



Part of Energy Queensland

Substation Standard

Standard for Climate and Natural Hazard Resilience

STNW3007

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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

Standard for Climate and Natural Hazard Resilience

CONTENTS

1	Overview	4
1.1	Purpose	4
1.2	Scope	4
2	References	4
2.1	Legislation, regulations, rules, and codes.....	4
2.2	Energy Queensland controlled documents.....	4
2.3	Other sources	5
3	Definitions, abbreviations, and symbols	6
3.1	Definitions	6
3.2	Abbreviations and symbols	7
4	Climatic and seismic impacts.....	8
4.1	General	8
4.2	Projections to 2050	9
4.3	Substation Plant Impacted by Climate Conditions	10
5	Period contract specifications	11
6	Site selection and site-specific design	12
6.1	Considering natural hazards and disasters	12
6.2	Minimum Recurrence Intervals.....	14
6.3	Bushfire.....	14
6.4	Earthquake	15
6.5	Flood.....	15
6.6	Rain	15
6.7	Wind	16
6.8	Hail	17
6.9	Lightning	17
6.10	Drought	17
6.11	Heat	17
6.12	Sunlight.....	19
6.13	Moisture and Dust.....	19
Annex A	Revision History.....	20

FIGURES

Standard for Climate and Natural Hazard Resilience



Figure 1 Effect of Emissions on Temperature 9

TABLES

Table 4-1 A sample of Category 5 cyclones affecting Queensland..... 10

Table 4-2 Climate Effects on Equipment 10

Table 5-1 Criteria for period contract specifications and acceptability of existing designs 11

Table 6-1 Site selection and design quick reference 13

Table 6-2 Minimum Average Recurrence Intervals..... 14

Table 6-3 Site wind speeds guidance for R = 2500 years 16

Table 6-4 Site wind speed guidance for non-essential assets less than 5 metres high..... 16

Table 6-5 Temperature limits for substation equipment..... 18

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 AS 1768 Lightning Protection and STNW3034 Substation Standard for Insulation Coordination.

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

2 References

2.1 Legislation, regulations, rules, and codes

Australian Building Codes Board - [National Construction Code](#)

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](#)

2.2 Energy Queensland controlled documents

Ergon Energy [Substation Design Manual](#) - 2868883

Energex [Standard Network Building Blocks – Substations](#) - 3061936

[Plant Rating Manual](#) - 4179110

STNW3022 [Standard for DC Supplies](#) - 3062917

STNW3034 [Standard for Insulation Co-ordination](#) - 3058912

STNW3035 [Standard for Substation Fire & Explosion Protection](#) - 3058013

STNW3047 [Standard for Substation Ventilation & Air Conditioning](#) - 3055324

Standard for Climate and Natural Hazard Resilience

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 - 2007	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 3500.3:2021	Plumbing and drainage – stormwater drainage
AS 3959:2018	Construction of buildings in bushfire prone areas
AS 60068.1 – 2003	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
IEC 60076-14:2013	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
Energy Networks Australia. Report prepared by Scientell Pty Ltd	Electricity networks - A guide to climate change and its likely effects
National Climate Centre, Bureau of Meteorology	Thunderstorm distribution and frequency in Australia, Australian Meteorological Magazine 51:3 September 2002

Standard for Climate and Natural Hazard Resilience

3 Definitions, abbreviations, and symbols

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 flash	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: Major switchyard 0.2% AEP 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.

Standard for Climate and Natural Hazard Resilience

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 • A tornado • Wind gusts ≥ 90 km/h at 10 m above ground • 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) Briefly for Queensland, reading “smoothed coastline” for “coast” : B1: up to 200 km in from the coast south of latitude 25°S (near Bundaberg) 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) C: up to 50 km in from the coast between latitudes 11°S and 25°S, and 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 and symbols

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 ₂ O, SF ₆ , etc.)
IED	Intelligent Electronic Device
IFD	Intensity-Frequency-Duration (BOM rainfall statistics)

Standard for Climate and Natural Hazard Resilience

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 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.

Standard for Climate and Natural Hazard Resilience

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 CO₂ 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 1 Effect of Emissions on Temperature

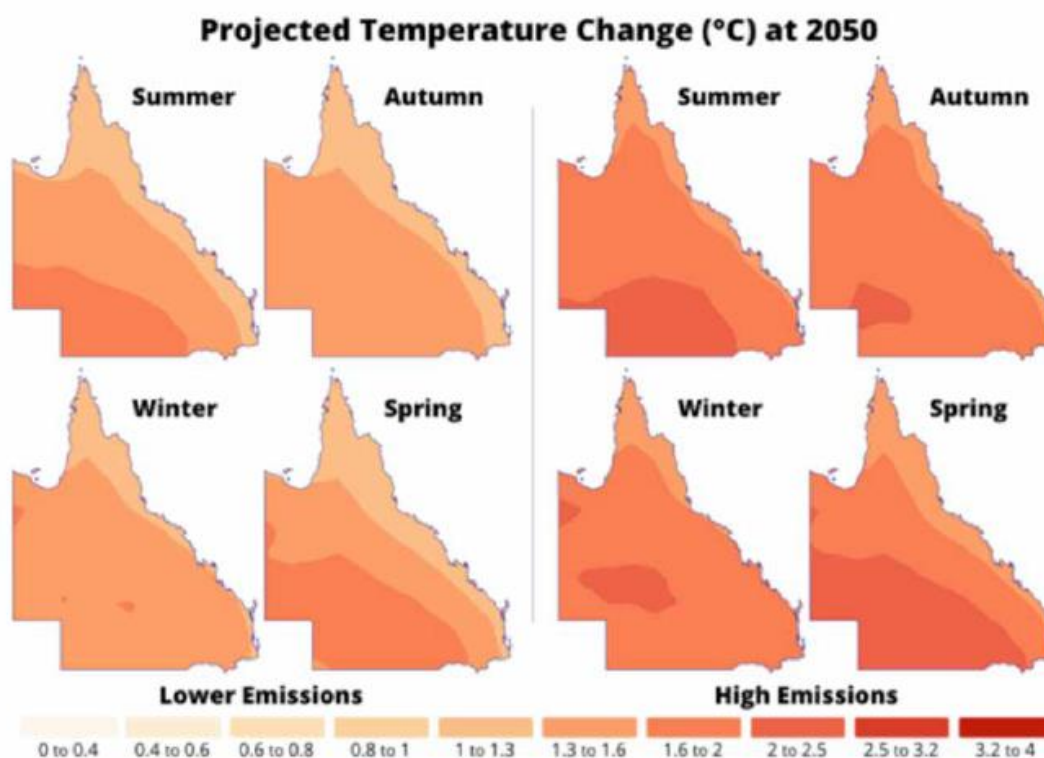


Figure 8: Temperature projection for Queensland for 2050 under lower emission (RCP4.5) and higher emission (RCP8.5) scenarios.

Source: The Climate Change in Queensland map application tool

(<http://aqsp.maps.arcgis.com/apps/MapJournal/index.html?appid=1f3c05235c6a44dcb1a6faebad4683fc>)

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.

Standard for Climate and Natural Hazard Resilience

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		✓		

Standard for Climate and Natural Hazard Resilience



Part of Energy Queensland

	Heat and drought	Rain flooding and humidity	Snow and ice	Wind
Equipment				
Ground grid and earthing		✓		
Energized bus contact and clearance			✓	
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	-5°C	AS 2067 2.4.3.4 "very hot climates"
	Highest	+50°C	
	Massive steel vessels e.g., transformer tanks: Lowest One Day Mean	0°C	AS 1210
Substations indoor air temperature	Lowest	-5°C	AS 2067 Cl. "-5 indoor"
	24-hour average	+40°C	AS 2067 normal + 5°C
	Highest	+45°C	AS 2067 normal + 5°C

Standard for Climate and Natural Hazard Resilience

Factor	Plant specification criteria		Reference
Temperature of cooling medium	Power Transformers: correction to <i>Normal cooling conditions</i>	-5 K	AS 60076.2, IEC 60076-14
Solar radiation	Maximum W/m ²	1,100	AS 2067 normal
Relative humidity, outdoor	Minimum Maximum	25% 100%	
Relative humidity, indoor	Minimum Maximum	25% 99%	AS 2067 tropical 24 hr + 1%
Ground temperature at 1000 mm depth	Winter Summer	+30°C +35°C	Plant Rating Manual Table 19
Thunder days	Annual	40	BOM
Ground flash density	Annual strokes/km ²	4	AS 1768 Fig 2.3
Hail	Hailstone diameter (mm) Accumulation depth (mm)	70 100	
Bushfire	All building construction elements	BAL-FZ	AS 3959
Wind speed (gusts)	Height h ≤ 5 m 227 km/h Height h = 10 m 248 km/h	63 m/s 69 m/s	AS/NZS 1170.2
Rainfall intensity	Five-minute duration mm/h	350	BOM IFD Wet tropics
Ingress Protection	Outdoor cubicles: Outdoor protection / indication instruments:	IP55 IP65	EQL
Atmospheric corrosivity	Exterior coatings category for plant not easily accessed for maintenance: Options for shorefront or industrial site:	C4 (High) C5 (Very High)	AS 2312 or ISO 12944-2 AS 2312: C5-M or C5-I
Pollution	Site pollution severity class Option for heavily polluted sites:	d (Heavy) e (Very Heavy)	SA TS 60815.1
Seismic	Probability x Hazard Factor $k_P Z$ Switchgear and control gear qualification	0.18 Yes	AS 1170.4 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,

Standard for Climate and Natural Hazard Resilience

- 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. 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. 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. 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) Eave gutters 1 in 20 AEP and valleys and box gutters 1 in 100 AEP, per the plumbing and drainage standard	BOM IFD stats AS/NZS 3500.3
Wind	Avoid very exposed open terrain, e.g., oceanfront sites. Avoid sites on or above slopes steeper than 1:20, unless there are mitigating factors such as distance from the coast. Evaluate site wind speed multipliers and determine design wind speeds from the regional gust wind speed at the required ARI. 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.

Standard for Climate and Natural Hazard Resilience

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 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.

Standard for Climate and Natural Hazard Resilience

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 $k_p Z = 0.18$ 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 \(bom.gov.au\)](https://www.bom.gov.au/rainfall/)

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.

Standard for Climate and Natural Hazard Resilience

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

Standard for Climate and Natural Hazard Resilience

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 STNW3034 Substation Standard for Insulation Coordination.

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.

6.11 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

Standard for Climate and Natural Hazard Resilience

- 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 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 (Battery life halves every 8 degrees above design life)
Battery chargers	100% power at 50°C 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
Cables	75°C (V-75) 90°C (V-90, XLPE, HFI)
Capacitor cans	55°C 45°C average over 24 hrs
AC switchboard and circuit breakers	45°C (without de-rating)

Standard for Climate and Natural Hazard Resilience

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.

6.12 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.

6.13 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.

Standard for Climate and Natural Hazard Resilience

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" Comprehensive revision