Transmission Line Design Standard

Summary

This standard defines the performance design parameters for overhead transmission lines constructed to connect to and form part of the TransGrid network.

TransGrid publishes this information under clause 5.2A.5 of the National Electricity Rules.

Document Control

Date of issue	July 2018	Update	Initial version

Contents

1. Purpose

This standard for Transmission Line Design specifies the minimum structural, electrical and geotechnical design required for overhead transmission lines used in TransGrid's network. This standard complies with AS/NZS 7000 and any exceptions are explicitly noted.

2. Scope

This standard specifies the requirements that shall be met for the design of new towers, poles or similar structures that support the conductor of TransGrid overhead transmission lines.

This standard is not intended as a substitute for AS/NZS 7000 or other Regulatory Standards, Codes or Acts. Every effort has been made to ensure that this standard complies with AS/NZS 7000 except where explicitly stated, however it remains the users' responsibility to ensure that all relevant regulatory requirements are satisfied, particularly where recent amendments have been made.

3. Objectives

TransGrid requires works to be carried out in accordance with this standard to ensure:

- That relevant Australian legal requirements are met
- That the requirements of the National Electricity Rules are met
- Personnel and public safety
- Safety of TransGrid's assets
- Ease in operation and maintenance
- Reliability and continuity of power supply from the power transmission network
- Minimum disruption to the power supply system following a fault
- Alignment with TransGrid's network management strategies and TransGrid's established maintenance practices
- That the exposure of TransGrid's business to risk is minimised.

4. Definitions

The meanings and interpretations of terms and phrases used in this document are as listed below.

Term	Definition
Conductor	This is generally a reference to the phase conductors on a transmission line but is also a generic term for the uninsulated cables that are used for either phase conductor or overhead earthwire.
Span	The horizontal distance between two adjacent structures.
Suspension Structure	A structure that primarily supports the transverse and vertical load of the conductors and is subject to minimal longitudinal load. The conductor is supported by insulation that is usually perpendicular to the conductor. Insulator types include I string, D string, V string, horizontal V, line post, braced line post.
Tension Structure	A structure where the conductors are terminated with insulators in-line with the conductor and supports longitudinal conductor loads in addition to the transverse and vertical loads. The structure is incapable of resisting termination loads on one face of the structure alone.
Termination (Dead-	A tension structure that is capable of resisting terminated conductor loads on one face of

end) Structure	the structure.

5. Acronyms and Abbreviations

Term	Definition
ALS	Aerial Laser Survey
CBL	Calculated Breaking Load (kN)
EDMS	Electronic Document Management System
EMF	Electromagnetic Field
ICNIRP	International Commission on Non-Ionising Radiation Protection
MOT	Maximum Operating Temperature
OHEW	Overhead Earth Wire
OPGW	Optical Fibre Ground Wire
RMS	Root mean square
RSL	Residual Static Load (kN)
SC/AC	Steel Conductor/Aluminium Clad
SC/GZ	Steel Conductor/Galvanized
SVD	Spiral vibration damper or impact damper
SWP	Standard Work Practices
TAMIS	TransGrid Asset Management Information System
TLS	Terrestrial Laser Survey
VAR	Reactive or apparent power (volt – ampere reactive)

6. General

6.1 Design parameters

The design scope shall include consideration of the following inputs:

- Approved line route and route length
- Climatic conditions (wind region, wind speed, wind direction, temperatures, lightning ground flash density)
- Seismic conditions (if they apply)
- Topographical features (terrain category, altitude)
- Pollution level
- Environmental and cultural heritage requirements
- Operating voltage
- Number of circuits
- Conductor type and size
- Overhead earthwire type and size

- Optical Fibre Overhead earthwire (if applicable)
- Structure type
- Line importance – Security Level
- Design working life for the line
- Lightning performance requirements
- OPGW requirements
- Details of the connection or terminal points of the line
- Maximum load
- Earth fault level at terminal substations
- Construction issues such as:
  - Outage restrictions and recall times
  - Overcrossings, undercrossings and traffic management
  - Construction staging if required
  - Induction from parallel transmission lines

6.2 Safety in design

Designs shall be in accordance with the Safe Work Australia Safe Design of Structures Code of Practice.

6.3 Design drawings

Where required design drawings for construction shall include the following:

- Plan & profile drawings. These shall include conductor type, maximum design temperature and the minimum clearance provision
- Line schedules shall be in a tabulated format, summarising the details of the line
- Stringing/sagging tables (including offset clipping if applicable)
- Vibration damper schedule and installation dimensions
- Construction staking tables
- Structure drawings (if utilising non-standard structures)
- Rail crossing drawings (if applicable)
- Other powerline crossing drawings (if applicable)
- Navigable waterway crossing drawings (if applicable)
- Landing span drawings for non-standard structures
  - General arrangement
  - Steelwork fabrication details
  - Pole manufacturing details
  - Insulator and earthwire arrangements and details
  - Electrical clearances
  - Design loading capacity with load factors
  - Structure test reports

7. Operational Requirements

The following issues shall be addressed in the transmission line design to ensure that the line meets the operation requirements of the TransGrid network:

- Structure security is required to limit the consequential damage in the event of a structural failure and particularly to reduce the risk of cascade failures
- Network Reliability should be maximised for all transmission line designs through all aspects of construction, operation and maintenance
- Thermal Rating – phase conductors and maximum operating temperature shall be selected to minimise annealing and maximise conductor life. All lines shall maintain statutory ground clearances at the maximum design operating temperature
- Fault Currents – current, future and ultimate fault levels should be considered in the selection of conductors and earthwires to ensure they are adequately rated
- Lightning Performance - The lightning performance of a transmission line shall be managed through control of earthwire shielding angle, structure earth resistance and insulation level to achieve the lightning outage rates shown in the table below:

Line Voltage	Radial Lines		Parallel Lines	
	Each Circuit	**Double Circuit**	**Each Circuit**	**Double Circuit**
500 kV	0.3	0.1	0.4	0.15
330 kV	0.3	0.15	0.6	0.3
220 kV	0.5		1.2	
132 kV	0.6	0.3	1.2	0.6
66 kV	1.2	0.6	2.4	1.2

Table 1: Design Lightning Outage Rates (outages/100 kilometre/year)

- Easement Widths are sized to ensure standard safety clearances under high wind conditions, provide an area where vegetation heights can be controlled and provide ease of access for ongoing maintenance and repairs. Easements shall be acquired for all transmission lines on private land according to the table of minimum easement widths below:

Transmission Line	Easement Width
500kV double circuit	70m
500kV single circuit	80m
330kV single or double circuit	60m
220kV single or double circuit	50m
132kV single or double circuit	45m
66kV single or double circuit	30m
Up to 33kV single or double circuit	20m

Table 2: Easement widths

- Required Clearances Around Structures - The following are the minimum requirements to provide for a safe work area around each type of structure:
  - 15m from any crossing power line structure or conductors
  - 15m to any road carriageway, or barricade outside the edge of the carriageway
  - 15m to the property boundary of any rail corridor
  - Consideration of conductor blowout towards structures to maintain safe electrical clearances
  - All parts of structures and conductors of any parallel electricity line to be outside the easement, overlapping easements are acceptable

8. Electrical Design

8.1 Insulation

Insulation co-ordination shall be in accordance with AS 1824.

8.2 Electrical clearances

8.2.1 Clearance to ground and roads

Minimum Clearance to ground and over the carriageway of roads for new transmission lines shall be in accordance with AS/NZS 7000.

Also when designing a new line, the following considerations should be given to for additional clearances:

- Include a margin to allow for minor inaccuracy in surveying and construction, as well as some small movement over time
- Additional clearance should be allowed if there is likely to be a future lower circuit constructed along the road or in special circumstances such as private roads and adjacent parts of public roads especially in mining and heavy industrial sites

Greater clearances over roads may be required where regular high loads are likely (National and State Highways and other major roads) and to allow for vehicle maintenance or breakdown activities (a person on top of the vehicle) which are not allowed for in the standard clearances.

8.2.2 Clearance to structures

Clearance to structures for conductors and insulator arrangements shall be shall be designed in accordance with AS/NZS 7000.

8.2.3 Maintenance clearances

All structure designs shall provide climbing access. On multiple circuit structures or line corridors, access shall be available to one circuit with the other circuit(s) live.

8.3 Transpositions

Phase conductors are transposed on long transmission lines to balance the mutual impedances and reduce the load current unbalance.

Transpositions are usually not required in 500kV lines or 330kV lines less than 100km in length. Where required, they will be specified by TransGrid.

For lines less than 50km transposition is not usually required. For lines greater than 50km, consultation with TransGrid is required regarding the possible need for a transposition.

8.4 Earthing

8.4.1 Earthing metalwork

In general all metallic pole fittings such as cross-arms, insulator bases and pole bands shall be bonded to the structure earthing system.

Step bolts are not required to be earthed.

8.4.2 Footing resistance

The design structure footing resistance or structure earth resistance shall be determined based on the lightning performance requirements of the transmission line.

8.4.3 Earthing safety

Where structures are located in public places and are deemed to have a high exposure to persons making frequent contact or being in close proximity for extended periods, the step and touch potentials at the structure should be assessed in accordance with AS/NZS 7000. Where step and touch potentials are found to be non-compliant, appropriate remediation should be determined and implemented as part of the design.

8.5 Electric and magnetic fields

Electric and magnetic fields attributable to the transmission line shall be in accordance with the ICNIRP Guidelines For Limiting Exposure To Time-Varying Electric and Magnetic Fields (1Hz – 100kHz).

8.6 Induction

Magnetic fields due to load or fault current can couple with nearby conductive infrastructure to produce hazardous voltages, particularly where the structure is long, parallel and close to the transmission line. Metallic pipelines, power lines, metallic fences, conveyor belts and copper telecommunication lines are typical examples.

The risk and mitigation measures shall be assessed in accordance with AS 4853 or HB 102.

Fences on the easement should generally be dealt with during construction according to the TransGrid Fencing Guideline.

8.7 Vibration

Where a conductor, earthwire or OPGW is strung at a tension in excess of the limits of AS/NZS 7000 vibration dampers shall be installed to limit fatigue.

9. Structural Design

9.1 General requirement

The mechanical and structural design shall ensure that the line performance will comply with all relevant National and State Legislation, that the line can be readily constructed and maintained using standard industry practices and tools, and that routine maintenance can be carried out without loss of supply.

The design shall ensure premature failure of components does not occur from fatigue stresses, abrasion or corrosion or other serviceability conditions that will be encountered within the design operating parameters for the line.

Design of structures and footing shall meet the requirements specified in in AS7000 to ensure that the line is suitable for its intended purpose and to ensure acceptable levels of safety for construction, maintenance and operation.

Appropriate security level shall be determined considering the importance of line, impact on TransGrid network reliability, its location, climate condition, public safety and design working life in consultation with TransGrid unless advised otherwise by TransGrid.

9.2 Loadings

Structures shall be designed to meet the loading requirements specified in AS/NZS7000 as the minimum including, but not limited to, the following load cases:

- Wind loads shall be calculated in accordance with AS 1170.2 and AS/NZS 7000 in conjunction with other relevant Australian codes and standards to achieve system security levels required
- Where lines of significant length crossover wind regions, the appropriate region can be applied to each respective section, however any change in wind pressure along the line should be done at a termination structure, with the higher wind pressure applied to the structure itself

9.3 Structure and design

Structure design shall comply with the requirements specified in AS/NZS 7000, AS 3995, ASCE standards and other referenced codes and standards as applicable unless advised by TransGrid.

Where load relief is provided by failure of steelwork, it should be in a ductile manner, whereby energy is absorbed by the plastic deformation of components.

9.4 Footing design

Footing design shall comply with the requirements specified in AS/NZS 7000 and in accordance with AS 3600, AS 2159 and other referenced codes and standards as applicable.

The foundation shall be designed for all soil strength conditions likely to be experienced over the design life of the line due to effects such as a fall or rise in the water table (including flooding) and erosion of nearby soil. The effect of long term and short term load conditions on soil strength should also be considered

Geotechnical investigation shall be carried out to determine the soil parameters for design of footings.

9.5 Prototype and testing

All structures shall be prototyped to ensure that fabrication is as per design and to meet the quality requirements specified on drawings and specifications.

Generally all new designs should be load tested. The decision to load test structures should be made by the design engineer, taking into account the following factors:

- Similarity of existing designs and design principles
- Quantity of structures to be used, including consideration should be given to their utilisation on future lines
- Confidence in the adequacy of the design

- Cost of testing

The load testing shall confirm the overall strength of the structure as well as the strength coordination between components.

9.6 Fauna consideration

All structures should be designed to be bird & vermin proof, including maintenance platform protection (minimise access). Consideration is to be given to minimising the impact on local fauna, such as bird diverters on conductors/earthwires and fauna safe anti-climbers where particular species of concern are noted. Stock have been known to get stuck in between tower leg members, also damage has occurred to structures from rubbing on guys etc.