
	Statistical Metering Panel Voltage Selection AC Wiring Schematic
	Statistical Metering Panel AC Wiring Schematic
	Statistical Metering Panel DC Wiring Schematic
	Statistical Metering Panel Connection Diagram

Electrical Drawings	Drawing
SCADA RTU	SCADA RTU Panel Equipment Layout
	SCADA RTU Panel Equipment Identification
	SCADA RTU Panel Power Supply, Cope Card & 8ch Serial Card Connections
	SCADA RTU Panel ADI Card Connections
	SCADA RTU Panel DO Cards Connections
	SCADA RTU Panel Cable Connection Diagram
	RTU Optonet Connections
Cable Schedules	Cables -Wxxx To -Wxxx Cable Schedule
Marshalling Box	CT Marshalling Box Fabrication Detail
	CT Marshalling Box Fitout
	VT Marshalling Box Fabrication Detail
	VT Marshalling Box Fitout

Civil Drawings	Drawing
Layout	Site Layout
	Site Contour Plan
	Site Survey Plan
	Site Roadworks & Earthworks Cross Sections and Details
	General Arrangement Foundations
	General Arrangement Ground Services Plan
Building	Building - Architectural
	Building - Electrical Services
	Building - Mechanical Services
	Building - Fire & Security Services
	Building - Equipment Layout
	Building - Cable Tray
	Building - Conduit Layout
	Building - Earthing
Structures	Earthing Transformer Cable Support
	Surge Arrestor Support
	Current Transformer Support
	Surge Arrestor and Cable Pothead Support

	Low Bus and Post Insulator Support
	Capacitor Voltage Transformer Support
	High Bus and Post Insulator Support
	Incoming Termination Strung Bus Support Concrete Pole
	Termination Strung Bus Support
	Lightning Mast