Part of Energy Queensland

Substation Standard

Standard for Climatic and Seismic Conditions

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

Keywords: Climate, Seismic, Recommended flood level, Probability factor, Hazard factor

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Joint Standard Document between Energex and Ergon Energy
Energex Limited ABN 40 078 849 055 ■ Ergon Energy Corporation Limited ABN 50 087 646 062

Standard for Climatic and Seismic Conditions

Part of Energy Queensland

1 Overview

1.1 Purpose

This standard is designed to outline the climatic and seismic requirements applicable to the design of Energy Queensland (EQL) substations connected to the EQL network.

2 References

2.1 Energy Queensland controlled documents

Document number or location (if applicable)	Document name	Document type
Ergon Energy ZSS	Zone Substation Standardisation	Design documents and templates
Energex RED692	Network Building Blocks – Substations	Standard
Ergon NA000000R100	Plant Rating Guidelines	Guideline
Ergon Energy STNW 3015	Primary Plant Ratings	Standard
Ergon Energy STNW 3034	Insulation Co-ordination	Standard

2.2 Other documents

Document number or location (if applicable)	Document name	Document type
AS1768 – 2007	Lightning Protection	Australian Standard
AS 2067 – 2016	Substations and high voltage installation above 1kV ac	Australian Standard
AS 62271.1 - 2012	High Voltage Switchgear & Controlgear – Common Specification	Australian Standard
AS 60076.1 – 2005	Power Transformers – General	Australian Standard
AS/NZS 1170.0 2002	Structural design actions – general principals	Australian Standard
AS/NZS 1170.1 2002	Structural design actions – permanent, imposed and other actions	Australian Standard
AS/NZS 1170.2 2011	Structural design actions – wind actions	Australian Standard
AS/NZS 1170.4 2007	Structural design actions – earthquake actions in Australia	Australian Standard
AS/NZS 3500.3	Plumbing and drainage – stormwater drainage	Australian Standard
AS 4436 – 1996	Guide for the selection of insulators in respect of polluted conditions	Australian Standard
AS 3959 - 2018	Construction of buildings in bushfire prone areas	Australian Standard
AS 60068.1 – 2003	Environmental testing part 1 – general and	Australian Standard

	guidance	
AS 2676.2 – 1992	Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings	Australian Standard
IEC 62271 – 2006	High voltage switchgear and controlgear part 300 – seismic qualification of alternating circuit breaker	Industry standards and technical references
IEEE 693 – 2005	IEEE recommended practice for seismic design of substations	Industry standards and technical references
CIGRE TB614 - 2015	Air insulated substation design for severe climate conditions	Industry guideline

3 Legislation, regulations, rules, and codes

This document refers to the following:

Legislation, regulations, rules, and codes
National Construction Code of Australia
Thunderstorm distribution and frequency in Australia, National climate control centre, Bureau of Meteorology, Melbourne Australia
Australian rainfall and runoff, A guide to flood estimate
Bureau of Meteorology (BOM) Australian Government website http://www.bom.gov.au/index.php
Queensland Government State Planning Policy – Mitigating the adverse impacts of floods, bushfire and landslides
Queensland Government Disaster Management Sector – Science of Climate Change (website)

4 Definitions, acronyms, and abbreviations

4.1 Definitions

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

Term	Definition
Annual exceedance probability	The likelihood of occurrence of a flood of a given size or larger in any one year, usually expressed as a percentage (see Queensland state planning policy guideline on mitigating the adverse impact of flood, bushfire and landslide- 2003)
Celsius temperature scale	Thermodynamic scale of temperature. Temperature in degrees Celsius can be obtained from value in degrees Fahrenheit by the following formula: C = (F-32) x 5/9
Climate	The atmospheric conditions for a long period of time, and generally refers to the normal or mean course of the weather. Includes the future expectation of long term weather, in the order of weeks, months or years ahead
Cyclone	Atmospheric circulations that rotate clockwise in the southern hemisphere, and anti-clockwise in the northern hemisphere. Cyclones are areas of lower pressure

Term	Definition
	and generally associated with stronger winds, unsettled conditions, cloudiness and rainfall. Tropical cyclones can cause extensive damage as a result of the strong wind, flooding (caused by either heavy rainfall or ocean storm surges) and landslides in mountainous areas as a result of heavy rainfall and saturated soil.
Dew	Droplets of water deposited when air cools and the water vapour in it condenses
Dew point temperature	This is a measure of the moisture content of the air and is the temperature to which air must be cooled in order for dew to form. The dew-point is generally derived theoretically from dry and wet-bulb temperatures, with a correction for the site's elevation
Dry bulb temperature	This is the shade temperature (degrees Celsius) registered by a mercury-in-glass thermometer exposed in a white louvered box or meteorological screen which is raised on legs one metre above the ground
Flash flooding	Flood of short duration with a relatively high peak discharge
Flood	A flood occurs when water inundates (covers) land which is normally dry
Hail	Precipitation (falling) of particles of ice (hailstones). Usually spheroid, conical or irregular in form and with a diameter varying generally between five and 50 millimetres
Kelvin	Unit of thermodynamic temperature. Symbol: K. K= C+273.2
Lightning	The flash of light accompanying a sudden electrical discharge which takes place from or inside a cloud, or less often from high structures or the ground or from mountains. A large electrical spark caused when the negative charge in the lower part of the cloud and the positive charge in the upper part of the cloud become so great that they can overcome the natural resistance of the air and discharge between negative and positive takes place
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
Probabilities, probabilistic forecast	An attempt to convey the uncertainty in a forecast by expressing its likelihood of occurrence as a probability, or percentage. Akin to odds in the gambling industry. High probabilities do not guarantee an outcome - they merely indicate that that outcome is highly likely. Probabilities are usually based on the frequency of occurrence in the historical record. For instance, if the chance of receiving above-median rainfall in a particular climate scenario is 60%, then 60% of past years when that scenario occurred had above median rainfall, and 40% had below-median rainfall.
Rainfall	The total liquid product of precipitation or condensation from the atmosphere, as received and measured in a rain gauge
Recommended flood level (RFL)	The flood event identified in Appendix 9 of the Queensland State Planning Policy on mitigating the adverse impacts of flood, bushfire and landslide 2003 as providing the recommended level of flood immunity for particular types of

Term	Definition
	community infrastructure
Relative humidity	A traditional indicator of the air's moisture content. It is the ratio of the amount of moisture actually in the air to the maximum amount of moisture which the air could hold at the same temperature. Relative humidity is normally expressed as a percentage and at saturation the relative humidity will be very close to 100%. The air can hold more moisture at higher temperatures, hence the relative humidity alone does not give an absolute measure of moisture content
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. Storm surges accompany a tropical cyclone as it comes ashore. They may also be formed by intense low-pressure systems in non-tropical areas
Thunder day	A thunder day at a given location is a calendar day which thunder is heard at least once
Thunderstorms	Sudden electrical discharges manifested by a flash of light (lightning) and a sharp rumbling sound. Thunderstorms are associated with convective clouds (Cumulonimbus) and are more often accompanied by precipitation. They are usually short-lived and hit on only a small area
Ultraviolet radiation (U/V)	Electromagnetic radiation with wavelengths shorter than visible light, but longer than x-rays
Wet bulb temperature	Wet-bulb temperature is measured using a standard mercury-in-glass thermometer, with the thermometer bulb wrapped in muslin, which is kept wet. The evaporation of water from the thermometer has a cooling effect, so the temperature indicated by the wet bulb thermometer is less than the temperature indicated by a dry-bulb (normal, unmodified) thermometer. The rate of evaporation from the wet-bulb thermometer depends on the humidity of the air - evaporation is slower when the air is already full of water vapour for this reason, the difference in the temperatures indicated by the two thermometers gives a measure of atmospheric humidity.

4.2 Acronyms and abbreviations

The following abbreviations and acronyms appear in this standard.

Term, abbreviation or acronym	Definition
AEP	Annual Exceedance Probability
RFL	Residential Flood Level
Std	Standard
ZSS	Zone substation standard

5 Climatic and seismic requirements

5.1 General

EQL is based in the state of Queensland. At various times locations in the state may be subject to:

- Severe heat, drought and dust
- Severe flooding
- Severe rain and humidity
- Severe wind

In addition, climate change caused by greenhouse gases is causing an increase in average temperature and severe weather events. The annual median temperature in Queensland is expected to increase by +1.4^{o}C under low emissions and +1.9^{o}C under high emissions by 2050. There is also a high level of certainty of increased frequency and intensity of heatwaves. Future substation design and plant specifications shall take account of these rising temperatures.

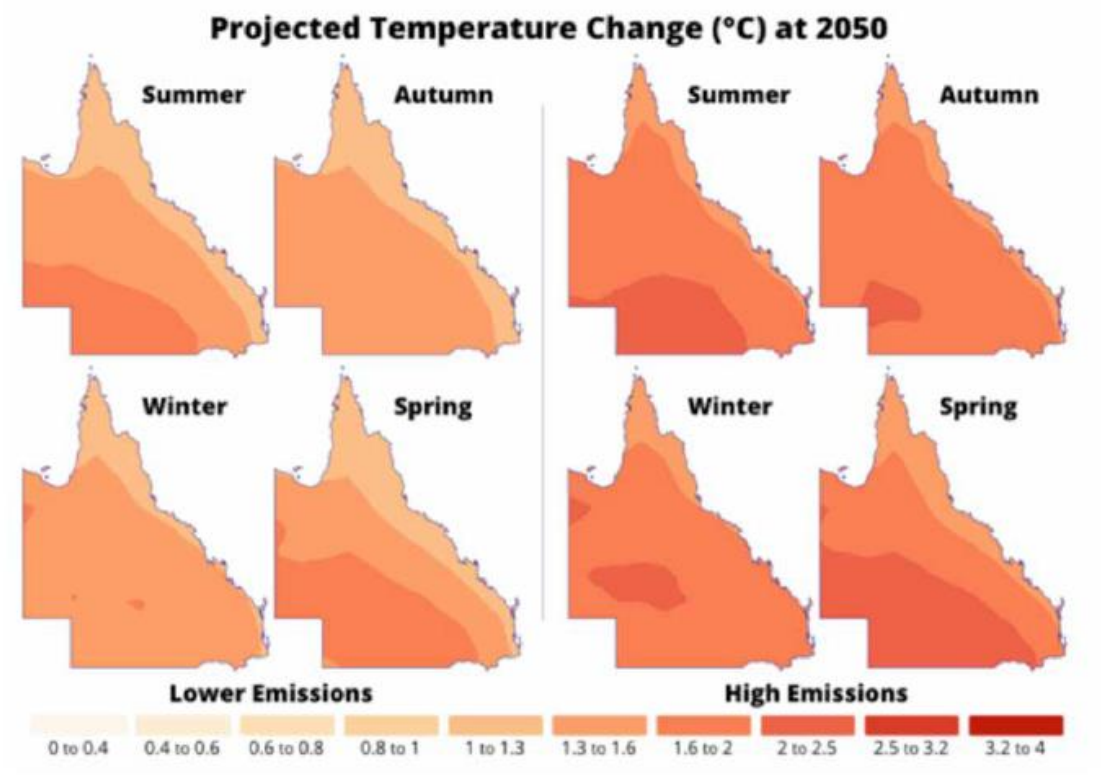

Figure 8: Temperature projection for Queensland for 2050 under lower emission (RCP 4.5) and higher emission (RCP8.5) scenarios.

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

Development around substations can lead to changes in drainage and flood levels.

AS1170.2 breaks the nation up into four wind regions. Design of substation plant, structures and buildings shall take account the wind region the assets will be installed.

5.2 Substation Plant Impacted by Climate Conditions

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

Table 1: Climate Effects on Equipment

Severe....	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			✔	
Static wires (lightning shield wires)			✔	
Lightning masts			✔	
Bushings	✔			
Capacitors	✔			
Energized Bus	✔			
Connectors and conductors	✔			
Bus Supports				✔

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5.3 Climatic requirements

The normal and extended requirements shown in Table 2, including minimum design criteria for civil works, are in line with AS2067-2016, AS62271.1-2012 and AS1170. Climatic requirements including tropical cyclone requirements, must be verified at each site, to ensure that the substation can withstand the most onerous conditions on site over the operating life cycle of the substation

Table 2: Rated climatic requirements

Factor	Measure		Notes
	Minimum	Maximum	
Shaded air temperature (no solar radiation)	-5°C	From +35°C to +45°C (extended)	Ref NA000000R 100 Section 7 for climate zones
Maximum 24 hour average		+40°C (extended)	
Solar radiation	Nil	1,000 W/m^2 1,200 W/m^2 (extended)	
Monthly rain fall	Nil	360 mm	
Relative humidity			
Outdoor	25%	100%	
Indoor (no air conditioning)	25%	95%	
Altitude	Less than 1,000 meters above sea level		
Typical ambient ground temperature at 900 mm depth	+20°C	+29°C +35°C	Ref NA000000R 100 Table 1
Typical soil thermal resistivity	1.2°K-m/W (Native soil & backfill) Unless additional data from in-situ tests		Ref NA000000R 100 Table 26
Thunder days	The average annual thunder-day map of Australia can be found from Bureau of Meteorology climatological records from 1990 to 1999. Ergon Energy standards and AS1768-2002 must be applied for lightning protection design		
Ground flash density	Up to 4 strokes/(km^2-yr)		AS1768 Fig 2.3
Hail	The building shall be designed to resist hail up to 30mm in diameter and up to 100mm deep		
Flood	The substation building floor level and electrical equipment in the yard shall be functioning after a 1:200 year flood level (0.5% AEP) with 300mm of margin.		
Flash flooding	Notwithstanding the flooding criteria, the substation shall be located in areas not affected by flash flooding		
Fire	Site selection and ground clearing shall		

Factor	Measure		Notes
	Minimum	Maximum	
	take into account the effect of bushfire in line with AS 3959 and Queensland Government State Planning Policy – Mitigating the Adverse Impacts of Flood, Bushfire and Landslide (Whichever is the most stringent)		
Wind Speed - The substation building, structure and equipment shall be designed to the wind loads in line with criteria in AS/NZS 1170.2 as follows:	a) Annual probability of exceedance 1:2000 b) Cyclone Region as per wind region @ V2000 c) Terrain Category 2, d) Shielding Multiplier 1.0 e) Topographical Multiplier to suit site f) Importance Level 4 Structure (post disaster function), in accordance with the National Construction Code of Australia g) Openings and protective shutters shall be designed for debris loading h) Strength limit state design pressures for overhead fixed and strung bus and overhead earth wires must be verified to withstand maximum wind speed		
Wind Speed – Substation Fencing, shall be designed to the wind loads in line with criteria in AS/NZS 1170.2 as follows:	<u>Chainwire Fencing:</u> a) Importance Level 2 b) Design life 25 years c) Wind speed 1:200 year return period <u>Timber and Palisade Fencing:</u> a) Importance Level 3 b) Design life 25 years c) Wind speed 1:500 year return period		Higher wind speed for timber and palisade due to additional damage they can cause if they become loose during cyclone.
Maximum rain fall (building):	As per AS/NZS3500.3 • Return Period = 20 years (100 years for box gutters) • Duration = five minutes • Rainfall intensity appropriate to the location		

5.4 Seismic requirements

The seismic requirements for substation building are shown as follows:

Earthquake	**The shelter and structure shall be designed for Earthquake in accordance with AS1170.4 for the following criteria:** **Structure Importance Level 4** **Probability factor kp = 1.5** **Hazard Factor Z = 0.12** **Structural Ductility Factor and Structural Performance Factor Sp/μ = 0.22**

Structural design criteria including the items above shall be clearly stated in the structural drawings.

Seismic qualification by test on the high voltage switchgear and control gear in line with TR62271.300 – 2008 must be completed to the appropriate severity level.

Seismic requirements must be verified at each site to ensure that the most stringent design criteria and structural yield is used for the total operating life cycle of the substation.

5.5 Ventilation and air conditioning requirements

Ventilation and air conditioning requirements are covered in EQL Standard STNW 3047.

6 Additional Climate Impacts on Substation Design, Plant & Equipment

The following design principles shall apply in areas prone to the following climate conditions.

6.1 Drought, Dust and Heat

- Ensure heat run and temperature rise tests for outdoor equipment have a $5^{O}C$ buffer to allow for extended ambient temperature of $45^{O}C$.
- Extended creepage length (Pollution Level IV – 31.5mm/kV) on all equipment insulators and bushings
- Expansion chambers/safety valves for oil filled equipment to cater for internal pressure increase due to increased temperature.
- Earth grid design to take account of seasonal variation including possible higher soil resistivity (deeper drilled rods in bentonite may be preferable)
- UV stabilisation for all cable insulation exposed to sunlight.
- Improved sealing of SF6 chambers due to higher pressures at elevated temperatures
- Control and protection buildings to have air conditioning
- Ensure batteries and any electronic equipment located outdoors are in suitably ventilated/air conditioned cabinets that maintain temperatures within expected operating temperature of equipment (see Table 3).
- Install oil and winding temperature monitoring on all new power transformers.
- For in-service substations, should the ground dry out around the foundations, in some instances can cause soil movement to the point that the substation structure foundations move. This can result in the stressing of the high voltage connections potentially giving rise to an outage.
- Oil separation/collection systems that normally rely on water being present need to be monitored to ensure the required amount of water is present.

Optional design considerations include:

- Power transformers to be rated at higher ambient temperatures, and to have the potential for upgrade to higher temperature rise by using thermally upgraded paper and potential replacement of mineral oil with ester oil for certain applications.
- Real time thermal modelling for all transformers 20MVA and above.

6.2 Flooding

- Build above 1 in 200 year flood level, especially for substation building floor level and equipment cable and control boxes. Allowance to be made in coastal areas for rising sea levels due to climate change (unless otherwise advised by councils estimate at 3.5mm per annum) for life of the substation.
- Ensure key components are elevated
- Control cable entry from the bottom to prevent moisture ingress
- Heaters in cabinets to reduce condensation
- Ensure control boxes made of non-corrosive metals
- Cable tray to be stainless steel or non-corrosive metal
- IP55 rating for control and marshalling boxes in switchyards.

- Seal up conduit entries into basements and plug spare conduits.
- No access to substation when flooded, and repair/dry out procedures to take place after flooding.

6.3 Severe Wind/Cyclone

- Design to wind load for location
- Remove unsecured objects from the substation yard
- Generator connections to external AC boards for portable generators to maintain DC supply.

6.4 Temperature limits for typical substation equipment

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

Table 3: Temperature limits for substation equipment

Equipment	Max Temp (^{o}C)
Substation batteries	10 year design life at 25^{O}C (Battery life halves every 8 degrees above design life)
Battery chargers	100% power at 50^{o}C 55% power at 70 ^{o}C
Protection relays and meters	55
Terminals	100
Cables	75 (V-75) 90 (V-90, XLPE, HFI)
Capacitor cans	55 (45^{o} average over 24 hrs)
AC switchboard and circuit breakers	45 (without de-rating)

Marshalling boxes utilising natural ventilation are the preferred option. However, single skinned marshalling boxes exposed to direct sunlight with no insufficient natural ventilation can experience temperatures inside up to 80^{0}C, as well as build-up of humidity/moisture due to rapid changes in temperature and humidity. Alternatives to consider when installing this equipment outside include:

- Vents diagonally opposite, of suitable size, to allow cool air in at the bottom and hot air out at the top. Filters on vents may need cleaning and replacement.
- Double skinned boxes or boxes with heat shields to provide a layer of insulation outside the box.
- Reflective paint coating on boxes to reduce absorbed heat.
- Sunshade or covers over outdoor panels to avoid direct sunlight during hottest part of the day.
- Forced ventilation with fans
- Air conditioned panels.