Substations – High Level Design Criteria – Guideline

Table of contents

1. Introduction

1.1 Purpose

The purpose of this document is to provide a high level overview of Powerlink's substation design criteria.

1.2 Scope

The scope of this document includes:

- Definitions of high level electrical, civil and structural requirements for Powerlink's substations.
- Reliability requirements.
- Key design requirements such as:
  - Electrical layout
  - Structural/civil requirements
  - Reliability requirements
  - Voltage rating & withstand levels
  - Insulation coordination
  - Earthing
  - AC supplies
  - Noise mitigation
  - Lighting
  - Environmental considerations
  - Security and access requirements
  - Environmental considerations
- Construction and maintenance requirements.

1.3 References

Document code	Document title
AS/NZS 1170	Standards Australia (2007) *Structural design actions*
AS/NZS 1170.2	Standards Australia (2011) *Structural design actions - Wind actions*
AS/NZS 2067	Standards Australia (2008) *Substations and high voltage installations exceeding 1kV a.c.*
AS/NZS 7000	Standards Australia (2016) *Overhead line design*
AS/NZS 1158.2 SAA	Standards Australia (2005) *Lighting for roads and public spaces*
Electrical Safety Act	Electrical Safety Act *2002* (Qld)
Electrical Safety Regulation	Electrical Safety Regulation *2013* (Qld)
ENA-EG1	Energy Networks Association (2006) *Substation Earthing Guide*
Environmental Protection (Noise) Policy	Environmental Protection (Noise) Policy *2008* (Qld)
Professional Engineers Act	Professional Engineers Act *2002* (Qld)
Professional Engineers Regulations	Professional Engineers Regulations *2003* (Qld)
NER	National Electricity Rules

Document code	Document title
Natural Hazards, Risk and Resilience	Natural Hazards, Risk and Resilience *2014* (Qld)
Work Health and Safety	Work Health and Safety Act *2011* (Qld) s.22

1.4 Defined terms

Terms	Definition
Boundary Clearance	The smallest permissible clearance between an external fence and live parts which may present hazardous voltages.
BIL	Basic Insulation Level which is the highest rated peak impulse voltage level for individual items of electrical equipment or a system.
NER	National Electricity Rules

2. High Level Overview

2.1 General

Powerlink owns and operates substations and switchyards at 110kV, 132kV, 275kV and 330kV nominal voltages. Substations and switchyards are designed and built to satisfy a range of requirements in accordance with Australian, International and Powerlink's internal standards as well as State and Federal legislation.

2.2 Reliability Requirements

New substations and switchyards or extension to an existing site is required to have a design and service life expectancy of 40 plus years for primary electrical infrastructure unless otherwise specified.

3. Key Design Requirements

3.1 Electrical Layout of Substations

There are a number of considerations for substation layout, such as electrical and safety clearances, phase / bay / busbar spacing, live and dead maintenance and access distance requirements and designated roadway requirements. Associated information and drawings specified in the Design Advice are required to be based on Specification SDE-001 Substation Electrical Design. These clearances take into account typical maintenance work methods and ensure that the routine and most corrective maintenance tasks can be performed in a safe and efficient manner.

The SDE-001 document aims to define the electrical, civil, and structural requirements for Powerlink's substations. It includes reliability requirements and key design aspects such as electrical layout, voltage ratings, insulation coordination, earthing, AC supplies, noise mitigation, lighting, environmental considerations, security, and access requirements.

The electrical air clearances provided in Powerlink's Specification SDE-001 Substation Electrical Design are the minimum values acceptable regardless of the rated BIL of the plant and equipment installed in the switchyard and need to be maintained in the switchyard.

Although electrical clearances may be met, particular care must also be taken at lower voltages (33kV or less) to minimise the risk of animals / reptiles / birds bridging this clearance and causing flashover. Typical routine maintenance tasks should also be considered and make appropriate ergonomic allowance for these to be performed.

3.2 Voltage, Current and BIL Ratings / Insulation Levels

These technical requirements for the substation as a whole as well as for primary electrical equipment, is covered in Powerlink's Specification SDE-001 Substation Electrical Design. The selection of the substation high voltage electrical equipment should therefore be compliant with this specification.

3.3 Insulation Coordination

Studies on lightning surges at all voltages and switching surges above 300kV entering the substation via transmission lines needs to be carried out. Electromagnetic Transient Program Software (EMTP-RV) is required to be utilised to ensure interchangeable design files with Powerlink, with the relevant files made available to Powerlink for any future substation development.

To avoid flashover within the substation, the insulation for strung bus associated with a feeder entry is to be greater than the feeder insulation outside the substation. This will need to be assessed for each strung bus section and may require additional information from transmission line designers.

Protection from back flashover on incoming feeders is assumed, over a distance of 2.5km outside the substation, by overhead earth-wires and tower footing resistances less than 5 ohms (verified by footing resistance measurement), allowing an attenuated 2.5/20 µsec lightning surge to be modelled at the substation entry point.

Peak over-voltages calculated to be greater than 75% of the high voltage equipment BIL level are to be suppressed by appropriate placement of surge arrestors.

3.4 Earthing

The earthing system of the substation is designed based on the guidelines indicated in ENA EG-1 Substation earthing guide. If a satisfactory or safe design can not be achieved using EG-1, EG-0 may be used.

The design should consider safety both within and outside the substation fence, as well as protecting all HV plant and equipment from damage, during fault conditions. Selection of earth-grid spacing, calculation of conductor and equipment risers, use and length of earth rods, gravel or bitumen surfacing and any other mitigation method must be considered to ensure that actual touch and step voltages are less than the allowable touch and step voltages both within the substation fenced area and external to the substation fenced area for the duration of backup protection times specified in NER.

For safety reasons, the substation earth must not be extended beyond the grading ring surrounding the substation fence via for example adjoining property owner's wire fencing, underground metal pipework, AC voltage supplies, etc.

3.5 AC Supplies

All substations have at least two independent sources of 400V AC supply, designated 'normal supply' and 'alternative supply'. Major substations and switchyards require a third supply designated 'standby supply' depending on strategic value to Powerlink's network or provision for standby generators if located in cyclonic areas as defined in AS/NZS 1170.2.

Auxiliary transformers connected to Power transformer tertiaries, power VTs (high burden), diesel alternators and local distribution supplies are defined as independent AC supplies.

3.6 Noise Attenuation Enclosures

Noise studies may be required as specified in the Design Advice. Studies performed require the use of CADNA-A or SoundPLAN software to ensure interchangeability of design files so that these files can be modified for any future substation development.

Potential noise sources such as power transformers, reactors (oil filled and air-cored) and capacitor banks if installed within the substation need to be included in noise level modelling.

The maximum ultimate development of the substation is a consideration before assessing noise, with for example information relating to future transformer, reactor, or capacitor bank requirements. This information can be provided by Powerlink on request.

3.7 Lighting

Suitable lighting levels are required for safe operation and maintenance of the substation. Switchyard lighting needs to consist of weatherproof low level lanterns or higher level floodlights provided they can be maintained without encroachment of any maintenance clearances. Design utilises "*Lighting Analysts Illumination Engineering* Software", AGI32, to ensure interchangeable of design files so that these files can be modified for any future substation development.

3.8 Operation and Maintenance Requirements

The substation electrical infrastructure layout needs to facilitate safe operation and both normal maintenance and 'live' substation maintenance of the substation equipment and site infrastructure.

3.9 Structural Load Requirements

Civil and structural components are designed to satisfy AS/NZS 1170 Structural design actions, short circuit loads, and loads supplied by the substation equipment manufacturers.

The substation infrastructure is designed for winds loads with Annual Probability of Exceedance (APE) of 1/1000.

Loads associated with maintenance procedures are carefully considered when designing substation structures.

3.10 Flood Security

The Powerlink substation sites are selected to ensure that the substations are functional in a flood event with the APE of 1/200.

3.11 Access Security

Safety and in particular, public safety, is an important aspect of every substation. Substations are fully fenced and are monitored sites to prevent and detect unauthorised access to high voltage and control equipment.

Electrical plant such as a capacitor bank that is mounted close to ground level and which could compromise safety clearances is fenced to prevent accidental approach to the live equipment.

3.12 Access and Internal Roads

Substations need to be accessible in all weather conditions. Access roads and drainage are designed and constructed to satisfy a range of criteria to enable safe and secure access for people and equipment that in many cases are large and heavy. Internal roads are designed to provide safe access to the substation equipment with particular emphasis on electrical clearances.

3.13 Buildings and Amenities

Control Buildings are required to house secondary systems, telecommunications as well as buildings for storage, workshop facilities, ancillary equipment and amenities. The following buildings are typically present:

- Control building
- Telecommunications building
- Workshop and storage shed
- Amenities

3.14 Environmental Requirements and Oil Containment

The substation sites are required to comply with a number of legislative requirements and in particular, water discharge purity. Some of the substation equipment contains large quantities of dielectric mineral oil, so use of containment systems is essential to prevent accidental discharge of oil into the environment. Powerlink oil containment systems are designed to limit oil content in discharged water to 10mg / litre.

3.15 Platforms

Substation platforms are designed and built to provide stable and secure access to all substation equipment and are typically covered with gravel. The platform drainage is an essential part of the stable platform design.

3.16 Substation Structures

Substation structures primarily provide support for the substation equipment and overhead conductors. The structures are designed to withstand ultimate loads as well as to provide limited deflections under variable serviceability conditions. The expected service life of such structures is 40 plus years.

3.17 Typical Materials

Substation structures are generally constructed from galvanized steel.

Common substation structure foundation types are pier and shallow slab foundations. The foundations are constructed from reinforced concrete.