Part of Energy Queensland

## Substation Standard

# Standard for Climate and Natural Hazard Resilience

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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.

| | | |
|---|---|---|
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Abstract: This standard is designed to outline the climatic and seismic requirements for the design of Energy Queensland substations

Keywords: Climate, Bushfire, Earthquake, Flood, Hail, Natural Hazard, Rain, Seismic, Wind

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# Standard for Climate and Natural Hazard Resilience

## 1 Overview

### 1.1 Purpose

This standard outlines the climate and natural hazard resilience requirements applicable to the siting and design of Energy Queensland substations and the specification of substation plant. The objective is to site and design substations that function effectively in extreme weather conditions and during and immediately after natural hazard events of a specified severity.

### 1.2 Scope

For design against lightning strokes to electrical plant, see Standard for Substation Direct Lightning Shielding – 20389422 (STNW3032).

For design of substation DC supplies, including calculation of battery and charger ratings to provide the standard autonomy times, see Standard for DC Supplies – 3062917 (STNW3022).

## 2 References

### 2.1 Legislation, regulations, rules, and codes

| Document | Type |
|---|---|
| *Electrical Safety Act* 2002 (Qld) | Legislation |
| Electrical Safety Code of Practice – Works, 2020 (Queensland Government) | Code |
| Electrical Safety Regulation 2013 (Qld) | Regulation |
| National Construction Code (Australian Building Code Board) | Code |

### 2.2 Energy Queensland controlled documents

| Document | Alternative Doc ID |
|---|---|
| Plant Rating Manual - 4179110 | |
| Standard for Substation Design Requirements - 20468486 | STNW3003 |
| Standard for DC Supplies – 3062917 | STNW3022 |
| Standard for Substation Direct Lightning Shielding – 20389422 | STNW3032 |
| Standard for Insulation Co-ordination – 3058912 | STNW3034 |
| Standard for Substation Fire and Explosion Protection – 3058013 | STNW3035 |
| Standard for Substation Ventilation & Air Conditioning – 3055324 | STNW3047 |

### 2.3 Other sources

AS/NZS 1170.0:2002, Structural design actions – general principals

AS/NZS 1170.1:2002, Structural design actions – permanent, imposed and other actions

AS/NZS 1170.2:2021, Amd 1:2023, Structural design actions – wind actions

AS 1170.4 – 2024, Structural design actions – earthquake actions in Australia

AS 1210-2010, Pressure vessels

AS 1768:2021, Lightning Protection

AS 2067:2016, Substations and high voltage installation above 1kV ac

AS 2676.2:2020, Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings – Sealed cells

AS/NZS 3500.3:2025, Plumbing and drainage – stormwater drainage

AS 3959:2018, Construction of buildings in bushfire prone areas

AS 60068.1 – 2023, Environmental testing part 1 – general and guidance

AS/NZS 60076.1:2014, Power Transformers – General

AS/NZS 60076.2:2013, Power transformers – Temperature rise for liquid immersed transformers

AS/NZS 60076.14:2025, Liquid-immersed power transformers using high-temperature insulation materials

SA TS 60815.1:2020, Selection and dimensioning of high-voltage insulators intended for use in polluted conditions, Part 1: Definitions, information and general principles (IEC/TS 60815-1:2008 (ED 1.0) MOD)

AS 62271.1:2019, High Voltage Switchgear & Controlgear – Common Specification

IEC/TR 62271-300:2006, High voltage switchgear and controlgear - Part 300: seismic qualification of alternating circuit breakers

IEEE 693 – 2018, IEEE recommended practice for seismic design of substations

CIGRE TB614 – 2015, Air insulated substation design for severe climate conditions

Geoscience Australia - Australian Rainfall and Runoff: A Guide to Flood Estimation

Bureau of Meteorology website

Bureau of Meteorology Rainfall Intensity Frequency Duration data

Queensland Government State Planning Policy 1/03 Guideline – Mitigating the adverse impacts of floods, bushfire and landslides

Queensland Government Disaster Management Sector – The Science of Climate Change

# 3 Definitions and abbreviations

## 3.1 Definitions

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

| | |
|---|---|
| Annual exceedance probability | The probability of an event being equalled or exceeded in any given year, usually expressed as a percentage. |

| | |
|---|---|
| Average recurrence interval (ARI, R) | The average interval between exceedances of a given event severity. For R > 5 years, this is the reciprocal of the annual exceedance probability. |
| Bushfire Attack Level | A measure of the bushfire threat to a building based on heat flux, which depends on the Fire Danger Index, the distance to vegetation, the type of vegetation and the slope underlying it. |
| Climate | The average of weather conditions over years to decades. |
| Cyclone | A system of winds rotating inwards to an area of low barometric pressure. See also Tropical Cyclone. |
| Dew point temperature | The temperature to which air must be cooled in order for dew to form. |
| Fire Danger Index (FDI) | A measure of fire risk at a location, based on the probability of coinciding strong wind, low humidity, high air temperature and dry fuel load. Uses the McArthur Mk5 Forest FDI scale. |
| Flash flooding | Flood of short duration with a relatively high peak discharge |
| Flood | A flood occurs when water extends over what is usually dry land |
| Ground lash | A lightning flash in which at least one discharge channel reaches the ground |
| Ground flash density | The number of ground flashes per square kilometre per annum; a better measure of lightning risk than annual thunder days, but harder data to collect. |
| Keraunic Level or Annual Thunder Days | The average number of thunder days per year at a given location. A simple but biased method for estimating lightning risk. |
| Natural hazard management area | An area that has been defined, in Annex 3 of the SPP, for the management of a natural hazard (flood, bushfire or landslide) |
| Probable maximum flood (PMF) | The most severe flood that is likely to occur at a particular location. Such a flood would result from the most severe combination of critical meteorological and hydrological conditions |
| Probable maximum precipitation (PMP) | The theoretically greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of year |
| Recommended flood level (RFL) | The level of flood immunity recommended in the SPPG for the given type of community infrastructure. Examples:<br>Major switchyard 0.2% AEP<br>Substation 0.5% AEP |
| Relative humidity | The ratio of actual moisture content to saturation moisture content. Relative humidity of the air is a traditional weather statistic. |
| Representative Concentration Pathways | A set of greenhouse gas concentration trajectories to the year 2100 adopted by the IPCC for climate modelling |
| Severe Thunderstorm | A thunderstorm causing one or more of<br>A tornado<br>Wind gusts ≥ 90 km/h at 10 m above ground<br>Hail ≥ 20 mm diameter |

| | |
|---|---|
| | Hourly rainfall intensity > 10-year ARI |
| Storm surge | A storm surge is a rise above the normal water level along a shore that is the result of strong onshore winds and /or reduced atmospheric pressure. |
| Synoptic scale | Of weather systems, more than 1000 km across |
| Thunder day | A day at a given location on which thunder is heard at least once. |
| Tropical cyclone | A synoptic-scale cyclone formed over warm waters with sustained wind speed near the centre exceeding 63 km/h for more than six hours. |
| Wind Region | See AS/NZS 1170.2:2021 (not an earlier edition) Figure 3.1(A)<br>Briefly for Queensland, reading "smoothed coastline" for "coast":<br>B1: up to 200 km in from the coast south of latitude 25°S (near Bundaberg)<br>B2: between 50 and 100 km in from the coast north of 25°S; also, any land north of 11°S (Bamaga and the Torres Strait islands)<br>C: up to 50 km in from the coast between latitudes 11°S and 25°S, and<br>A0: everywhere else. |
| Wind speed | Wind speeds increase with height above ground. Statistics and forecasts are the speed 10 m above the surface. Sustained wind speed is averaged over 10 minutes; gusts can be 40% or more faster. Gust speed statistics are the basis for design. Design wind speeds for a structure can be determined for several directions and depend on site location, topology, shielding by vegetation and other buildings, structure height and shape, and the desired probability of exceedance. (See AS/NZS 1170.2) |

## 3.2 Abbreviations

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

| | |
|---|---|
| AEP | Annual Exceedance Probability |
| ARI | Average Recurrence Interval |
| BAL | Bushfire Attack Level (refer AS 3959) |
| BOM | Bureau of Meteorology |
| ECM | Enterprise Content Management |
| FDI | Fire Danger Index (refer AS 3959) |
| GHG | Greenhouse gasses ($CO_2$, $CH_4$, $N_2O$, $SF_6$, etc.) |
| IED | Intelligent Electronic Device |
| IFD | Intensity-Frequency-Duration (BOM rainfall statistics) |
| IPCC | Intergovernmental Panel on Climate Change |
| $k_p$ | Probability factor, related to seismic AEP (refer AS 1170.4) |
| $L$ | Design working life (refer AS 1170.0) |
| LODMAT | Lowest One Day Mean Ambient Temperature (refer AS 1210) |

| | |
|---|---|
| NCC | National Construction Code of Australia |
| SPP | Queensland Government State Planning Policy 1/03<br>Mitigating the Adverse Impacts of Flood, Bushfire and Landslide |
| SPPG | Queensland Government State Planning Policy 1/03 Guideline |
| *R* | Average recurrence interval |
| RCP | Representative Concentration Pathway |
| RFL | Recommended Flood Level |
| RTD | Resistance temperature detector |
| UV | Ultraviolet |
| $V_{2500}$ | Regional gust wind speed (m/s) for *R* = 2500 years |
| Z | Earthquake hazard design factor (refer AS 1170.4) |

# 4 Climatic and seismic impacts

## 4.1 General

EQL's territory is the state of Queensland. Locations in the state may be subject to:

- Very high insolation, severe heat, drought, and dust
- Bushfires
- Prolonged high humidity, dew, mist, saline fog
- Intense rainfall, storm surges and major flooding
- Tropical cyclones, thunderstorms, hailstorms, and tornados
- Earthquake
- Landslides

Rising concentrations of greenhouse gases in the atmosphere are causing an increase in average temperature and influencing the severity of weather events. Substation plant and structures shall be designed to withstand the climate extremes projected for the lifetimes of the assets in the location in which they will be installed.

Plant purchased under period contracts should be rated for service in at least 95% of Queensland substations. Where it is too expensive to specify suitability for all substations, specifications shall request quotes for optional enhancements to deal with the more extreme conditions, such as corrosive or polluted atmospheres, or arduous load profiles.

Structures designed for a particular site, and plant purchased to serve only at one site, may be designed to the local conditions, provided the ramifications on spares holdings, training and procedures are properly taken into account.

## 4.2 Projections to 2050

The Climate Change Act 2022 (Cth) codified Australia's greenhouse gas emissions reductions targets under the Paris Agreement. The targets are 43% below 2005 emissions by 2030, no more than 4381 Mt $CO_2$ equivalent emitted from 2021 to 2030, and net zero emissions by 2050. Achieving these targets will involve extensive electrification of transport and domestic, commercial and industrial energy consumption. With higher dependence on electricity, the reliability of electricity supply infrastructure will be even more important.

Global surface temperatures are expected to plateau a few years after global net zero emissions are achieved. Sea levels will continue to rise for centuries.

In 2018, the annual median temperature in Queensland was forecast to increase by +1.4°C by 2050 under a Lower Emissions (RCP4.5) scenario and +1.9°C under the Higher Emissions (RCP8.5) scenario, with the greatest impact in the Southwest. See Figure 1. Heatwaves are likely to be more frequent and more intense.

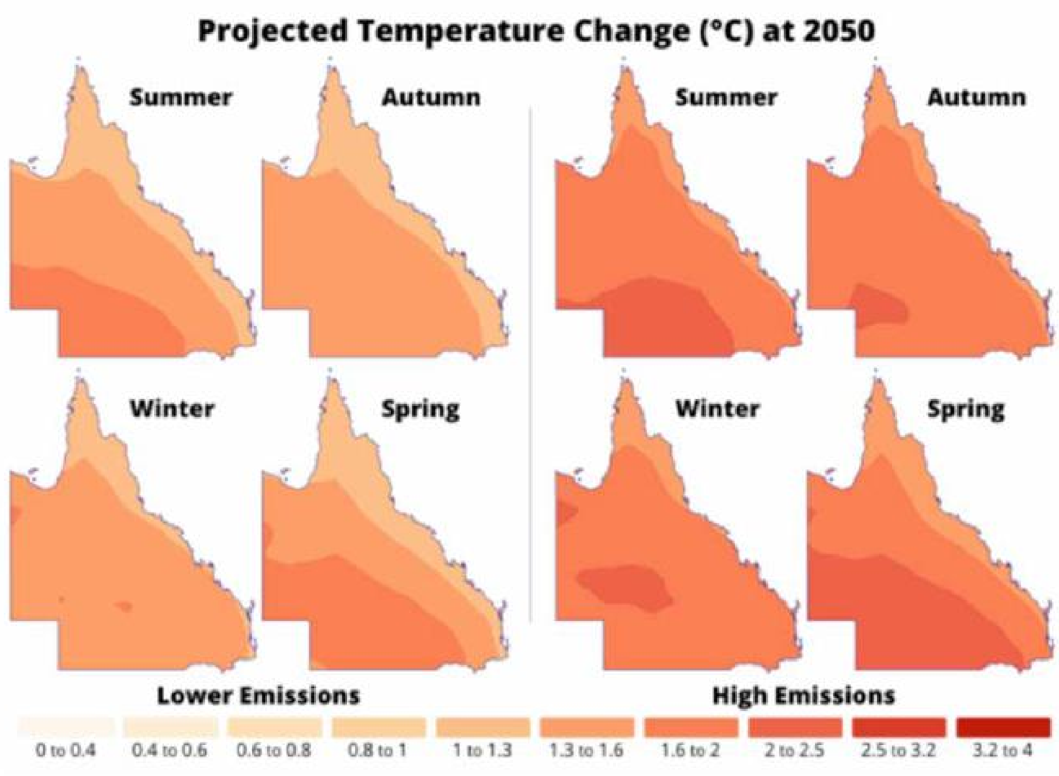


*Figure 8: Temperature projection for Queensland for 2050 under lower emission (RCP 4.5) and higher emission (RCP8.5) scenarios.*

*Source: The Climate Change in Queensland map application tool (http://qgsp.maps.arcgis.com/apps/MapJournal/index.html?appid=1f3c05235c6a44dcb1a6faebad4683fc)*

**Figure 1: Effect of Emissions on Temperature**

Fire seasons are expected to be longer, with more severe fire danger days. Gradual changes are expected in vegetation health, vigour, and species, but the SPPG suggests it is not practicable to consider the impacts of climate change in bushfire hazard assessment studies at present.

Predictions of sea level rises vary significantly, but we know the rate is accelerating. The Queensland Coastal Plan has adopted 80 cm above the year 2000 levels by 2100, of which 26 cm is by 2050. Storm surges could be worse than now due to deeper barometric lows and stronger storm winds.

Extreme rain events are projected to become more intense. Development around substations may change drainage and flood levels.

Tropical cyclones and east coast lows may occur less often than now, but the proportion of intense storms is projected to increase.

**Table 4-1 A sample of Category 5 cyclones affecting Queensland**

| Cyclone | Date | Wind speed (km/hr) | Gust speed (km/hr) | Pressure (hPa) | Landfall | Major impact |
|---|---|---|---|---|---|---|
| Monica | Apr, 2006 | 250 | 350 | 916 | Arnhem Land | NT |
| Yasi | Feb, 2011 | 205 | 280 | 929 | Mission Beach | NQ |
| Winston | Feb, 2016 | 280 | 306 | 884 | Viti Levu | Fiji |

Thunderstorms are also likely to be more severe; Australian hailstone size records were broken in 2020 (14 cm, Logan) and again in 2021 (16 cm, Yalboroo, NQ).

### 4.3 Substation Plant Impacted by Climate Conditions

The following substation equipment was identified in CIGRE TB614 as being impacted by climate conditions.

**Table 4-2 Climate Effects on Equipment**

| Equipment | Heat and drought | Rain flooding and humidity | Snow and ice | Wind |
|---|---|---|---|---|
| Transformers | ✓ | ✓ | ✓ | ✓ |
| Circuit breakers | ✓ | ✓ | ✓ | ✓ |
| Switches/isolators/disconnectors | ✓ | ✓ | ✓ | ✓ |
| Insulators or insulation | | ✓ | ✓ | ✓ |
| Foundations | | ✓ | ✓ | ✓ |
| Control houses and associated protection equipment | ✓ | ✓ | ✓ | ✓ |
| Cable trays | | ✓ | ✓ | ✓ |
| Fence and roads | | ✓ | ✓ | ✓ |
| Drains and pumps | | ✓ | | |
| Ground grid and earthing | | ✓ | | |
| Energized bus contact and clearance | | | ✓ | |

| Equipment | Heat and drought | Rain flooding and humidity | Snow and ice | Wind |
|---|---|---|---|---|
| Lightning shield wires | | | ✓ | |
| Lightning masts | | | ✓ | |
| Bushings | ✓ | | | |
| Capacitors | ✓ | | | |
| Energized Bus | ✓ | | | |
| Connectors and conductors | ✓ | | | |
| Bus Supports | | | | ✓ |

# 5 Period contract specifications

The design criteria here have been chosen so that the probability of an exceedance coinciding with other compounding factors is acceptably low. Some of the requirements are quite stringent. Where a tendered design fails to meet a criterion in the first pass, or the cost of compliance is too high, manage the risk. Examples:

Items with less wind resilience may be included as standard items if their deployment is restricted to non-cyclonic wind regions or sheltered sites. See Table 6-3 for guidance.

Modular buildings could have design variations with different Bushfire Attack Levels suited for different distances to classified vegetation. Refer AS 3959.

Higher levels of resilience can be specified for the types of plant where these are naturally easy to achieve.

**Table 5-1 Criteria for period contract specifications and acceptability of existing designs**

| Factor | Plant specification criteria | | Reference |
|---|---|---|---|
| Altitude | meters above sea level | 1,000 | Standards |
| Ambient air temperature | Lowest<br>Highest | -5°C<br>+50°C | AS 2067 2.4.3.4 "very hot climates" |
| | Massive steel vessels e.g., transformer tanks:<br>Lowest One Day Mean | 0°C | AS 1210 |
| Substations indoor air temperature | Lowest<br>24-hour average<br>Highest | -5°C<br>+40°C<br>+45°C | AS 2067 Cl. "-5 indoor"<br>AS 2067 normal + 5°C<br>AS 2067 normal + 5°C |
| Temperature of cooling medium | Power Transformers:<br>correction to *Normal cooling conditions* | -5 K | AS 60076.2,<br>IEC 60076-14 |

| Factor | Plant specification criteria | | Reference |
|---|---|---|---|
| Solar radiation | Maximum W/m² | 1,100 | AS 2067 normal |
| Relative humidity, outdoor | Minimum<br>Maximum | 25%<br>100% | |
| Relative humidity, indoor | Minimum<br>Maximum | 25%<br>99% | AS 2067 tropical 24 hr + 1% |
| Ground temperature at 1000 mm depth | Winter<br>Summer | +30°C<br>+35°C | Plant Rating Manual<br>Table 19 |
| Thunder days | Annual | 40 | BOM |
| Ground flash density | Annual strokes/km² | 4 | AS 1768 Fig 2.3 |
| Hail | Hailstone diameter (mm)<br>Accumulation depth (mm) | 70<br>100 | |
| Bushfire | All building construction elements | BAL-FZ | AS 3959 |
| Wind speed (gusts) | Height h ≤ 5 m 227 km/h<br>Height h = 10 m 248 km/h | 63 m/s<br>69 m/s | AS/NZS 1170.2 |
| Rainfall intensity | Five-minute duration mm/h | 350 | BOM IFD Wet tropics |
| Ingress Protection | Outdoor cubicles:<br>Outdoor protection / indication instruments: | IP55<br>IP65 | EQL |
| Atmospheric corrosivity | Exterior coatings category for plant not easily accessed for maintenance:<br>Options for shorefront or industrial site: | C4 (High)<br>C5 (Very High) | AS 2312 or<br>ISO 12944-2<br>AS 2312: C5-M or C5-I |
| Pollution | Site pollution severity class<br>Option for heavily polluted sites: | d (Heavy)<br>e (Very Heavy) | SA TS 60815.1 |
| Seismic | Probability x Hazard Factor $k_P Z$<br>Switchgear and control gear qualification | 0.18<br>Yes | AS 1170.4<br>IEC/TR 62271-300 |

# 6 Site selection and site-specific design

## 6.1 Considering natural hazards and disasters

When there are several candidate sites, consider the following requirements of the SPP:

If the site is in a natural hazard management area and use of the site will involve

- vegetation clearing,
- net filling exceeding 50 cubic meters or
- redirecting surface or ground water in a landslide area, additional justification and documentation will be required.

If the site is subject to a High or Medium bushfire hazard, the development application should include and comply with a comprehensive Bushfire Management Plan

If the site is in a landslide hazard area, the development application should include geotechnical analysis describing measures to ensure the long-term stability of the site, security of access and protection from landslides originating above the site.

**Table 6-1 Site selection and design quick reference**

| Factor | Criteria | Notes |
|---|---|---|
| Bushfire | Assess the BALs required for each candidate site.<br>Design buildings to their maximum assessed BAL. | AS 3959 |
| Earthquake | Give preference to sites with stronger sub-soil class, particularly in higher hazard factor areas.<br>Design to Earthquake Design Category II for structure heights < 25 m, else Category III. Demonstrate immediate serviceability following the design event for Importance Level 2 structures.<br>Design non-structural parts and components in accordance with Section 8 of AS 1170.4 | AS 1170.4 |
| Flood | Floor and plant serviceability level: RFL + 300mm | SPPG + EQL margin |
| Hail | The keraunic level map indicates the frequency of hailstorms | Thunder days |
| Landslide | In a landslide hazard area, commission a geotechnical analysis | |
| Rain | Essential plant to remain functional at five-minute intensity = BOM “1 in 2000” AEP rainfall depth x 12 (mm/hr)<br>Eave gutters 1 in 20 AEP and valleys and box gutters 1 in 100 AEP, per the plumbing and drainage standard | BOM IFD stats<br>AS/NZS 3500.3 |
| Wind | Avoid very exposed open terrain, e.g., oceanfront sites.<br>Avoid sites on or above slopes steeper than 1:20, unless there are mitigating factors such as distance from the coast.<br>Evaluate site wind speed multipliers and determine design wind speeds from the regional gust wind speed at the required ARI.<br>Verify busbars, strung bus, and overhead earth wires strength limit state design pressures | AS/NZS 1170.2 |

Where local supply transformers are supplied from outgoing feeders, select the least exposed feeders, and consider underfrequency load shedding. Install connections to external AC boards for portable generators to provide emergency local supply.

### 6.2 Minimum Recurrence Intervals

Buildings or structures that are essential for post-disaster recovery are designated Importance Level 4 in the NCC and AS/NZS 1170. This determines the severity (ARI) of disasters that the buildings shall be capable of withstanding. Specify essential outdoor substation assets to achieve at least the same level of resilience as buildings unless the asset can be readily replaced from spares on hand. Assets that are not essential to a functioning substation may be designed to lesser severity events.

**Table 6-2 Minimum Average Recurrence Intervals**

| Asset | ARI (years) | Reference |
|---|---|---|
| **Bushfire** | | |
| All | 2000 | NCC Part G5 Construction in bushfire prone areas, Table GV5.1 |
| **Earthquake** | | |
| Buildings | 1500 | NCC Part B1 Structural provisions (Deemed to Satisfy) Table B1.2b |
| Wire Fence | 200 | EQL |
| Paling Fence | 500 | EQL |
| Plant | 40 x *L* | AS/NZS 1170.0 Table F2, Note 2, where *L* is design working life |
| **Flood** | | |
| Substations | 200 | SPPG Appendix 9. **Add 300 mm margin**. (EQL) |
| Major switchyard | 500 | |
| **Rainfall** | | |
| All | 2000 | EQL, aiming for similar resilience in intense rainfall as for other hazards |
| **Wind** | | |
| Buildings | 2000 | NCC Part B1 Structural provisions (Deemed to Satisfy) Table B1.2b |
| Wire Fence | 200 | EQL |
| Paling Fence | 500 | EQL |
| Plant | 40 x *L* | AS/NZS 1170.0 Table F2, Note 2, where *L* is design working life |

The ARIs in Table 6-2 Minimum Average Recurrence Intervals are absolute minimum values. For Australian Importance Level 4 structures for which design events are not given elsewhere, AS/NZS 1170.0 sets *R* = 2500 years for 50-year design life, for both wind and earthquake events.

### 6.3 Bushfire

Assess sites and locate and design structures within site envelopes in accordance with AS 3959.

The default FDI for Queensland is 40. The best sites from a bushfire perspective are where structures will be at least 100 m from classified vegetation (50 m for unmanaged grassland). Next best are sites where the vegetated ground is flat or slopes up with distance from the site. Vegetated areas that may be excluded from assessment include those that are small and isolated, mangroves, maintained parklands, orchards, some crops, and windbreaks. See AS 3959 2.2.3.2.

### 6.4 Earthquake

Using $R$ = 2500 rather than $R$ = 1500 increases the seismic probability factor $k_p$ from 1.5 to 1.8. Designing to $k_pZ$ = 0.18 withstands $R \geq 1500$ events for sites within 150 km of Bundaberg (where $0.10 \leq Z \leq 0.12$) and $R \geq 2500$ everywhere else in Queensland (where $Z \leq 0.10$).

### 6.5 Flood

When selecting a site, consider accessibility during floods and how to achieve the EQL standard flood resilience level in Table 6-2. The floors of new substation buildings shall be no lower. Design transformer pads, switchgear structures and high voltage plant enclosures so that only impermeable or expendable equipment will be below this level. Check plant specifications, or the general arrangement drawings of standard items, for the minimum height above foundations for cable boxes, marshalling and control boxes, outdoor switchboards and protection panels, auxiliary switches, mechanisms, and breathers.

At flood prone sites:

Perform risk assessments and document procedures for temporary protection or removal of equipment, emergency interruptions, safe access and repair or dry out after flooding. Underslung transformer cooling fans may be sacrificed in a severe flood if they can't be rescued beforehand.

Where fast overland flow is possible, consider erosion, debris, dynamic effects, and the impact of obstruction on surrounding properties.

Seal up conduit entries and plug spare conduits.

Install backflow preventers in drains where necessary.

Elevate or flood-proof key components. Consider means to temporarily elevate breathers.

### 6.6 Rain

Intensity-frequency-duration statistics for rainfall are available at

Rainfall IFD Data System: Water Information: Bureau of Meteorology (bom.gov.au)

Select the Single Point radio button, enter the geographical coordinates and click Submit. Tick the "1 - 45 minutes" duration.

For extreme events, select the Rare radio button. The extreme 5-minute intensity in mm/hr is 12 times the "1 in 2000" AEP Rare Design Rainfall Depth for 5 min duration. For example, Babinda's coordinates are -17.3422°, 145.9236°, the "1 in 2000" depth is 40.8 mm in 5 minutes, so the extreme 5-minute intensity is 490 mm.

For roof drainage, select the IFDs radio button and the 5% and 1% AEP intensities are 12 times the 5 min figure in the corresponding AEP column. Alternatively, figures for the location, or one close by, can be looked up in Appendix D of AS/NZS 3500.3.

### 6.7 Wind

The site gust wind speed is calculated by multiplying the regional gust wind speed for the selected ARI by five multipliers. (Refer AS/NZS 1170.2)

$M_d$ the direction multiplier, 0.75 to 1, depending on wind region and direction

$M_d$ is 0.9 in regions B2 and C, regardless of wind direction

$M_c$ the climate change multiplier, currently 1.05 in cyclonic regions, elsewhere 1

$M_{z/cat}$ the terrain/height multiplier. Away from very exposed open terrain, safe values are

$M_{z/cat} = 0.91$ for structures up to 5 m high

$M_{z/cat} = 0.91 + 0.018 \times (h-5)$ for structures $5 \leq h \leq 10$ m high

$M_s$ the shielding multiplier. 1 is safe (in case the shielding building is removed)

$M_t$ the topographic multiplier. This is 1 for sites on or above slopes less than 1:20

Using *R* = 2500 rather than *R* = 2000 increases design wind speeds by no more than 1.5%. Assuming the site satisfies the restrictions on terrain and topography above, Table 6-3 shows conservative values of site wind speed for *R* = 2500 years, and structure heights up to 5 metres and also for a structure height of 10 metres.

**Table 6-3 Site wind speeds guidance for R = 2500 years**

| Parameter | Units | Wind Regions in Queensland | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | A0 | | B1 | | B2 | | C | |
| $V_{2500}$ | (m/s) | 48 | | 64 | | 64 | | 74 | |
| $M_d$ (max) | | 1.00 | | 0.95 | | 0.9 | | 0.9 | |
| $M_c$ | | 1.00 | | 1.00 | | 1.05 | | 1.05 | |
| $M_s$ | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| $M_t$ | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| h | (m) | ≤ 5 | 10 | ≤ 5 | 10 | ≤ 5 | 10 | ≤ 5 | 10 |
| $M_{z/cat}$ | | 0.91 | 1.00 | 0.91 | 1.00 | 0.91 | 1.00 | 0.91 | 1.00 |
| **Site wind speed** | (m/s) | 44 | 48 | 55 | 61 | 55 | 60 | 64 | 70 |
| | (km/h) | 158 | 174 | 199 | 219 | 198 | 217 | 230 | 253 |
| Cyclone Category | | 3 | | 3 | | 3 | | 4 | |

**Note:** Region C site wind speed declines linearly with distance from the smoothed coastline to the corresponding Region B speed at the B/C region boundary. At *R* = 2500 years and the multipliers shown, for structures up to 5 metres high the rate of change is 0.63 km/hr per kilometre.

Table 6-4 shows conservative values of site wind speed for *R* = 500 years and *R* = 200 years and structures up to 5 metres, based on the same multipliers as in Table 6-3.

**Table 6-4 Site wind speed guidance for non-essential assets less than 5 metres high**

| Asset | Parameter | Units | Wind Regions in Queensland | | |
|---|---|---|---|---|---|
| | | | A0 | B1 and B2 | C |
| Paling fences | $V_{500}$ | (m/s) | 45 | 57 | 66 |
| | Site wind speed | (m/s) | 41 | 49 | 57 |

| | | | | | |
|---|---|---|---|---|---|
| | | (km/h) | 148 | 176 | 205 |
| | Cyclone Category | | 2 | 3 | 3 |
| Wire fences | $V_{200}$ | (m/s) | 43 | 52 | 61 |
| | Site wind speed | (m/s) | 39 | 45 | 52 |
| | | (km/h) | 140 | 162 | 187 |
| | Cyclone Category | | 2 | 2 | 3 |

**Note:** Multipliers are as in Table 6-3. In Region C the site wind speeds for fence design decline by approximately 0.5 km/hr per kilometre from the coast.

Design doors and shutters to resist the site wind pressure. Those that are large enough to compromise the building if accidentally left open shall be included in the intrusion alarm system. In Region C, design for impact by windborne debris.

Provide means to secure objects likely to become airborne if stored in the substation yard.

### 6.8 Hail

Design roof structures for hail loading if the roof pitch is less than 5 degrees. Avoid roof pitches less than 3 degrees, box gutters and roof obstructions that encourage the accumulation of hail drift.

Steeper roof pitch reduces the impact energy of hailstones. Corrugated roofing sheets are less likely to be punctured by giant hail than flat-pan profiles.

### 6.9 Lightning

Refer to AS1768 and Standard for Insulation Co-ordination – 3058912 (STNW3034).

### 6.10 Drought

Design earth grids for seasonal variations in soil resistivity, providing deeper drilled rods in bentonite if necessary.

Provide for oil separator water levels to be maintained efficiently and reliably.

Design substation structure foundations to cater for ground movement due to variation in moisture content.

### 6.12 Heat

Outdoor equipment must be able to survive the specified highest ambient temperature, but this temperature is not necessarily the basis for load ratings. Ratings are chosen considering ambient temperature and load profiles, thermal time constants, the acceleration of ageing with temperature, etc. For locations that are consistently very hot, options include

selecting a higher MVA or current rating than the forecast load indicates, or

specifying lower temperature rise at rated load, or

specifying an option with a higher tolerance to temperature, e.g., ester fluid transformers, thermally upgraded paper insulation, higher thermal mass, or

accepting a shorter service life at that location.

Power transformers rated 5 MVA and greater shall be purchased with RTDs monitoring ambient and top oil temperature, and an IED calculating winding hotspot temperatures and performing pre-emptive cooler control. Transformers rated 20 MVA and greater shall, in addition, be purchased with fibreoptic thermometers monitoring winding temperatures. Transformers smaller than 20 MVA may be purchased with fibreoptic thermometers when economic. Retrofit RTD ambient and oil temperature monitoring and pre-emptive cooler control to all transformers subjected to arduous load profiles or significant risk of overload.

Expansion chambers/safety valves for oil filled equipment shall cater for the volume / internal pressure at maximum oil temperature.

Sealing of gas-insulated equipment shall cater for the pressure at maximum gas temperature.

Design the ventilation and air conditioning of control and protection buildings according to Standard for Substation Ventilation & Air Conditioning – 3055324 (STNW3047).

Ensure batteries and any electronic equipment located outdoors are in suitably temperature-controlled cubicles (see Table 6-5).

The following temperature limits are typical for substation equipment that may be housed in outdoor marshalling or control cubicles:

**Table 6-5 Temperature limits for substation equipment**

| Equipment | Maximum Temperature (°C) |
|---|---|
| Substation batteries | 10-year design life at 25°C<br>(Battery life halves every 8 degrees above design life) |
| Battery chargers | 100% power at 50°C<br>55% power at 70°C |
| Protection relays and meters | 55°C |
| Transformer management IEDs | 80°C |
| Liquid Crystal Displays (LCDs) | 85°C withstand, 70°C self switch off |
| Terminals | 100°C |

| Equipment | Maximum Temperature (°C) |
|---|---|
| Cables | 75°C (V-75)<br>90°C (V-90, XLPE, HFI) |
| Capacitor cans | 55°C<br>45°C average over 24 hrs |
| AC switchboard and circuit breakers | 45°C (without de-rating) |

Cubicles utilising natural ventilation are preferred. Vents should be in the vertical sides near the top and bottom of the box and screened to exclude ants and mason flies. The vents shall permit easy cleaning and replacement.

Where unshielded single-skinned boxes will get too hot, consider alternatives:

- double skinned boxes or boxes with heat shields and/or sunshades
- reflective paint
- thermostat-controlled fans
- air conditioning.

### 6.13 Sunlight

Cable insulation and sheaths exposed to sunlight shall be UV stable to the equivalent of 2% carbon black content.

Consider sunshades, pergolas, or reflective paint to extend the life of equipment.

Orient or shade sensitive surfaces, such as electronic displays and cubicle viewing windows, to minimise exposure to the sun.

### 6.14 Moisture and Dust

Outdoor control and marshalling cubicles shall have IP55 ingress protection with the door closed.

Control cables are to enter cubicles from the bottom to minimise moisture ingress.

Specify controlled or self-regulating heaters to prevent condensation in cubicles other than those housing only terminal blocks or strips.

Cubicles and cable trays are to be made of corrosion-resistant metals.

Instruments and gauges exposed to the weather, including their terminal boxes, shall have IP65 or better ingress protection.

Perform site-specific insulator selection and dimensioning (see SA TS 60815.1) where insulators in the vicinity have a history of flashover or the site is directly subjected to high-conductivity contaminants, sea spray, or a combination of dust and condensation.

### 6.15 Blasting and Vibration Around Substations

Substations may contain equipment sensitive to ground vibrations. This includes:

- Power transformers – bushings, Bucholz relays, pipework

- Gas insulated switchgear – potential leaks at flanges or pipework
- Protection relays – particularly older electro-mechanical relays
- Circuitry – older mercury switches

Effects of blasting and vibration are measured in Peak Particle Velocity (PPV) typically in units of mm/s. The following table provides limits to all locations within the substation fence and are based on comparison with other utility guidelines and research into vibration limits on power transformers. Factors such as age, condition and sensitivity of electrical equipment may further reduce these limits.

**Table 6 - Substation Equipment PPV Limits (mm/s)**

| Equipment Type/Category | 90% blasting events | Max blasting event |
|---|---|---|
| Substations with power transformers with OIP bushings | ≤10 | 15 |
| Substation sites with sensitive equipment | ≤10 | 15 |
| All other substation sites | ≤20 | 25 |

# Annex A

## Revision History

| Revision date | Version number | Author | Description of change/revision |
|---|---|---|---|
| 29/05/2011 | 0.1A | DC | First draft |
| 03/05/2012 | 0.2 | DC | Endorsed by SDOF |
| 07/05/2013 | 0.3 | PM | Minor formatting changes |
| 27/06/2014 | 0.4 | Cassie Caldwell | Transferred to new document template |
| 1/1/2020 | 0.5 | John Lansley | Combined EQL document, added more climate impacts |
| 27/3/2020 | 1.0 | John Lansley | Final revision after comments |
| 28/12/2020 | 2.0 | John Lansley | Amendment to Wind Code Design for substation fencing. |
| 16/06/2022 | 3 | John Lansley | Transferred to new document template |
| 06/06/2023 | 4.0 | Peter Rollings | Renamed from “Climatic and Seismic Conditions”<br>Comprehensive revision |
| 16/04/2026 | 5 | John Lansley | Update references. Added 6.15 on blasting & vibration |