Standard for

Sub-Transmission Overhead

Line Design

This standard and any referenced standards were created and made available for the construction of Ergon Energy infrastructure. Application of these standards ensures meeting of Ergon Energy's requirements. External companies should not use these standards to construct non-Ergon Energy assets.

This standard is uncontrolled in a printed version. To ensure compliance, reference must be made to the Ergon Energy internet site www.ergon.com.au to obtain the latest version.

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Standard detailing Ergon Energy's design requirements for lines built using the sub-transmission construction standards.

Standard for Sub-Transmission Overhead Line Design

For definitive document version and control detail, please refer to the information stored on the Process Zone.

Revision history

Revision date	Version number	Author	Description of change/revision
25/03/2013	1.0	Steve Brooks/Greg Chapman	Original Issue
15/05/2014	2.0	Steve Brooks/Greg Chapman	Addition of 132kV and 66kV double circuit
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Document approvals

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1 Overview

1.1 Purpose

This standard for Sub-transmission Line Design specifies the minimum structural, electrical and geotechnical design requirements for the overhead sub-transmission structures used in Ergon Energy's Queensland network. This standard complies with AS/NZS 7000:2010 and any exceptions are explicitly noted.

1.2 Scope

This standard provides detail on Ergon Energy's specific requirements for the design of overhead sub-transmission lines, thereby ensuring that lines are built to suit the conditions encountered within the Ergon Energy network as well as providing commonality within the Ergon Energy owned network. It is not intended as a substitute for AS/NZS7000, or other Regulatory Standards, Codes or Acts. The use of this standard does not negate the need for Professional Engineering Certification of the design or modification of lines, structures or components. Every effort has been made to ensure that this standard complies with AS/NZS7000 except where explicitly stated, however it remains the users' responsibility to ensure that all relevant regulatory requirements are satisfied, particularly where recent amendments may have been made.

This standard is specifically customised for the local conditions in Ergon Energy's distribution area in Queensland and should not be applied in other localities. This standard should only be used for sub-transmission voltages from 33kV up to 132kV. For design purposes all 110kV transmission lines shall be built in accordance to the 132kV requirements. Distribution voltages up to and including 33kV should be designed in accordance with the Ergon Energy Distribution Design and Construction Manuals.

The designer shall provide certification of the design and drawings for all of the design works required for the project. Such certification is to be provided by a Professional engineer who is a Registered Professional engineer of Queensland (RPEQ).

2 References

2.1 Ergon Energy controlled documents

Document number or location (if applicable)	Document name	Document type
EE Subtransmission Construction Manual	Ergon Energy Sub Transmission Construction Manual	Standard Drawings
EE Intranet	Ergon Energy Sub Transmission Standard Specifications	Standard Specification document
PW000702F100	Simple Project Risk Management Plan	(Form)
ES000905F102	Safety in Design Risk Assessment	(Form)
ES000904R104	EMF Guideline for New Infrastructure (Reference)	Document

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ES000905R104	Safety in Design (Reference)	Document
NA000000R100	Plant Rating Guidelines	Document
SS-1-1.8	Ergon Energy Substation Standard – Standard for Climatic and Seismic Conditions	Standard Document
STMP001	Standard for Network Performance	Standard Document
STMP003	Standard for Transmission and Distribution Planning	Standard Document
Weather Parameter Analysis for Ergon Energy Overhead Line Ratings	Weather Parameter Analysis for Ergon Energy Overhead Line Ratings	Weather Parameter Analysis for Ergon Energy Overhead Line Ratings
BS001405R104	Excavations Around Overhead Electrical Parts Guideline	Standard Document
NA000404R100	Power Coordination Guideline. Agreement between Ergon Energy and Telstra.	Reference Document

2.2 Other documents

Document number or location (if applicable)	Document name	Document type
AS 1154.1:2009	Insulator and Conductor Fitting for Overhead Powerlines - Performance, Material, General Requirements and Dimensions	Standard
AS 1154.3:2009	Insulator and Conductor Fittings for Overhead Powerlines - Performance and General Requirements for Helical Fittings	Standard
AS/NZS 1170.0:2002	Structural Design Actions Part 0: General	Standard
AS/NZS 1170.2:2011	AS/NZS 1170.2:2011	Standard
AS 1170.4:2007	Structural Design Actions - Earthquake Actions in Australia	Standard
AS 1824.1:1995	Insulation Co-ordination - Definitions, Principles and Rules	Standard
AS 1824.2:1985	Insulation Co-ordination – Part 2 – Application Guide	Standard
AS 3600:2009	Concrete Structures	Standard
AS 4436:1996	Guide for the selection of insulators in respect of polluted conditions	Standard
AS 4100:1998	Steel Structures	Standard
AS/NZS 4600:2005	Cold Formed Steel Structures	Standard
AS 4799:2000	Installation of Underground Utility Services and Pipelines within Railway Boundaries	Standard

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AS/NZS 4853:2012	Electrical hazards on metallic pipelines	Standard
AS/NZS 7000:2010	Overhead Line Design – Detailed Procedures	Standard
HB 331:2012	Handbook – Overhead Line Design	Standard
IEEE Std 1222:2004	IEEE Standard for All-Dielectric Self-Supporting Fiber Optic Cable	Standard

3 Legislation, regulations, rules, and codes

This document refers to the following:

Legislation, regulations, rules, and codes
QLD Electrical Safety Act 2002
QLD Electrical Safety Regulation 2013
QLD Work Health and Safety Act 2011
QLD Work Health and Safety Regulation 2011
QLD Electricity Act 1994
QLD Electricity Regulation 2006
ASCE No. 74 - Guidelines for Electrical Transmission Line Structural Loading - 3rd Ed.
Building Code of Australia (BCA) – National Construction Code 2012
CIGRE SC 22 WG 05, Permanent Elongation of Conductors. Prediction Equation and Evaluation Methods, ELECTRA 75 (1981)
Southwire Company Overhead Conductor Manual – Second edition (2007)
Reding, J.L. 2003. BPAs Probability-Based Clearance Buffers-Part 1: General Development, IEEE Transactions on Power Delivery, 18(1), 226-231

4 Definitions, acronyms, and abbreviations

4.1 Definitions

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

<Term>	<Definition>
Cable	Any aerial cable e.g. stranded conductor, earthwire, OPGW, ADSS, pilot cable, aerial bundled cable, covered conductor
Capacity	There are two ways of increasing the capacity of a transmission network: uprating the capacity of the existing network and building new transmission lines. Building new transmission lines is considerably more expensive, more time consuming and more difficult because of the need to acquire new wayleaves/easements. Additional lines alleviate transmission constraints caused by thermal limitations because the power transfer is shared among more paths. They also enhance the system's voltage and angular stability because they reduce the overall impedance of the network.

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	Uprating an existing network is usually the cheaper and environmentally-friendlier option because it does not require the acquisition of new easements.
Network Reliability	The reliability of electricity supply to customers can be improved by network planning, maintenance, operation and outage response times. The majority of sustained outages (duration greater than one minute) occur in the distribution network. Therefore reliability indices are used to measure the performance of the network and of the distribution business. Regulators apply reliability specific planning and performance requirements to counter cost reduction by reducing reliability. Ergon operates under the Australian Energy Regulator's (AER) Service Target Performance Incentive Scheme (STPIS). Refer to "Standard for Network Performance" document number STMP001.Network reliability is quantified by Network Reliability Indices that encapsulate outage duration, frequency of outages, system availability, and response times. • SAIDI System Average Interruption Duration Index. Definition: Total minutes, on average, that customers are without electricity (both planned and unplanned minutes). • SAIFI System Average Interruption Frequency Index. Definition: The average number of occasions each customer is interrupted. • CAIDI Customer Average Interruption Duration Index. Definition: Average duration of each interruption (=SAIDI/SAIFI).
Network Security	Security is the vulnerability of the network to unserved power caused by a credible contingency. Clause 4.2.3 of the National Electricity Rules gives the definitions of credible and non-credible contingency events. Security analysis forms the basis for making investment decisions for the network to maintain a high level of reliability. The planning method affects the level of redundancy and over-investment in assets. Network security planning is based on one of the following methods - a. The deterministic approach specifies a level of redundancy in terms of "N-x" which refers to a supply situation where x components fail and the remaining components continue to supply customers. b. The probabilistic approach indicates that network augmentation should proceed only when loading has increased to the extent that the cost of unserved energy at risk justifies the expenditure. c. The energy cap approach limits (caps) the size of customer load or energy that can be lost after a credible contingency event. Deterministic "N-x" planning generally results in a higher cost system because it builds in a level of duplication and/or redundancy which may only be drawn upon in limited circumstances. In comparison probabilistic planning exposes customers to supply interruption risks that need to be managed. Ergon (2014) is preparing for a hybrid network security methodology.

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Refurbishment	Refurbishment of a line refers to repair or replacement of components to extend the life of the line.
Structural Reliability	Structural Reliability is the probability that a structural system performs a given mechanical purpose, under a set of conditions, during a reference period. Reliability is thus a measure of the success of a system in accomplishing its purpose.
Importance Levels	AS/NZS 7000 clause 6.2.2 refers to line security levels. However this term should be called "importance level" in accordance with Appendix F of AS/NZS 1170.0:2002 because it relates to the risk to life, property, economy and community in the event of loss of supply (failure). An increase in importance (security level) requires an increase in structural reliability. Refer to line security.
Line Security	Security refers to the limiting of consequential damage (cascading failures) in the event of an initiating failure (AS/NZS 7000:2010 clause 6.2.4). This is generally achieved by minimising the effects of longitudinal loads by creating failure containment load cases. However consequential failure may also be limited by the use of regular "stop" structures and/or utilising load release mechanisms such as slipping suspension clamps or frangible crossarms. The security of stayed structures is improved by designing for a broken staywire load case
Power Quality	Power quality determines the fitness of electrical power for use with electrical devices. Poor quality power may cause the device to malfunction, fail prematurely or not operate at all. Power quality is measured by a number of parameters such as voltage fluctuations (sags, swells, and flicker), abnormal waveforms (harmonic distortions, transients), frequency, momentary interruptions (less than one minute) and phase imbalance. Refer to "Standard for Network Performance" document number STMP001.
Thermal Rating	The thermal rating is the current (or power transfer) that produces the maximum operating conductor temperature that the line was designed for. This is derived from the balance of solar heating and resistive heating against convective cooling and radiated heat loss. The real-time (dynamic) thermal rating varies depending upon the weather conditions existing at the time. The static thermal rating is calculated using static, conservative values of weather variables. For long lines, the transmission capacity may be determined by voltage control rather than the thermal rating
Upgrading (Mechanical)	Mechanical upgrading refers to increasing the mechanical strength of the structures to handle larger or additional conductors or to improve reliability (higher meteorological actions eg wind).
Upgrading (Voltage)	Voltage upgrading refers to increasing the operating voltage of an existing line. Voltage upgrading is a consideration when a lines transfer capacity is limited by voltage drop or stability. The increase in loading is approximately the square of the ratio of the voltage increase. Increasing voltage may reduce power losses, whereas increasing the thermal capacity increases the power losses
Uprating	In many cases the transmission capacity is restricted by thermal limitations on existing lines. For these instances, improved capacity may be achieved by • reassessing the conservative assumptions used to calculate the static

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	thermal rating • real-time thermal monitoring of the line (weather parameters, conductor temperature, sag or tension) • replacing existing conductors with larger ones • replacing the existing conductors with high temperature low sag (HTLS) conductors • improving the ground clearance to operate the line at a higher temperature (increase structure height or increase conductor tension) When capacity is limited by voltage drop or angular stability considerations - • install Static VAR Compensators (SVC) to provide dynamic reactive support • insert series compensation to reduce the apparent impedance of long lines • install advanced control schemes, such as power system stabilizers or inter-tripping schemes that disconnect some customers in a controlled manner to limit disturbances • upgrade the line for a higher operating voltage
Intermediate (Tangent) Structure	A structure where the conductor is supported by insulation that is usually perpendicular to the conductor. Insulator types include I string, V string, horizontal V, line post, braced line post
Strain Structure	A structure where the conductors are terminated with insulators in-line with the conductor. The structure is incapable of resisting termination loads on one face of the structure alone.
Termination (Dead-End) Structure	A structure where the conductors are terminated with insulators in line with the conductor. The structure is capable of resisting terminated conductor loads on one face of the structure.
Span	Usually refers to the horizontal distance between two adjacent structures.
Level Span	A span where the conductor attachment points are at the same level.
Inclined Span	A span where the conductor attachment points are at different levels.
Dead-End Span	A single span where the conductor is terminated at both ends to either a strain structure or a termination structure.
Ruling Span	A level, dead-end span where the tension behaviour, is equivalent to a series of inclined spans where the intermediate supports permit longitudinal swing or deflection such that tension equalisation occurs.
Weight Span	The length of conductor used to calculate the vertical load that the conductor imposes on the supporting structure. The horizontal distance between the low point of sag in the back span and the low point of sag in the fore span is normally used as an approximation where there is uniform vertical loading in both spans. The weight span on a particular structure may change as the conductor loading changes (wind pressure, conductor temperature, and ice thickness).
Wind Span	The length of conductor used to calculate the wind load that the conductor imposes on the supporting structure. The average of the back span and the fore span is normally used as an approximation where there is uniform horizontal transverse loading in both spans.

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Vertical Structure Load	Conductor loads (intact or broken) and maintenance loads imposed on the structure in the vertical direction (usually but not necessarily on crossarms). This will typically include the weight of conductor, the vertical component of conductor tension during stringing, the weight of insulators and fittings, men and tools.
Longitudinal Structure Load	Conductor loads (intact or broken), wind loads and maintenance loads applied to the structure in the longitudinal direction of the structure centreline (generally in the direction of the conductors).
Transverse Structure Load	Conductor loads (intact or broken), wind loads and maintenance loads applied to the structure in the transverse direction of the structure centreline (generally in the direction perpendicular to the conductors or along the bisect of centreline deviations).
Wind Load	The wind load is the force resulting from wind imposed onto an object with a nominated area exposed to the direction of the wind and with a nominated aerodynamic shape factor (drag coefficient). For objects (e.g. conductor) larger than the width of the wind gust, a pressure reduction (span reduction) factor is applied. For objects that are not solid (e.g. lattice tower), the drag coefficient is determined by the solidity ratio and wind direction.
Wind Effect	The effect of wind is to produce stresses in resisting structural components. Examples of these effects are axial stress, shear stress, bending stress, torsional stress or combined stress.
Wind Pressure	For strength limit state design the wind pressure is derived from the 3 second wind gust (design wind speed) with the specified return period that has been factored for direction, terrain, height, shielding and topography.
Residual Static Load (RSL)	RSL is the redistributed and equalised (static) conductor tension subsequent to a broken conductor.
Broken Conductor Load	The conductor loads imparted to a structure upon the failure of one or more conductors. Usually taken as a load factor on the RSL.
Construction and Maintenance Load	Loads due to the weight of linespersons and associated tools, and conductor loads associated with stringing activities, such as vertical loads imparted from brakes and winches and additional weight span caused by conductors being removed from adjacent structures. The loads are dependent on work practices and load factors are nominated in AS/NZS7000.
Dead Load	Dead loads or permanent loads are static forces that are relatively constant for an extended time while the structure remains unmodified. Dead loads include the structure self weight and weight of conductors and fittings.
Live Load	Live loads, imposed loads or dynamic loads are temporary, or moving, and of short duration (not cyclic). Live loads are also referred to as probabilistic loads and include environmental loads such as wind, ice, temperature changes and seismic loads.
Limit State Design	Limit state design philosophy takes into account the statistical nature of loads and material strengths, thereby providing consistent levels of component reliability and safety. It also considers other requirements such as serviceability and fatigue. Design strength≥Design action effect

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	ØR_n≥S^* ØR_n≥effect of loads (γX) "for linear analysis" ØR_n≥γ×effect of loads (X) "for non-linear analysis" where ΦRn = design strength, design resistance, design capacity Rn = nominal or characteristic strength, nominal resistance, nominal capacity S* = design action effect, effect of factored loads Φ = strength reduction factor, capacity factor γ = load factor X = load, characteristic load γX = design load or design load combination (linear analysis only) The design action effect S* represents the internal action (axial force, shear force, bending moment) that is obtained by structural analysis after applying factored loads γX. Load factors γ vary with the type of load, combination of loads, the particular limit state and the method of analysis. Capacity factors Φ vary with the variation in material strength and accuracy of fabrication (tolerances). The loads X are dead loads, live loads (including wind loads) or combination thereof. The loads are vectors (with magnitude and direction) and their sum is not algebraic unless they are co-linear. For linear elastic structures the “effect of loads” is proportional to the load eg stress is proportional to tensile load. For geometrically nonlinear structures such as conductors, doubling the wind load does not double the tension. In these instances the load factor is applied to the effect of load. The combined effect of design loads γX is analysed to determine the minimum design strength and hence the nominal strength of the resisting component (element). Limit State Design Process:

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	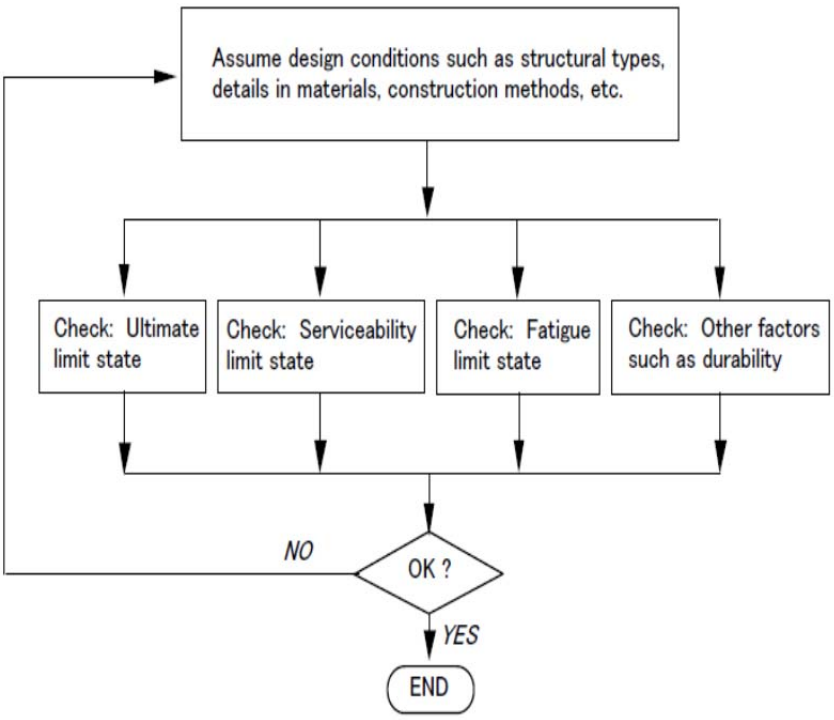
Strength Limit State	The Strength Limit State is the governing criteria for the strength design of structural elements. The strength limit state is deemed to be satisfied if all design action effects (effect of factored loads) are less than the factored design capacity of the structural element.
Serviceability Limit State	Serviceability Limit States relate to the criteria governing normal use such as deflection, vibration, durability or fire resistance. To satisfy the serviceability limit state criterion, a structure must remain functional for its intended use subject to everyday loading for its design life.
Fatigue Limit State	The fatigue limit state is associated with the fatigue failure of the structure or structural members due to load repetition. The fatigue limit state can be considered to be one of the ultimate limit states, because the structure fails at the fatigue limit state. However, since the fatigue failure under repeat loading involves a variable strength not a static strength as in the ultimate limit state, the fatigue limit state is treated separately. For conductors, a strength reduction factor (Φ) is defined for a given terrain category and damping system that is considered safe (bending stress below 150 micro-strain peak-to-peak for aluminium measured at 100mm from the support) under the design load (vibration weather case) with unity load factor.
Return Period	Natural phenomena such as wind, snowfall, floods and earthquakes are random events in time as well as space. The return period is defined as the average time (years) between two successive statistically independent events. The actual time between events is a random variable. Therefore the probability of the event occurring within the return period is not 100% but rather 63%. However the probability of occurrence of the event within any one year is the reciprocal of the return period. An event constitutes the exceedance of a certain threshold (eg wind speed > 100

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	m/s). Therefore random wind speeds are transformed into a time-independent value that is determined for a certain reference return period. This value is used to define a design load and the design of the structure itself is then done deterministically. Hence this design method is only partially probabilistic.
Maximum Design Cantilever Load (MDCL)	Load level above which damage to the core begins to occur and which is the limit for serviceability loads. The post insulator is loaded at 110% of the rated MDCL and held for 96 hours without cracks or delamination of the core (AS 4435.4:2005, IEC 61952:2002). The MDCL is the allowable tensile load using the older Allowable Strength Design (ASD) method with a safety factor of 2 (non-ceramic) to 2.5 (ceramic) i.e. 40% to 50% of the SCL.
Specified Cantilever Load (SCL)	The specified cantilever load of the post insulator is the maximum limit state cantilever load which can be applied to the insulator at the line end fitting. This is also referred to as the ultimate strength limit state cantilever load or ultimate cantilever load. The post insulator is tested quickly until SCL is reached without breakage of the core or end fitting (AS 4435.4:2005, IEC 61952:2002). Most manufactures will only provide the MDCL, however the SCL is required for limit state design.
Specified Tensile Load (STL)	The specified tensile load of the post insulator is the maximum limit state tensile load which can be applied in-line with the longitudinal axis of the core; away from the end metal fitting (away from the pole); at or near the intended conductor attachment point. This is sometimes referred to as the ultimate tensile load capacity of the insulator. The insulator is rapidly loaded to the rated STL without pull-out of the core or breakage of the end fitting (AS 4435.4:2005, IEC 61952:2002). Most manufactures will only provide the Rated Tensile Load (RTL see 3.6.4), however the STL is required for limit state design. The compression load is usually not provided.
Rated Tensile Load (RTL)	The RTL is the allowable tensile load using the older Allowable Strength Design (ASD) method with a safety factor of 2 i.e. 50% of the STL.
Standard Impulse Waveshapes	The lightning and switching impulse waveshapes are described by their time to crest and their time to half value of the tail. The standard lightning impulse waveshape is 1.2/50 μs. This standard is chosen, not because lightning conforms to this waveshape, but because testing laboratories can readily produce this waveshape. The standard switching impulse waveshape is 250/2500 μs. The magnitude of the crest voltage and the polarity are required to completely describe the waveshape.
Critical Flashover Voltage (CFO)	The crest (maximum) voltage for which the probability of flashover is 0.50 for the standard lightning or switching impulse waveshape.
Power Frequency Flashover Voltage	The rms voltage at power frequency (50 or 60 Hz) for which the probability of flashover is 0.5. For transmission lines, the power frequency flashover voltage under clean conditions is rarely used for insulation design. It is the performance under contaminated (polluted) conditions that dictates the insulation design.
Basic (lightning) Impulse Insulation Level (BIL)	The crest voltage of the standard lightning impulse for which the probability of flashover is 0.10. The BIL is also known as the lightning impulse withstand voltage. The BIL is universally defined for dry conditions under standard atmospheric conditions. By assuming a Gaussian distribution for the insulation characteristic, the BIL is

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	the crest voltage 1.28 standard deviations below the CFO for lightning impulses. Therefore BIL = 0.962 CFO assuming a coefficient of variation of 3% for lightning impulses.
Basic (switching) Surge Impulse Insulation Level (BSL)	The crest voltage of the standard switching impulse for which the probability of flashover is 0.10. The BSL is also known as the switching impulse withstand voltage. The BSL is universally defined for wet conditions. By assuming a Gaussian distribution for the insulation characteristic, the BSL is the crest voltage 1.28 standard deviations below the CFO for switching impulses. BSL = 0.936 CFO assuming a coefficient of variation of 5% for switching impulses.
Apparent Power	Apparent power as the magnitude of the vector sum of real and reactive power. It is the product of the rms voltage and the rms current. The unit of measure of apparent power is VA (volt-ampere).
Phase Sequence	Australia follows an anti-clockwise phase sequence and the convention for this sequence is RWB (Red White Blue). Other sequences such as ABC, RYB (Red Yellow Blue) may be found on old drawings. Rotating machines use the UVW and L1 L2 L3 markings (AS 60034.8 Rotating electrical machines - Part 8: Terminal markings and direction of rotation).
Power Factor	The power factor of a load is a measure of the fraction of the apparent power that is real power performing actual work. When power factor is equal to 0, the energy flow is entirely reactive, and stored energy in the load returns to the source on each cycle. When the power factor is 1, all the energy supplied by the source is consumed by the load. Power factors are usually stated as "leading" or "lagging" to indicate the sign of the phase angle. Capacitive loads are leading (current leads voltage), and inductive loads are lagging (current lags voltage). A load with a low power factor draws more current than a load with unity power factor for the same amount of useful power transferred. The higher currents increase the energy losses in the distribution system.. Some utilities charge a higher cost to industrial or commercial customers where there is a low power factor. Presently this is not the case with Ergon.
Reactive Power	AC power systems consist of reactive components that possess capacitive (electric field) and/or inductive (magnetic field) properties. These electrical properties cause the current to get out of phase with the voltage, thus creating reactive power. The unit of measure of reactive power is VAR (volt-ampere reactive). Reactive power may be considered as the imaginary component of apparent power. Reactive power can be produced or consumed by different load/generation elements. It is essential for voltage regulation. The current associated with reactive power does no work at the load, it heats the wires, wasting energy. Conductors, transformers and generators must be sized to carry the total current, not just the current that does useful work.
Real Power	Real, active or true power is the power that performs work and it is measured in Watts (W). Real power is measured by revenue meters and forms the basis for energy consumption (kWh) for customer billing.
RMS (Root Mean	The square root of the mean of the square of a continuous waveform (usually

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Square)	voltage or current). For a resistive load with a time-varying applied voltage, the average power dissipation is P_avg=(V_rms^2)/R=I_rms^2 R=V_rms I_rms For a sinusoidal waveform (AC power) the rms value is the peak value divided by √2.
Space Potential	Space potential is the voltage (electric potential) of a point in space relative to remote earth. Points with the same voltage define an equipotential surface. The rate of change of space potential with distance defines an electric field or voltage gradient.

4.2 Acronyms and abbreviations

The following abbreviations and acronyms appear in this standard.

<Term, abbreviation or acronym>	<Definition>
AAC	All Aluminium Conductor
AAAC	All Aluminium Alloy Conductor
ACSR/AC	Aluminium Conductor Steel Reinforced (Aluminium Clad)
ACSR/GZ	Aluminium Conductor Steel Reinforced (Galvanized)
ADSS	All Dielectric Self Supporting Optical Fibre Cable
CBL	Calculated Breaking Load (kN)
DTM	Digital Terrain Model or Digital Elevation Model
EDMS	Electronic Document Management System
EMF	Electromagnetic Field
GIS	Geographical Information System (Smallworld)
LIDAR	A remote sensing technology that measures distance by illuminating a target with a laser and analysing the reflected light. The term comes from combining the words light and radar.
MOV	Metal oxide varistor
OHEW	Overhead Earth Wire
OPGW	Optical Fibre Ground Wire
RMS	Root mean square
RS	Ruling Span (m)
RSL	Residual Static Load (kN)
SAS	System Alteration Sketch
SC/AC	Steel Conductor (Aluminium Clad)
SC/GZ	Steel Conductor (Galvanized)
SRF	Span Reduction Factor (unitless)
SVD	Spiral vibration damper or impact damper
SWMS	Safe Work Method Statements
SWP	Standard Work Practices
TSRF	Tension Section Reduction Factor (unitless)

VAR	Reactive or apparent power (volt – ampere reactive)

5 GENERAL

5.1 ROUTE ACQUISITION

Securing the line route precedes the detailed engineering design. Alternative routes may need to be investigated.

Most of the design parameters in the following section will be required to assess the engineering feasibility of route options. The deliverables suffixed with an asterisk form part of the engineering design.

- Approved route plan on cadastral background (*)
- Schedule of property owners and access requirements
- Third party approvals (Telstra, Railways, Main Roads, Council, PowerLink) (*)
- Noxious weed survey
- Vegetation clearing approvals where construction is expected to occur within 5 years
- Technical specification for clearing and access (*)
- Estimated clearing and access cost (*)
- Vegetation clearing and access complete
- Environmental planning for work - risk assessment
- EMF report (for community consultation) (*)
- Engineering report indicating typical structure types, typical structure heights and span lengths on flat terrain, minimum ground clearances, conductor swing, easement width, and typical staying requirements (for community consultation) (*)
- “Dial Before You Dig” search (*)
- Technical specification for surveying (cadastral and engineering) (*)
- Estimated surveying cost (*)
- Registered easement surveys and signed wayleaves
- Centreline survey (DTM) suitable for complete design (*)
- High resolution orthorectified imagery (*)
- Resumptions and compensation complete
- Technical specification for site investigation (geotechnical, soil resistivity) (*)
- Estimated site investigation cost (*)
- Geotechnical assessment or investigation (*)

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If structure positions are a necessary requirement for community consultation then the route acquisition shall be finalised after design. The specification shall clearly state the iterative nature of the design, given that route approval is conditional upon centreline location and structure locations

5.2 DESIGN PARAMETERS

At the commencement of design the project scope shall include as a minimum

- Approved line route which provides:
  - Route length
  - Climatic conditions (wind region, wind speed, wind direction, temperatures, lightning ground flash density)
  - Seismic conditions
  - Topographical features (terrain category, altitude)
  - Pollution level (insulation, conductor and earthwire construction type)
  - Environmental and cultural heritage requirements
- Operating voltage (the line may initially be energised at a lower voltage) which provides:
  - Minimum conductor diameter
  - Minimum ground clearances (reference height for wind speed)
  - Structure family
- Design working life for the line (typically 50 years)
- Security level (importance level, reliability)
- Operational requirements which provides:
  - Construction type (live maintenance)
  - Switch locations
  - Protection settings – auto reclose times
  - Lightning performance requirements (shielding, arresters)
  - Communication requirements (OPGW and fibre count)
- Connection points:
  - Substation general arrangement drawing, to scale, with dimensions and survey reference
  - Reactive power compensation
  - Tee in existing structure details
  - Phasing arrangement
- Number of circuits including subsidiary circuits
- Maximum power demand which provides:

- Conductor size (voltage drop)
- Maximum operating temperature
- EMF exposure

- Earth fault current level which provides:
  - Earthwire size
  - Step and touch potential hazard
  - Induction hazard
- Constructability issues that may determine the location of termination structures:
  - Outage restrictions
  - Powerline crossing requirements
  - Staged construction requirements
  - Time to restore line to service during an emergency
  - Induction from parallel powerlines

5.3 DESIGN DELIVERABLES

The completed design shall incorporate:

- Approved drawings suitable for entering into Ergon's EDMS (Electronic Document Management System)
- Construction specification and schedules for pricing
- Safety in design - risk assessment
- Bill of materials
- Structure pegging complete
- Assets recorded into Ergon's GIS (Geographical Information System)
- System operating diagram updated with a SAS (System Alteration Sketch)
- For minor jobs the designer may be required to complete an Environmental and Cultural Heritage Risk Assessment. The requirement for these will be nominated in the Project Scope.
- All design calculations undertaken during the design (including sag/tension, structure loadings and footings).

5.4 CONSTRUCTION SUPPORT

Where the contractor is required to offer construction support it shall include:

- On-site supervision
- Engineering certification that the line was constructed in accordance with the design specification
- Engineering support and certification where departures are required

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- Sourcing of material shortfalls
- Dispute resolution (technical not commercial)
- Construction records
- “As-built” mark ups of design drawings and Ergon Energy’s GIS.
- Compilation of a technical data manual – an example of which is available on request.

5.5 DESIGN DRAWINGS

- Profile and long section drawings. These shall include conductor type, maximum design temperature and the minimum clearance provision.
- Pole schedules. These shall be in a tabulated format, summarising the details of the line.
- Conductor schedule that includes the design tensions (stringing charts)
- Phasing diagrams
- Stringing/sagging tables (offset clipping if applicable)
- Vibration damper schedule and installation dimensions
- Stay layout sheets
- Pegging sheets
- 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 and bill of materials
    - Steelwork fabrication details
    - Pole manufacturing details
    - Electrical clearances
    - Design loading capacity with load factors
    - Structure test reports

5.6 DRAWING STANDARD

All drawings shall be produced via a computer aided drafting (CAD) package suitable for uploading to, and being stored within, Ergon’s eDMS system. Drawings which, in the opinion of the Superintendent, are of an inadequate standard will be rejected.

All drawings shall comply to AS 1100.101 - Technical drawing, Part 101: General principles for:

- Sheet sizes A4, A3 (preferred) and A2.

- Title blocks.
- Types of lines.
- Scales.
- Projection - third angle preferred.
- Sections and dimensioning.
- Lettering, numerals and symbols.
- Conventions for the representation of components.

All drawings shall have a standard Ergon Energy drawing frame and title block. Contractor's title blocks may be added above the Ergon Energy title block.

Each drawing will be allocated an Ergon Energy drawing number and sheet numbers as required by Ergon Energy. A separate number will be allocated for each drawing type in the series of drawings covering the project. The drawing number and the agreed title conforming to the Ergon Energy drawing registration requirement shall be placed in the title block area by the Contractor. Where drawing numbers are used for cross reference purposes within a drawing the applicable Ergon Energy reference number shall be used. Contractors may add their specific number if required in the contractors allocated area.

For general drafting Ergon Energy uses AutoCAD. Drawing files shall be supplied in .DWG format if suitable or in interchange .DXF format on a recordable compact disk, recordable DVD or USB memory card (any such media shall be non-returnable).

A Transmittal Form shall accompany all document deliveries. An example is Ergon Energy's Transmittal Form - NI000401F104

The layering convention used by the Contractor supplying drawings in .DWG or .DXF format shall be forwarded identifying the information created in each layer.

System operating schematics shall use the Ergon Energy Schematics Common Standard.

5.7 STANDARD CONSTRUCTION DRAWINGS

Line layouts shall utilise the Sub-transmission Construction Standards wherever possible. Deviation from the standards requires Ergon management approval and RPEQ certification.

5.8 SPECIFICATIONS

The design shall incorporate and be in accordance with the Ergon Energy Sub-transmission Construction Manual Drawings and Sub-transmission Standards Specifications. Any proposed deviation from these standards requires Ergon Ergon approval.

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6 OPERATIONAL REQUIREMENTS

6.1 NETWORK SECURITY

Network security is addressed at the planning phase. Ergon's planning policy is provided in the joint Ergon/Energex document Standard for Transmission and Distribution Planning (Ergon process document STMP003).

ENA Doc 029:2011 Electricity Network Development (Subtransmission and Distribution) provides additional guidance.

Lines may be interdependent such that one event results in the failure of two circuits. Examples -]

- common structures
- common protection communication paths
- cables in common trenches
- common stay wires
- common overcrossing by transmission circuit
- common isolation point
- at risk of damage from the collapse of common large trees
- close physical proximity such that a common storm event fails both circuits

Once introduced, interdependence between circuits can be difficult and expensive to remove. In some cases interdependence can be very subtle and be very difficult to detect. It needs to be the objective of all planners to minimise or eliminate interdependency wherever possible at all stages of the planning process.

6.2 STRUCTURE SECURITY

Structure security is required to limit the consequential damage in the event of a structural failure whatever its cause. The design approaches for limiting cascade failures are based on reducing the effects of torsional and longitudinal loads. Increased security comes at a price and additional security beyond that coded in AS/NZS 7000 needs to be justified.

AS/NZS 7000 (clause 7.2.7) provides minimum requirements for security loads, however intermediate distribution structures using pin or post insulators with ties are exempt. The proposed later revision of the standard does permit ductile failure of a crossarm or a post insulator gain base as a means of limiting cascade failures.

Providing structure security is generally achieved by introducing longitudinal restraint design rules for broken wire loads. It may also be improved by designing stay configurations such that the structure will not fail under everyday loads with a broken staywire or anchor failure.

Other means to provide security apart from managing failure containment loads are

- increase the structure strength (reliability)
- using load release mechanisms eg slipping suspension clamps or frangible crossarms

- accept failure of a limited number of adjacent structures i.e accept a reduced longitudinal capacity
- utilise termination (stop) structures at regular intervals

6.3 NETWORK RELIABILITY

To measure Network Reliabiility, the electricity industry has developed several performance measures. These reliability indices include measures of outage duration, frequency of outages, system availability, and response times.

Reliability indices such as SAIDI, SAIFI and CAIDI targets are set in the Minimum Service Standards (MSS), as detailed in Queensland Electricity Industry Code (STMP001 Standard for Network Performance). In practice, a very small proportion of any reliability index is attributed to transmission and subtransmission outages. This is because of the higher reliability and security of the transmission and subtransmission network over the distribution network. However a single outage affects a great number of customers and therefore it has to be more reliable and secure.

The following table lists some factors affecting the frequency and duration of network outages and whether line design influences these factors.

Factors Affecting Reliability	Influenced by Line Design?
Bushfires – conductor annealed and requires replacement	Yes – poor conductor selection in high risk areas
Bushfires – flashover	Yes – inadequate electrical clearances in high risk areas
Corrosion – hardware failure	Yes – poor quality hardware Yes - poor workmanship/ poor supervision No – inadequate inspection/maintenance
Equipment malfunction (recloser)	No
Failure to detect and fix serious defects	No – inspection/maintenance regime failure
Flooding – foundation erosion	Yes – poor structure placement or foundation design
Flooding – submerged conductors	Yes – inadequate flood clearance
Line overload – requiring load shedding	No – thermal rating is a planning decision No – network security is a planning decision
Operational error	No Yes – if operational signage is inadequate
Planned maintenance – requiring outage – no alternative supply	No – if inadequate procedures for working live from EWP Yes – if no provision for live-line access from structure or EWP
Pollution – insulator flashover	Yes – poor insulator selection No – if infrequent insulator washing in high pollution environment
Restoration times after a failure	No Yes – if non-standard equipment used

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	Yes – if oversize EWP is required
Sabotage – removal of bolts or lattice members	No – if not foreseen Yes – if foreseen and poor structure or stay selection
Storms – debris severing conduct	No – if uneconomic Yes – poor conductor selection
Storms – lightning flashover followed by power arc	No Yes – if underinsulated
Storms – rain and wind causing foundation failure	No – if unforeseen Yes – if poorly designed or installed
Storms – wind causing electrical failure	No – if designed to the code Yes – inadequate suspension insulator swing angle or inadequate mid-span separation
Storms – wind causing structural failure	No – if wind speed beyond design Yes – if structural reliability does not match the importance of the line
Theft – removal of lattice steel members	No – removal of secondary bracing will not cause failure under everyday loads, routine inspection will discover missing members
Upstream outages (generation or transmission)	No
Vandalism – shooting insulators	No – failed glass discs should be identified during inspection
Vegetation infringement	No – regrowth permitted by failure of inspection/maintenance regime Yes – if vegetation clearance is inadequate
Vehicular impacts - structure	No - accidental Yes – if involved with route selection or failure to use guard rails for high risk areas
Vehicular impacts - conductor	No – accidental or poor high load management Yes – if inadequate clearance for high vehicle access
Vibration causing conductor breakage	Yes – poor vibration damping system design
Wildlife - flashover	Yes – inadequate electrical clearances No – if uneconomical to achieve

Table 6.3 – Factors Affecting Reliability

6.4 POWER QUALITY

Power quality is influenced by loads and is considered in the planning phase. Ergon document STMP003 has a section on power quality. The subtransmission line design has very little impact on power quality such as

- Harmonics – line design has no effect

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- Voltage Flicker – line design has no effect
- Voltage Unbalance – transpose long lines
- Transient Events – lightning performance

6.5 THERMAL CURRENT RATING

A line is designed so that statutory ground clearances are maintained at the maximum operating conductor temperature. This temperature forms the basis for all current ratings (except the zero wind rating) used for planning or operational purposes. Two rating categories are generally applicable to overhead lines –

- Normal (static) rating: A fixed (static) value that depends upon climatic region, season (summer/winter) and solar intensity (day/night). Based on statistical data.
- Real-time (dynamic) rating: Varies dynamically depending upon real-time measurements of ambient temperature and wind velocity, or alternatively conductor tension, sag or temperature. Used during contingency events and to defer costly upgrades.

A zero wind rating is introduced to limit the conductor temperature to 140°C under still conditions. At this temperature the conductor will sag unacceptably low but Ergon accepts this risk to achieve a balance between effective utilisation and cost. The zero wind condition may exist where there is wind sheltering from trees, buildings, hills, etc. The lower value of the static rating and the zero wind rating is taken as the thermal rating of the line.

Planners will either

- Specify a static thermal rating for summer/winter day/night. This is the preferred option because it gives the designer the opportunity to optimise the conductor selection.
- Recommend a conductor type and maximum operating temperature. This option is least preferred.

The climatic conditions for the static ratings are provided in table 6.5.

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	Summer Day		Summer Evening		Summer Night/Morning		Winter Day		Winter Evening		Winter Night/Morning		
	Dec-Mar (9am - 5pm)		Dec-Mar (5pm to 10pm)		Dec-Mar (10pm - 9am)		Jun-Aug (9am - 5pm)		Jun-Aug (5pm to 10pm)		Jun-Aug (10pm - 9am)		
Region	Wind m/s	Temp. °C	Wind m/s	Temp. °C	Wind m/s	Temp. °C	Wind m/s	Temp. °C	Wind m/s	Temp. °C	Wind m/s	Temp. °C	**Full description**
Far North	0.8	38	0.4	34	0.2	30	1.4	32	0.7	28	0.3	24	Gulf and Cape York
Eastern & Coastal	1.3	35	0.8	31	0.3	27	1.2	28	0.5	23	0.3	23	East of Great Divide excluding Mackay & Special zones
Mackay	1.9	33	1.5	27	1.2	27	1.8	24	0.5	19	0.5	19	Mackay area
Eastern & Coastal - Special	1.7	33	1.3	27	0.4	27	1.2	25	0.4	19	0.4	19	Along the coast from Yeppoon to Hervey Bay
Toowoomba	1.8	33	1.8	27	1.8	21	1.8	19	1.5	14	1.3	11	Toowoomba area
Central Tablelands - North	1.3	37	0.7	34	0.2	29	0.8	30	0.4	26	0.2	20	West of the Great Divide and from between Emerald & Roma to Far North region
Central Tablelands - South	1.3	37	0.7	34	0.2	29	0.8	25	0.4	22	0.2	15	West of the Great Divide and from between Emerald & Roma to NSW border
Western	1.7	42	1.4	40	1.4	36	1.4	32	1.2	29	0.7	20	
Western - Special	1.5	41	0.8	37	0.3	32	1.1	32	0.4	28	0.3	20	Mt Isa/Cloncurry & Blackall/Charleville

Table 6.5 – Climactic Conditions for Static Ratings

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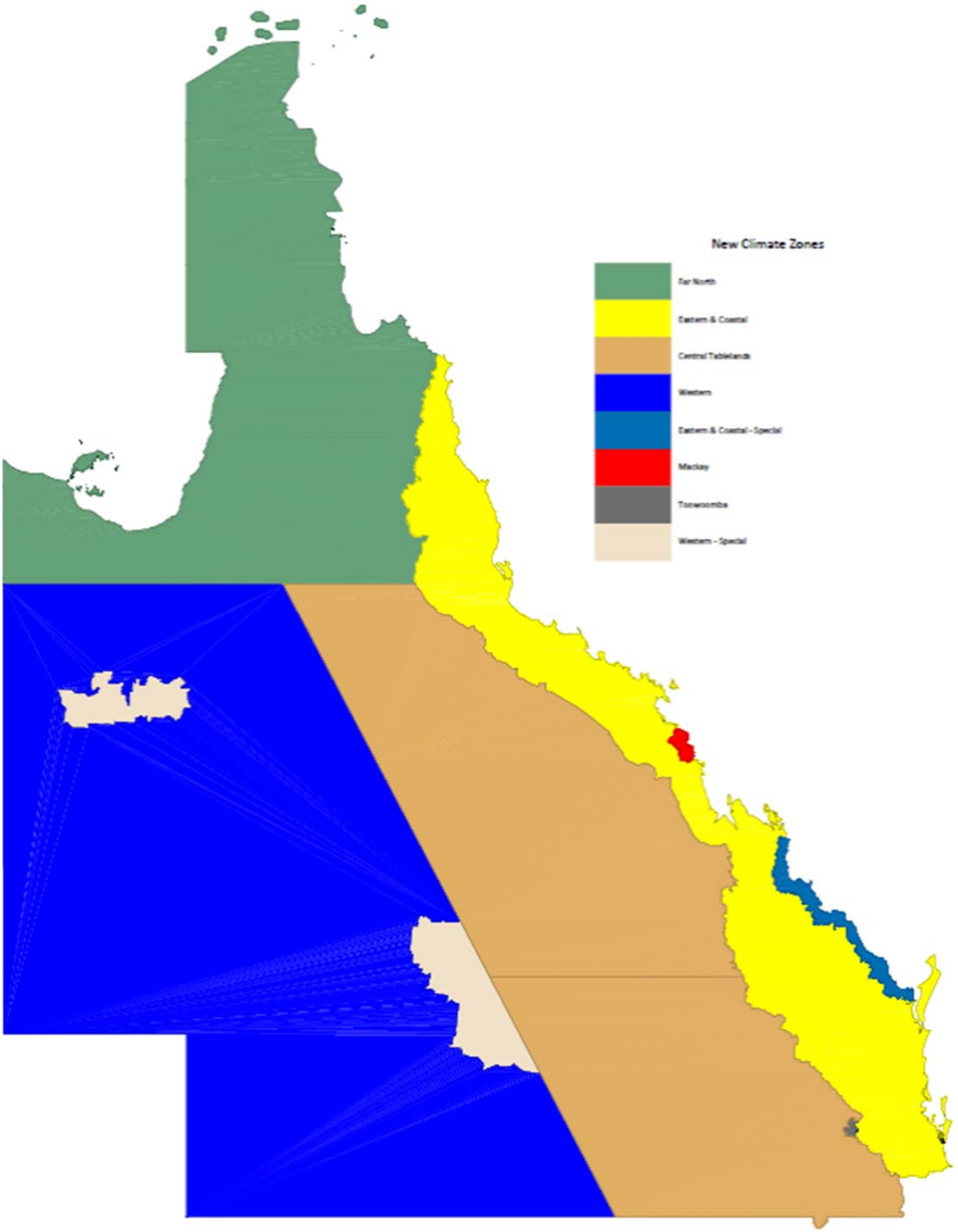

Figure 6.5 - Ergon's Climate Zones for Static Rating Calculations

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6.6 LOSSES

The main factors that contribute to excessive losses are small cross sectional area conductors, long circuit lengths, unbalanced loads, poor power factors and low operating voltages.

The peak demand loss (kW) is generally obtained from a load flow analysis. A check shall be made to verify that reasonable (less than 10%) power losses are achieved at the thermal current rating for the line at normal power factors (0.95 lagging to unity).

The energy losses (kWh) can vary from year to year due to changes in network utilisation, network configuration, the shape of the load profile, the level of reactive power support (power factor) and generator patterns.

6.7 VOLTAGE REGULATION

It is preferred to normally operate the subtransmission network at the higher end of the allowable voltage range. Reasons for this include reduced losses, easier voltage regulation and greater reach into the distribution network. The receiving voltage range of ±10% of nominal voltage is allowable under the Queensland Electricity Regulations (QER). Power transformers typically have tap changers with an operating range from -15% to +5%. A check shall be done to verify that reasonable (less than 10%) voltage regulation is achieved for the selected conductor size. Voltage regulation is defined as

- $Regulation = \frac{|No\ Load\ Voltage| - |Full\ Load\ Voltage|}{|No\ Load\ Voltage|} \times 100$

where the voltage magnitude is measured at the load for normal power factors (0.95 lagging to unity)

6.8 NETWORK STABILITY

Electrical energy is produced at the same time as it is consumed and a balance between production and consumption is required for stability (constant frequency and voltage). Generators, loads and the electrical networks which connect them have mechanical and/or electrical inertias which complicate the maintaining of a balance.

When confronted with a disturbance, the electrical system normally resumes a stable state after a few oscillations. However in certain cases the oscillating state can diverge, and studies are then required to avoid this phenomenon and guarantee the stability of the electrical network. These studies are of particular importance in the case of wind turbines that use induction generators.

Stability studies are a planning function and minor variations of the line impedance due to design changes will not affect the outcome.

6.9 LIGHTNING PERFORMANCE

Typical lightning fault rates for overhead lines are provided in Table U1 of AS/NZS 7000. Predicted outage rates for Ergon's standard structures are proportional to the average annual lightning flash density. Refer to the figure provided in 6.9.

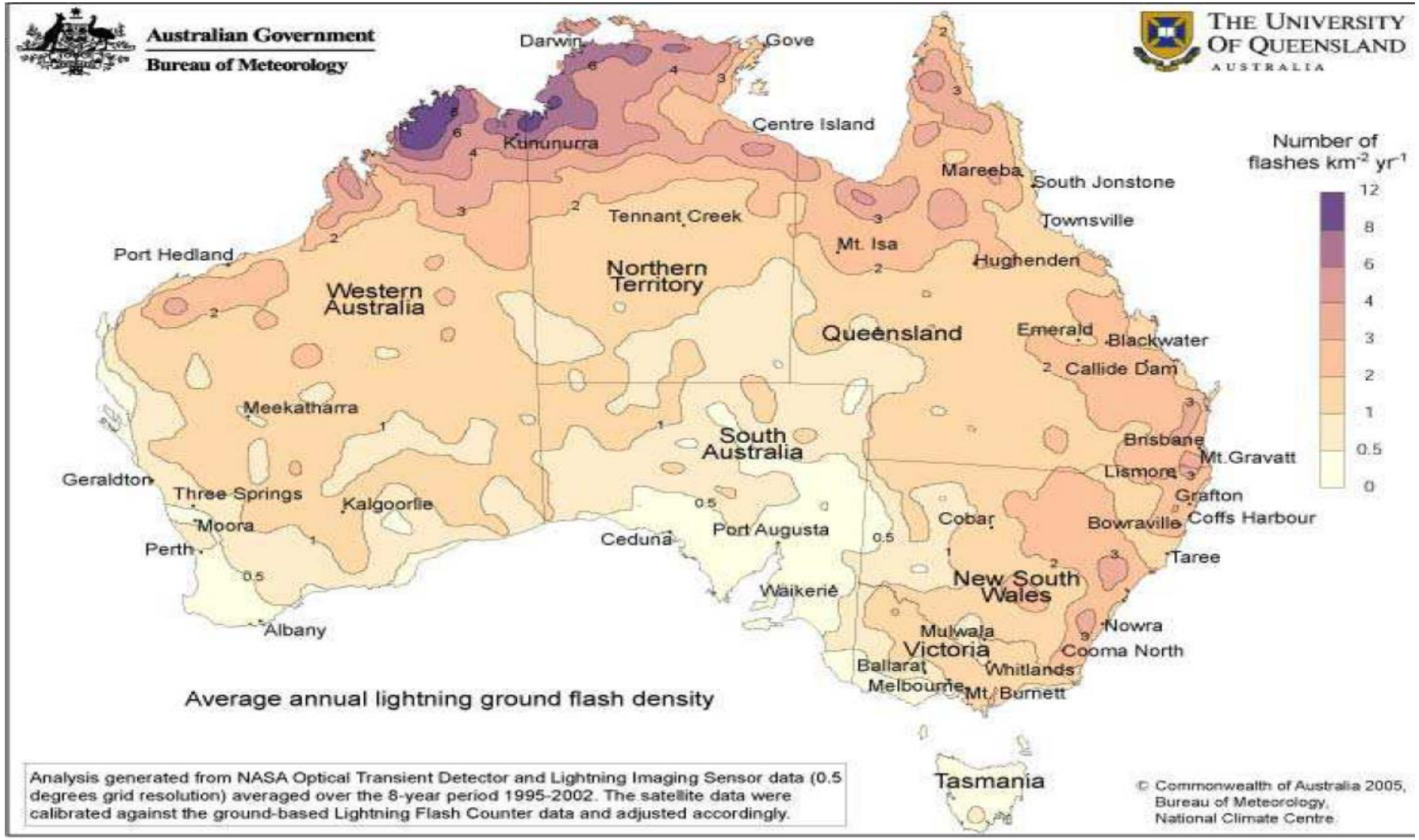

Figure 6.9 – Average annual lightning ground flash density

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6.10 FAULT CURENTS

The fault ratings of any network equipment should be designed to exceed the maximum fault level of the network they belong to at any time. Short circuit fault levels vary with network augmentation and network reconfiguration. The designer shall carefully assess normal and potential network configurations, and the resultant fault levels that the line may be exposed to, to ensure that the conductor and the earthwire are adequately rated. The target fault ratings given in STMP003 are 25kA for 3s for new subtransmission and distribution equipment installation.

The maximum allowable temperature of the conductor is determined by the material properties (such as annealing or loss of zinc). The thermal energy developed during a short circuit is determined by the short-circuit magnitude and duration. The duration is determined by the protection clearing times and the number of recloses to lock out (usually 2 to 4).

Earth fault currents produce step and touch potentials at each earthed structure. These need to be managed in accordance with Section 10 of AS/NZS 7000. Induction into adjacent metallic circuits (pipelines, telecommunications and fences) is another consideration.

6.11 EASEMENT WIDTHS

An easement shall be sized to satisfy the following constraints at its edge

- acceptable EMF levels
- acceptable audible noise levels
- regulation safety clearances under high wind conditions

Where lines are located on road reserves, the conductors shall not encroach over the adjoining property with no wind. An easement over the adjoining property is required where the calculated easement width (refer to method below) is beyond the building setback requirement of the local municipal authority.

Annex E provides easement and inter-circuit distances based solely on electrical clearance considerations. The easement shall encompass the entire asset including stays. Generally, ground stays can be located anywhere within a 25m radius from the centre of a structure.

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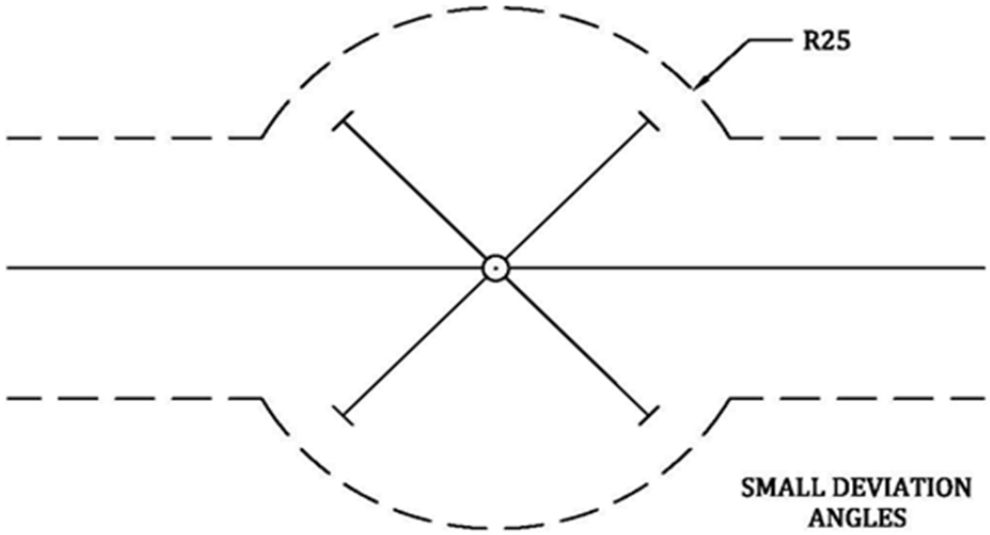

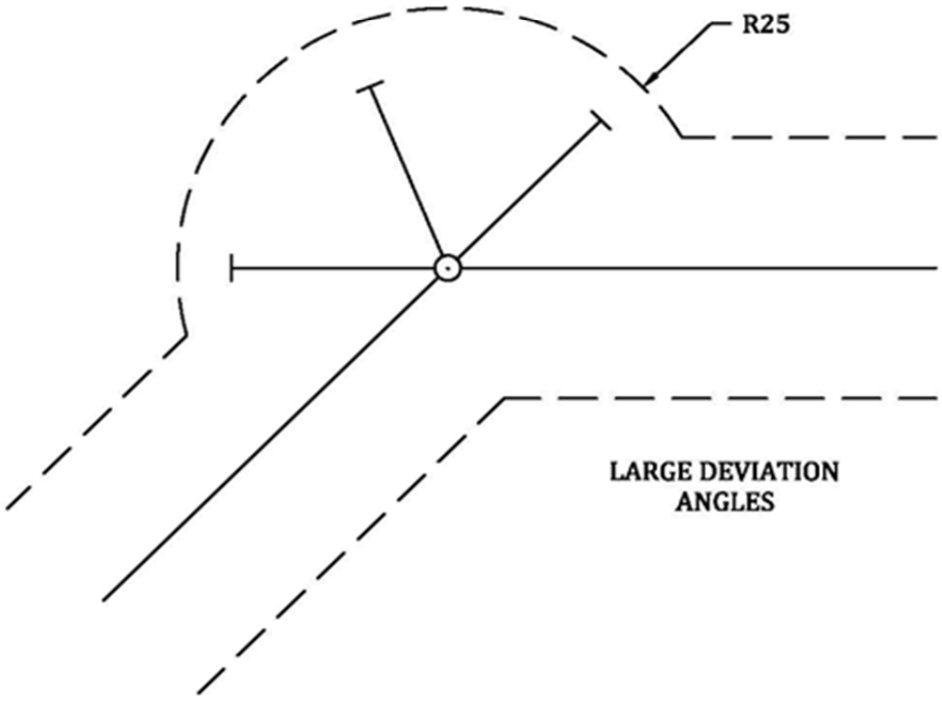

- **Figure 6.11.1 Easement Around Stayed Structures**

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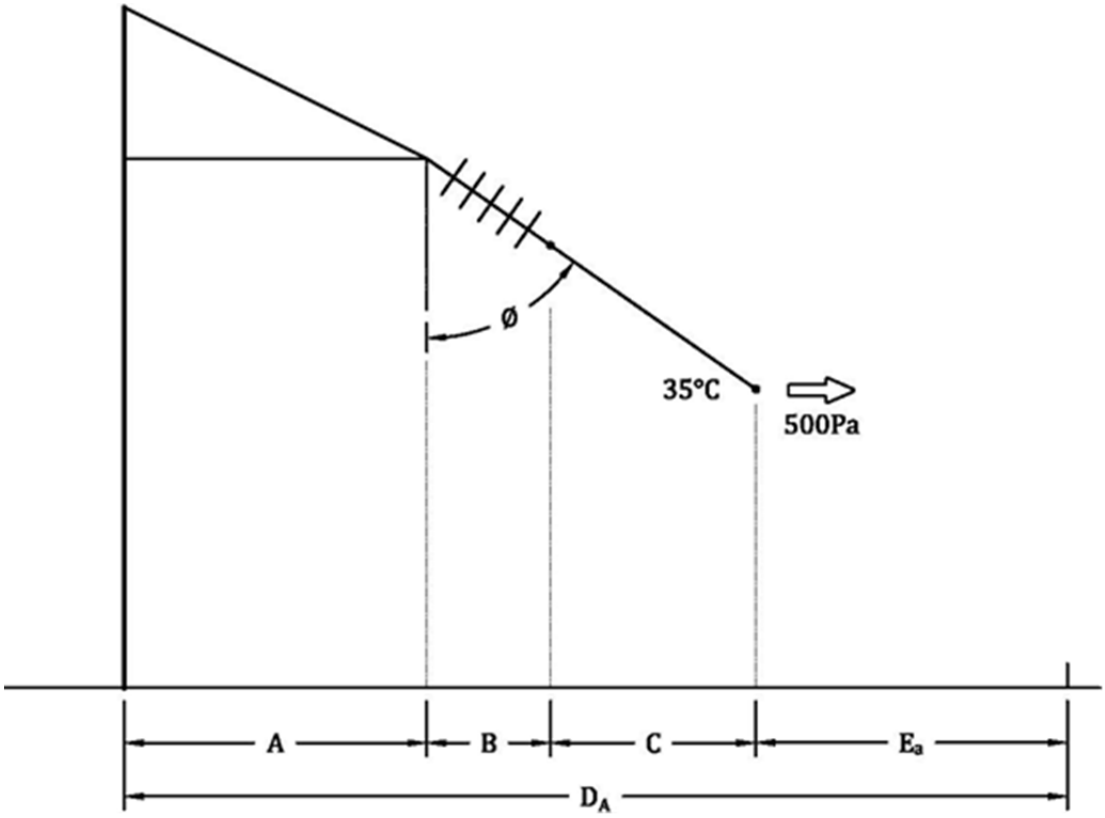

- **Figure 6.11.2** Distance to Edge of Easement

A – crossarm width

B – horizontal component of insulator swing

C – horizontal component of conductor swing at 500 Pa transverse wind pressure

Ea –horizontal clearance to structures normally accessible to persons

Electrical Safety Regulation 2002 – Schedule 4 – Part 4.1

DA -minimum distance from centreline to edge of easement

ϕ - conductor swing angle at 500 Pa transverse wind pressure

(insulator swing angle assumed to be the same)

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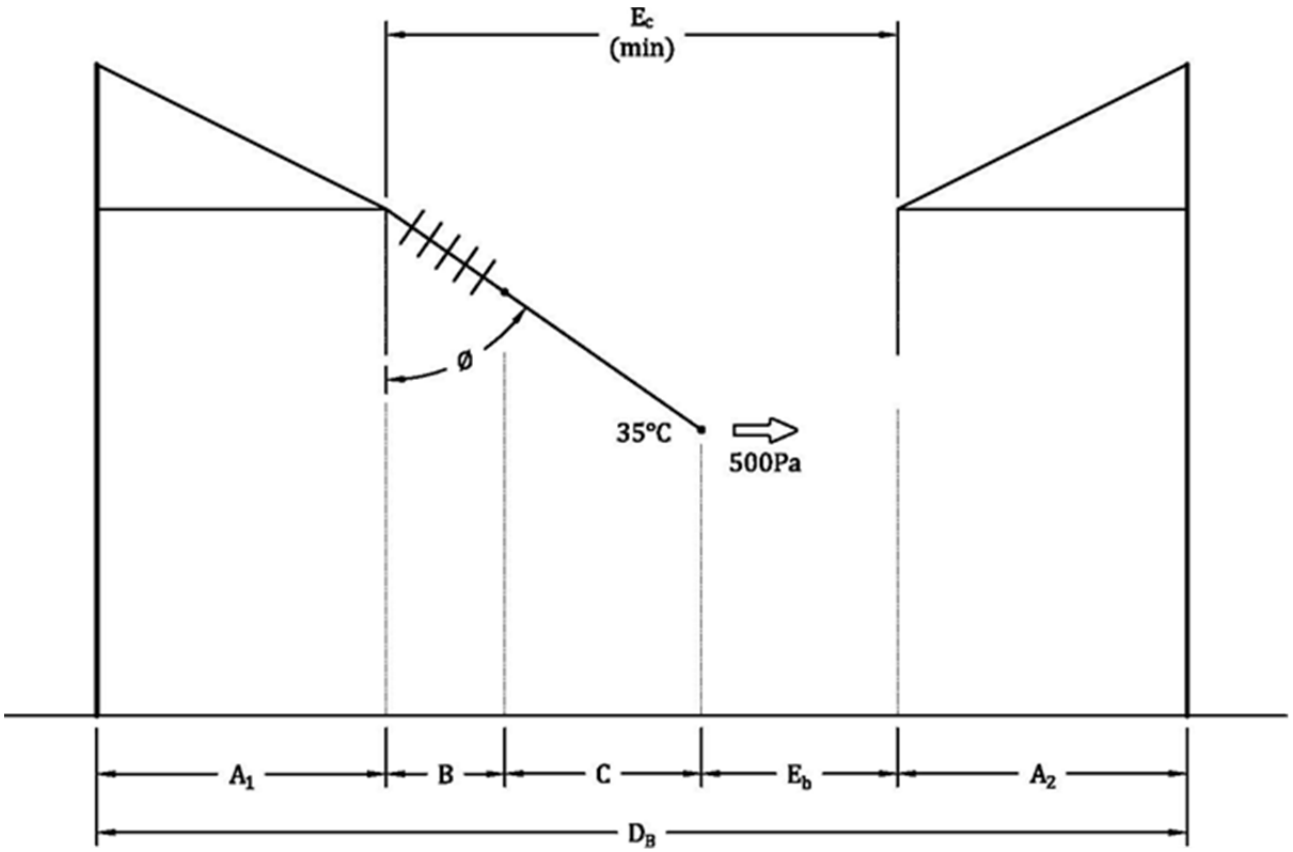

- **Figure 6.11.3 Inter-Circuit Distance for Structures Out-of-Step**

A1, A2 – crossarm width of structures

B – horizontal component of insulator swing

C – horizontal component of conductor swing at 500 Pa transverse wind pressure

Eb –horizontal clearance to structures NOT normally accessible to persons

Electrical Safety Regulation 2002 – Schedule 4 – Part 4.5

Ec –exclusion zone for plant operated by untrained persons

Electrical Safety Regulation 2002 – Schedule 2 – Part 1

DB -circuit separation for out-of-step structure alignment

ϕ - conductor swing angle at 500 Pa transverse wind pressure

(insulator swing angle assumed to be the same)

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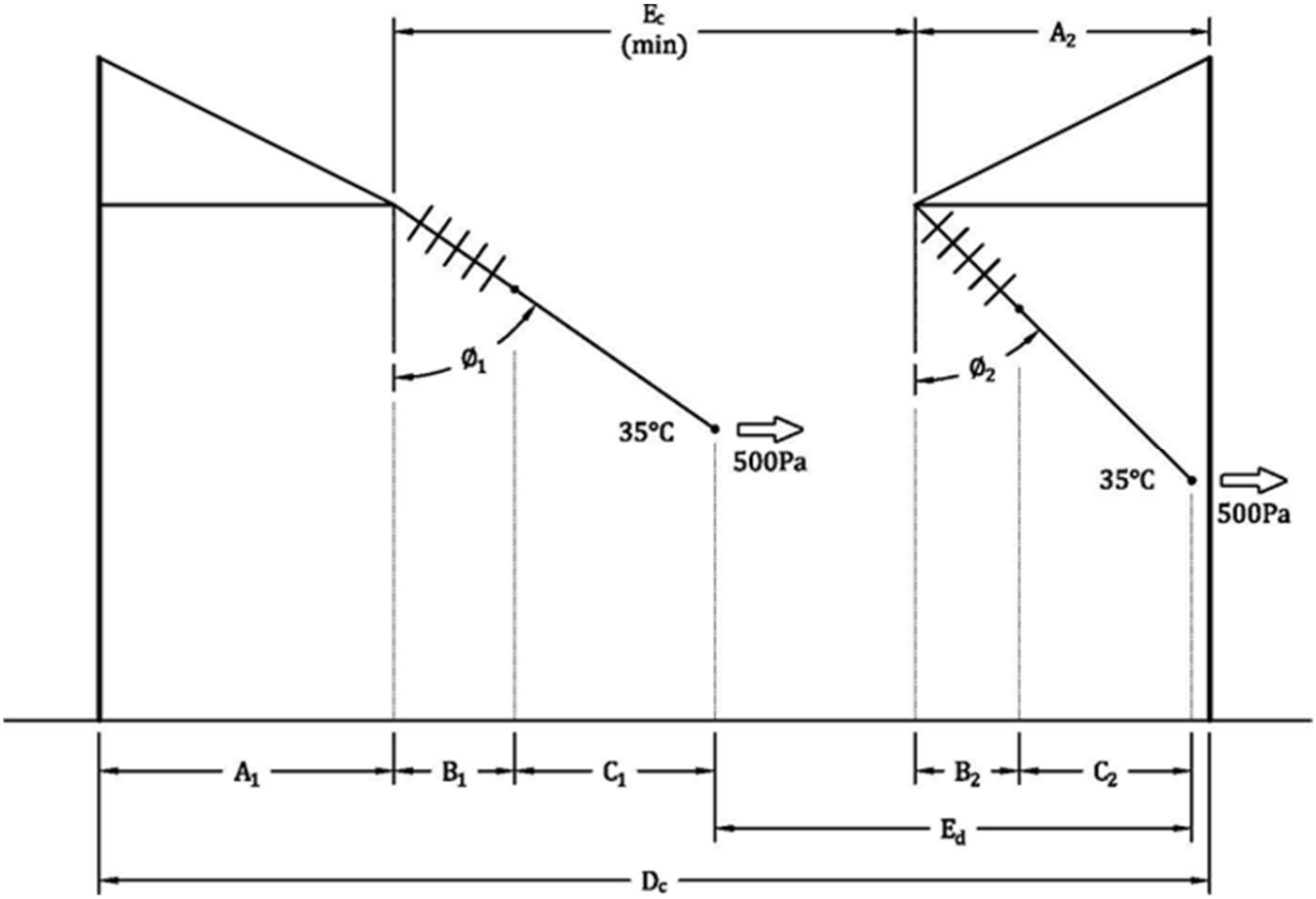

- **Figure 6.11.4 Inter-Circuit Distance for Structures Out-of-Step**

  - A_1, A_2 crossarm width of structures
  - B_1, B_2 horizontal component of insulator swing
  - C horizontal component of conductor swing at 500 Pa transverse wind pressure
  - E_c exclusion zone for plant operated by untrained persons Electrical Safety Regulation 2002 – Schedule 2 – Part 1
  - E_d horizontal clearance that allows for out-of-phase conductor swing between circuits under turbulent winds. AS/NZS 7000:2010 equation 3.1.

$$E_d = \frac{U}{150} + 0.6\sqrt{\frac{B_1 + C_1}{sin\emptyset_1}}$$

  - D_C circuit separation for in-step structure alignment
  - D_C circuit separation for in-step structure alignment
  - ϕ_1, ϕ_2 conductor swing angle at 500 Pa transverse wind pressure - assume ϕ_2 = 40° (large conductor – low swing angle) (insulator swing angle assumed to be the same)

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- U maximum voltage difference between the two circuits (kV) $U = \frac{V_1+V_2}{\sqrt{3}} = \frac{2V}{\sqrt{3}}$ for the worst case (60° phase shift)
- V_1, V_2 phase-to-phase r.m.s. voltage of circuit 1 and 2 (kV)
- V maximum voltage of the two circuits – max(V_1,V_2)

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7 MAINTENANCE REQUIREMENTS

7.1 STRUCTURE HEIGHT LIMITATIONS

Ergon EWP vehicles suitable for live line work are typically

- 6x4 (6 wheels with 4 driven)
- height to the floor of the bucket 16.5 to 21.5m
- basket safe working load 325kg

55m EWPs that are rated to 500kV are available for hire in Queensland. The standard subtransmission structures are high reliability and will not normally require maintenance for 20 years or more. So no structure height restriction shall be imposed upon the design of new lines. Hiring EWPs is considered to be the appropriate maintenance response.

Subtransmission structures with subsidiary circuits shall have the upper subsidiary conductor no higher than 20m above ground.

7.2 CLIMBING REQUIREMENTS

Climbing provision shall be made on all structures. Where stepbolts are used, ferrules shall be provided but the stepbolts do not have to be installed. Stepbolts shall be fitted where

- structures do not have all weather access
- the line cannot be de-energised (no alternative supply)

Climbing aids shall commence from the top of the extension ladder (6 to 7m) to 1.2 to 1.5m from the top of the structure.

Maintenance Type		EWP access to the structure	No EWP access during inclement weather	No EWP access at any time
Corrective or preventative	Line can be de-energised anytime or during light loads	EWP dead (stepbolts may be omitted)	EWP dead (postpone maintenance)	Manual dead
Corrective or preventative	Line cannot be de-energised	EWP live	EWP live (postpone maintenance)	Manual live
Emergency	Line de-energised due to sustained fault	EWP dead	EWP dead (access) Manual dead (no access)	Manual dead

Table 7.2 – Maintenance Strategy

Legend

EWP live – live maintenance (stick method) from an EWP

EWP dead – maintenance from an EWP (de-energised/dead)

Manual live – live maintenance (stick method) from the structure – manual climbing

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Manual dead – maintenance from the structure with the line de-energised – manual climbing

Structures shall be designed to facilitate live stick working from an EWP where there is no alternative means of supplying the electrical demand. Single circuit delta structures in suburbia shall be fitted with the two phases on the kerb side for ease of access. For an EWP with insulated boom and basket, the minimum horizontal phase to phase clearance at 66kV is 1200 (basket width) + 2 x 600 (MAD) = 2400mm. At 132kV the minimum horizontal phase to phase clearance is 1200 (basket width) + 2 x 1200 (MAD) = 3600mm. Where a structure is inaccessible to an EWP it shall be live climbable.

The area operations staff will usually be the first to respond to an emergency. The limited EWP height may increase the time to restore service but it is also likely that spares will not be on hand and tools inadequately rated.

7.2.1 Subsidiary Circuits

Where subsidiary circuits (up to 33kV) are added, climbing through the live subsidiary is generally not possible. Stepbolts should only be fitted above 1500mm from the top subsidiary conductor and none below the subsidiary. This will allow manual live climbing out of an EWP if necessary.

The minimum vertical separation between a subsidiary circuit (up to 33kV) and a 66kV super circuit is 450 (33kV MAD) + 1000 (basket height) + 350 (head height) + 600 (66kV MAD) = 2400mm.

Live work above an energised subsidiary is permissible, however dead work (under access permit) above an energised subsidiary is not. However dead work on a subsidiary circuit with an energised super-circuit is permissible.

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8 ELECTRICAL DESIGN

8.1 INSULATION

Insulation coordination shall be in accordance with AS1824.

Ergon Energy utilises the following insulation arrangements (on conductive structures):

Line Type	Insulation Arrangement	Creepage Distance (mm)
66kV Suspension Strings	5x70kN Glass Discs With Zinc Sleeves and W Clips	5x320=1600
66kV Strain Strings[1] **(Dependant on conductor size)**	6x70kN Glass Discs With Zinc Sleeves and W Clips	6x320=1920
	6x125kN Porcelain Discs With Zinc Sleeves and R Clips	6x292=1752
66kV Bridging Strings	5x70kN Glass Discs With Zinc Sleeves and W Clips	5x320=1600
	Ceramic Post Insulator	1800
66kV Line Post Insulators	Silicone Line Post Insulator	2354
132kV Suspension Strings	9x70kN Glass Discs With Zinc Sleeves and W Clips	9x320=2880
132kV Strain Strings[1]	10x125kN Porcelain Discs With Zinc Sleeves and R Clips	10x292=2920
132kV Bridging Strings	9x70kN Glass Discs With Zinc Sleeves and W Clips	9x320=2880
132kV Line Post Insulators	Silicone Line Post Insulator	3736

Note 1: Disc insulator strength capacity cannot be varied without the express approval from Ergon Energy

Note 2: The quantity of insulator discs shown in the above table are the minimum requirement for each line type. Additional creepage is required for heavy pollution levels.

[1]For landing spans: Termination strings on substation landing spans should contain an extra disc or equivalent

Table 8.1 – Insulation per line type.

Standard insulator assemblies are detailed in the Ergon Energy Sub-transmission Construction Manual, and shall be used unless otherwise negotiated. It remains the responsibility of the designer to notify Ergon Energy if the Standard assemblies are not suitable for use. Requests to use alternate equivalent products should be submitted to the Manager Engineering Line Design Standards however, Ergon Energy reserves the right to refuse such requests.

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Contaminated environments require insulator selection based on the surface creepage distance as recommended in AS4436 Table 2. These specific creepage distances are based on testing done on ceramic insulation. These same values are also used for composite insulation, however silicone rubber has superior flashover performance in contaminated environments. Silicone has the unique ability to impart hydrophobicity to the contaminated layer due to the migration of low molecular weight silicone polymer molecules into the contaminate.

Insulation shall be co-ordinated such that strain assemblies have higher levels of insulation than bridging, suspension and post insulator assemblies.

Disc insulators shall be placed such that the sheds do not collect water or debris, i.e. discs may need to be inverted on landing spans.

Air break switches should also have higher levels of insulation (impulse withstand voltage) because of switching surges and proximity of the switching operator.

Wherever possible, disc insulators shall be used in preference to synthetic long rods, due to their superior lifespan and the susceptibility of synthetic insulators to wildlife attack.

8.2 CONDUCTORS

Standard conductors are provided in the table below with the applicable voltages. There are many in-service lines built over the last 60 years that utilise conductors other than these. If modifications are required to these lines, an assessment with the Asset Owner is required to determine the conductor to be used.

No new lines shall utilise HDBC. No new line shall utilise AAC where the vibration catenary constant is greater than 1000m. ACSR shall only be considered where

- the line is located in a cyclonic region (to resist severance from flying debris)
- there is a high fire risk – especially on ridges (annealing of aluminium)
- the tension is high enough to straighten kinks (vibration catenary constant greater than 1000m)

The fire risk may be assessed at http://www.ruralfire.qld.gov.au/Bushfire%20Planning/

All ACSR conductors shall be greased.

The selection of conductor type shall be based on the rating, spanning requirements, land use along the line, cyclonic region, cost, and pollution levels.

Construction	Conductor	Diameter (mm)	OHEW	33 /66kV	110 /132kV
SC	7/2.75 SC/AC	8.25	Y	N	N
ACSR	Sultana	9.0	Y	N	N
	Banana	11.3	Y	N	N
	Cherry	14.3	Y	Y	N
	Grape	17.5	N	Y	Y
	Lime	24.5	N	Y***	Y***
AAAC	Iodine	14.3	N	Y**	N

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	Neon	18.8	N	Y	Y
	Nitrogen	21.0	N	Y	Y
	Oxygen	23.8	N	Y	Y
	Selenium	29.3	N	Y***	Y***
	Sulphur	33.8	N	Y***	Y***

Table 8.2.1 – Sub-Transmission Conductors

1. *Where conditions warrant, e.g. high pollution levels, the equivalent ACSR/AC conductor may be used instead of the ACSR/GZ conductor listed.
2. ** in rural applications Iodine conductor should be avoided due to swing problems encountered due to its low weight to diameter ratio.
3. ***Ergon Energy Standard Structure Types do not support these conductors.

Minimum single wire conductor sizes for corona are:

Nominal Voltage	Min. Phase – Phase Separation (m)	Min. Conductor Diameter (Dry and weathered) (mm)	Min. Conductor Diameter (Wet) (mm)
33kV	1.0 & 1.5	2.0 & 1.8	7.5 & 7
66kV	1.5 & 2.0	5.4 & 5.0	19 & 17.5
132kV	3.2	12.5	42
220kV	5.0	23.1	bundle

Table 8.2.2 – Sub-transmission voltage phase separation and conductor diameters.

8.3 ELECTRICAL CLEARANCES – INTERNAL

Internal clearances are confined to circuits attached to the structure and located at the structure or in the span. They exclude clearances to the ground or clearances to parallel power lines or obstacles.

8.3.1 Climbing Clearances

If a structure is not designed to be climbed with the conductors energised, then no safe climbing clearance to the conductors is required since they are de-energised. However live-line maintenance from an EWP may be possible.

For live climbing for inspection or maintenance refer to clause 3.5.2 of AS/NZS7000.

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8.3.2 Insulator Swing

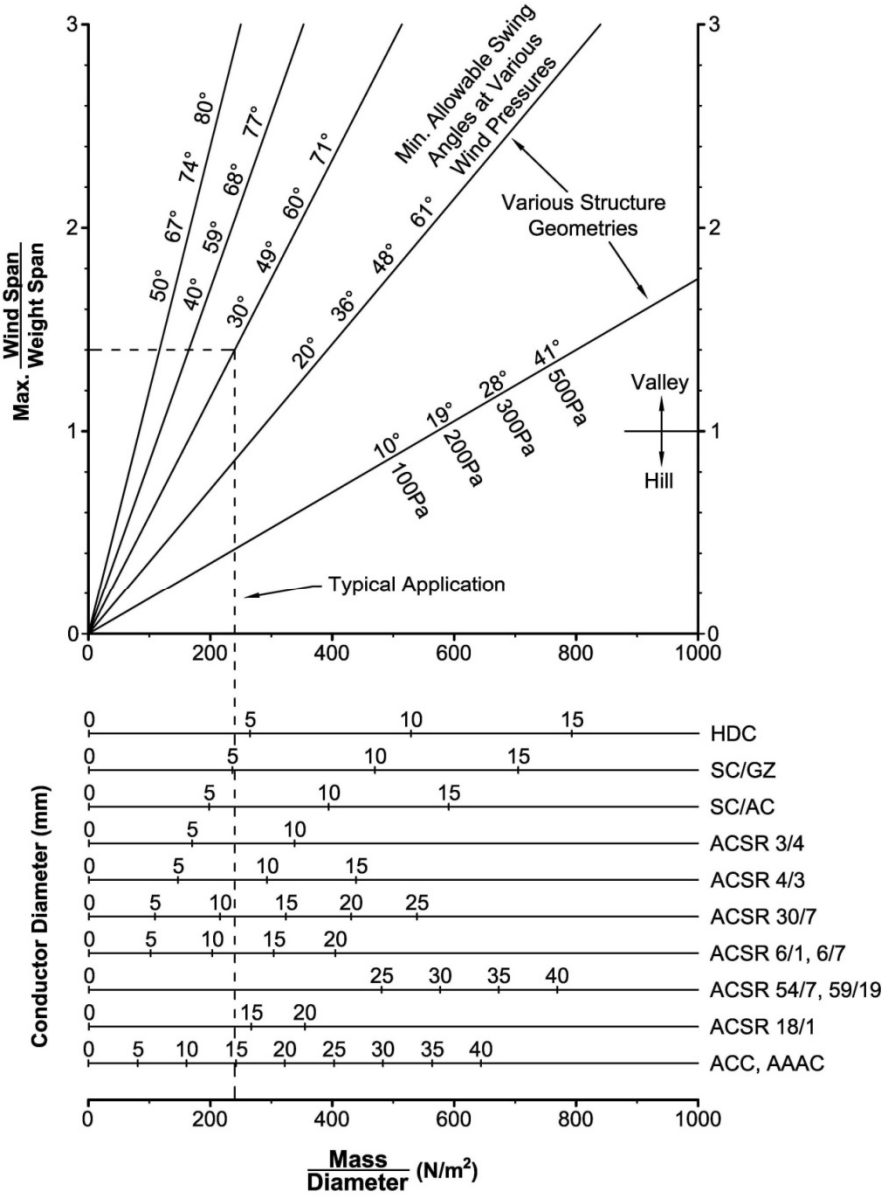

Figure 8.3.2 – Wind Span to Weight Span Ratios for Various Conductors and Structure Geometries (0° line deviation angle)

Suspension insulators require sufficient conductor weight to limit their swing under transverse winds. The allowable swing angle is determined by electrical clearance requirements. If the weight of the insulator string is ignored and there is no deviation of line direction, then the insulator swing angle can be calculated for various wind pressures.

- $\emptyset_2 = \tan^{-1}\left(\frac{P_2}{P_1}\tan\emptyset_1\right)$
- ϕ_1=maximum allowable insulator swing from vertical under P_1
- ϕ_2=minimum required insulator swing from vertical under P_2
- P_1=transverse wind pressure 1

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- P_2 =transverse wind pressure 2

For example, from figure 7.3.2 above, a maximum allowable swing angle of 30° at 100Pa wind requires a minimum allowable swing angle 71° at 500Pa. Conversely a maximum allowable swing angle of 71° at 500Pa wind requires a minimum allowable swing angle 30° at 100Pa. This allows the limitation of the structure geometry (used where there is no line deviation) to be readily assessed.

The typical application curve in the above diagram is plotted for a specific structure geometry (30° swing at 100Pa). If this structure is placed in a valley where the wind-span to weight-span ratio is 1.4, then the layout would work for AAAC conductors greater than 15mm diameter but would not work for diameters less than 15mm. Alternatively a 15mm AAAC conductor used with this structure will permit layout wind-span to weight-span ratios of less than 1.4. To layout using ratios greater than 1.4 requires a structure geometry with more liberal swing angles.

Application

It is proposed to use a suspension structure for laying out a line over undulating terrain with an average ground slope of 3.5% over the span length. (This gradient is calculated based on a fixed structure height. In reality, a steeper gradient can be accommodated by varying the structure heights.) This corresponds to a maximum wind span to weight span ratio of 1.4. The proposed pole top geometry has the following minimum permissible swing angles that satisfy the electrical requirements for its nominal insulation: 30° at 100 Pa; 60° at 300 Pa and 71° at 500 Pa. Is the structure suitable for Hydrogen (AAAC 13.5 mm diameter) or its electrical equivalent, Cherry (6/7 ACSR 14.3 mm)? Figure 7.3.2 shows that the structure geometry is unsuitable for Hydrogen. A minimum diameter of 15 mm is required for AAAC. However the geometry is suitable for Cherry (minimum of 12 mm required for 6/1 and 6/7 ACSR). If Hydrogen is used with this structure then the terrain gradient would have to be shallower. Alternatively, a structure with more generous insulator swing angles would be required.

8.3.3 Midspan Separation

Refer AS/NZS7000 CL 3.7.3. for midspan separation formulae and application.

8.4 TRANSPOSITIONS

Phase conductors are transposed on long transmission lines to balance the mutual impedances and reduce the load current unbalance. Unbalanced phase currents result in zero and negative sequence currents that increase power losses. In a fully transposed line, each phase is changed so that it occupies each geometric position for an equal length of the line. In this document, transposition shall refer to the rolling of the phase conductors.

The ideal phase configuration is an equilateral triangle. For a delta phase configuration, it is not necessary to transpose the phases provided that the minimum phase-to-phase separation is within 25% of the maximum phase-to-phase separation. Transpositions of delta configurations are easily achieved (refer to drawing below) and incur minimum cost penalties

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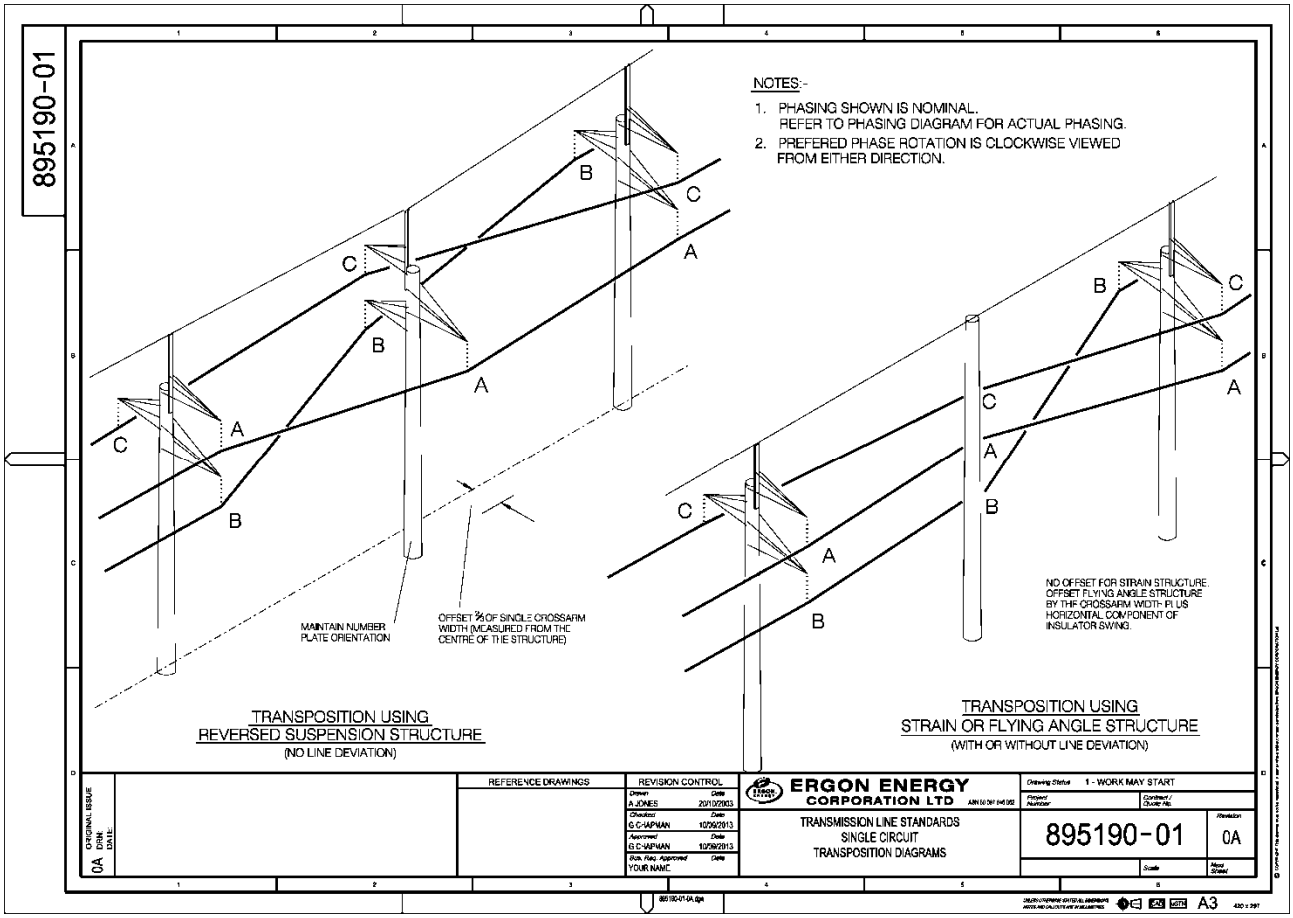

Figure 8.4.1 – Transposition Diagram for Sub-transmission Single Circuit Lines.

Vertical or horizontal phase configurations are more difficult to transpose and require special structures. The cost of the difference in losses between a transposed and untransposed line is approximately 20 times more for the horizontal (or vertical) configuration versus the delta configuration.

Route Length	Number of Transpositions	Number of Different Phasing Sections
<25 km	Nil	1
25 to 75 km	1	2
>75 km	2	3

Table 8.4 – Guideline for Transpositions

The route length can be divided into phasing sections as indicated in the following diagram. These transpositions achieve complete impedance balance. If it is impractical to achieve the ideal transposition locations then section differences up to 15% of the route length are acceptable. A single transposition improves the impedance balance but is incomplete

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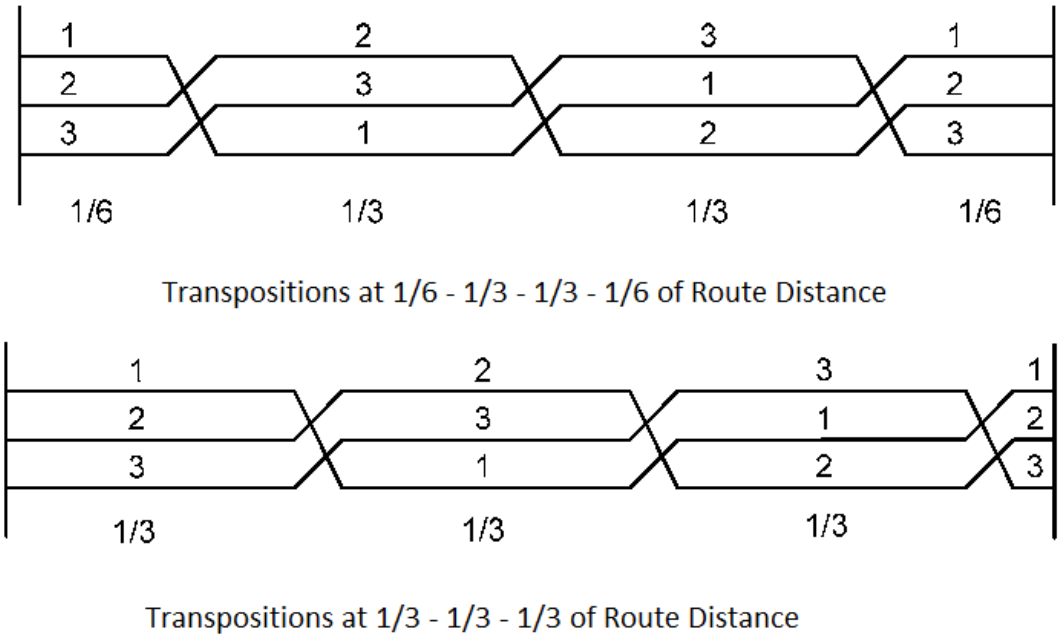

Figure 8.4.2 – Phasing Section Options

8.5 EARTHING

8.5.1 Earthing Metalwork

For a conductive structure, all metalwork that forms part of the electrical circuit during an earth fault shall be positively earthed to carry its share of the fault current. For conductive and non-conductive structures, all metalwork within 2.4m of the ground surface level shall be positively earthed but does not require full fault current rating unless it is an earth downlead or a power cable guard. Other metalwork may be inherently earthed (such as step bolts on conductive poles) or unearthed (such as step bolts on non-conductive poles).

Item	Capacity $(kA)^2.s$	Assumed Area (mm^2)	Initial & Final Temp. (°C)
1 x M12 S/S bolt	41.5	92.6	45 - 870
2 x M12 S/S bolt	166	185.2	45 - 870
1 x M16 S/S bolt	140	169.7	45 - 870
2 x M16 S/S bolt	560	339.4	45 - 870
1 x 35mm^2 copper wire	96	35	45 - 850
2 x 35mm^2 copper wire	384	70	45 - 850
1 x 70mm^2 copper wire	384	70	45 - 850
1 x 50 x 5 galv. steel (22 hole)	82	140	45 - 400
2 x 75 x 5 galv. steel (22 hole)	294	265	45 - 400

Table - Fault Capacities for Earthing Equipment

ENA EG1:2006 section 10.2.2 provides further guidance regarding conductor sizing

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8.5.2 Footing Resistance

Structures shall be designed so that an earthing resistance of 10 ohms is achieved at each structure along the line and 5 ohms where structures are within 2km of a substation (unless otherwise detailed in the scope), these readings shall be taken before the OHEW is connected. Additional earthing may need to be installed to meet this requirement.

8.5.3 Earthing Electrodes

Copper clad steel earth rods shall be used unless otherwise directed. Stainless steel clad earth rods may be used

- for hard driving conditions (stainless steel is more abrasive resistant than copper)
- in tidal lands, salt marshes and land fill consisting of coke ash or coke breeze
- where galvanic corrosion will occur with copper e.g. direct buried galvanised steel poles

Ground rods are ineffective when placed closer to a conductive pole than the depth of the pole in the ground.

8.5.4 Voltage Gradient Control

Grading rings shall be nominated on all poles with OHEW that are accessible to the public in urban areas. A risk assessment shall be undertaken to determine if poles on rural lines require grading rings.

8.5.5 Overhead Earthwire

The OHEW shall be sized to carry (without damage) the designated earth fault currents that could be reasonably anticipated over the life of the line. For a line with reclosers, the earthwire shall survive the initial fault plus one reclose onto the fault. In the absence of quantitative data, the following assumptions shall be:

- the arc resistance at the fault is 10 ohms
- the first span of OHEW outside the substation shall take 100% of the fault current (this usually requires two OHEWs, however two may also be required for shielding from lightning)
- the first 2 km of OHEW outside a substation (source or destination) shall handle 80% of the earth fault current
- the remainder of the OHEW shall survive 50% of the fault current

OHEW shall have a steel content so that any failure of protective equipment that causes annealing of aluminium stands will not allow the OHEW to permanently sag into the phase conductors. Examples include OPGW, ACSR or SC construction. The minimum outer strand size shall be 2.75mm for steel and 3.0mm for aluminium to reduce the likelihood of strand fusion from a direct lightning strike.

8.6 LIGHTNING

Where Standard Ergon Energy structures are not able to be used, the structure geometry shall be designed to achieve the lightning performance better than 2 outages per 100km per year.

Insulation coordination at cable termination structures shall be designed in accordance with AS1824.2 Section 6.

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8.7 COMMUNICATION CABLES

The standard communications cables for lines shall be OPGW. Ergon Energy uses special designs for these, being:

- 11.4mm (24 fibre)
- 14.0mm (24 and 48 fibre)
- 17.7mm (24 fibre)

Refer Annex B for OPGW specifications.

New lines shall typically utilise OPGW as an earthwire and communication path. Where existing lines and structures are modified for communications, it may be possible to under sling OPGW where clearances and structural capacities permit. Do not use standard polyethylene ADSS where the space potential is greater than 12kV(rms) due to the dry band arcing failure mechanism. Special track-resistant jackets are required for space potentials up to 20kV(rms) or high pollution areas.

8.8 ELECTRIC AND MAGNETIC FIELDS

The designer shall undertake EMF calculations for submission to Ergon Energy's Environmental Projects engineer. Designs shall be in accordance with ES000904R104 – EMF Guideline for New Infrastructure.

8.9 INDUCTION

Magnetic fields, caused by line current under load or fault, can be coupled with adjacent conductive and insulated circuits to produce hazardous voltages. The risk and mitigation measures shall be assessed in accordance with AS/NZS 4853 or HB 102. Such circuits are metallic pipelines, other power lines, fences (timber posts), long agricultural trellises, conveyor belts, copper telecommunication lines.

8.10 EARTH POTENTIAL RISE

Where it is impractical to eliminate the step and touch voltage hazard using the deterministic approach (AS/NZS 7000 clause 10.6.8.2), then AS/NZS 7000 allows for a risk based approach to earthing. Refer to AS/NZS 7000 section 10.5 for design requirements as well as Appendix U for the risk based process.

The proportion of the earth fault current that flows to ground via any structure with OHEW can be estimated from HB 331 section 17.8. The earth potential rise (EPR) at this structure is estimated from HB 331 section 17.9. The step voltage depends on the earth electrode geometry at this site. For a conductive structure with no additional earthing, the touch voltage is approximately 73% of the EPR. Values for other electrode geometries are given in Table 17.6. If the touch voltage falls below the criteria given in AS/NZS 7000 Figure 10.1 and the assumptions provided in Table 10.2 are valid, then no further analysis is required.

8.11 CORONA

From a design perspective, corona is not an issue at 66kV. At 132kV and above, conductor size and hardware fittings become important.

A conductor surface voltage gradient of 16kV peak per cm is generally accepted as a design criterion for sizing conductor; however corona losses will increase during wet weather.

9 STRUCTURAL LOADING

9.1 GENERAL

The mechanical and civil design must ensure that the line performance will comply with all relative National and State Legislation, that the line can be readily constructed and maintained using standard industry practices and tooling, and that routine maintenance can be affected 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.

The structural loads on lines shall be designed in accordance with AS/NZS 7000 and the following Ergon Energy requirements.

Where Ergon Energy Standard structures are used, the structural limit state design loads must be within the structure capacities given in Annex B.

9.2 WIND LOADS

Wind loads shall be calculated in accordance with AS/NZS 1170.2 – 2011, AS/NZS 7000 -2010 and the Building Code of Australia.

The following criteria shall apply as a minimum

- Wind region as per AS/NZS 1170.2

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.

- Regional wind V200 wind speed.
- Terrain category 2
- Shielding multiplier 1.0
- Height and topographic multiplier as encountered.
- Drag coefficient for conductor 1.0 (where standard Ergon conductors are used).

The drag coefficients for pole structures and steel work should be determined as per AS/NZS 1170.2.

A load factor of 1.2 shall be applied to the wind forces on the conductors and structures in cyclonic regions. Due to the geographic nature of the Ergon Energy network, there are higher concentrations of lines within cyclonic regions, where multiple failures are likely to occur, and there is a high probability of loss of life and damage as a result. The V200 wind pressures for non-cyclonic areas also remain in line with past design practices and have proven satisfactory in these regions.

Design wind pressures for conductors shall be determined as per AS/NZS 7000

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Refer Annex D for indicative wind pressures.

9.2.1 Substation Landing Spans

Higher wind pressures are generally used for landing spans entering substations and associated supporting structures, as these assets are designed to a higher importance level. These should be designed in accordance with SS-1-1.8 which requires:

- Cyclonic region C
- V2000
- Terrain category 2

The pressures used for structure electrical clearances (AS/NZS7000 clause 3.8.2) shall be the low wind, moderate wind and high wind weather cases given in 7.4.4.

9.3 CONDUCTOR LOADS

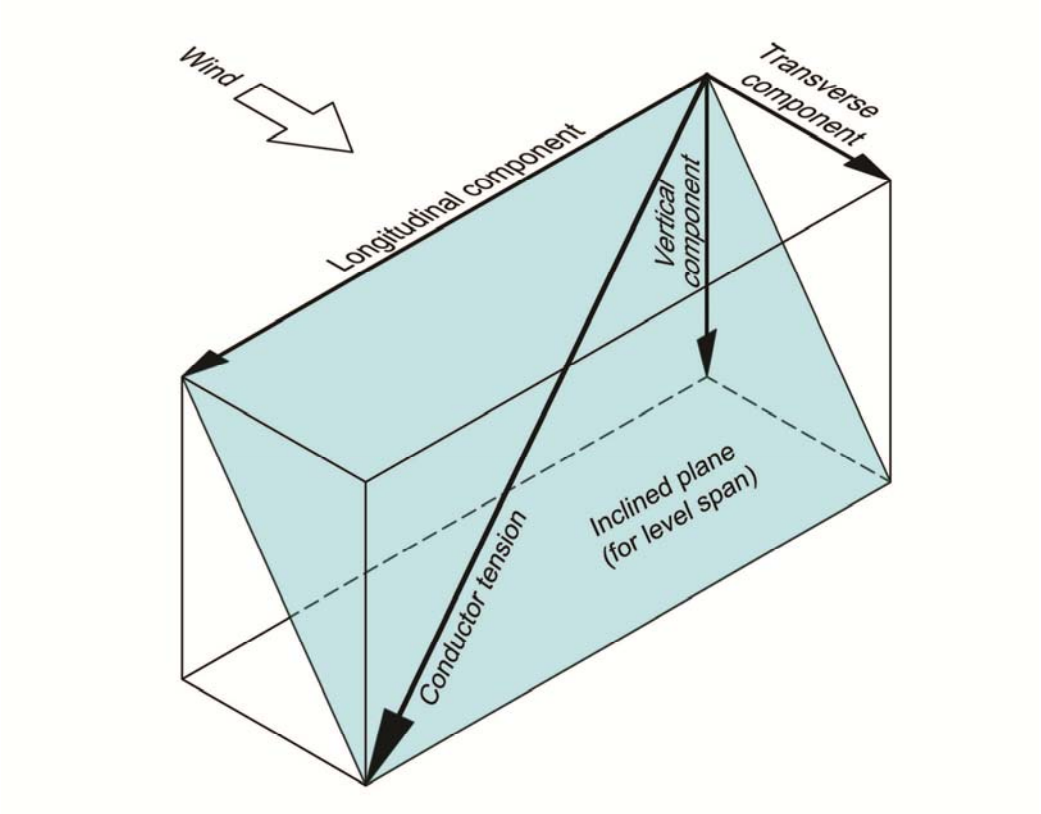

Figure 9.3 – Conductor Loads Relative to Direction of Span

The components of conductor tension (figure above) for each weather case (8.5) are calculated as

- Longitudinal tension component = horizontal tension derived via a tension change to the appropriate weather case with the TSRF applied to the wind pressure
- Transverse tension component = wind span x appropriate wind pressure x SRF x conductor diameter

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- Vertical tension component = weight span in the vertical plane x conductor weight. The wind pressure is reduced by the appropriate SRF.

Structure loads are applied relative to the structure axes, which will be different from the span axes for strain/termination structures. Refer to clause 27.4 of HB331:2012 to determine longitudinal, transverse and vertical structure loads.

Load Case	Weather Case -Wind	Longitudinal Tension (TSRF)	Transverse Tension (SRF)	Vertical Tension (SRF)
Strength limit (synoptic and downdraft)	"Ultimate" V_{200}	1.25	1.2 Region C 1.0 Region A & B	1.25 max. weight 0.0 no weight 1.25 max. uplift
Failure containment	"Failure Containment" 0.25 x V_{200}	1.25	1.0	1.25
Maintenance – intact loads	"Low Wind" 100 Pa	1.5 (TSRF = 1)	1.5 (SRF = 1)	1.5 (SRF = 1)
Maintenance – live loads	"Low Wind" 100 Pa	2.0 (TSRF = 1)	2.0 (SRF = 1)	2.0 (SRF = 1)

Table 9.3 - Conductor Load Factors

The TSRF results in lower wind pressures and thus tensions than those obtained using the SRF. When designing a new strain/termination structure, consideration shall be given to the fact that strain/termination structures may be used for single dead-end spans where the section length equals the wind span length and SRF equals TSRF.

9.4 SEISMIC CONDITIONS

Generally, transmission lines are not susceptible to damage from dynamic forces resulting from seismic activity. Non-standard structures with ancillary equipment such as transformers may experience negative impacts and these should be considered in accordance with AS1170.4

9.5 STANDARD WEATHER CASES

9.5.1 Weather Case

Many strength and serviceability criteria assume that the line is subjected to a given combination of wind, ice (or snow) and conductor temperature. Such a combination is called a "weather case".

All cable sag and tension calculations, and consequently all loads and clearance calculations, are done at designated weather cases. A table of weather cases is typically used for:

- Specifying the tension constraints
- Checking the strength of the structures
- Checking various geometric clearances (to ground, blowout, between phases, swings, galloping etc.)
- Checking ground wires and conductors tensions
- The weather case assumed to cause metallurgical creep on conductors
- The heavy load case which potentially causes permanent stretch of the cable

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- Displaying the cable at various temperatures

The weather cases required for producing sag tables are not tabulated.

Wind direction is required for structure strength calculations at line deviations. The wind direction for sag/tension calculations is assumed to be normal to the span and defined as blowing from the left or the right hand side.

9.5.2 Cable Condition (PLS CADD modelling)

Whenever a weather case is required then the cable condition and analysis method is also required. The cable conditions are:

Condition	Description
Initial	New cable is assumed to be in its *Initial* condition for the few hours that follow its installation.
Creep	Cable is in its final after *Creep* condition after it has been assumed exposed to a particular creep weather condition for a long period of time, Ergon Energy uses 10 years. The permanent elongation is predominately due to metallurgical creep. It is normally assumed that the weather case that causes creep consists of a no wind or ice condition at some average temperature. The “Creep” weather case given in 9.5.4 Queensland Weather Cases is used to determine the cable stress and subsequently the long term strain value to apply for the after creep condition. The same cable temperature shall be used in the creep prediction calculations used to define the “after creep” stress/strain curve.
Load	The final after *Load* condition assumes that the cable has been permanently stretched by a specified weather condition that causes large tensions. The permanent elongation is predominately due to strand settlement. For the linear elastic cable model, the Initial and After Load conditions are identical.
Max Sag	This is NOT a cable condition. It is used to display the maximum sag produced by either the *Creep* or the *Load* cable condition. The *Initial* cable condition will never produce the maximum sag.

Table 9.5.2 – Cable Conditions

9.5.3 Analysis Method

The type of analysis performed to generate the cable tensions are the Ruling Span (RS) and the Finite Element (FE) method.

With the ruling span (RS) method, the actual length of cable in each span is not used in the analysis, as tensions are based on the equivalent ruling span. The horizontal tensions in all the spans in the tension section are the same. This is the traditional method used for line design.

With the finite element (FE) method, the analysis is based on fixed unstressed lengths for each cable in each span. This method assumes that the horizontal tensions in all the spans in the tension section are the same at the reference sagging weather case and cable condition. This results in suspension insulators being plumb only for this sagging condition. The following actions will result in tension differences (longitudinal structure loads) in the tension section:

- changing the weather case or cable condition
- movement of a structure (longitudinally, transversely or vertically)
- changing the structure geometry or structure stiffness

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- adding or removing a structure
- adding a concentrated load in a span
- removing or adding a length of cable into a span

Therefore the following combinations of cable condition and analysis methods are available

- Initial RS
- Creep RS
- Load RS
- Initial FE
- Creep FE
- Load FE

The cable condition (Creep or Load) producing the largest sag for the specified weather case is displayed when the following “cable condition” is selected

- Max Sag RS
- Max Sag FE

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9.5.4 Queensland Weather Cases

Name	Temperature	Wind Pressure	Cable Condition	Usage
Cold	Daily mean minimum temperature of the coldest month. Refer to Figure 1 for typical values. Suitable value 15°C.	No wind.	Initial	(1)Serviceability limit state tension constraint whilst stringing new conductor. The cable tension shall be no greater than 1.25 times the vibration tension limit. (2) Weight span check.
Vibration	Average conductor temperature of the coldest month. In the absence of detailed data the average of the daily mean maximum temperature and the daily mean minimum temperature may be used. It is assumed that the ambient temperature and the conductor temperature are the same. Refer to Figure 2 for typical values. Suitable value 10°C.	No wind.	After creep	Fatigue limit state for tension constraint - AS/NZS 7000 Table Z1 therein defined as "everyday load". Used to limit fatigue damage due to Aeolian vibration. For OPGW a fatigue limit of 18% CBL shall apply. Also to determine the minimum amount of slack in short spans.
Creep	The average day/night cable temperature over its economic life. For heavily loaded feeders (e.g. from a generator) the cable temperature will be above the ambient temperature. Refer to Figure 3 for ambient temperatures. Suitable value 20°C.	No wind.	N/A	Weather case used to calculate the permanent stretch due to creep.
50C	50°C as specified in AS/NZS 7000 equation 3.1	No wind.	Max sag	Used to check mid-span conductor separation.

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Name	Temperature	Wind Pressure	Cable Condition	Usage
Hot Ambient	The hot ambient temperature used for calculating the maximum operating temperature of the cable. Refer to Figure 4 for trends. Also refer to: *Weather Parameter Analysis for Ergon Energy Overhead Line Ratings* http://esp/am/sd/dpc/ncu/Shared%20Documents/Weather%20Parameter%20Analysis%20for%20Ergon%20Energy%20Overhead%20Line%20Ratings%20V2.0%20Final.pdf	No wind.	Max sag	Used for calculating intercircuit clearances. Example upper circuit at maximum operating temperature coincident with the lower subsidiary circuit at the hot ambient temperature for maximum demand during summer. If the maximum demand is in winter then the lower subsidiary circuit may be at the winter evening temperature. ENA C(b)1-2006 required the subsidiary circuit to be at everyday temperature (Fig 10.4.2) but this is not required by AS/NZS 7000:2010 Fig 3.7.
Max Op Temp	Maximum operating cable temperature with rated current at hot ambient temperature and low coincident wind speed. Typical range 75 to 100°C.	No wind.	Max sag	Used to calculate ground clearances, weight spans and intercircuit clearances. The maximum operating temperature for a subsidiary circuit may differ from the primary circuit. Use Max Op Temp xxC and Max Op Temp yyC.
Low Wind	Coldest temperature for maintenance activities with coincident wind. Suitable value 15°C.	The wind pressure when maintenance activities such as live structure climbing are ceased. Typical deterministic value 100Pa (46km/hr).	After creep	(1) Serviceability tension constraint where the cable tension is limited to 40% of its CBL to allow for maintenance activities that affect cable tensions. (2) Used to calculate suspension insulator swing angles and electrical clearances for live line climbing and working. A warmer temperature will produce tighter clearances for flying angle structures with the wind opposing the line deviation but these structures are in the minority.

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Name	Temperature	Wind Pressure	Cable Condition	Usage
Moderate Wind	Temperature during a thunder storm event. Suitable value 20°C	The transverse wind pressure assumed to occur (with low probability) simultaneously with a lightning event. Typical deterministic range 100Pa (46km/hr) to 300Pa (80km/hr).	Max sag	Used to calculate suspension insulator swing angles and electrical clearances to withstand a lightning impulse (or back flashover for properly shielded lines). Clearances based on AS/NZS 7000 Table 3.4.
High Wind	Low temperature during a high wind event. Suitable value 25°C	The infrequent transverse wind pressure that could lead to a power frequency flashover. Typical deterministic value 500Pa (104km/hr).	Max sag	Used to calculate suspension insulator swing angles and electrical clearances to withstand a power frequency flashover.
Blowout	High temperature during a high wind event. Suitable value 35°C	The infrequent transverse wind pressure that could blow conductors close to adjacent buildings. Typical deterministic value 500Pa (104km/hr). #1	Max sag	Calculate midspan swing to buildings. Clearances based on AS/NZS 7000 Table 3.8.
Failure Containment	Cable temperature of the “Creep” weather case.	0.25 times the ultimate wind pressure.	Max sag	Used to calculate the longitudinal loads resulting from a broken cable. AS/NZS 7000 clause 7.2.7.1.
Ultimate Wind	Coincident conductor temperature at the ultimate wind speed. Tropical cyclones and thunder storms usually occur in summer. Suitable value 25°C.	Ultimate 3 sec. wind pressure when factored for return period, wind region, terrain category, height, wind span, shielding and topography. PLS factors being Weather Load Factor = 1 Wind Ht Adjust Model = None Wire Gust Response Factor = 1	After load.	(1) Strength limit state tension constraint. The strength reduction factor (AS/NZS 7000 Table 6.2) shall be no greater than 0.7 for conductor, 0.5 for OPGW; 0.4 for LV ABC and ADSS. (2) Weather case used to calculate the permanent stretch due to load. For the linear elastic cable model there is no permanent stretch.

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Table 9.5.4 – Queensland Weather Cases

Notes

#1 – The ruling span (RS) analysis method assumes that the wind blows uniformly in every span of the section and that the tension is the same in each span. More realistically the wind will have a narrow gust front that will produce much greater blowout when suspension insulators are used. These swing longitudinally into the higher pressure zone producing more slack. The effect of this increased blowout should be considered with regards to the required horizontal clearances.

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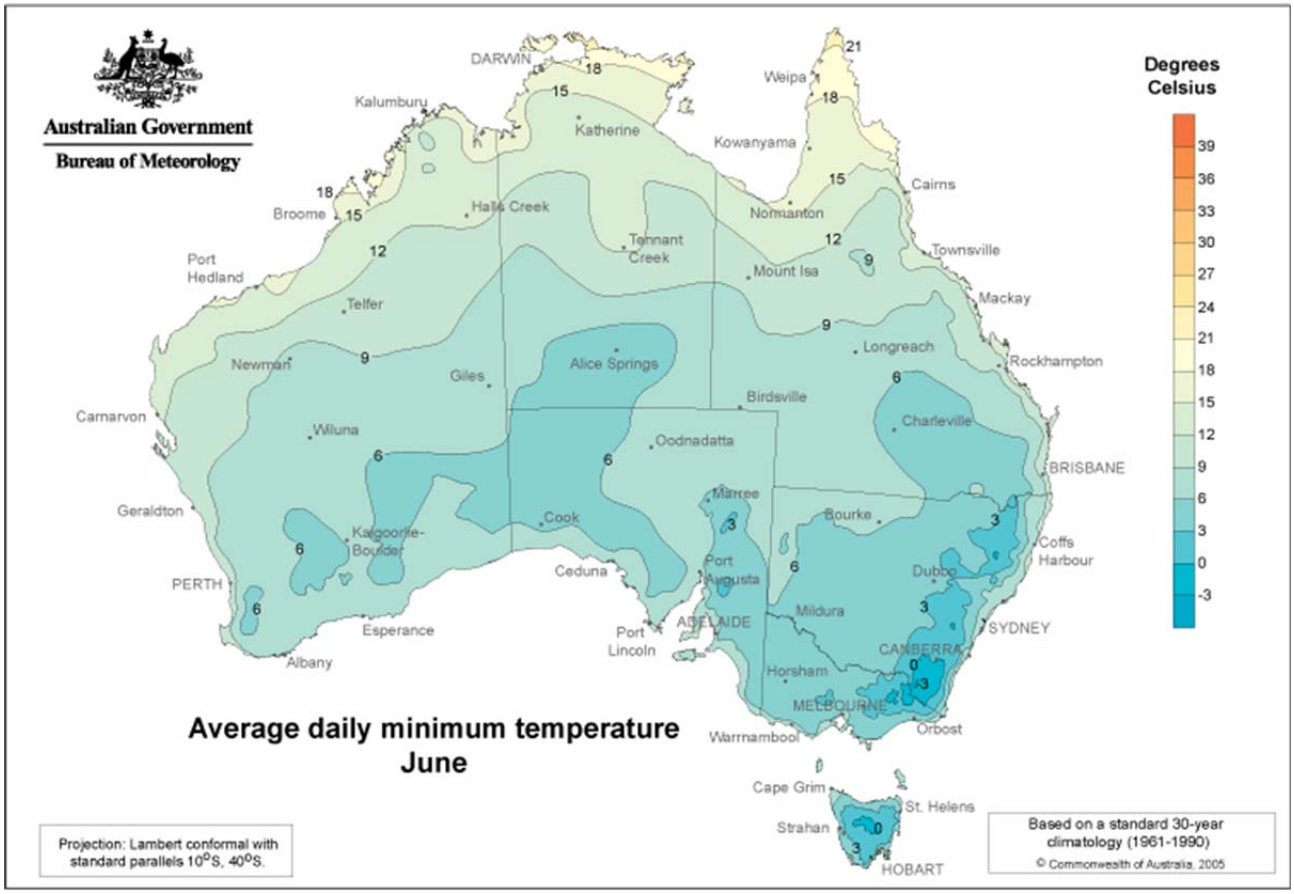

Figure 9.5.4.1 - Cold Weather Case

http://www.bom.gov.au/jsp/ncc/climate_averages/temperature/index.jsp?maptype=3&period=jun

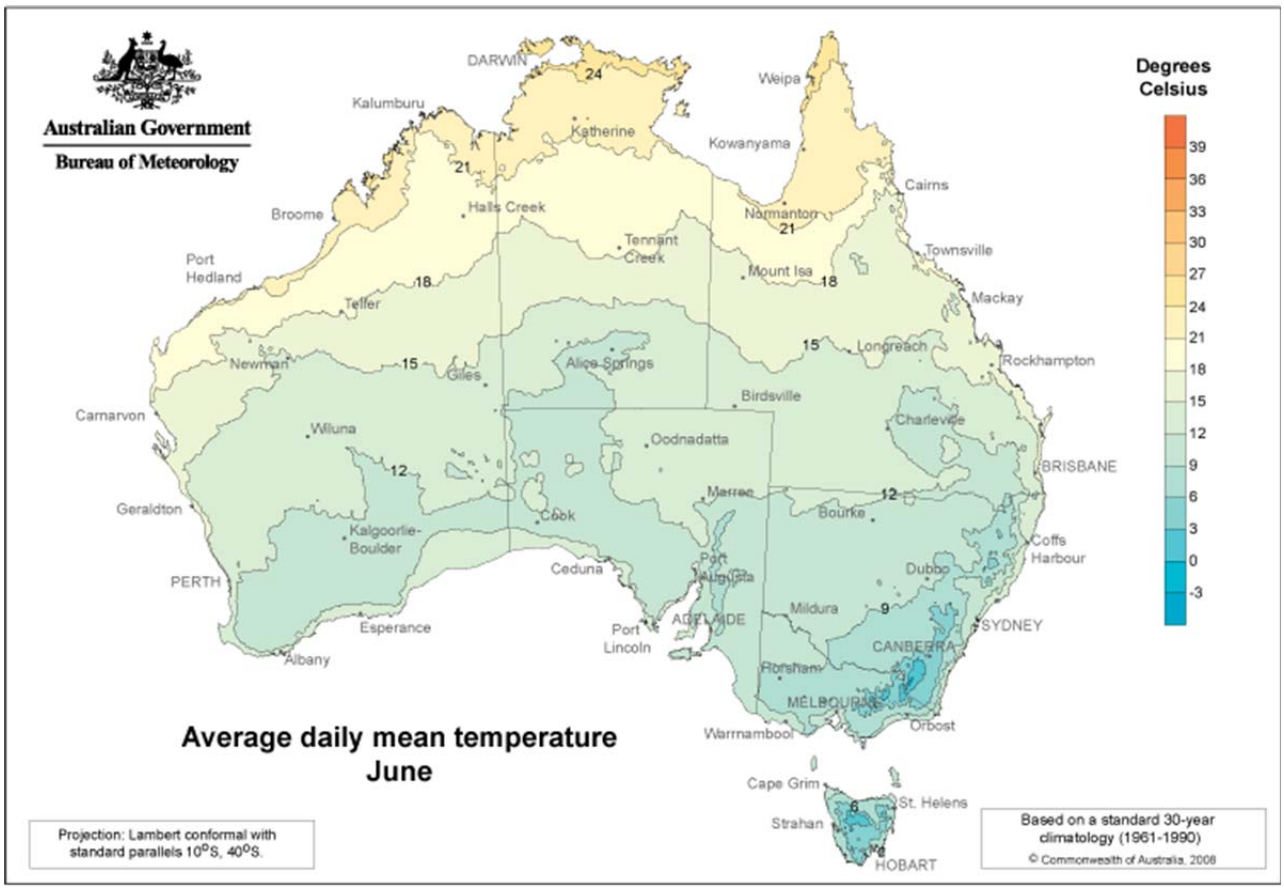

Figure 9.5.4.2 - Vibration Weather Case
http://www.bom.gov.au/jsp/ncc/climate_averages/temperature/index.jsp?maptype=6&period=jun

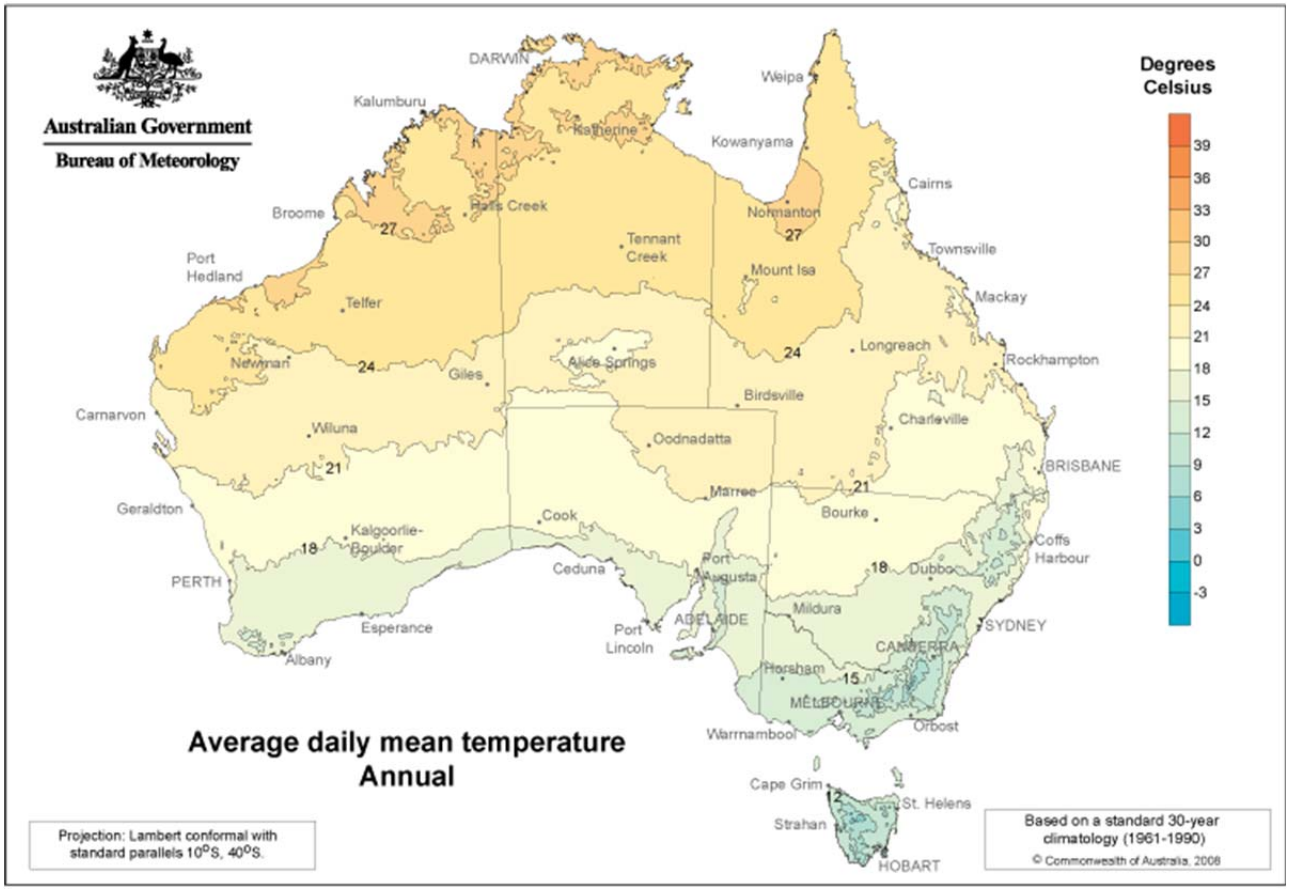

Figure 9.5.4.3 - Everyday Ambient Temperature

Everyday weather case temperature will be higher for heavily loaded lines.

http://www.bom.gov.au/jsp/ncc/climate_averages/temperature/index.jsp?maptype=6&period=an

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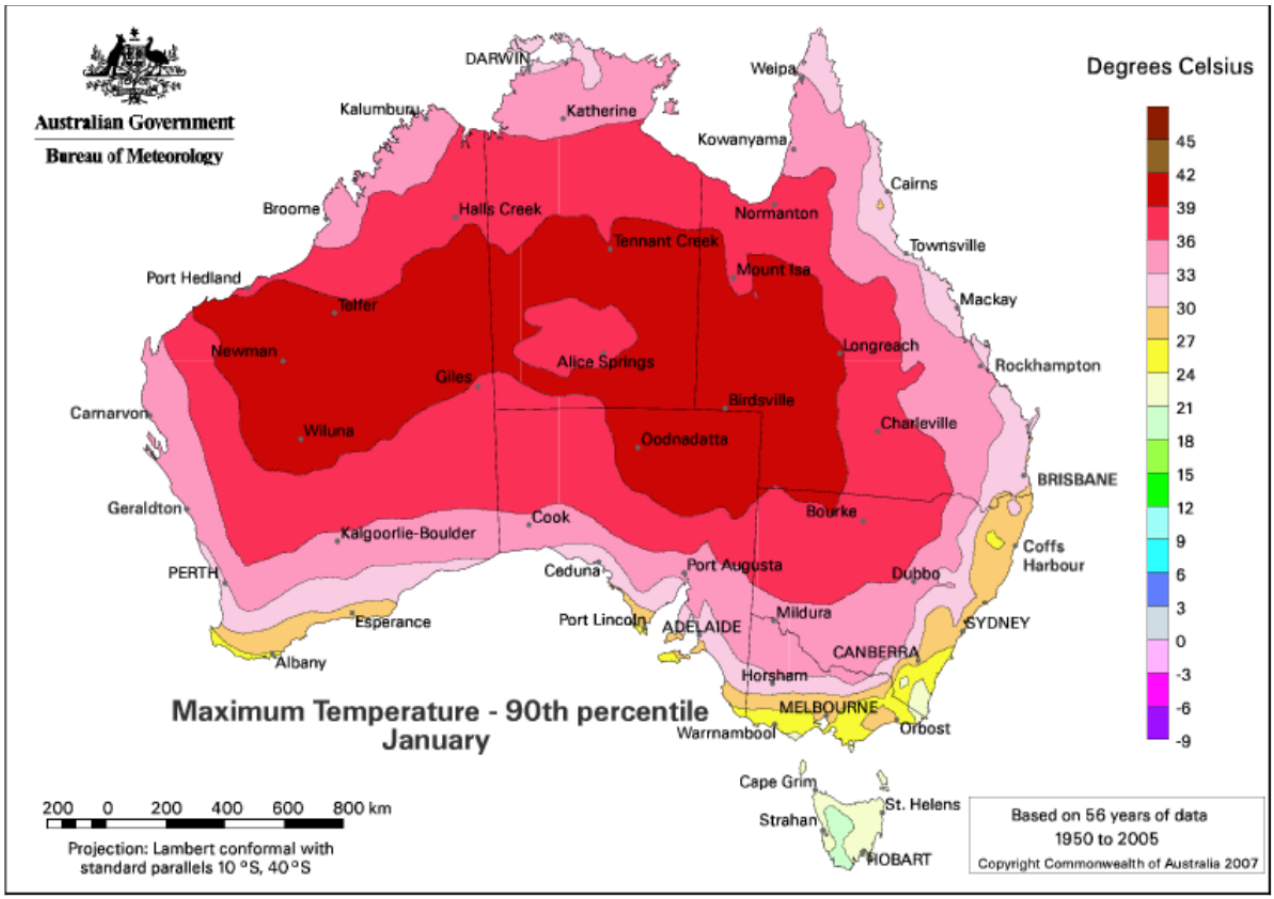

Figure 9.5.4.4 Hot Ambient Weather Case
http://www.bom.gov.au/jsp/ncc/climate_averages/temperature-percentiles/index.jsp?prodtype=1&maptype=1&period=January&product=90th

9.6 CONDUCTOR TENSIONS

9.6.1 Slack Spans

No ruling span of earthwire shall have less than 70mm of slack and no ruling span of conductor shall have less than 100mm of slack. This will provide an earthwire sag to conductor sag ratio of 84%. The conductor slack allows the load to be released off strain insulators while they are being replaced without over-tensioning the conductor. This slack is to be applied under the vibration weather case. The following catenary constants are tabulated for various ruling spans.

Ruling Span (m)	Maximum Earthwire Catenary Constant (70mm slack) (m)	Maximum Conductor Catenary Constant (100mm slack) (m)
10	24	20
15	45	38
20	69	58
25	96	81
30	127	106
35	160	134
40	195	163
45	233	195

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Ruling Span (m)	Maximum Earthwire Catenary Constant (70mm slack) (m)	Maximum Conductor Catenary Constant (100mm slack) (m)
50	273	228
55	315	263
60	359	300
65	404	338
70	452	378
75	501	419
80	552	462
85	605	506
90	659	551
95	714	598
100	772	645
110	890	745
120	1014	849
130	1144	957
140	1278	1069
150	1417	1186
160	1561	1306
170	1710	1431
180	1863	1559
190	2021	1691
200	2182	1826

Table 9.6.1 – Maximum Catenaries for Slack Spans

To determine the ruling span tension:

Where H = maximum ruling span tension (N)

C = maximum catenary constant from the table above (m)

w = cable weight (N/m)

This constraint cannot be automated in PLS and manual intervention is required for each ruling span section. It is a method of maintaining slack tensions for short span lengths. There is very little additional structure height required to implement this design rule. The vibration tension constraint eventually governs for larger ruling span lengths.

For larger ruling spans where the slack rule does not apply, the earthwire tensions are calculated based on an earthwire sag to conductor sag ratio of approximately 84%. This provides a greater shielding angle from the earthwire to the conductor at midspan without wind.

Where:

CE = earthwire catenary constant (m)

CC = conductor catenary constant (m)

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HE = earthwire tension (N)

HC = conductor tension (N)

wE = earthwire weight (N/m)

wC = conductor weight (N/m)

PLS gives the option to sag the cable using tensions or catenary constants. This option is in the "Preferences" menu.

9.6.2 Slack Dead-end Spans

For slack dead-end spans the weight of the strain insulator is significant. Excessive sag of the stain insulator may create electrical clearance issues on poles and be aesthetically displeasing.

Figure A provides guidance for slack spans strung with 100mm of slack and using normal disc insulators (4 kg each). The curves are plotted for level spans where there is a difference of 10° between the take-off angle of the strain string (assumed rigid) and the conductor take-off angle.

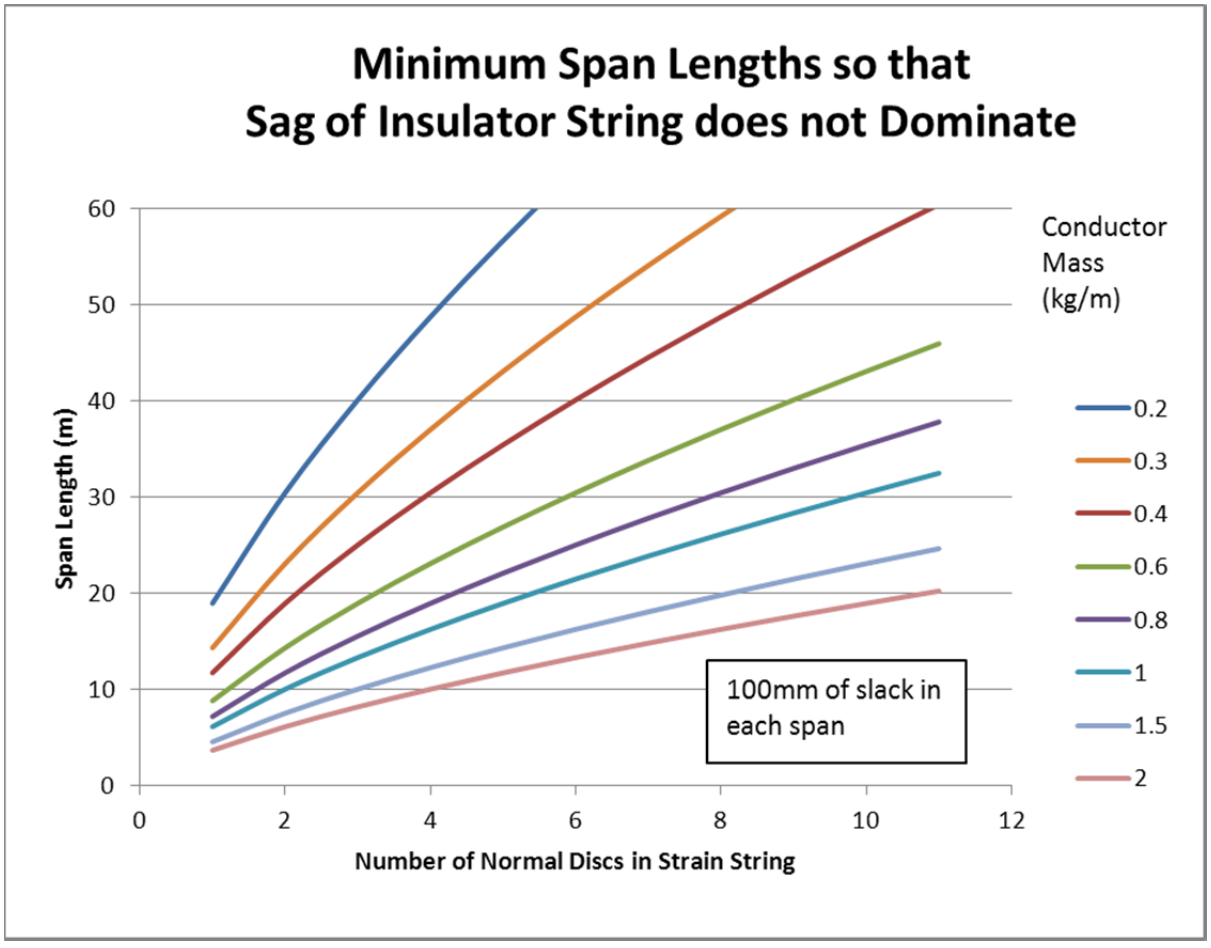

Figure 9.6.2.1 – Minimum span lengths for various conductors and voltages (number of discs)

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Composite longrods are frequently used to overcome the excessive sag caused by discs. The curves in Figure B are based on a 5° difference between the take-off angle of the longrod and the conductor take-off angle. The longrod is assumed to have a mass of 3.5 kg/m (22mm fibreglass core).

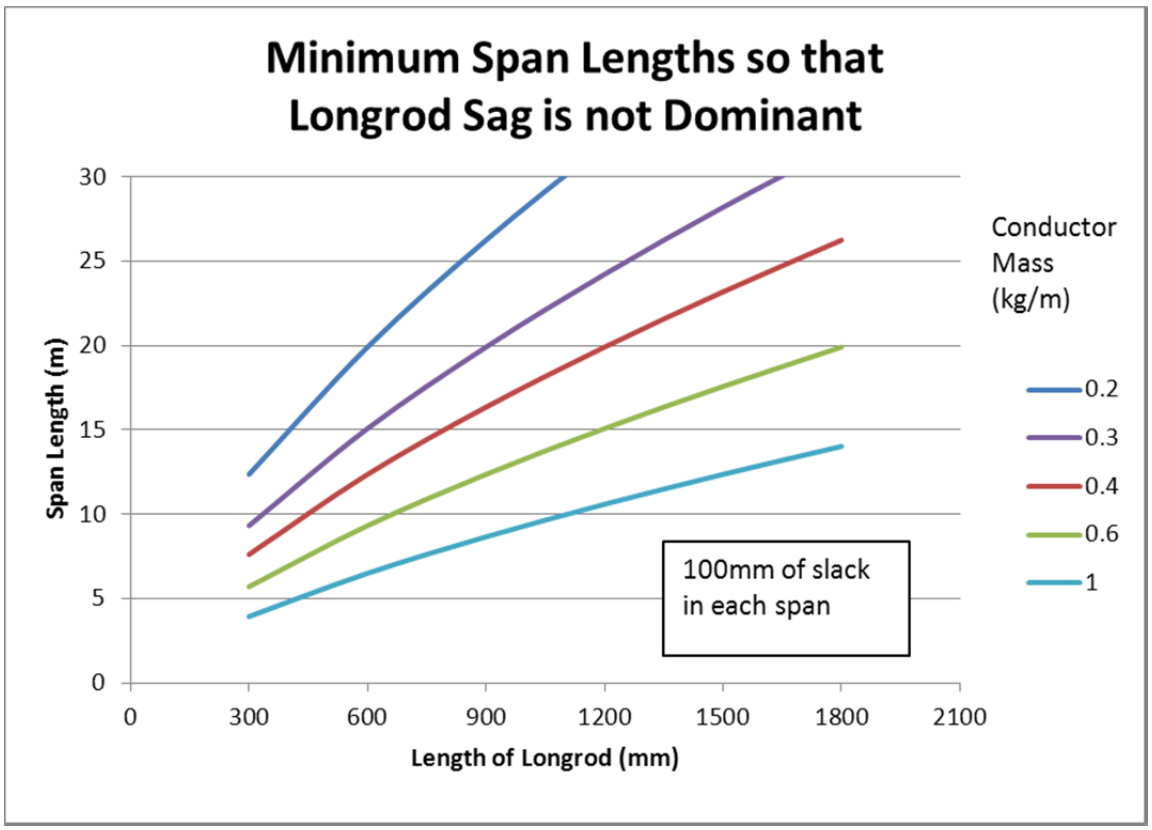

Figure 9.6.2.2 - Minimum span lengths for various conductors and voltages (length of longrod)

Example Application of Figure 9.6.2.1

A 40m dead-end span of AAAC/1120 Nitrogen (0.72 kg/m) is to be installed using 6 normal discs (66kV). To achieve 100mm of slack, it is tensioned with a catenary constant of 163m at 15°C (1.15 kN or 1.8% NBL). The 10° difference in take-off angles is achieved with a minimum span length of 27m (Table A). Therefore the 40m span (which is greater than 27m) does not have aesthetic issues. The insulator take-off angle (for a level 27m span with 100mm of slack) is 18.5° and the conductor take-off angle is 8.5° (i.e. 10° difference). For the 40m level span the insulator take-off angle is 12.7° and the conductor take-off angle is 7° (i.e. the 5.7° difference is acceptable). The additional ground clearance allowance for the 40m span is 85mm (not from Figure 9.6.2.1). If a longrod of the same length is used instead, the additional clearance allowance would be 8mm.

9.7 PERMANENT ELONGATION

Permanent (plastic) elongation (strain) has two components –

- Strand settling and deformation that occurs when tension is initially applied to the conductor.

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• Metallurgical creep that occurs over the life of the conductor. The amount of creep strain depends upon the conductor design, tension history and temperature history.

The plastic elongation due to high loads and the plastic elongation due to metallurgical creep over a long duration are not additive. The total permanent elongation is not the sum of the two, but is approximated as the larger of the two. PLS-CADD calculates both independently and refers to the final cable conditions as “after creep” and “after load”. Therefore, two weather cases have to be assumed in the design criteria before any sag-tension calculation is performed. These are:

• the weather case under which metallurgical creep is assumed to occur over a long duration, i.e. the “creep” weather case of 9.5.4

• the severe weather case that causes the maximum strand settlement to occur i.e. the “ultimate wind” weather case of 9.5.4.

There is a school of thought that a 3 second wind gust is of insufficient duration to develop the strand settlement that is derived from a stress-strain cable test where the stress is maintained for 30 minutes. By assuming that the full amount of strand settling does occur, conservative values of permanent elongation will be calculated when strand settlement is the dominant factor.

9.8 CONDUCTOR MODELLING

A minimum of 10 years of metallurgical creep shall be estimated for the “creep” weather case. An average temperature of not less than 20°C shall be used even though the average annual ambient temperature may be below this value. For heavily loaded feeders (e.g. from a generator) the cable temperature will be above the ambient temperature. Thermal modelling will be required to estimate the average temperature over the life of the conductor.

Stress-strain modelling shall be used when test data is available. For composite cables such as ACSR, the “outer” stress-strain curve is derived by subtracting the “core” curve from the composite curve as per the PLS-CADD User’s Manual.

In the absence of stress-strain data, the linear elastic model shall be used. In this instance the strand settling elongation is ignored and it is irrelevant which weather case is selected for “final after load”. However it is recommended that the “ultimate wind” weather case is selected in case a non-linear conductor model is used later in the design process.

Where the linear model is used, the model with the creep proportional to the load shall be selected. The metallurgical creep compensation temperature at 20% NBL shall be estimated for the “creep” weather case for a minimum duration of 10 years.

In the absence of creep test data, the following minimum values of creep compensation temperatures shall be used.

Construction	**Stranding**	**Average temperature over a period of 10 years**		
		20°C	**30°C**	**40°C**
AAC/1350 – wire drawn from hot- rolled rod	7	19°C	34°C	50°C
	19	18°C	33°C	49°C
	37	17°C	30°C	45°C
	61	15°C	27°C	41°C

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AAC/1350 wire drawn from continuous-cast (Properzi) rod - common manufacturing process today	7	12°C	21°C	31°C
	19	12°C	21°C	31°C
	37	11°C	19°C	28°C
	61	9°C	16°C	24°C
AAAC/6201A hot rolled	All strandings	22°C	38°C	57°C
AAAC/1120	All strandings	19°C	27°C	38°C
ACSR – 1350 strands drawn from hot-rolled rod	3/4	47°C	47°C	47°C
	4/3	43°C	43°C	43°C
	30/7	36°C	36°C	36°C
	6/1	34°C	34°C	34°C
	6/7	33°C	33°C	33°C
	54/7	33°C	33°C	33°C
	54/19	33°C	33°C	33°C
ACSR – 1350 strands drawn from continuous-cast (Properzi) rod - common manufacturing process today	3/4	26°C	26°C	26°C
	4/3	23°C	23°C	23°C
	30/7	19°C	19°C	19°C
	6/1	19°C	19°C	19°C
	6/7	18°C	18°C	18°C
	54/7	18°C	18°C	18°C
	54/19	18°C	18°C	18°C
ACSR – 6201 strands (OPGW)	Same as ACSR – 1350 Properzi			
ACAR	Refer to Southwire Conductor Manual			

Table 9.8.1Temperature Compensation for 10 yrs of Creep

The metallurgical creep prediction for AAC/1350 and AAAC/6201 conductors is based on the following equation –

$\epsilon = KT^{1.4} \sigma^{1.3} t^{0.16}$

where

ε = creep strain (mm/km or micro-strain)

K = constant listed in the table below

T = temperature (°C)

σ = tensile stress (MPa)

t = elapsed time (hours)

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The following table is taken from the Southwire Conductor Manual – Table 3-16. The constants have been modified to suit metric units.

# Strands	7	19	37	61
AAC/1350 (wire drawn from hot-rolled rod)	0.0148	0.0142	0.0136	0.0129
AAC/1350 (wire drawn from continuous-cast (Properzi) rod - common manufacturing process today	0.0090	0.0090	0.0084	0.0077
AAAC/6201	0.0077	0.0077	0.0077	0.0077

Table of K Values for AAC/1350 & AAAC/6201 Conductors

The metallurgical creep prediction for AAAC/1120 conductor is based on the following equation –

$\epsilon=K\sigma^{a1}\, t^{a2}\, e^{(a3(T-20))}$

where

ε = creep strain (mm/km or micro-strain)

σ = tensile stress (MPa)

t = elapsed time (hours

T = temperature (°C)

K = strain multiplier = 0.034

a1 = stress exponent = 1.516

a2 = time exponent = 0.321

a3 = empirical constant = 0.034

Data taken from Olex Cables report for Selenium conductor 7 Jan 1999 and modified to suit field results.

The metallurgical creep prediction for ACSR conductor is based on the following equation –

$\epsilon=G\,〚(\%NBL)〛^{1.3}\, t^{0.16}$

where

ε = creep strain (mm/km or micro-strain)

G = constant listed in the table below

%NBL = tension as percentage of nominal breaking load (%NBL)

t = elapsed time (hours)

For ACSR conductors with steel areas greater than 7.5%, the additional creep at elevated temperatures is not significant.

The following table is taken from the Southwire Conductor Manual which is identical to ELECTRA No. 75 Table II

ACSR with 1350 strands drawn from hot-rolled rod	2.4
ACSR with 1350 strands drawn from continuous-cast (Properzi) rod	1.4

Table 9.8.2 - G Values for ACSR Conductors

9.9 CONSTRUCTION AND MAINTENANCE LOADS

Construction and maintenance loads, unlike weather related loads, are controllable and are directly related to construction and maintenance practices. Construction loads are those that are imposed during the erection of structures and the installation of earthwires, conductors, insulators and hardware. Maintenance loads are those imposed as a result of planned or emergency replacement of all or part of a structure, earthwire, conductor, insulator or hardware.

Construction and maintenance loads shall include all loads that may arise during construction and maintenance of the line including stringing, rigging and men and equipment loads. These loads shall be applied with the “low wind” weather case (100Pa) applied to the structure, fittings and conductor.

In addition to the load combinations detailed in AS/NZS 7000 an unfactored vertical load of (2 x weight span x conductor weight) + fittings + insulators shall be applied to crossarms. The weight span on a structure may be doubled if the conductor is lowered from adjacent structures and it does not reach the ground. After applying a live load factor of 2, the crossarm is capable of restraining more than 4 times the normal weight span. This is not onerous for steel crossarms and provides a healthy safety margin. An engineering review shall be performed for maintenance practices that involve lowering wires at one or more structures. The lowering of wires to ground will almost double the original tension unless there is longitudinal movement (eg insulator swing). This could impose a dangerous combination of vertical and longitudinal loads on the adjacent structures.

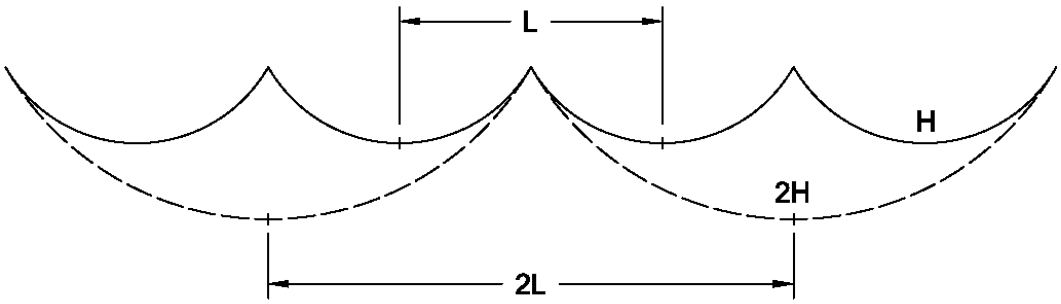

Figure 9.9.1 – Conductor Dropped from Adjacent Structures

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The conductor tension under the low wind weather case, Ftm should be applied to longitudinal and transverse loads using a load factor of 1.5 (AS/NZS 7000 Table 7.3). It is assumed that only one phase will be maintained at any one time and this with a live load factor of 2.0 whilst the other phases have a 1.5 load factor. The unfactored load of men and equipment is specified in AS/NZS 7000 clause 7.2.5.

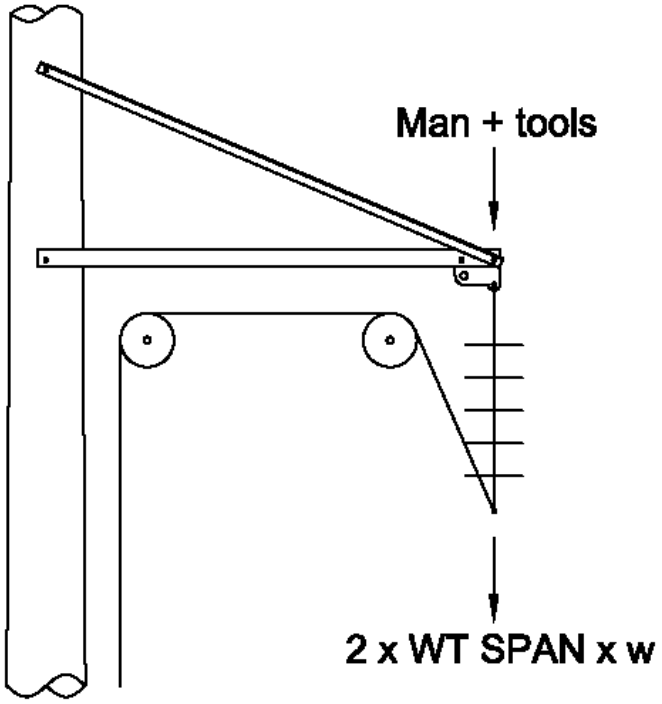

Figure 9.9.2 – Square Rigging During Insulator Replacement

The longitudinal capacity of intermediate structures shall allow for the conductors and earthwires to be terminated on the ground at a minimum horizontal distance of three times their attachment height. This imposes a longitudinal load of 5% of the stringing tension and a vertical load of 31% of the stringing tension. The live load factor of 2 shall be applied.

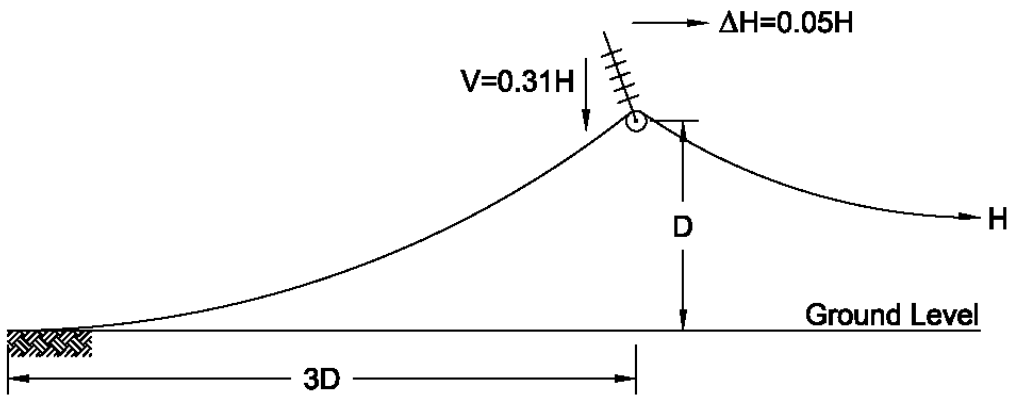

Figure 9.9.3 – Temporary Termination During Stringing

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The vertical capacity of termination structures shall be sufficient to allow for the possibility of pulling the conductors from directly below the attachment point, i.e. vertical capacity = stringing tension (ignoring weight span). The live load factor is 2.

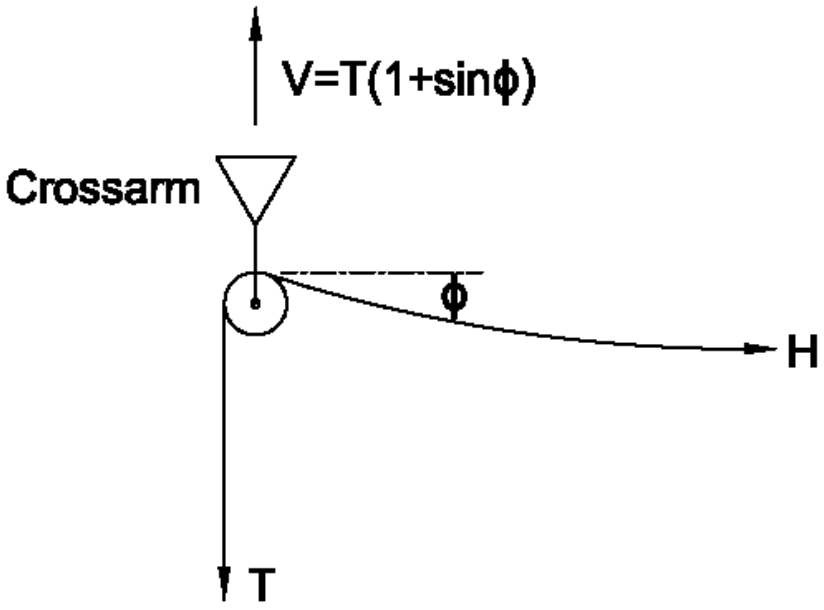
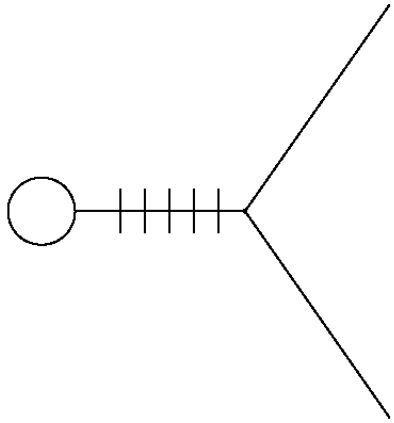


Figure 9.9.4 – Termination Load

Additionally loads factors of 0.7 and 1.5 shall be applied to conductor tensions relating to flying angle structures. The value of 0.7 is applied where the wind is blowing into the reflex angle and 1.5 when the wind is blowing into the obtuse angle.



Wind Direction	Maintenance Load Factor on Conductor Tensions
⇦ Reflex	0.7
⇨ Obtuse	1.5

Figure 9.9.5 – Flying Angle Loads

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9.10 LOAD AMPLIFICATION (P-DELTA) EFFECTS

The loads on the structure shall include and allow for second order moments caused by structure deflection.

9.11 DISPROPORTIONATE LOAD SHARING AMONGST STAYS

Poles shall be of sufficient strength and stiffness between stays to prevent excessive deflection.. Yoke plates or sheaves shall be used to balance loads onto a common stay anchor.

9.12 POLE RAKING

Where unstayed pole structures are used, the poles shall be raked such that under everyday load conditions, the tip of the pole is vertically above the base at the groundline. The direction to be raked may need to be adjusted to allow for the conductor stringing sequence.

Temporary stays may need to be allowed for as per section 10.6.

9.13 RESIDUAL STATIC LOAD

In the event of conductor breakage, the conductor tensions in adjacent spans are redistributed, due to movement in suspension strings and line post insulators, torsional rotation of poles and foundations, as well as deflection in steelwork. The unbalanced tension in the conductor or earthwire in the span adjacent to the break is known as the Residual Static Load (RSL).

The RSL can be determined under the “creep” weather case (AS/NZS 7000 clause 7.2.7.1.5). The RSL as a proportion of the conductor tension prior to the break can be estimated using the following equation -

RSL=0.8Hx^((-0.07 log x+0.14)) (0.002≤x≤5)

assume RSL = H for x > 5 i.e. earthwires with short suspension clamps and post insulators

where

RSL = tension in the first span adjacent to a span with a broken wire after the conductors have settled (N)

H = tension prior to the breakage (N)

x = Δ/D (m/m)

Δ = slack prior to breakage (m)

D = suspension insulator length or pivot length (m)

Slack can be calculated as

∆=(ω^2 L^3)/(24H^2)

where

Δ = conductor slack (m)

ω = distributed conductor weight (N/m)

L = span length (m)

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A number of assumptions are inherent in this equation –

the span lengths in the section are equal

the attachment elevations are the same (level spans)

the suspension insulator lengths are identical

the next strain structure is beyond the influence of the breakage (this gives pessimistic (larger) RSL values)

Prior to and after the breakage, the weather case is the same

This equation is unpublished and is original work done by Ergon's Transmission Line Design Department.

To determine whether a given structure, span lengths, conductor type, size and tension satisfy the failure containment criterion is difficult in the case of suspension insulators. AS/NZS 7000 specifies a wind pressure of 25% of the ultimate wind pressure for failure containment. This is uncharacteristic of international practice. The RSL calculation under wind requires a detailed finite element model of the structure and conductor system. The RSL calculation under no wind is well documented in the literature. An analytic solution is provided above However, after a conductor breaks, the assumptions regarding the remaining ruling span section are no longer valid. When wind is applied to the remaining ruling span section, the tension is not equalised in every span.

For simplicity, the failure containment load, Fb shall be calculated by applying a wind pressure of 0.25 times the ultimate wind pressure (with TSRF – clause 8.3) to the RSL using a ruling span value of L. Generally this will result in longitudinal failure containment design loads greater than the Vibration (everyday) tension.

9.14 NEW CIRCUITS ON EXISTING POLES

Where it is proposed to utilise existing structures to support heavier conductors or additional circuits, the structures are required to comply with current standards. This may require an assessment of the structure capacity and the loads applied to the structures.

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10 STRUCTURE DESIGN

10.1 GENERAL

Where Ergon Energy's standard structure suite is not suitable for the line, the designer shall be responsible for the design and detailing of the line structures.

Thus, the designer shall:

- Determine limit state design loads if not supplied by Ergon Energy.
- Prepare design calculations to ensure that the structures are adequate for the strength limit state loads specified and the specified serviceability conditions.
- Prepare detail drawings of all structure elements.
- Provide Certification of the design and drawings for all of the works, not coved by standard structures. Such Certification is to be provided by a Registered Professional Engineer of Queensland (RPEQ).
- Be responsible for ensuring that designs meet all of the strength, limit state, serviceability, dimensional, clearance and performance requirements of this manual, and all relevant Australian Regulations, Codes and Standards.
- Provide all of the construction, operation, maintenance and other facilities shown on or implicit in Ergon Energy's typical designs, and in the Specification, Schedules and accompanying drawings.

The designer shall be responsible for the design and detailing of all joints, bolts, plates, packers, splices and connections to be in accord with the design loads for members.

The designer shall detail ladders, platforms, step bolts, access landings, identification plates, anti-climbing barriers, maintenance facilities, earthing requirements and foundation set out dimensions and all information required to fabricate and erect the structures and foundations.

The design of the structures used shall include structure loading tree drawings, detailing limit state structure capacities for

- Strength
- Maintenance/Stringing
- Broken Wire.

Other load conditions shall be detailed as the designer sees fit.

10.2 FAILURE CONTAINMENT

Strength co-ordination should be considered so that an appropriate failure sequence of components takes place in order to minimise damage to the transmission line and its structures. The general order of failure shall be:

1. Intermediate conductor supports (conductor clamp slippage)
2. Steelwork (cross arms, gainbases)
3. Pole

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4. Foundations

5. Conductor

Successful failure containment may be achieved by

1. Providing sufficient longitudinal strength on all structures.

2. Providing redundancy in the event of a failed staywire/stay anchor (section 9.6).

3. Providing termination structures at regular intervals (section 10.6).

4. Limiting the effect of longitudinal loads by utilising a controlled load release mechanism (such as plastic deformation of steelwork or clamp slippage but not sudden load release caused by bolt shear).

5. Limiting the Residual Static Load (RSL) by utilizing hanger brackets, hinged horizontal V insulators or elastic structures.

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. Where load relief is provided by conductor clamp slippage the strength co-ordination needs to be considered. AS 1154.3-2009 provides a holding tension (withstand slip) test for helical suspension or support fittings. Where a load release mechanism is critical to the design then the manufacturers Nominated Holding Tension (NHT) shall be specified on the drawings as part of the material requirements.

10.3 STRUCTURE DESIGN CODES

Structures shall be designed for the appropriate loads and load combinations in accordance with this manual and the relevant Australian Standards. The strength reduction factor of all components shall be as per AS/NZS 7000.

Structure Type	Design Standard
Reinforced and Prestressed Concrete Poles	AS 3600
Spun Reinforced Concrete Poles	AS 4065 and/or relevant British Standard
Steel Poles	AS 4100 and AS/NZS 4600 as appropriate
Steel Towers	AS 3995

Table 10.3 – Structure Design Codes

10.4 POLE MATERIAL

Poles on new lines shall be concrete structures with an OHEW in accordance with the Ergon Energy Sub-transmission Construction Manual. Where the sub-transmission construction manual is unable to be used due to strength or height limitations, poles outside of the sub-transmission construction manual shall be designed in either steel or concrete and shall be provided with RPEQ certification. Maintenance or modifications on existing timber pole lines may utilise timber poles. If conductive structures are used on existing non-conductive lines without OHEW, consideration shall be given to the insulation co-ordination (section 14.1.3.3).

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10.4.1 CONCRETE POLE DESIGN STRENGTH CAPACITIES

Limit state concrete pole strength capacity tables for sub-transmission construction manual poles are provided in ANNEX J. Factored applied loadings shall not induce forces or moments which exceed the strength capacities listed in these tables. Any pole designed with factored applied loadings which induce forces or moments exceeding the strength capacities listed in ANNEX J will not be accepted by Ergon Energy and will not be covered by RPEQ certification. ANNEX J tables are derived from manufacturer supplied strength and design data.

10.5 CROSSARMS

Designs shall be arranged so that the pole steelwork (e.g. crossarms, earth peaks, ladders etc.) can be bolted to the pole and can be removed.

For the double circuit lines, the design shall allow removal of crossarms or post insulator brackets on one circuit whilst the adjacent circuit is live.

10.6 STAYS

The use of stays are an economical method to transfer the conductor tensions and wind loads from termination and flying angle structures to ground without significantly increasing the pole size. However they increase the overall footprint of a structure, this is undesirable in urban areas or where easement widths are constrained.

Stayed termination and strain structures shall be designed so all loading criteria can be met when the conductors are fully terminated in one direction. The appropriate load factors and capacity reduction factors shall be used in accordance with AS/NZS7000.

In order to minimise the risk of a line cascade in the event of a stay failure, stayed poles shall be designed so that at 500Pa any one stay is redundant, with the remaining stays and/or pole being able to take all wind and conductor loads, without failure.

As a general rule, suspension structures without deviation angles shall be unstayed (self-supporting).

For partially stayed structures, such as those stayed in one direction only, the load amplification due to stays shall be taken into account in the pole design i.e. the P-Delta load is amplified by the vertical component of stay tension.

Bollards may be used in built up areas or when staying across roads and driveways is required. The bollards shall be designed so that deflection under everyday conditions is minimised.

Where it is not possible to locate a stay in a safe location, and such a stay would only be required due to unbalanced stringing or maintenance loads, the provision for the installation of temporary stays should be allowed for by way of stay brackets and, if possible foundations. The construction schedules and Work Health & Safety Plan should be clearly marked, advising the need for the use of temporary stays.

For conductive poles (steel or concrete), stay insulators are to be included in the design to prevent circulating currents and thus to prevent electrolytic corrosion of the stay anchor. The insulation provided by porcelain guy insulators is sufficient for this purpose.

10.7 DURABILITY AND DESIGN LIFE

The structures and their footings shall be designed for a maintenance free life of 50 years. Thus, steel poles or towers shall be galvanised. All steel up to 300 mm above ground level and below to full depth of foundation shall be concrete encased.

These requirements may be modified for temporary structures at the discretion of the engineer.

10.8 PROTOTYPING AND TESTING

Prototyping shall take place for all structures not previously used, as well as when poles or steelwork is fabricated by an alternative supplier.

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

- Similarity of existing designs and design principles.
- Quantity of structures to be used, 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.

10.9 DETAILING

All structure drawings shall be prepared with the inclusion of the following items which detail the Principal's requirements for the structures.

All structures shall incorporate attachment fittings such as hanger brackets and landing plates and shall provide a position for attachment of insulators.

The number of different parts shall be kept to a minimum in order to facilitate transport, erection and inspection. Pockets and depressions likely to hold water shall be avoided and all vertical flanges of members shall be orientated downward unless requirements dictate otherwise. If pockets are unavoidable then holes or outlets must be provided to ensure proper drainage.

Fasteners (nuts and bolts) shall be capable of being installed such that adequate clearance from adjacent structural members is provided to enable standard tools to be used for tightening.

Gusset plates shall be reduced to the minimum dimensions possible with all surplus material, sharp corners etc., cropped for safety and aesthetic reasons. The minimum thickness of gusset plates and angles shall be 6 mm and 5 mm respectively.

Bolt groups shall be compact and arranged for minimum eccentricity.

At all tension, suspension and maintenance plates and/or brackets the flanges of angles or any part of the structure shall not interfere with the free insertion or removal of any bolt or pin associated with line hardware or maintenance equipment.

The positioning of the various parts of a structure shall be such that contact areas are flat. Where necessary, members shall be cropped to maintain clearance from any adjacent member or corner radius.

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10.10 ERECTION MARKS

All members shall be stamped with an alphanumeric mark number to identify the member and also a mark to show whether the member is of high tensile or mild steel. Only fully interchangeable members shall have the same mark number. The Contractor shall supply appropriate information on the Drawings to enable the Superintendent to quickly and easily identify the position or mark of any member.

10.11 BOLTS AND NUTS

All field connections between tower members shall be by means of galvanised or stainless steel bolts and nuts to Australian Standards.

The diameter of bolts shall be not less than 12 mm. The threads of all bolts shall be of I.S.O. Coarse Pitch series and bolt heads and nuts of the hexagonal type. The design capacity of bolts shall be in accordance with AS 4100.

All nominal braces shall be capable of transferring 2.5 percent (%) of connected main member loads and fastened with a minimum of one 16 mm diameter bolt.

All bolts shall be fitted with galvanised spring washers to AS 1968 and nuts.

Bolts in tension shall be also fitted with lock nuts or stainless steel split pins.

The threads of bolts shall in all cases project past the depth of the nut, when the nut is fully tightened, but such projection shall not exceed 10 mm.

The length of bolt shank shall be chosen to ensure that the plane or planes of shear of the members connected are clear of the bolt thread, and also the nut shall not be thread bound when tightened.

11 STRUCTURE FOUNDATIONS

Standard foundation depths have been determined for standard structure types. The designer will determine whether the in-situ ground conditions are adequate for the standard foundation design and setting depth. Where they are deemed not to be suitable the designer shall design alternative foundations.

The sub-transmission line structure capacity shall not be limited by the capacity of the structure foundations. Structure foundations (including stays) shall be designed to accommodate the maximum design loads for the type of structure, as opposed to the maximum site loads that the structure will experience at the particular site. This will enable the structure to be loaded to its maximum design capacity if the line configuration is changed in the future, without the need to redesign/construct the foundation which may be costly and difficult to achieve with an in-service pole.

The preferred design for concrete poles is for direct buried pole foundations. Steel pole foundations shall be assessed on a case-by-case basis.

11.1 GEOTECHNICAL INVESTIGATIONS

The foundation design shall be based on an assessment of the soil strength made for each structure site. Local construction crews may be able to provide an overview of the typical soil profiles found in the area. The adopted soil strengths shall be based on site specific investigations or a desktop study. Some areas may contain sufficient data from previous geotechnical investigations, from other infrastructure, such that further testing may not be required. The designer shall determine the level of geotechnical investigation necessary for each site and record

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the soil strength used and the basis of the adopted soil strength on the drawings or schedule. Due to the nature of transmission lines being spread along a large area, it is often not cost efficient to perform site tests at each pole location. The designer should make an assessment of the number and location of tests required, based on which structures are more heavily loaded, visual changes in topography and geography and distance between test locations.

To enable the Geotechnical engineer to provide the most useful information they should be provided with:

- Line route
- The design loads, sustained and ultimate, (or estimated if not yet finalised)
- Pole and stay capacities and types
- Expected foundation depths
- Proposed construction methodology.

The exact requirements for geotechnical tests will vary with each design, however these would likely include:

- The soil profile to approximately 2 m deeper than the anticipated foundation depth at each site.
- Strength characteristics to enable design of the foundations, including soil cohesion, internal angle of friction, rock mass cohesion, unit weight, skin friction and allowable lateral bearing pressures.
- Anticipated excavation and construction conditions, including water table.

11.2 FOUNDATION DESIGN

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.

The strength reduction factor selected for use should be in accordance with AS/NZS 7000, with consideration to the confidence in the soil parameters used in the design, type of foundation (i.e. temporary loading (suspension pole) or permanent loading (unstayed termination pole, stay anchor)) and level of engineering supervision during construction.

The designer should take into account the various strengths and elasticity's of soil and rock encountered in the soil profile and ensure that foundation loads are suitably transferred into the pole, such that the shear capacity of the pole is not exceeded.

Constructability should be taken into account in the design, such as the requirements for shoring and access to concrete in remote areas.

The Brinch Hansen method is acceptable to Ergon Energy for foundation design of short rigid piles subjected to lateral loads, however, the design method used shall be up to the designing engineer.

The designer shall provide options to increase the strength of the foundations should soil parameters differ from those anticipated. These options shall be submitted to Ergon Energy for review prior to construction along with accompanying RPEQ design certification.

Where pore water pressures are likely to be encountered which may cause the walls of the foundation to collapse during construction, the use of concrete or steel caissons should be advised by the designer. These may be a reusable or sacrificial design.

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All steel pole designs shall incorporate concrete foundations extending above ground line, such that there is no exposed steel within 500mm of ground line. Concrete shall incorporate sufficient steel reinforcing to prevent cracking of the concrete as per the requirements of AS/NZS 3600.

Stay rods shall utilise concrete/ grout or denso tape (or equivalent) covering 500mm above ground line.

In corrosive environments more onerous requirements may be required.

11.3 FOUNDATION DETAILS

The following foundation details shall be determined and provided on the drawings or construction schedules:

- Minimum footing size (pier diameter and depth or for mass concrete provide excavation width, length and depth.)
- Minimum pole embedment depth
- Backfill details (e.g. concrete, stabilised soil, unstabilised soil, compaction, etc.)
- Bearing pad details
- Minimum soil strength or soil profile with strengths for differing soil types.
- Geotechnical Report, if available.

11.4 CONSTRUCTION AND MAINTENANCE CONSIDERATIONS

Constructability, cost, access to plant, condition monitoring

11.4.1 Excavations Near Foundations

Refer to Ergon document BS001405R104 “Excavations Around Overhead Electrical Parts Guideline”

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12 LAYOUT

12.1 SURVEY

The line route survey should be undertaken in accordance with the Standard for Line Survey.

12.2 LAYOUT CLEARANCE BUFFER

An electricity entity must ensure the distance from the conductors of its overhead electric lines is in accordance with the Electrical Safety Act and Electrical Safety Regulation. There are tolerances in the design and the construction of an overhead line such that "as-built" clearances will differ from the design clearances. These tolerances are closely tied to the design and construction practices. Traditionally a deterministic clearance buffer has been applied to maintain compliance with the code. The method detailed below offers a probabilistic method that incorporates the various design and construction practices into the design clearance.

A ground clearance buffer shall be provided to allow for the following sources of error:

Error Source	Method	New Construction (Note A)	Rating Study (Notes A & B)
Survey Level Errors			
	GPS	0±100	0±100
	Theodolite	0±50	0±50
	Lidar	0±150	0±150
	Rangefinder	0±200	0±200
Pegging Error or Pole Planting Error			
	1 m in 300m, C = 1500m	0±50 or 0.7% sag	N/A
	1 m in 150m, C = 1500m	0±25 or 1.3% sag	N/A
Conductor Modelling			
	No creep allowance – AAC, AAAC (not recommended)	-25±10^{o}C?	N/A
	No creep allowance – ACSR (not recommended)	-30±10^{o}C Typical Span Only	
	Creep prediction	0±5°C	N/A (creep virtually complete)
	RS assumption, max span/ min span less than 2	?	?
	RS assumption, max span/ min span less than 4	?	?
	Parabola instead of catenary L = 300m, C = 1500m	-10±0	N/A (catenary tension or parabola tension derived from measured sag)
Conductor Temperature	Using measured conductor temperature	N/A	0±2°C

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Error Source	Method	New Construction (Note A)	Rating Study (Notes A & B)
Conductor Temperature - Using Ambient Temperature Instead Of Measuring Conductor Temperature			
	Measured at mid-day, no cloud, lightly loaded feeder, slight breeze	N/A	10±10°C
	Measured at mid-day, no cloud, moderately loaded feeder, slight breeze	N/A	15±15°C
	Measured at mid-day, cloud cover, lightly loaded feeder, slight breeze	N/A	5±5°C
Sag Error In Unsagged Spans			
	Sheave friction – large sheaves, rugged terrain, less than 10 successive unsagged spans	±	N/A
	Sheave friction – small sheaves, flat terrain, up to 10 successive unsagged spans	±	N/A
Tensioning Errors			
	Dynamometer (used correctly)	0±250	N/A
	Line-of-sight (eyeballed, poor target, no correction for temperature changes during sagging operation)	0±150 and 0±10°C	N/A
	Line-of-sight (telescope, accurate target, corrected for temperature changes)	0±50 and 0±5°C	
	Theodolite (offset method)	0±50	N/A
	Theodolite (tangent method)	0±100	N/A
	Return wave method (1s in 3 returns, L = 300m, C = 1500m)	?	N/A
Conductor Fabrication Tolerances			
	Mass	±1% Sag	±
	Elastic modulus	±	±
	Thermal coefficient	±	±
	Alloy temper	±	±
Structure Fabrication Tolerances			
	Steel pole with slip joint	0±100	N/A
	Concrete pole	0±50	N/A
	Lattice tower	0±75	N/A

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Error Source	Method	New Construction (Note A)	Rating Study (Notes A & B)
Foundation Depth – Direct Buried Poles			
	Well supervised	±150	N/A
	Poorly supervised	±400	N/A
	Benched sites	±300	N/A
Foundation Depth			
	Flange based pole	50±100 (50 grout)	N/A
	Towers	0±100	N/A

Table 12.2 – Margins of Error in Construction.

Notes

A. Tabulated values of offset and typical tolerance (mean and standard deviation) in millimetres unless indicated otherwise. The offset is positive when the additional ground clearance is provided. For example if the tower height is measured from the K point and the K point is typically 300mm above the centre peg then the offset is 300mm.

B. The “as-built” line is surveyed and there are no construction errors to account for. However if modifications to the line are required to uprate the line then construction errors will be introduced depending on the nature of the modifications. For example, retensioning the conductor will introduce sagging errors. Unfortunately this means that a different buffer is required for different portions of the line, a task that layout software applications do not normally accommodate.

It is assumed that each error source is statistically independent and is normally distributed. The sum of these random variables is also normal such that:

$$\mu = \sum_{n=1}^{N} \mu_n$$

$$\sigma = \sqrt{\sum_{n=1}^{N} \sigma_n^2}$$

Where N is the number of errors involved, μn is the offset (mean) of error number n and σn is the tolerance (standard deviation) of error number n.

To allow for these sources of error with a confidence of 84% the required clearance buffer is

$$B_{1\sigma} = -(\mu - \sigma)$$

To increase the confidence to 98% requires

$$B_{2\sigma} = -(\mu - 2\sigma)$$

Reding (2007) details this method adopted by Bonneville Power Administration, Pacific Northwest region of USA.

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12.3 USING THE BUFFER

Lines shall be designed with a clearance buffer and a temperature buffer based on the 84% confidence limit. The assumed values tabulated above may be altered to suit the degree of control exercised during the design and construction phases.

For example, a new line with a thermal rating of 75°C and a temperature buffer of 5°C shall be spotted with a temperature of 80°C. If the statutory ground clearance requirement is 6.7m and the clearance buffer is 0.5m then the line shall be spotted with 7.2m of clearance.

The records shall state the following:

Maximum operating temperature = 75°C with 5°C buffer

Minimum ground clearance = 6.7m with 0.5m buffer

No line shall be designed with a vertical clearance buffer of less than 0.3m and a temperature buffer less than 5°C.

The clearance buffer does not apply to

- Vertical separation for unattached crossings
- Vertical separation for attached crossings
- Mid-span phase separation
- Electrical clearances to the supporting structures

The clearance buffer does apply to

- Unroofed terraces, balconies and sun decks
- Roofs
- Covered places of traffic
- Structures not normally accessible to persons

The horizontal clearance buffer is much more difficult to evaluate because of

- Structure deflection
- Insulator swing
- Distributed nature of wind gusts

Neither the Electrical Safety Regulations nor AS/NZS7000 specifies a wind pressure to use for horizontal clearances. The “blowout” weather case shall be used to calculate horizontal clearances. Clearances may be infringed with a lower wind pressure because the conductor moves in an arc. No additional horizontal buffer is required because the hazard to humans is considerably lessened during “blowout” wind speeds.

12.4 LAYOUT CLEARANCES

Unless otherwise specified in the project scope, structures shall be located so that the required clearances below are satisfied at a maximum operating temperature of 75°C, 10 years after commissioning. That is, the designer shall allow 10 years of conductor creep. For the purpose of calculating creep the “creep” weather case shall be used.

Where the statuary guidelines (AS/NZS 7000, Electricity Act) differs from the figures below, the more onerous shall apply. The horizontal clearances shall be satisfied under the high wind weather case.

LOCATION	DIRECTION	DISTANCE		
		1kV to 33kV	66kV	132kV
Roads: carriageway crossing Roads: other locations	Vertically Vertically	7.0m 7.0	7.0m 7.0m	7.5m 7.5m
High load corridor routes	Vertically	7.5m	8.0m	9.0m
Other than roads	Vertically	6.0m	7.0m	7.5m
Over truck stop areas / high load areas	Vertically	8.5m	9.0m	10.0m
Extremely steep or swampy terrain that traffic or mobile machinery cannot cross.	Vertically	4.8m	5.5m	6.0m
Road cuttings, embankments etc.	Horizontally	2.1m	4.6m	
Over or adjacent cultivation	Vertically	8.0m	8.5m	12.0m
Over or adjacent to cane	Vertically	8.0m	8.5m	12.0m
Sugar cane bin unloading areas	Vertically	12.5	12.5m	13.0m
Waterways – Recreational/navigable Refer to the Distribution Design Manual Dwg 3143 Sh 1 to 10.	Vertically	As agreed with appropriate controlling body / AS6947		
Waterway main channels – Above flood (allowance for debris)	Vertically	5.0m	5.5m	6.0m
Waterway backwaters – Above flood (allowance for dingies)	Vertically	3.0m	3.5m	4.0m

Table 12.4.1 – Clearances from Ground and Roads

LOCATION	DIRECTION	DISTANCE		
		1kV to 33kV	66kV	132kV
Unroofed terraces, balconies, sun decks, paved areas and similar areas subject to pedestrian traffic only, that have a handrail or wall surrounding the area and on which a person may stand. Easement Boundaries.	Vertically	4.6m	5.5m	7.0m
	Horizontally	2.1m	4.6m	5.5m
Roofs or similar structures not used for traffic, but on which a person may stand – includes parapets	Vertically	3.7m	4.6m	6.1m
	Horizontally	2.1m	4.6m	6.0m
Covered balconies, open verandas, opening windows	In any direction	2.1m	4.6m	6.5m

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Blank walls and windows, which cannot be opened. Circuit separation.	Horizontally	1.5m	3.0m	4.5m
Other structures not normally accessible to persons. e.g. TV aerials, clothes hoists.	Vertically	3.0m	3.0m	4.5m
	Horizontally	1.5m	3.0m	4.5m
Real property boundaries	Horizontally	0.0m	0.0m	0.0m

Table 12.4.2 – Clearances from Structures, Buildings & Boundaries

Intercircuit clearances shall be determined in accordance with the Ergon Energy Standard for Distribution Line Design and AS/NZS7000.

12.5 LAYOUT CHECKS

The following additional requirements should also be met:

- Avoid structure and stay locations in erodible areas and flooded areas.
- Avoid Telecom(s) facilities and other infrastructure, refer to NA000404R100 : Power Coordination Guideline.
- Avoid areas of Cultural Heritage significance.
- Constrain maximum wind limit state loads (factored) to termination structures in substations to the requirements shown on Ergon Energy Drawing EESS 10075.
- Allow for extra clearance over riparian vegetation and rare and endangered flora.
- Satisfy the specified electrical clearances on the structures.
- Avoid overloading of structures.
- Consider aesthetics and amenity where there is impact around local community.
- Gain agreement from local councils and other corporations and authorities with infrastructure in the area.

12.6 Layout for Security – Cascade Failure Prevention

The maximum length of line between termination structures shall be 5km. These termination structures shall be capable of supporting the full termination loads of all conductors and earthwires.

13 LINE UPGRADING

13.1 VOLTAGE UPGRADING

A technical feasibility study needs to be conducted initially. An economic comparison of feasible alternatives (including new construction) provides a rational basis for choice. Such analysis shall include the present worth of future electrical losses.

Extensive reference material is available to provide guidance for the voltage upgrading of existing lines. For example

- Southwire Overhead Conductor Manual – Chapter 6
- Uprate and upgrade of overhead transmission lines methodologies and reliability,

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CIGRE B2-202_2008

- Transmission Line Reference Book 115-138kV Compact Line Design, EPRI
- IEEE journals

In Ergon's network, the most promising upgrade path is from 110kV to 132kV. The minimum ground clearance requirement before 1989 was 6.4m and is currently 6.7m.

There is a misconception that increasing the voltage will lead to an increased loading capacity equal to the square of the voltage increase. The following simplified analysis (for short lines) based on single line diagrams, provides some guidance for the power transfer improvement by uprating the voltage.

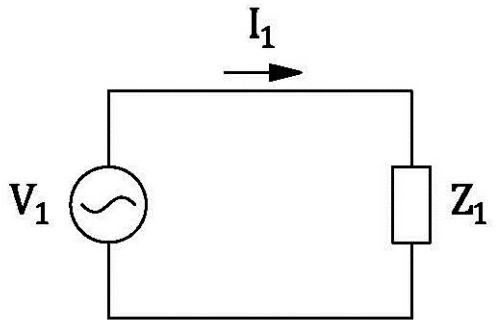

Figure 13.1.1 – Base Case Single Line Diagram

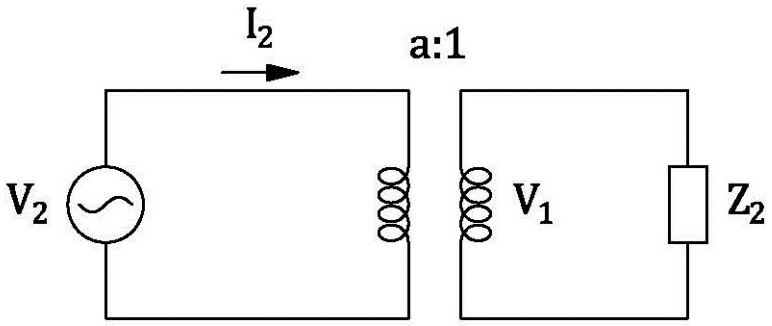

Figure 13.1.2 – Uprated Single Line Diagram

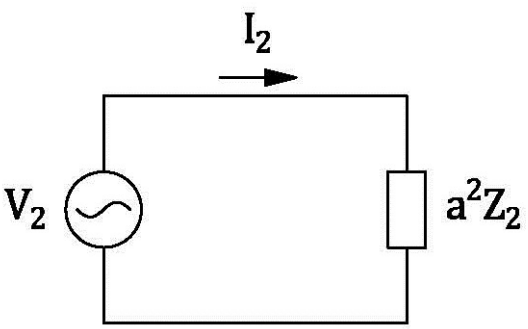

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Figure 13.1.3 – Equivalent Uprated Single Line Diagram

From Figure 1

$$P_1 = \frac{V_1^2}{Z_1}$$

From Figure 2

$$P_2 = \frac{V_1^2}{Z_2} = P_1 \frac{Z_1}{Z_2}$$

$$a = \frac{V_2}{V_1}$$

From Figure 3

$$I_2 = \frac{V_1}{aZ_2} = \frac{V_1 P_2}{aP_1 Z_1} = \frac{P_2}{P_1}\frac{I_1}{a} = \frac{P_2}{P_1}\frac{V_1}{V_2} I_1$$

where
V_1 = base case voltage (p-g)
I_1 = base case line current
Z_1 = base case load impedance (p-g)
P_1 = base case load (p-g)
V_2 = uprated voltage (p-g)
I_2 = uprated line current
Z_2 = uprated load impedance (p-g)
P_2 = uprated load (p-g)
a = turns ratio of the transformer
Since the equation for I_2 is based on ratios, the voltages can be phase-to-phase values and the loads can be three phase values.

Examples

An 110kV line is to be uprated to 132kV.

- If the maximum load remains unchanged ($P_2 = P_1$), what is the thermal current rating of the uprated line?

$$I_2 = \frac{P_2}{P_1}\frac{V_1}{V_2} I_1 = \frac{110}{132} I_1 = 0.83\, I_1$$

- If the conductor is unchanged and the statutory ground clearance is achieved at the same operating temperature then the thermal current rating will be the same ($I_2 = I_1$). What is the maximum power transfer of the uprated line?

$$P_2 = \frac{I_2}{I_1}\frac{V_2}{V_1} P_1 = \frac{132}{110} P_1 = 1.2\, P_1$$

  The power increase is proportional to the voltage increase.

- If a 50% increase in load capacity is required ($P_2 = 1.5\, P_1$), what thermal current rating is required for the uprated line?

$$I_2 = \frac{P_2}{P_1}\frac{V_1}{V_2} I_1 = 1.5\, \frac{110}{132} I_1 = 1.25\, I_1$$

- A second conductor is bundled with the original to combat a corona problem ($I_2 = 2\, I_1$) and the line is operated to the same temperature limit. What is the maximum power transfer of the uprated line (assuming that no extra ground clearance is required for the higher voltage)?

$$P_2 = \frac{I_2}{I_1}\frac{V_2}{V_1} P_1 = 2\, \frac{132}{110} P_1 = 2.4\, P_1$$

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13.2 STRUCTURAL UPGRADING

AS/NZS 7000 Appendix N is an informative appendix covering this topic.

14 LINE UPRATING

14.1 RATING STUDY

A rating study determines the maximum electrical load that a feeder can carry without violating statutory ground clearances. Where more than one conductor size has been used, each may be operating at different temperatures under the same load current and ambient conditions. A survey of the feeder along with conductor temperature measurements is used to create a model. The conductor tension is derived from the model. The conductor temperature that infringes statutory ground clearance in the worst span or produces unsafe clearances at crossing of other services is used to determine the thermal load rating. The model is then used to determine the extent of work required to achieve the required load rating (uprating).

14.1.1 Survey Methods

The accuracy of survey methods is listed below from the most accurate to the least accurate.

- Lidar data taken from a plane flying at night with the line out of service. The conductor temperature is taken as the ambient temperature because there is no heat input from the sun nor from resistive heating.
- Lidar flown at night with the line in service. At the same time the actual conductor temperature is measured. This way the whole line is surveyed in a short period with very little ambient temperature variation or load variation.
- Day time Lidar with the line out of service.
- Day time Lidar with the line in service.
- Terrestrial scanning with conductor temperature measurement.
- Terrestrial scanning with conductor temperature estimation (ambient or calculated).
- GPS surveying with total station measurement of conductor levels with conductor temperature measurement.
- GPS surveying with total station measurement of conductor levels with conductor temperature estimation (ambient or calculated).
- GPS surveying with rangefinder measurement of conductor levels with conductor temperature measurement.
- GPS surveying with rangefinder measurement of conductor levels with conductor temperature estimation (ambient or calculated).

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The preferred method for determining the conductor temperature is a direct contact method using a thermocouple and conductive grease. Data loggers are available that can measure the line current and conductor temperature. These are applied using a hot stick. Data loggers provide a means of coordinating (time stamping) the survey measurements with the conductor temperature. There are several commercial loggers available for use on bare overhead conductors e.g. Gridsense Line IQ (5 to 138kV, 6 to 36mm diam., -40 to 130°C); GE Multilin FMC-T6 (0.5 to 140kV, 10 to 28mm, -10 to 85°C ±2°C); Horstmann Navigator (≤ 46kV, 8 to 29mm diam., -40 to 130°C ±5°C).

Instantaneous temperature measuring devices are also available for use with a hot sick e.g. Change Digital Thermo-Tector.

Infrared cameras require calibration due to surface emissivity variations and do not normally have sufficient zoom capability.

14.1.2 Legacy Clearances

Queensland Electric Light and Power Regulations of 1938

The ground clearances are at an ambient temperature of 120°F (49°C) in still air.

SEC – as approved by the State Electricity Commission of Queensland

Location		LV Conductors		HV Conductors			
		Insulated Aerial Cable	Bare	>650 & ≤33kV	>33kV & ≤66kV	>66kV & ≤110kV	>110kV & ≤275kV
Roads - carriage way	Vert.	19’ 5.8m	19’ 5.8m	20’ 6.1m	20’ 6.1m	21’ 6.4m	SEC
Road - at other locations	Vert.	17’ 5.1m	17’ 5.1m	20’ 6.1m	20’ 6.1m	21’ 6.4m	SEC
Other than roads	Vert.	16’ 4.8m	16’ 4.8m	20’ 6.1m	20’ 6.1m	21’ 6.4m	SEC
Inaccessible areas, road cuttings and the like	Vert.	16’ 4.8m	16’ 4.8m	20’ 6.1m	20’ 6.1m	21’ 6.4m	SEC
	Horiz						

Table 14.1.2.1 Regulation 33

Queensland Electricity Act 1976 Regulations 1977

Location		LV Conductors		HV Conductors			
		Insulated Aerial Cable	Bare	>650 & ≤33kV	>33kV & ≤66kV	>66kV & ≤110kV	>110kV & ≤275kV
Road - carriageway	Vert.	5.8	5.8	6.0	6.4	6.4	7.5
Road - at other positions	Vert.	5.2	5.2	6.0	6.4	6.4	7.5
Other than roads	Vert.	5.2	5.2	6.0	6.4	6.4	7.5
Road cuttings, embankments	Vert.						
Road cuttings, embankments	Horiz.	1.5	1.5	2.1	4.6	4.6	5.5

Table 14.1.2.2 Regulation 21

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Queensland Electricity Regulations – 1989

Location		LV Conductors		HV Conductors			
		Insulated Aerial Cable	Bare	>650 & ≤33kV	>33kV & ≤66kV	>66kV & ≤132kV	>132kV & ≤275kV
Road - carriageway	Vert.	5.8	5.8	6.0	6.4	6.4	7.5
Road - At other positions	Vert.	5.2	5.2	6.0	6.4	6.4	7.5
Other than roads	Vert.	5.2	5.2	6.0	6.4	6.4	7.5
Road cuttings, embankments	Vert.						
Road cuttings, embankments	Horiz	1.5	1.5	2.1	4.6	4.6	5.5

Table 13.1.2.3 Regulation 25

Queensland Electricity Regulations – 1994

Location		LV Conductors		HV Conductors			
		Insulated Aerial Cable	Bare	>1kV & ≤33kV	>33kV & ≤66kV	>66kV & 132kV	>132kV & 275kV
Road - carriageway	Vert.	5.5	5.5	6.7	6.7	6.7	7.5
Road – other places	Vert.	5.5	5.5	5.5	6.7	6.7	7.5
Other than roads	Vert.	5.5	5.5	5.5	6.7	6.7	7.5
Nontrafficable land (steep, swampy)	Vert.	4.5	4.5	4.5	5.5	5.5	6.0
Road cuttings, embankments	Horiz.	1.5	1.5	2.1	4.6	4.6	5.5

Table 14.1.2.4 Schedule 2

Queensland Electrical Safety Regulation 2002

Location		LV Conductors		HV Conductors			
		Insulated Aerial Cable	Bare	>1kV & 33kV	>33kV & 66kV	>66kV & 132kV	>132kV & 275kV
Road - carriageway	Vert.	5.5	5.5	6.7	6.7	6.7	7.5
Road – other places	Vert.	5.5	5.5	5.5	6.7	6.7	7.5
Other than roads	Vert.	5.5	5.5	5.5	6.7	6.7	7.5
Nontrafficable land (steep, swampy)	Vert.	4.5	4.5	4.5	5.5	5.5	6.0
Road cuttings, embankments	Horiz.	1.5	1.5	2.1	4.6	4.6	5.5

Table 14.1.2.5 Schedule 4

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14.1.3 Modification Requirements

14.1.3.1 Structural

AS/NZS 7000 does not apply to the refurbishment of existing lines. Whenever alterations overload components according to the legacy standard then the structure shall comply (clause 1.1) with AS/NZS 7000. Given that the uprating is required on an already aged asset, it is acceptable to reduce the design working life of the structure and adopt a reduced return period for strength limit states (AS/NZS 1170.0:2002 Table 3.3, AS/NZS 7000 clause 12.2.2). Whenever new structures are added, these shall comply with AS/NZS 7000 and the requirements of this document. Appendix N of AS/NZS 7000 provides guidance for structural upgrading including foundations.

14.1.3.2 Ground clearances

A rating study shall report the thermal rating based on the legacy ground clearance at the time of construction. Any works (other than refurbishment) required to improve the thermal rating shall bring the ground clearance in the vicinity of the works up to the requirements of the current Electrical Safety Regulation. If the conductor is retensioned then the ground clearance at the maximum operating temperature in all spans in that section shall meet the current statutory requirements. If the conductor attachment is raised or the structure is replaced then the spans either side of that structure shall meet the current statutory requirements. If the ground level is lowered (e.g. by dozer) then the clearance in that span is required to comply.

14.1.3.3 Electrical

The following table lists the modifications that are permitted on existing line construction types. The table should be used when like-for-like replacements are not feasible. Conductive structures are concrete poles; steel poles; steel lattice towers; etc. Insulated structures are wood poles; fibre reinforced plastic (FRP) poles; fibre reinforced concrete; etc. Insulated poles with an overhead earthwire (OHEW) have an earth downlead to ground. The downlead may or may not stand off the pole as it bypasses the phase conductors. The stand-off downlead improves lightning performance

Proposed Structure Type to Replace Existing	**Existing Overhead Construction Type**			
	Insulated	Insulated with OHEW	Conductive	Conductive with OHEW
Insulated	Yes	No – breaks continuity of OHEW. Yes for calf poles.	Yes	No – breaks continuity of OHEW. Yes in an emergency only. Yes for calf poles.
Insulated with OHEW	Yes but redundant OHEW attachment	Yes	Yes but redundant OHEW attachment	Yes but not preferred.
Conductive	No – step/touch issue. Yes if low footing	No – breaks continuity of OHEW. Yes as calf pole with	Yes in remote locations	No – breaks continuity of OHEW. Yes as calf pole with

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	resistance; step/touch issue addressed; lightning arrestor considered.	low footing resistance & step/touch issue addressed (eg horiz. ABS).		low footing resistance & step/touch issue addressed (eg horiz. ABS).
Conductive with OHEW	No – step/touch issue & redundant OHEW attachment. Yes if OHEW added to at least 2 insulated poles & earthed.	Yes	Yes but redundant OHEW attachment	Yes

Table 14.1.3.3 - Permitted Structure Additions to Existing Powerlines

Lightning arresters need to be considered at the interface between higher lightning impulse withstand structures (wood without OHEW and perhaps wood with OHEW) and lower lightning impulse withstand structures (conductive with and without OHEW). The lightning arrestors may take the form of Darverters on the de-energised end of insulators for insulated structures (or crossarms); or MOV arrestors on the energised end of insulators for conductive structures. A lightning arrestor will reduce the likelihood of a power arc following a lightning flashover and minimise transient outages of the line.

14.2 UPRATING WITHOUT RECONDUCTORING

14.2.1 Weather Parameter Reassessment

Static thermal ratings are based on conservative estimates of air temperature, wind speed and direction, intensity of solar radiation, conductor emissivity and absorptivity. Ergon has reviewed the weather parameters across Queensland published its recommendations in the internal document “Weather Parameter Analysis for Ergon Energy Overhead Line Ratings”. Ergon has adopted static ratings for 9 geographic regions and the following 6 weather cases

- summer and winter day (9 am to 5 pm)
- summer and winter evening (5 pm to 10 pm)
- summer and winter night/morning (10 pm to 9 am)

Care should be exercised when rating lines that are partially shielded from the wind by trees or terrain. The static thermal rating of long lines should generally be less than short lines because the wind cannot blow perpendicular to the conductor for all sections of the line.

14.2.2 Real Time Rating

Real time rating methods use actual measurements of the variables that influence the transfer capacity of the line. The real time thermal rating of the line is almost always higher than the conservative static thermal rating. Real time rating methods provide an increased transfer capacity without the large capital expenditure and outages required by invasive uprating methods.

14.2.3 Increase Maximum Operating Temperature

An increase in the maximum operating conductor temperature may be possible if the additional thermal capacity is required for emergencies only i.e. annealing is not significant. The increase in sag at the higher operating temperature can be offset by

- removing hanger brackets
- raising the lowest crossarm

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- raising the structure (additional body section for lattice towers, rebutting for wood poles)
- replacing suspension insulators with horizontal post insulators
- replacing the structure with a taller one
- adding extra structures (interpoling)
- removing soil at the critical ground clearance locations
- increasing the conductor tension by resagging the ruling span section
- increasing the conductor tension by removing a segment of conductor - this places a slight longitudinal load on intermediate structures (not recommended)
- increase the conductor tension by adding weights to distort the catenary shape (not recommended)

An increase in conductor tension requires

- calculation of ultimate tension and a review of the loading capacity of strain and termination structures
- a review of damper requirement or damper placement
- no creep allowance when sagging

14.3 UPRATING BY RECONDUCTORING

14.3.1 Conventional Conductors

The figure below shows the current rating for AAAC/1120 conductor at two operating temperatures.

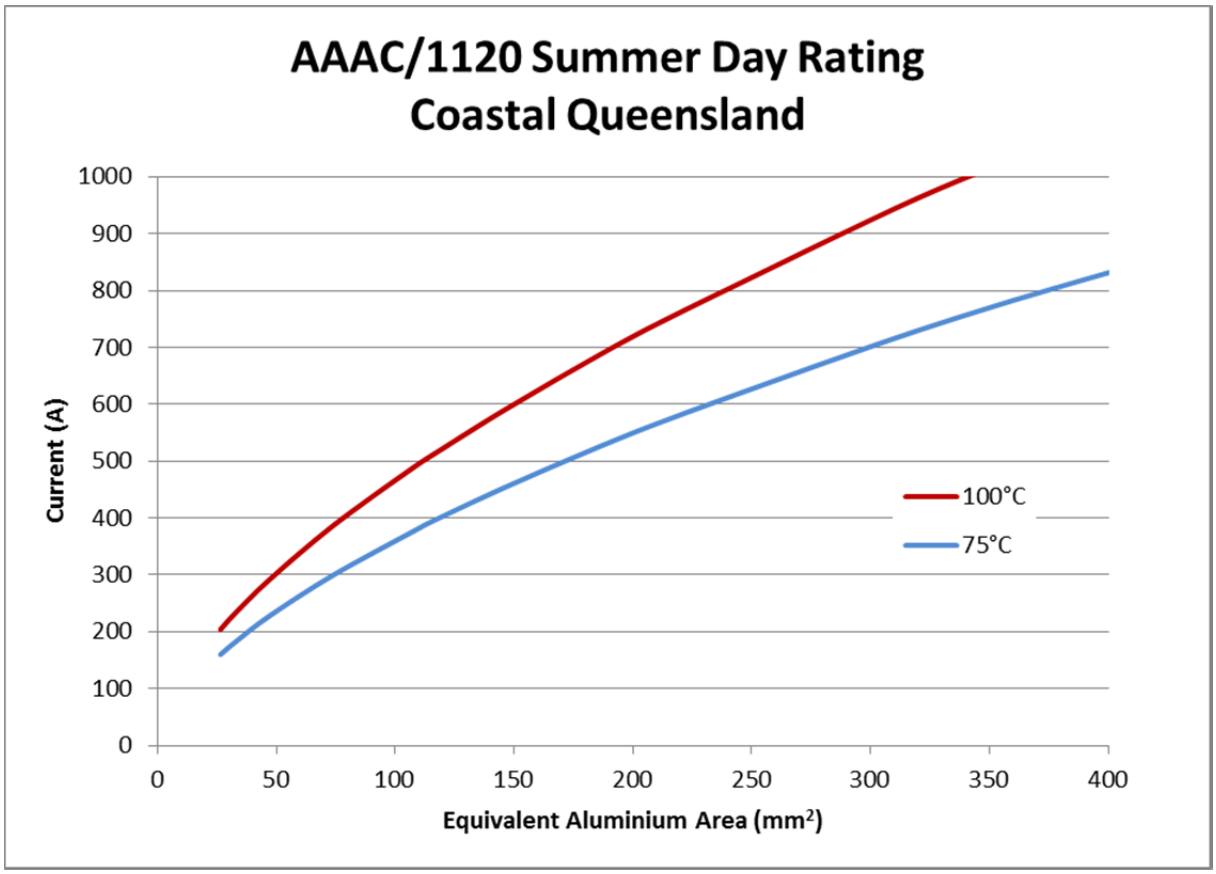

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Figure 13.3.1 – AAAC/1120 Rating

Example

An existing transmission line designed for a maximum operating temperature of 75°C using Kryton (150 mm2 eq. aluminium) conductor needs to be uprated by 50%. The current rating at 75°C is 475A and 712A is required. Using conventional conductor, 248 mm2 Nitrogen (712A at 82°C) is required. The structures will experience an increased conductor wind load of (21-16.3)/16.3 = 29%. To maintain the original ground clearances the "vibration" conductor tension of Nitrogen has to be increased by 75%. Refer to option 1 in the table below. This uprating can only be achieved if the structures were considerably overdesigned or if the structures are upgraded.

Typically, conductor diameter increases up to 10% are economically viable. For an increase of 50% or more, a new line may be the economic option.

14.3.2 High Temperature Low Sag Conductors

Uprating using high temperature low sag (HTLS) conductors is an expensive option. Of the available HTLS conductors, ACSS (aluminium conductor steel supported) is extensively used in the United States. The cost of ACSS is approximately twice the cost of equivalent ACSR. The advantages are

- structure modifications are minimised
- high operating temperatures - up to 250°C continuously without loss of strength
- corrosion protection of steel strands by a coating of zinc-aluminium-mischmetal alloy
- low thermal expansion
- self-damping improves with age
- broken outer strands do not degrade the mechanical strength
- no creep – aluminium strands are fully annealed
- standard strength; high strength and ultra-high strength cores are available

The disadvantages are

- soft aluminium strands are susceptible to damage and bird- caging
- extra stringing precautions required – longer socks, rubber lined sheaves
- not initially self-damping but improves with age or if pre-stressed
- more expensive than conventional conductors

Example

A 66kV line constructed using Krypton requires uprating by 50%. ACSS Partridge does not require any structural uprating. The wind loads are identical and the ultimate longitudinal tension is lower. The vibration tension and catenary constant are higher, however ACSS has excellent self-damping as it ages and this tension increase is acceptable. The losses with ACSS are higher but most lines are highly loaded under a rare single network contingency. Refer to option 2 in the table below.

	Base Case	**Uprating Option 1**	**Uprating Option 2**
Conductor	19/3.25 AAAC/1120 Krypton	37/3.00 AAAC/1120 Nitrogen	26/7 ACSS Partridge

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Equiv. aluminium area	150 mm^2	248 mm^2	135 mm^2
AC resistance	0.230 Ω/km at 75°C	0.143 Ω/km at 82°C	0.302 Ω/km at 138°C
Overall diameter (wind load increase)	16.3 mm	21.0 mm (29% increase)	16.3 mm (no increase)
Mass	433 kg/km	721 kg/km	546 kg/km
Nominal breaking load	37.4 kN	62.2 kN	39.5 kN
Summer noon rating [1]	475 A at 75°C	712 A at 82°C (50% increase)	712 A at 138°C (50% increase)
Power transfer at 66kV	54 MVA	81 MVA	81 MVA
Losses at max. current	52 W/m	72 W/m	153 W/m
Final catenary constant	1260 m at 75°C	1260 m at 82°C	1260 m at 138°C
Final vibration tension [2] at 15°C	1762 m 7.5 kN 20% NBL	1847 m 13.1 kN 21% NBL	2102 m 11.3 kN 28% NBL
Initial vibration tension [2] at 15°C	1994 m 8.5 kN 23% NBL	2115 m 15.0 kN 24% NBL	2102 m 11.3 kN 28% NBL
Ultimate wind tension [2] at 25°C 1500 Pa	25.7 kN 69% NBL	36.4 kN (42% increase) 59% NBL	23.9 kN (7% decrease) 61% NBL

1 Based on IEEE Std 738:2006, 35°C ambient, 1.3 m/s wind at 45°, 0.5 absorptance, 0.5 emissivity
2 Based on 300m ruling span

Table 14.3.2 – Uprating Options for 50% Increase

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15 AGREEMENTS

The designer shall liaise with the relevant Owners and Authorities with regards to crossings of other infrastructure such as roads, rail, communications, pipelines and other electrical infrastructure.

15.1 Queensland Transport and Main Roads (TMR)

If applicable complete Template Document ES000905T108: Written Agreement for Proposed Works – Works on Roads DTMR.

The distance (clear zone) that powerpoles need to be off the roadway depends upon factors such as

- TMR plans to widen the carriageway
- Annual average daily traffic numbers
- Vehicle speed zoning
- Radius and direction of horizontal curves
- Slope of embankment

The following advice was taken from TMR *Road Planning and Design Manual – 2nd Edition* at

http://www.tmr.qld.gov.au/~/media/busind/techstdpubs/Road%20Planning%20and%20Design%202nd%20edition/RPDM2ndEdVolume3.pdf

TMR has further work (as of July 2013) to complete the transition from the Road Planning and Design Manual (1st edition) to align with Austroads guides. Until then the criteria within the Road Planning and Design Manual (1st edition) should be used in lieu of those in the Austroads Guide to Road Design – Part 6. This will ensure that no new criteria are introduced that may later be rejected. The relevant chapter of the Road Planning and Design Manual (1st edition) is Chapter 8 – Safety Barriers and Roadside Furniture and is found at

http://www.tmr.qld.gov.au/~/media/busind/techstdpubs/Road%20planning%20and%20design%20manual/Current%20document/RPDM_Chapter8.pdf

15.2 QR

For Overhead QR Design Requirements refer to Dwg 3141 Sh 1 & 2 of the Distribution Design Manual and for Underground QR Design Requirements refer to Dwg 3401 Sh 1 & 2 of the Distribution Design Manual.

The proposed works need to comply with the relevant Engineering Technical Requirements:

MCE-SR-003 – Requirements for Work Adjacent to Overhead Line Equipment

MCE-SR-002 – Requirements for Work in or About QR Property

MCE-SR-016 – Services Under Rail Corridor.

Technical drawings need to comply with AS 4799-2000: Installation of underground utility services and pipelines within railway boundaries.

15.2.1 QR Wayleave Applications

The relevant applications below should be completed and submitted to:

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QRPROPERTYWAYLEAVES@QR.COM.AU to ensure they are received and processed as soon as possible.

Wayleave Application Conditions (FRM0113)

Wayleave Applications for Electrical Crossing – Underground (FRM0112)

Wayleave Applications for Electrical Crossing – Overhead (FRM0115)

Wayleave Application Form and Tax Invoice

15.3 Aurizon (previously QR National)

For Overhead QR Design Requirements refer to Dwg 3141 Sh 1 & 2 of the Distribution Design Manual and for Underground QR Design Requirements refer to Dwg 3401 Sh 1 & 2 of the Distribution Design Manual.

The proposed works need to comply with the relevant Engineering Technical Requirements:

MCE-SR-003 – Requirements for Work Adjacent to Overhead Line Equipment

MCE-SR-002 – Requirements for Work in or About QR Property

MCE-SR-016 – Services under Rail Corridor

Technical drawings need to comply with AS 4799-2000: Installation of underground utility services and pipelines within railway boundaries.

15.3.1 Aurizon (previously QR National) Wayleave Applications

The relevant applications below should be completed and submitted to:

PropertyEnquiries@qrnational.com.au to ensure they are received and processed as soon as possible.

Wayleave Application Conditions

Wayleave Applications for Electrical Crossing – Underground

Wayleave Applications for Electrical Crossing – Overhead

15.4 Telstra

Refer to Reference Document NA000404R100: Power Coordination Guideline.

The designer is responsible for ensuring the placement of structures complies with the Power Coordination Guidelines.

If applicable complete Template Document PW000802T100: Telstra HV Approval Letter.

15.5 Local Council

Where the line route utilises council land or road reserve the designer shall liaise with the relevant Council on the design. Complete Template Document ES000905T103: Written Agreement for Proposed Works – Works on Council Roads.

15.6 Harbour Board

Procedures for Obtaining Sanction of Water Crossings refer to the Distribution Design Manual

Dwg 3143 Sh 1 to 10.

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If applicable complete Form Document MN000301F137: Water Crossing Works Checklist.

15.7 Aircraft

The Civil Aviation Safety Authority (CASA) has produced *Manual of Standards Part 139 – Aerodromes* which is available at http://www.comlaw.gov.au/Details/F2012C00280/Download. Volume 1 consists of Chapters 1 - 8 and Volume 2 consists of Chapters 9 – 14. Chapter 7 *Obstacle Restriction and Limitation* details the technical requirements for obstacles near the runway approach.

Aircraft warning markers may be required on cables in excess of 90m above the ground. Refer to AS 3891.1:2008 *Air navigation—Cables and their supporting structures—Marking and safety requirements Part 1: Permanent marking of overhead cables and their supporting structures for other than planned low-level flying.*

For low level flying e.g. crop dusting, mustering, power line inspection and ballooning, refer to AS 3891.2:2008 *Air navigation—Cables and their supporting structures—Marking and safety requirements Part 2: Marking of overhead cables for planned low-level flying operations*

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16 ANNEX A - SAFETY LEGISLATION AND POLICIES

16.1 GENERAL

Safety is a paramount concern of Ergon Energy and all design and supply of lines and materials must take into account all safety implications for its construction, maintenance, operations, and ultimate disposal.

16.2 ERGON ENERGY WORK HEALTH AND SAFETY POLICY

Ergon Energy is committed to working in a way that ensures the health and safety of its employees, contractors, customers and members of the public.

To support this commitment, Ergon Energy shall:

- Continually reinforce that working safely is a mandatory condition of employment for all employees and contractors.
- Implement a Health and Safety Management System that not only meets all statutory and industry health and safety requirements, but also aims to achieve best practice.
- Ensure all levels of management demonstrate commitment to and are accountable for community and workplace health and safety.
- Establish and measure occupational health and safety programs to reduce work-related injury and illness.
- Continue to deliver comprehensive safety leadership programs.
- Integrate community and workplace health and safety requirements into all relevant business processes and decisions.
- Consult and involve employees in the development and implementation of workplace health and safety programs that strive for continuous improvement towards zero injuries.
- Develop and implement procedures and work practices which minimise and manage exposure to workplace hazards and risks.
- Ensure all employees and contractors have the information, training and equipment required to competently and safely perform their work.
- Provide and manage the rehabilitation of injured/ill employees.
- Recognise, reward and promote employees who demonstrate positive safety behaviours and take personal responsibility for their safety and those around them.
- Allocate adequate resources to fulfil the aims of this policy.
- Monitor and report compliance with statutory, industry and corporate health and safety requirements.

16.3 QUEENSLAND ELECTRICAL SAFETY LEGISLATION

(i) The Qld Electrical Safety Act 2002 provides that an electricity entity has an obligation to ensure that its works:-

(a) are electrically safe, and

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(b) are operated in a way that is electrically safe

(ii) The Qld Electrical Safety Act 2002 provides that the designer of electrical equipment or an electrical installation has an obligation to ensure that:-

(a) the electrical equipment or installation is designed to be electrically safe, and

(b) if the designer gives the design to another entity who is to give effect to the design, the design is accompanied by information about the way the electrical or installation must be used and installed to ensure the equipment or installation is electrically safe.

(iii) The Qld Electrical Safety Regulation 2013 provides the following requirements that apply for the works of an electricity entity:-

(a) the works must be able to perform under the service conditions and the physical environment in which the works operate;

(b) the works must have enough thermal capacity to pass the electrical load for which they are designed, without reduction of electrical or mechanical properties to a level below that at which safe operational performance can be provided;

(c) to the greatest practicable extent, the works must have enough capacity to pass short circuit currents to allow protective devices to operate correctly;

(d) the works must have enough mechanical strength to withstand anticipated mechanical stresses caused by environmental, construction or electrical service conditions;

(e) the works must be—

(iv) designed and constructed to restrict unauthorised access by a person to live exposed parts; and

(v) operated in a way that restricts unauthorised access by a person to live exposed parts;

(f) design, construction, operation and maintenance records necessary for the electrical safety of the works must be kept in an accessible form;

(g) parts of the works whose identity or purpose is not obvious must be clearly identified by labels, and the labels must be updated as soon as possible after any change is made to the works;

electrical equipment intended to form part of the works of an electricity entity must undergo commissioning tests and inspection to verify that the electrical equipment is suitable for service and can be operated safely when initially installed or altered.

16.4 WORK HEALTH AND SAFETY

16.4.1 Work Health and Safety Act

• The Queensland Work Health and Safety Act 2011 provides the framework to protect the health, safety, and welfare of all workers at work, and of all other people who might be affected by the work.

Under the WH&S Act everyone has duties (obligations), and the duties for a person conducting a business or undertaking are defined and involve:

- management or control of workplaces
- management or control of fixtures, fittings or plant at workplaces
- design of plant, substances or structures

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- manufacture plant, substances or structures
- Importation of plant, substances or structures
- supply plant, substances or structures
- installation, construction, commissioning plant or structures

Designers of plant, structures or substances have a duty:

(a) To Ensure Health and Safety in The Workplace
A designer of a plant, structure or substance that is to be used, or could reasonably be expected to be used, at a workplace must ensure all workplace activity relating to the plant, structure or substance, including its handling or construction, storage, dismantling and disposal is designed to be without risks to health or safety.

(b) To Test
A designer of the plant, structure or substance must carry out tests and examinations sufficient to ensure that when used for its intended purpose it is safe and without risks to health or safety.

(c) To Provide Information
*Information must be made available to those for whom the plant, structure or substance was designed about its intended purpose, test results and any conditions necessary to ensure that it is safe and without risks to health or safety, when used for its intended pur*pose.

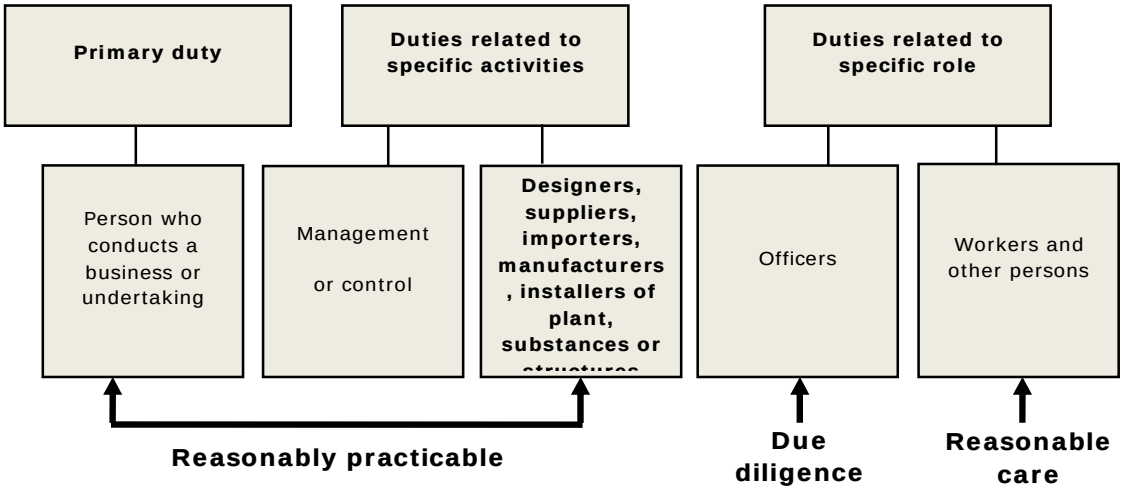

Figure 16.4.1 – Work Health and Safety Act Duties.

16.4.2 Reasonably Practicable

A Person conducting a business or undertaking must ensure, so far as is reasonably practicable the health and safety of:

- workers (broadly defined) engaged, or caused to be engaged by the person; and
- workers whose activities in carrying out work are influenced or directed by the person; and
- other persons are not put at risk from work carried out as part of the conduct of the business or undertaking

A person conducting a business or undertaking must ensure, so far as is reasonably practicable:

- provision and maintenance of a work environment without risks to health and safety
- provision and maintenance of safe plant and structures

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- Provision and maintenance of safe systems of work
- Safe use, handling and storage of plant, structures and substances
- Provision of adequate facilities
- Provision of information, training, instructions or supervision
- Monitoring of workplace conditions

Reasonably practicable, in relation to a duty to ensure health and safety, means that which is, or was at a particular time, reasonably able to be done in relation to ensuring health and safety, taking into account and weighing up all relevant matters including:

(a) the likelihood of the hazard or the risk concerned occurring; and

(b) the degree of harm that might result from the hazard or the risk; and

(c) what the person concerned knows, or ought reasonably to know, about the hazard or the risk; and

(d) ways of eliminating or minimising the risk; and

(e) the availability and suitability of ways to eliminate or minimise the risk; and

(f) after assessing the extent of the risk and the available ways of eliminating or minimising the risk, the cost associated with available ways of eliminating or minimising the risk, including whether the cost is grossly disproportionate to the risk.

16.4.3 Safety in Design (Risk Management)

Safety in Design is defined as the integration of hazard identification and risk assessment and control methods early in the design process to eliminate, and if this is not reasonably practicable, minimise the risk to health and safety throughout the life of the product being designed.

The designer shall document using the Safety in Design Risk Assessment Form any hazards or risks associated with the design, construction or ongoing operation and maintenance of the structure in the design development phase. These risks must be assessed, and any residual risks assessed as higher than a low risk must be documented in the Simple Project Risk Management Plan. For design works undertaken by an Ergon Energy designer, the designer will supply a Simple Project Risk Management Plan (SPRMP) detailing any specific risks or hazards not covered by Ergon Energy's Standard Safe Work Method Statements (SWMS), Standard Work Practices (SWP), or Work Instructions for identified risks or hazards for the construction work.

Refer: ES000905R104 Safety in Design Reference

ES000905F102 Safety in Design Risk Assessment Form

PW000702F100 Simple Project Risk Management Plan

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17 ANNEX B – COMPONENT CAPACITIES – SUB-TRANSMISSION CONSTRUCTION MANUAL

Load capacities for fabricated components/assemblies								
Component / Assembly			Load Capacities (Φ = 0.9 applied U.N.O.)					
Reference Drawing	Description	Ref. Fabrication DWG's	Load Capabilities	Limit State Wind Load	Failure Containment		Maintenance Load	Notes
					Yeild	Significant Deflection		
5-2-1001(0A)	OHEW Bracket	930104-01 (0A)	Limited by Bracket capacity M16 grade 4.6 bolts (each). Bolts Φ= 0.8 Tension capacity ΦN_{tf} - 50 kN Shear capacity ΦV_f (Threads) - 27kN	**15 kN** transverse @ **0 kN** vertical **23 kN** transverse @ **4 kN** vertical	**4.1 kN** longitudinal @ **1 kN** vertical	**15 kN** longitudinal @ **1 kN** vertical	-	(Rockfield Stage 1 Add #1) (Rockfield Stage 1 Add #1)
5-2-1004 (0A)	OHEW Strain Eyebolt	907224-05 (0A)	Limited by eye bolt shear & Bow Shackle Tension. **M20 eye bolt -** grade 4.6 Bolts Φ= 0.8 Shear capacity **ΦVf (Threads) - 43kN** **Bow Shackle capacity -** $ØR_u$ = 0.625 x rated capacity Tension capacity **ΦR_u = 75 kN**	-	-	-	-	AS7000 CL 6.3.2 allows for ductile yeilding of ductile structural elements at the discretion of the designer. Testing of forged fittings allows for no yeild @ 50% of Breaking load. Therfore 62.5% has been chosen as the design factor which allows for some minor ductile yield while not approaching the minimum braking force.
5-2-1005 (0A)	Stay Bracket for Earthwire Termination & Line Deviation	929568-01 (0A)	Stay side limited by Bracket capacity M24 grade 8.8 bolts (each). Bolts Φ= 0.8 Tension capacity ΦN_{tf} - 163 kN Shear capacity ΦV_f (Threads) - 89kN (Non-symetric loads should be avoided to limit pole torque load and potential bending of bolts.) Earthwire side limited by Shackle capacity $ØR_u$ = 0.625 x rated capacity	**Stay side** **Stay Bracket - (load in stay direction)** **125 kN** at centre hole only @ 45° from vertical and 0° from transverse plane. **108 kN** at centre hole only @ 45° from vertical and 15° from transverse plane. **125 kN** per inclined hole (both loaded) @ 45° from vertical and 0° from transverse plane. **125 kN** per inclined hole (both loaded) @ 45° from vertical and 15° from transverse plane. **Earthwire side** **Earthwire Connection** Max Earthwire tension - **75kN**	- -	- -	- - AS7000 CL 6.3.2 allows for ductile yeilding of ductile structural elements at the discretion of the designer. Testing of forged fittings allows for no yeild @ 50% of Breaking load. Therfore 62.5% has been chosen as the design factor which allows for some minor ductile yield while not approaching the minimum	Stay bracket loaded lower centre hole only Stay bracket loaded lower centre hole only Stay load to inclined holes only (Rockfield Stage 1 Add #1) Stay load to inclined holes only (Rockfield Stage 1 Add #1)
5-2-1006 (0A)	OHEW Earthing Connections		N/A Non-Structural assembly					
5-2-1007 (0A)	Stay Brackets Back to Back	929568-01 (0A)	Limited by Bracket capacity M24 grade 8.8 bolts (each). Bolts Φ= 0.8 Tension capacity ΦN_{tf} - 163 kN Shear capacity ΦV_f (Threads) - 89kN (Non-symetric loads should be avoided to limit pole torque load and potential bending of bolts.)	**113 kN** at centre hole only @ 45° from vertical and 0° from transverse plane. **98 kN** at centre hole only @ 45° from vertical and 15° from transverse plane. **113 kN** per inclined hole (both loaded) @ 45° from vertical and 0° from transverse plane. **113 kN** per inclined hole (both loaded) @ 45° from vertical and 15° from transverse plane.			AS7000 CL 6.3.2 allows for ductile yeilding of ductile structural elements at the discretion of the designer. Testing of forged fittings allows for no yeild @ 50% of Breaking load. Therfore 62.5% has been chosen as the design factor which allows for some minor ductile yield while not approaching the minimum braking force.	Stay bracket loaded lower centre hole only Stay bracket loaded lower centre hole only Stay load to inclined holes only (Rockfield Stage 1 Add #1) Stay load to inclined holes only (Rockfield Stage 1 Add #1)

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Component / Assembly			Load Capacities (Φ = 0.9 applied U.N.O.)					
Reference Drawing	Description	Ref. Fabrication DWG's	Load Capabilities	Limit State Wind Load	Failure Containment		Maintenance Load	Notes
					Yeild	Significant Deflection		
5-2-1008 (0A)	M20 Eyebolt to Pole	QESI 01-02-02	Limited by Eye Bolt shear. **M20 eye bolt -** grade 4.6 Bolts Φ= 0.8 Shear capacity **ΦVf (Threads) - 44.6kN**	-	-	-	-	
5-2-1009 (0A)	OHEW Heavy Duty Raiser 10 315/405 tip pole.	930543-01 (0A)	Limited by Bracket capacity M20 grade 4.6 bolts (each). Bolts Φ= 0.8 Tension capacity ΦN_{tf} - 78 kN Shear capacity ΦV_f (No thread) - 62kN	±12.9 kN transverse @ 4 kN vertical (Limited by SHS section capacity)	4.1 kN longitudinal (Limited by cleat plate yield)	13 kN longitudinal (Limited by M20 top bolt shear)		
5-2-1010 (0A)	OPGW Strain Connection to OHEW Raiser Bracket		Limited by Eye Bolt Capacity. **M16 eye bolt -** grade 4.6 Bolts Φ= 0.8 Tension capacity ΦN_{tf} - 50 kN Shear capacity ΦV_f (thread) - 28kN					
5-2-1016 (0A)	Composite Post insulator		Limited by Bolt shear. **M20 bolt -** grade 4.6 Bolts Φ= 0.8 Shear capacity **ΦVf (no Threads) - 62kN**					
5-2-1018 (0A)	Gain Base Bracket & Insulator	987653-01 (0A)	Limited by Bracket capacity Insulator weight plus 6kN Vertical or Insulator Weight plus 4kN Longitudinal. M20 bolts - grade 4.6 Bolts Φ= 0.8 Tension capacity ΦN_{tf} - 78 kN Shear capacity ΦV_f (Threads) - 43kN		Insulator weight plus 6kN Vertical or Insulator Weight plus 4kN Longitudinal.	8kN Longitudinal		
5-2-1023 (0A)	Insulator Composite longrod		Limited by Insulator capacity **Insulator capacity - ΦR_u = 60 kN** $\emptyset R_u$ = 0.5 x rated capacity AS7000:2010 Table 6.2 Tension capacity **ΦR_u = 60 kN**					
5-2-1030 (0A)	Insulator Composite longrod with extension link		Limited by Insulator capacity **Insulator capacity - ΦR_u = 60 kN** $\emptyset R_u$ = 0.5 x rated capacity AS7000:2010 Table 6.2 Tension capacity **ΦR_u = 60 kN**					
5-2-1031 (0A)	Eyebolt to Pole	QESI 01-02-02	Limited by Eyebolt capacity M20 grade 4.6 eyebolt. Bolts Φ= 0.8 Tension capacity **ΦN_{tf} - 78 kN** Shear capacity **ΦV_f - 43kN (Threads)**					

Component / Assembly			Load Capacities (Φ = 0.9 applied U.N.O.)					
Reference Drawing	Description	Ref. Fabrication DWG's	Load Capabilities	Limit State Wind Load	Failure Containment		Maintenance Load	Notes
					Yeild	Significant Deflection		
5-2-1046 (0A)	Normal Insulator to Single Conductor Support		Limited by Insulator capacity **Insulator capacity - ΦR_u = 35 kN** $\emptyset R_u$ = 0.5 x rated capacity AS7000:2010 Table 6.2 Tension capacity **ΦR_u = 35 kN**					
5-2-1047 (0A)	Rural Intermediate Normal Crossarm to Pole	930838-01 (0A) 930615-01 (0A) 930525-01 (0A)	Limited by bolt shear in thread. Φ= 0.8	**20kN** vertical load in combination with ± **20 kN** transverse load	**7 kN** longitudinal load		**24 kN** vertical load.	
5-2-1049 (0A)	Vertical Flying Angle Crossarm to Pole	930838-01 (0A) 930613-01 (0A)	Limited by bolt shear in thread. Φ= 0.8	**20kN** vertical load in combination with ± **20 kN** transverse load	**7 kN** longitudinal load		**24 kN** vertical load.	
5-2-1054 (0A)	Extension Eyebolt to 315 Tip Pole	875223-01 (0A)	Limited by Eybolt bracket capacity	**9 kN** vertical	**3.2 kN** longitudinal **@ 1 kN** vertical	**10 kN** longitudinal **@ 1 kN** vertical		
5-2-1055 (0A)	Rural Intermediate Extended Crossarm to Pole	930539-01 (0A) 930531-01 (0A) 930584-01 (0A) 930565-01 (0A)	Limited by bolt shear in thread. Φ= 0.8	**15 kN** vertical load in combination with ± **20 kN** transverse load	**5.8 kN** longitudinal load		**20 kN** vertical load.	
5-2-1061 (0A)	Normal Insulator Termination with Extension Link	907224-06 (0A) 907224-04 (0A)	Limited by Insulator capacity **Insulator capacity - ΦR_u = 35 kN** $\emptyset R_u$ = 0.5 x rated capacity AS7000:2010 Table 6.2 Tension capacity **ΦR_u = 35 kN**					
5-2-1062 (0A)	Normal Insulator Termination with Adjustable Sag Link	907224-04 (0A)	Limited by Insulator capacity **Insulator capacity - ΦR_u = 35 kN** $\emptyset R_u$ = 0.5 x rated capacity AS7000:2010 Table 6.3 Tension capacity **ΦR_u = 35 kN**					
5-2-1063	Porcelain Insulator Stub Mounted, Tie Top Bridging Apllication	949355-01 0	Limited by Bracket Capacity	**1.4 kN** vertical **1.0 kN** longitudinal				Insulator Capacity Minimum Failing Load Cantilever = 12.5kN
5-2-1064	Flanged Eyebolt to pole	907224-05 (0A)	Limited by Eyebolt capacity M20 grade 4.6 eyebolt. Bolts Φ= 0.8 Tension capacity **ΦN_{tf} - 78.4 kN** Shear capacity **ΦV_f - 43kN (Threads)**					

Component / Assembly			Load Capacities (Φ = 0.9 applied U.N.O.)					
Reference Drawing	Description	Ref. Fabrication DWG's	Load Capabilities	Limit State Wind Load	Failure Containment		Maintenance Load	Notes
					Yeild	Significant Deflection		
5-2-1071	Stay Bracket & Backing Plate	929568-01 (0A) 929878-01 (0A)	Stay side limited by Bracket capacity M24 grade 8.8 bolts (each). Bolts Φ= 0.8 Tension capacity ΦN_{tf} - 163 kN Shear capacity ΦV_f(Threads) - 89kN (Non-symetric loads should be avoided to limit pole torque load and potential bending of bolts.)	**Stay Bracket - (load in stay direction)** **125 kN** at centre hole only @ 45° from vertical and 0° from transverse plane. **108 kN** at centre hole only @ 45° from vertical and 15° from transverse plane.				Stay load to centre lower hole Stay load to centre lower hole
5-2-1077	Bisect Stay brackets & Backing Plate.	929568-01 (0A) 929878-01 (0A)	Stay side limited by Bracket capacity M24 grade 8.8 bolts (each). Bolts Φ= 0.8 Tension capacity ΦN_{tf} - 163 kN Shear capacity ΦV_f(Threads) - 89kN (Non-symetric loads should be avoided to limit pole torque load and potential bending of bolts.)	**Stay Bracket - (load in stay direction)** **125 kN** at centre hole only @ 45° from vertical and 0° from transverse plane. **108 kN** at centre hole only @ 45° from vertical and 15° from transverse plane.				Stay load to centre lower holes Stay load to centre lower holes
5-2-1084	M24 Eyebolt to Pole		Limited by Eyebolt bending capacity M20 grade 8.8 eyebolt. Bolts Φ= 0.8 Tension capacity ΦN_{tf} - 163 kN Shear capacity ΦV_f - 89kN (Threads)	Load per stay Stay Load **23 kN** @ 45° to vertical **16 kN** vertical (resultant load)				
	Pole Stock Code Assemby drawings							
5-2-1100	Urban Pole SC Conc. Delta/Ver Intermediate		N/A - Non-Structural assembly					
5-2-1102	Urban Pole SC Conc. Vert Fly Ang No Xarm		N/A - Non-Structural assembly					
5-2-1105	Urban Pole SC Conc. Vert Strain 15° - 45°		N/A - Non-Structural assembly					
5-2-1106	Urban Pole SC Conc. Vert Strain 0° - 15°		N/A - Non-Structural assembly					
5-2-1107	Urban Pole SC Conc. Vert Strain 45° - 75°		N/A - Non-Structural assembly					
5-2-1108	Urban Pole SC Conc. Vert Strain 75° - 105°		N/A - Non-Structural assembly					
5-2-1126	Rural Pole SC Conc. Delta Susp Norm/1 Ext		N/A - Non-Structural assembly					
5-2-1127	Rural Pole SC Conc. Delta Susp 2 Ext Xarms		N/A - Non-Structural assembly					
5-2-1134	Rural Pole SC Conc. Vert Fly Ang+Xarms		N/A - Non-Structural assembly					
5-2-1135	Rural Pole SC Conc. Vert Fly Ang No Xarm		N/A - Non-Structural assembly					
5-2-1139	Rural Pole SC Conc. Vert Strain 0° - 5°		N/A - Non-Structural assembly					
5-2-1140	Rural Pole SC Conc. Vert Strain 5° - 15°		N/A - Non-Structural assembly					
5-2-1141	Rural Pole SC Conc. Vert Strain 15° - 35°		N/A - Non-Structural assembly					
5-2-1143	Rural Pole SC Conc. Vert Strain 35° - 45°		N/A - Non-Structural assembly					
5-2-1144	Rural Pole SC Conc. Vert Strain 45° - 55°		N/A - Non-Structural assembly					
5-2-1145	Rural Pole SC Conc. Vert Strain 55° - 65°		N/A - Non-Structural assembly					
5-2-1146	Rural Pole SC Conc. Vert Strain 65° - 75°		N/A - Non-Structural assembly					
5-2-1147	Rural Pole SC Conc. Vert Strain 75° - 85°		N/A - Non-Structural assembly					
5-2-1148	Rural Pole SC Conc. Vert Strain 85° - 95°		N/A - Non-Structural assembly					
5-2-1149	Rural Pole SC Conc. Vert Strain 95° - 105°		N/A - Non-Structural assembly					
5-2-1150	Stayed Bollard 100kN Capacity		N/A - Non-Structural assembly					
5-2-1151	Unstayed bollard 100 kN Capacity		N/A - Non-Structural assembly					

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Component / Assembly			Load Capacities (Φ = 0.9 applied U.N.O.)					
Reference Drawing	Description	Ref. Fabrication DWG's	Load Capabilities	Limit State Wind Load	Failure Containment		Maintenance Load	Notes
					Yeild	Significant Deflection		
	Subsidiary Assemblies							
5-2-1160	11kV Crossarm Composite Fibre							
5-2-1161	Insulator Disk Ball & Socket							
5-2-1162	11kV Crossarm to Concrete pole.							
5-2-1163	Extension eyebolt to composite crossarm							
5-2-1164	Double brace to composite crossarm							
5-2-1165	M16 Bolt & Nut to Concrete pole							
5-2-1166	Normal Insulator Disk Starin/Termination 11kV							
5-2-1167	M20 Eyebolt to Composite Crossarm							
5-2-1168	11/22/33kV Insulator Pin							
5-2-1169	11/22/33kV Pin Insulators							
5-2-1170	200kV BIL Porcelain Tie Top Insulator to Concrete Pole		Limited by Bracket capacity **Insulator weight plus 6kN Vertical** **or** **Insulator Weight plus 4kN Longitudinal.** M20 bolts - grade 4.6 Bolts Φ= 0.8 Tension capacity ΦN_{tf} - 78 kN Shear capacity ΦV_f (Threads) - 43kN		Insulator weight plus 6kN Vertical or Insulator Weight plus 4kN Longitudinal.	8kN Longitudinal		
5-2-1171	Termination Bracket to Pole 70kN							
5-2-1172	Crossarm clampband to concrete pole							
5-2-1173	Ball & Socket Connection							
	Conductor Hardware Assembly Drawings.							
5-2-1200	AGSU single to OHEW support		N/A - Non-Structural assembly					
5-2-1201	AGSU single to Phase Conductor		N/A - Non-Structural assembly					
5-2-1202	AGSU double to OHEW support		N/A - Non-Structural assembly					
5-2-1203	AGSU double to Phase Conductor		N/A - Non-Structural assembly					
5-2-1204	AGSU single to OPGW support		N/A - Non-Structural assembly					
5-2-1205	AGSU single to OPGW Conductor		N/A - Non-Structural assembly					
5-2-1206	Armour grip support w/o armor rods		N/A - Non-Structural assembly					
5-2-1208	Trunion support clamp		N/A - Non-Structural assembly					
5-2-1209	Trunion support clampw/ armour rods		N/A - Non-Structural assembly					
5-2-1213	Compression Dead end trans palm w/ eye		N/A - Non-Structural assembly					
5-2-1214	Compression Dead end in-line palm w/ eye		N/A - Non-Structural assembly					
5-2-1215	Preform Dead end+thimble for cond & OH		N/A - Non-Structural assembly					
5-2-1216	Preformed tie top insulator for conductor		N/A - Non-Structural assembly					
5-2-1217	Preformed tie top insulator w/ armor rods f		N/A - Non-Structural assembly					
5-2-1219	Stockbridge vibration dampers		N/A - Non-Structural assembly					
	Earthing Assemblies							
5-2-1251	Grading ring - Earthing Arrangement		N/A - Non-Structural assembly					
5-2-1252	Earth to Concrete Pole.		N/A - Non-Structural assembly					

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Component / Assembly			Load Capacities (Φ = 0.9 applied U.N.O.)					
Reference Drawing	Description	Ref. Fabrication DWG's	Load Capabilities	Limit State Wind Load	Failure Containment		Maintenance Load	Notes
					Yeild	Significant Deflection		
	Foundation Assemblies.							
	Stay Anchors							
5-2-1276	Conc Bedlog - M24 Rod	929511-01 (0A) 929393-01 (0A)	1276-1 Limited by Rod Tensile Capacity M24 Grade 4.6 - **ΦN$_{tf}$ = 113 kN**					Φ = 0.8
	Conc Bedlog - M36 Rod	929512-01 (0A) 929394-01 (0A)	1276-2 Limited by soil bearing capacity 100kPa soil - **ΦP = 240 kN**					Φ = 0.8 M36 Grade 4.6 - ΦNtf = 261 kN
5-2-1277	Stay Anchors		Limited by Rod Tensile Capacity					
	Inclined Soil/Rock M24 ro	929511-01 (0A)	M24 Grade 4.6 - **ΦN$_{tf}$ = 113 kN**					Φ = 0.8
	Inclined Soil/Rock M36 ro	929512-01 (0A)	M36 Grade 4.6 - **ΦN$_{tf}$ = 261 kN**					
5-2-1278	Stay Anchors		Limited by Rod Tensile Capacity					
	MassCon 1-M24	929511-01 (0A)	M24 Grade 4.6 - **ΦN$_{tf}$ = 113 kN**					Φ = 0..8
	MassConc M36	929512-01 (0A)	M36 Grade 4.6 - **ΦN$_{tf}$ = 261 kN**					
	MassConc2-M24		2xM24 Grade 4.6 - **ΦN$_{tf}$ = 226 kN**					
5-2-1279	600Dia Vertical Pier	929568-01 (0A) 929825-01 (0A)	Limited by soil capacity Max Stay Load = 100kN (in plane of stay)					
5-2-1280	900 Dia Vertical Pier	929569-01 (0A) 929824-01 (0A)	Limited by soil capacity Max Stay Load = 200kN (in plane of stay)					
5-2-1290	Precast Concrete Biscuit	940557-01 (0A)	Compression base non-structural. Transfer DL to subbase. Load spreading device.					
5-2-1320	Fall Arrest Bracket & Pole Steps	907224-07 (0A) QESI 01-01-02 ETS 01-02-01	Limited by Pole step Bending Can support **1- 61 kG person** standing on the bolt head.					

18 ANNEX C – OPGW SPECIFICATIONS

Manufacturer	AFL Telecommunications	AFL Telecommunications	AFL Telecommunications	Suzhou Furukawa Power Optic Cable (SFPOC)
Catalogue Number	CC-30/30/449 CentraCore Single layer 30 mm^2 AC 30 mm^2 AA	CC-38/48/551 CentraCore Single layer 38 mm^2 AC 48 mm^2 AA	CC-38/48/551 CentraCore Single layer 38 mm^2 AC 48 mm^2 AA	SFSJ-J-3377 Dual Tube Two layers 31 mm^2 AC 140 mm^2 AA
Description	0.449" OD	0.551" OD	0.551" OD	0.449" OD
Overall Diameter (mm)	11.4	14.0	14.0	17.7
Nominal Sectional Area (mm^2)	75.83	116.46	116.46	171
Fibre Count (single mode)	24	24	48	48
Approximate Mass (kg/km)	341	527	527	612
Calculated Breaking Load (kN)	48.88	73.26	73.26	69.00
DC Resistance at 20°C (Ω/km)	0.5809	0.3787	0.3787	0.2080
Final Modulus of Elasticity (GPa)	105	105	105	76
Coefficient of Linear Expansion (per °C)	16.6E-06	16.5E-06	16.5E-06	19.8E-06
Short Circuit Rating $(kA)^2.s$	45	109	109	300 UN
Short Circuit Current for 1s (kA)	6.7	10.4	10.4	17.3 UN

Table 18.0 – OPGW Specifications

Notes:

1. AC – aluminium clad steel strand

   AA – aluminium alloy 6201 strand

   OD – overall diameter

   UN – unknown rating assumptions

2. Short circuit rating based on

- adiabatic heating
- cable temperature prior to fault of 40°C
- allowable cable temperature after fault of 210°C

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19 ANNEX D – CONDUCTOR WIND PRESSURE

	REGION		
Span Length (m)	**A4 (Downdraft)**	**B (Downdraft)**	**C (Synoptic)**
0 (no SRF)	1109	1464	2221
50	1109	1464	2028
100	1109	1464	1876
150	1109	1464	1757
200	1109	1464	1662
300	1075	1418	1529
400	1040	1373	1446

Table 19.0 - Transverse Conductor Wind Pressures

The values in the above table are indicative only. It remains the Designers responsibility to ensure that the appropriate terrain category, height and topographic multipliers are applied as encountered and in accordance with Section 9.2 of this manual.

Summary of table above:

- V200 wind speed
- Terrain category 2
- Average conductor height 10m
- Shielding multiplier 1.0
- Drag coefficient for conductor 1.0 (where standard Ergon conductors are used).

The wind forces on poles, towers and insulators shall be in accordance with AS/NZS 7000 Appendix B.

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20 ANNEX E – EASEMENTS

The following assumptions are inherent in the tabulated values below -

- Parallel circuits are the same voltage or lower.
- 2.0 m crossarms for 66 kV and 2.5 m crossarms for 132 kV.
- Sags and tensions based on AAAC/1120 conductors with a minimum slack of 100mm and a maximum tension of 20% NBL at 15°C.
- Conductor swing at 35°C and 500 Pa wind pressure (no localised wind shear).

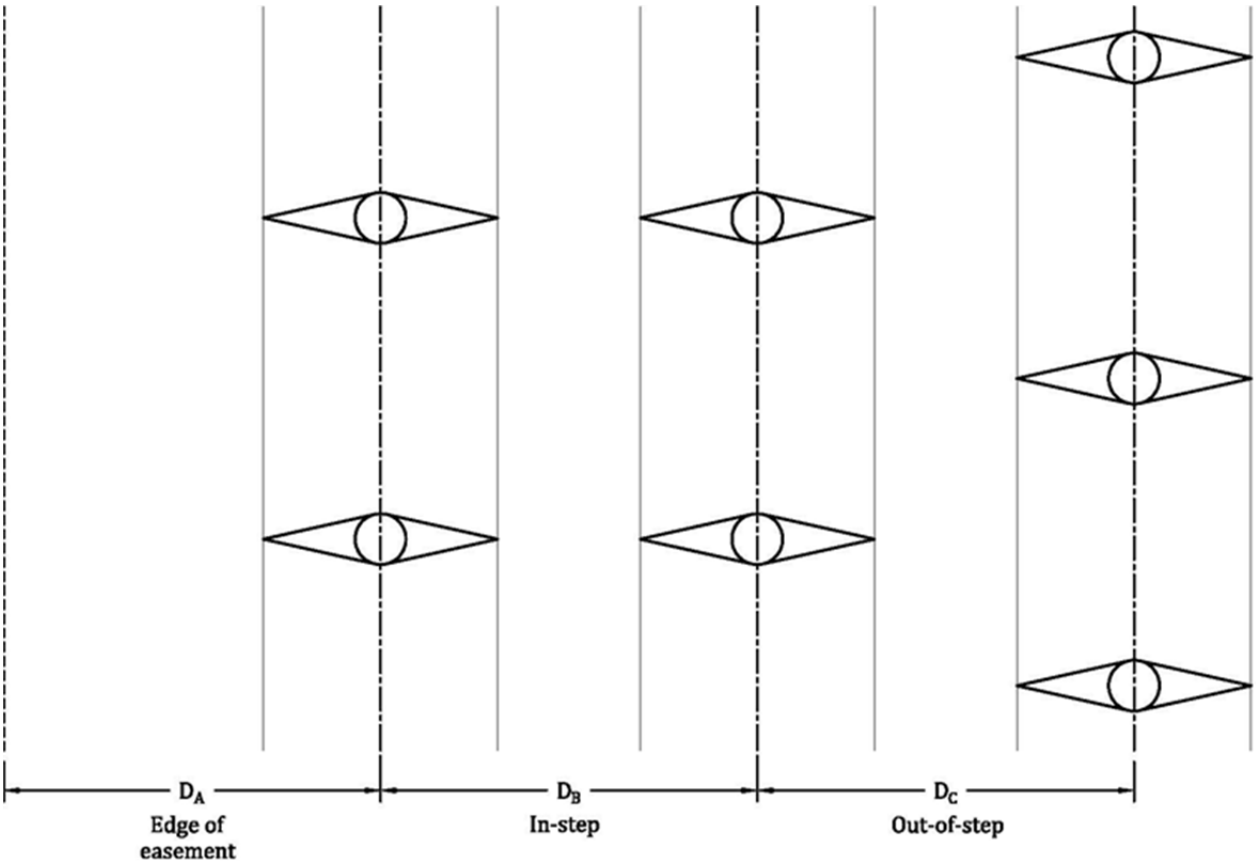

Figure 20.0 - Graphical Representation of the Tabulated Distances Below

DA – Distance from the centreline to the edge of the easement.

DB – Distance from centreline to centreline for structures placed in-step with each other.

The conductors blow out together.

DC – Distance from centreline to centreline for structures placed out-of-step with each other.

The conductors blow out towards a structure placed opposite the midspan of the other circuit.

Table E1 is a sample of conductors and their swing angle from vertical at 500 Pa of transverse wind pressure.

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Construction	Stranding	Swing Angle at 500Pa (°)	Swing Angle Range (°)	Diameter (mm)
HDC	37 / 0.064"	39.9	35 - 45	11.4
HDC	19 / 0.083"	41.8	35 - 45	10.5
HDC	7 / 0.136"	41.9	35 - 45	10.4
HDC	19 / 0.072"	46.0	45 - 55	9.1
HDC	19 / 0.064"	49.2	45 - 55	8.1
HDC	7 / 0.104"	49.5	45 - 55	7.9
AAC & AAAC	61 / 3.75	42.8	35 - 45	33.8
AAC & AAAC	61 / 3.50	44.7	35 - 45	31.5
AAC & AAAC	61 / 3.25	46.8	45 - 55	29.3
AAC & AAAC	37 / 3.75	49.9	45 - 55	26.3
AAC & AAAC	19 / 4.75	52.7	45 - 55	23.8
AAC & AAAC	37 / 3.00	56.0	55 - 65	21.0
AAC & AAAC	19 / 3.75	58.9	55 - 65	18.8
AAC & AAAC	19 / 3.25	62.4	55 - 65	16.3
AAC & AAAC	7 / 4.75	65.1	65 - 75	14.3
AAC & AAAC	7 / 4.50	66.2	65 - 75	13.5
AAC & AAAC	7 / 3.75	69.9	65 - 75	11.3
AAC & AAAC	7 / 3.00	73.6	65 - 75	9.0
ACSR	54 / 3.75 + 19/2.25	37.4	35 - 45	33.8
ACSR	54 / 7 / 3.5	39.3	35 - 45	31.5
ACSR	54 / 7 / 3.25	41.5	35 - 45	29.3
ACSR	30 / 7 / 3.5	43.4	35 - 45	24.5
ACSR	54 / 7 / 3.0	43.7	35 - 45	27.0
ACSR	30 / 7 / 3.25	45.5	45 - 55	22.8
ACSR	30 / 7 / 3.0	47.7	45 - 55	21.0
ACSR	30 / 7 / 2.5	52.9	45 - 55	17.5
ACSR	4 / 3 / 3.75	56.7	55 - 65	11.3
ACSR	6 / 4.75 + 7 / 1.60	61.0	55 - 65	14.3
ACSR	4 / 3 / 3.0	62.2	55 - 65	9.0
ACSR	6 / 1 / 3.75	65.0	65 - 75	11.3
ACSR	6 / 1 / 3.0	69.6	65 - 75	9.0

Table 20.0 – Conductor Swing Angles at 500 Pa

For conductors not listed in Table E1, the conductor swing angle Φ is

- $\emptyset = tan^{-1}\left(\frac{Pd}{w}\right)$

where

P – wind pressure of 500 Pa

d – conductor overall diameter (m)

w – conductor weight (N/m)

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66 kV	Conductor Swing Angle at 500Pa		35° - 45°			45° - 55°			55° - 65°			65° - 75°		
Ruling Span (m)	Maximum Span (m)	Insulation	D_A	D_B	D_C	D_A	D_B	D_C	D_A	D_B	D_C	D_A	D_B	D_C
20	28	Post	7.9	7.0	8.3	8.1	7.0	8.5	8.2	7.0	8.6	8.3	7.0	8.7
40	56	Post	8.5	7.0	8.9	8.8	7.0	9.2	9.0	7.0	9.4	9.2	7.0	9.6
60	84	Post	9.0	7.0	9.4	9.4	7.0	9.8	9.7	7.0	10.1	10.0	7.0	10.4
80	112	Post	9.4	7.0	9.8	9.9	7.0	10.3	10.4	7.0	10.8	10.9	7.2	11.3
100	140	Post	9.9	7.0	10.3	10.5	7.0	10.9	11.1	7.1	11.5	11.7	7.6	12.1
150	210	Suspension	11.7	7.0	12.1	12.7	7.3	13.1	13.7	8.0	14.1	15.0	8.8	15.4
200	280	Suspension	13.1	7.0	13.5	14.1	7.8	14.5	15.9	8.9	16.3	17.5	9.8	17.9
250	350	Suspension	15.8	7.4	16.2	17.1	8.7	17.5	19.5	10.3	19.9	21.5	11.5	21.9
300	420	Suspension	18.9	8.1	19.3	20.5	9.8	20.9	23.7	11.8	24.1	26.1	13.4	26.5
350	490	Suspension	22.6	8.8	23.0	24.5	11.0	24.9	28.5	13.6	28.9	31.2	15.4	31.6

Table 20.1 - Minimum Easement and Inter-Circuit Distances (m) at 66kV

132 kV	Conductor Swing Angle at 500Pa		35° - 45°			45° - 55°			55° - 65°			65° - 75°		
Ruling Span (m)	Maximum Span (m)	Insulation	D_A	D_B	D_C	D_A	D_B	D_C	D_A	D_B	D_C	D_A	D_B	D_C
20	28	Post	8.4	8.0	10.9	8.6	8.0	11.1	8.7	8.0	11.2	8.8	8.0	11.3
40	56	Post	9.0	8.0	11.5	9.3	8.0	11.8	9.5	8.0	12.0	9.7	8.0	12.2
60	84	Post	9.5	8.0	12.0	9.9	8.0	12.4	10.2	8.0	12.7	10.5	8.3	13.0
80	112	Post	9.9	8.0	12.4	10.4	8.0	12.9	10.9	8.3	13.4	11.4	8.7	13.9
100	140	Post	10.4	8.0	12.9	11.0	8.2	13.5	11.6	8.7	14.1	12.2	9.1	14.7
150	210	Suspension	12.6	8.1	15.1	13.7	8.9	16.2	14.8	9.6	17.3	16.1	10.3	18.6
200	280	Suspension	14.0	8.4	16.5	15.1	9.3	17.6	16.9	10.4	19.4	18.6	11.4	21.1
250	350	Suspension	16.7	9.0	19.2	18.1	10.3	20.6	20.5	11.8	23.0	22.6	13.1	25.1
300	420	Suspension	19.8	9.6	22.3	21.5	11.4	24.0	24.7	13.4	27.2	27.2	14.9	29.7
350	490	Suspension	23.5	10.3	26.0	25.5	12.5	28.0	29.5	15.1	32.0	32.3	17.0	34.8

Table 20.2 - Minimum Easement and Inter-Circuit Distances (m) at 132kV

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21 ANNEX F – DESIGN CHECKLIST

For internal Ergon Energy use only.

PROJECT: _____

DESIGN PHASE CHECKLIST

Work Order No: x

Required By Date: 28/02/2011

Hours Allocated: x

	Milestone Checklist	Hyperlink	Target Date	Date Completed
	WORK ACCEPTANCE ESSENTIAL CHECKS			
_	PIA and other documents received. Check "Work Request Documents" site for all Project Documentation	Site Content - Work Request Documents		
_	Survey complete / Data received and checked. ***If not complete is Variation Required? Contact PM? Do not accept Work?***			
_	Review PIA and other documentation and confirm requirements with PM			
_	Ensure Work orders are correct and Achievable ***If unacceptable let Wendy know prior to booking to work order!!***			
_	Review Priority Report for DC and other Milestones to ensure achievable	PS Reports		
_	Advise Mapping Officers of Design Requirements & check time frames required for entry are achievable			
	PRE-DESIGN TASKS			
_	Complete Safety in Design Risk Assessment - Form ES000905F102 *(Do not copy from another project - use hyperlink to ensure you have the latest version)*	http://enet/Docs/ES00_Manage%20Health,%20Safety%20and%20Environment/ES0009Published/ES000905F102.doc		
_	Complete Cultural Heritage Risk Management Plan - Form ES000906F100 *(Do not copy from another project - use hyperlink to ensure you have the latest version)*	http://enet/docs/ES00_Manage%20Health,%20Safety%20and%20Environment/ES0009Published/ES000906F100.doc		
_	Complete EPW Risk Assessment - Form ME000304F100 *(Do not copy from another project - use hyperlink to ensure you have the latest version)*	http://enet/docs/ES00_Manage%20Health,%20Safety%20and%20Environment/ES0009Published/ES000905F100.doc		
_	Complete Simple Project Risk Management Plan - Form PW000702F100 *(Do not copy from another project - use hyperlink to ensure you have the latest version)*	http://enet/Docs/PW_Manage%20Planned%20Work/PW0007Published/PW000702F100.doc		
_	Set up Folders and Directory on Shared Corporate Drive	G:\Group - TADS\Engineering Services\Transmission Line Design\6 Projects		
_	Arrange asset ID in EDMS (ICT Request) - Check Feeder ID NO# and naming with Operations Engineer (e.g. Charlie Gianoulis)			
_	Additional Survey required (if not completed above)			
_	Check Easements and Wayleaves - If not in place or property group not engaged notify PM			
_	DBYD - Design Request			
_	Telstra Fault Level Co-Ordination (Advise Telstra of proposed work in the area before design starts to confirm any issues early.) *(email: powercoordination@team.telstra.com)*			
_	Obtain Substation GA & Rack Details			
_	Obtain Substation and/or Property Access Keys if Required - Contact relevant Asset Maint Officer for region			
_	Line Route Inspection and Initial Site Visit			
_	Arrange Geotechnical Investigation ***(if applicable)***			
_	Complete EMF Calculations **For Feeder Loads Contact -** Lochie Gaylard for FN, MK or WB regions, Karl Romano for NQ, CA, SW regions *(Calculations to be forwarded to Ray Anderson for Sign Off)*			

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	PRELIMINARY LAYOUT			
–	Check weather cases & wind loading with John or Steve			
–	Check Fault Levels and OHEW capacity to handle them Contact Patrick Gunn for fault levels in all regions			
–	Tension/Creep Calculations			
–	Pole Calculations			
–	Foundation Design			
–	Lightning Calculations			
–	Stay Calculations			
–	Line Separation and Phasing checks			
–	Obtain switch names (Operations Engineer) and switch numbers (Bridie) *(if Applicable)*			
–	Cut in drawings			
–	Landing Span Drawings, coordinated with Sub Design and Structural Integrity confirmed.			
–	Arrange Procurement of Asset Plates for inclusion on drawings (Pole type and location to be forwarded to Bridie so she can input them into Smallworld to have Asset Numbers generated.)			
–	Prepare System Alteration Sketch and submit to Operations Engineers for Approvals *(if Applicable)*			
–	Submit Drawings to Stakeholders for "Meets Business Requirements" Approvals			
	COMPLETE MANDATORY FORMS AS APPLICABLE & OBTAIN APPROVALS			
–	Main Roads Crossings *(Townsville - towdawe@tmr.qld.gov.au) Other locations - please check email address with Main Roads Dept*			
–	Regional Council Notification			
–	Telstra Fault Level Co-Ordination (Advise Telstra of proposed pole locations to confirm any issues.) *(email: powercoordination@team.telstra.com)*			
–	Powerlink QLD Under-Crossing Form	http://www.powerlink.com.au/Landowners_and_Property/Activities_on_an_easement/Co-use.aspx		
–	Complete Water Crossing Works Checklist - Form MN000301F137 *(Do not copy from another project - use hyperlink to ensure you have the latest version)*	http://enet/Docs/MN_Maintain%20the%20Network/MN0003Published/MN000301F137.doc		
–	Harbour Boards - Tidal water crossings (Distribution Design Manual, Agreements, Dwg 3143)			
–	Determine whether rail belongs to QR or Aurizon and complete appropriate forms			
–	Aurizon Forms	G:\Group - TADS\Engineering Services\Transmission Line Design\8 Templates\2 Project Folder Template\3 Approvals\3.6 QR\QR National Forms		
–	QR Froms	G:\Group - TADS\Engineering Services\Transmission Line Design\8 Templates\2 Project Folder Template\3 Approvals\3.6 QR\QR Forms		
–	Sugar Tramway Approvals			

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	PRELIMINARY DESIGN CHECK			
–	Preliminary Design Complete & transition drawings to Check			
–	Compile Construction Specification while Design is being checked			
–	Preliminary Design to be checked by SDO or Engineer			
–	Check DBYD's have been returned			
–	Check all appropriate Approvals have been submitted			
	CHECKING ALL APPROVALS HAVE BEEN RECEIVED			
–	Date of "Meets Business Requirements" Approval			
–	Date of EMF Approval			
–	Date of Main Roads Approval			
–	Date Approvals received back			
–	Date of Council Approval			
–	Date of Powerlink Approval			
–	Date of Harbour Board Approval			
–	Date of Telstra Power Co-ordination Approval			
–	Confirm Naming Conventions and Operational Requirements - Switches			
–	Date of System Alteration Sketch Approval			
–	Confirm SCADA is not impacted email the SAS to Comms			
–	Forward endorsed SAS to Sean McGuinness			
	SUPPLEMENTARY DESIGN			
–	Plan and Profile Drawings			
–	Prepare Stay Sheets			
–	Prepare Ferrule Drawings			
–	Prepare Pole Schedules			
–	Prepare Stringing Schedules			
–	Temperature Compensation Chart			
–	Check damper requirements			
–	Organise Structure Testing (if required)			
–	Update design/drawings as required - Transition Drawings to Check			

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	AFTER APPROVAL OF DESIGN			
–	Approvals Complete & Drawings in Ready for Signing			
–	Drawings to Released for Construction			
–	Preparation of Project Folder for Handover			
–	Bill of Materials List formulated *(if required)*			
Whole of Design Includes	Drawing Transmittal (NI000401F104) *(Do not copy from another project - use hyperlink to ensure you have the latest version)*	http://enet/Docs/NI_Manage%20Network%20Initiated%20Capital%20Works/NI0004Published/NI000401F104.dochttp://enet/Docs/NI_Manage%20Network%20Initiated%20Capital%20Works/NI0		
	RPEQ Certification Statement			
	WHS Risk Statement			
	Construction Specification			
	Construction Schedules (check intranet for latest documents)			
	DBYD Design information			
	Bill of Materials *(if required)*			
	Fully Signed Drawings Including Drawing Index Page			
	Approval letters *(if required)*			
–	Issue Whole of Design including above items to: - Project Manager - Terrry Kelly - David Baldwin / Scott Sologinkin (Procurement) - Bridie Lighbound (Smallworld)			
–	Handover meeting held			
–	Smallworld Design has been completed, checked and approved			
–	Materials have been procured and Dave and Scott are finished with the Work Order			
–	Advise Scheduler that design handed over & Work Order can be closed			
–	Work Order Closed			

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22 ANNEX G – VIBRATION DAMPERS

Uncontrolled vibration is very destructive, leading to loosened hardware, fretting and strand breakages. Vibration dampers are used to reduce the amplitude of Aeolian conductor vibration. Two types are in common use today, the mass damper (Stockbridge type damper) and the impact damper (spiral damper).

Mass dampers resonate with the forced frequency caused by wind excitation but the reactive force is out of phase with it. These dampers dissipate energy through interstrand friction of the messenger cable. Mass dampers are effective at low frequencies and therefore suit large conductors (greater than about 15mm diameter).

Impact dampers are long enough to cover the loop lengths of multiple frequencies. The vibration is dissipated by impacting (slapping) against the conductor. These dampers do not dissipate energy. Impact dampers are effective at high frequencies and thus suit small conductors (less than about 12mm diameter).

The design of the damping system is determined by the following factors -

(a) Span lengths

(b) Characteristics of the conductor: type, stranding, distributed mass

(c) Bundle configuration

(d) Tensile load of the conductor at the Vibration weather case

(e) Degree of conductor self-damping

(f) Type of conductor clamp (clamped or tied, unarmoured or armoured, helically formed armour grip with elastomer insert, etc.)

(g) Terrain category (flat, coastal area, suburban area, etc.)

(h) Yearly distribution of the 10 minute average wind velocity

(i) Characteristics of in-span devices (e.g. warning spheres) and their distribution.

This standard is for conventional, concentric-lay, stranded, round wire construction. It does not include trapezoidal wire conductors, vibration resistant conductors, self-damping conductors or high temperature conductors. No recommendations have been made for bundled conductor

22.1 NO DAMPERS

No external damping is required for single conductors strung with tensions (catenary constants) less than those tabulated below.

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AS/NZS 1170.2 Terrain Category	IEC 60826 Terrain Category	Terrain Characteristics (AS/NZS 1170.2:2011 Section 4)
1.5	1	Near or across a large body of water
2	2	Open, flat, no obstruction eg grassland with well scattered obstructions generally from 1.5 to 5m, and fewer than 2 obstructions per hectare
2.5	3	Open, flat or undulating with isolated obstacles (fewer than 10 per hectare) e.g. large acreage development, farmland with few trees
3	4	Built-up with trees and buildings generally from 3 to 10m e.g. residential suburbs, light industrial, woodland

Table 22.1.1 - CIGRE Safe Design Tensions

Spiral Dampers – Quantity, Selection and Placement
The minimum quantity of spiral vibration dampers is

Span Length	**Number of Spiral Dampers per Span**
Slack spans up to 110 m (Section 9.6.1)	0
Full tension up to 250 m	2
250 m – 500 m	4
500 m – 750 m	6

Table 22.1.2 – Spiral Vibration Damper (SVD) Quantities

Spiral damper selection is based solely on the conductor diameter. SVDs do not have any specified performance criterion. Spiral dampers are not placed over armour rods. Typical ranges are

Conductor Diameter Range (mm)	Colour Code
4.4 – 6.3	red
6.4 – 8.2	blue
8.3 – 11.7	black
11.8 – 14.4	yellow
14.5 – 19.5	green

Table 22.1.3 – SVD Selection

Engineering calculations are unnecessary for the placement of spiral dampers. The gripping section faces the closer span-end and is nominally located 100mm from the deadends, armour rods, mass dampers or other conductor hardware. Two or three spiral dampers may be intertwined together. If they bind together they lose their overall effectiveness.

22.2 Mass Dampers – Quantity

The quantity of mass dampers is determined from an energy balance equation where the energy input from the wind matches the energy dissipated by the dampers and the inter-strand friction of the conductor.

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The calculated quantity of mass dampers is a minimum quantity. The marginal cost of dampers is very small and it is prudent to "overdamp" provided that the interaction of multiple dampers is not detrimental to the overall performance. This is usually confirmed by testing. Additional dampers are not required to prevent fatigue of the messenger cables. The messenger cable of a well designed and manufactured damper will not fatigue during its lifetime. Drooping damper weights may be the result of conductor galloping (associated with ice) or poor handling during transport and erection.

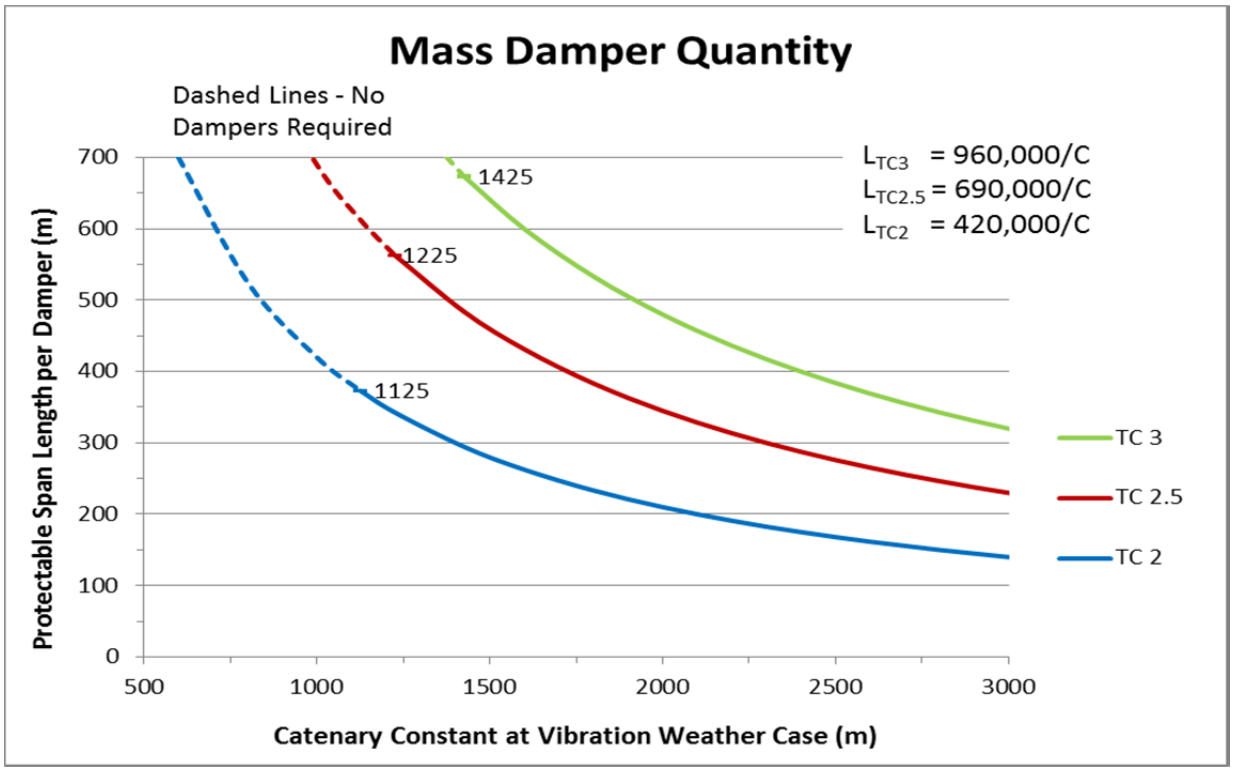

Figure 22.2 - Mass Damper – Protectable Span Length

22.3 Mass Damper – Selection

The performance of mass dampers shall satisfy the requirements of AS 1154.1:2009 Section 7.2. Preferred dampers have unequal weights and unequal messenger lengths that produce multiple resonance modes.

Unless otherwise recommended by the damper manufacturer, the type of damping system shall be selected using the criteria given in the following table. The colour codes identify the damping systems in subsequent tables for AAC and AAAC; ACSR; SC/GZ and SC/AC.

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Colour	Damping System (masses are nominal)	Selection Criteria	
		Conductor Impedance Range (kg/s)	Mass of Loop Length at 2m/s Wind (kg)
	SVD (approx. 0.3 kg)		< 0.5
	SVD + 1.4 kg Mass Damper		0.5 - 1.2
	1.4 kg Mass Damper		1.2 - 2.0
	2.5 kg Mass Damper	< 200	> 2.0
	4.7 kg Mass Damper	200 - 315	
	5.5 kg Mass Damper	> 315	

Table 22.3.1 – Damper System Selection Criteria

Manufacturer	Model	Approximate Assembled Mass (kg)	Clamp Range (mm)
Dulmison - Dogbone (now PLP)	DB05 DB1 DB2 DB3	1.2 2.3 4.7 6.8	7.1 – 27.0 18.1 – 24.0 21.1 – 31.0 31.1 – 34.0
PLP - VORTX	VSD-10 VSD-20 VSD-25 VSD-35 VSD-40 VSD-50	1.7 2.0 2.4 3.5 5.2 5.5	9.7 – 20.0 12.3 – 32.0 15.5 – 32.0 20.0 – 50.0 25.0 – 61.0 32.0 – 61.0
Dulhunty - 4D (normal clamp ranges)	4D10 4D20 4D30 4D40 4D50	1.0 1.4 2.5 4.7 5.5	7.0 - 11.5 11.0 – 18.0 16.5 – 27.0 24.5 – 34.0 32.3 – 43.0

Table 22.3.2 – Damper Clamp Ranges.

The variables used in the selection criteria can be derived from the following equations.

$C = \frac{T}{gm}$

C = catenary constant (m)

T = conductor tension (N)

g = gravitational acceleration (m/s^2)

m = conductor mass (kg/m)

$$V = \sqrt{\frac{T}{m}} = \sqrt{\frac{gmC}{m}} = \sqrt{gC}$$

V = transverse wave velocity (m/s)

- $Z = \sqrt{Tm}$

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- $= m\sqrt{gC}$
- $= mV$

Z = conductor mechanical impedance (kg/s)

- $f = \frac{0.185\, V_w}{d}$

f = forced excitation frequency due to vortex shedding (Hz)

V_w = laminar wind velocity (m/s)

d = conductor diameter (m)

- $L = \frac{V}{2f}$

L = loop length of standing wave (m)

- $M_L = m\, L$
- $= \frac{mV}{2f}$
- $= \frac{Z}{2f}$

M_L = mass of conductor in a single loop length (kg)

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	Catenary Constant (m) at Vibration Weather Case											Approx. Diameter (mm)	Frequency (Hz) at 7 m/s Wind	Colour Legend
	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000			
Conductor Mass (kg/km)	**Mass (kg) of Loop Length at 2 m/s Wind**													
100	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	7.8	166	SVD
200	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	11.0	118	SVD + 1.4 kg
300	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	13.6	95	1.4 kg
400	0.8	0.9	1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.5	15.8	82	2.5kg
500	1.2	1.3	1.4	1.5	1.6	1.7	1.7	1.8	1.9	2.0	2.0	17.6	74	4.7 kg
600	1.5	1.7	1.8	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	19.3	67	5.5 kg
700	2.0	2.1	2.3	2.5	2.6	2.8	2.9	3.0	3.1	3.3	3.4	20.8	62	
800	2.4	2.6	2.8	3.0	3.2	3.4	3.5	3.7	3.8	4.0	4.1	22.3	58	
900	2.8	3.1	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	4.9	23.6	55	
1000	3.3	3.7	4.0	4.2	4.5	4.7	5.0	5.2	5.4	5.6	5.8	25.0	52	
1200	4.4	4.8	5.2	5.6	5.9	6.2	6.5	6.8	7.1	7.4	7.6	27.4	47	
1400	5.5	6.1	6.6	7.0	7.4	7.8	8.2	8.6	8.9	9.3	9.6	29.6	44	
1600	6.8	7.4	8.0	8.6	9.1	9.6	10.1	10.5	10.9	11.3	11.7	31.7	41	
1800	8.1	8.9	9.6	10.2	10.9	11.4	12.0	12.5	13.0	13.5	14.0	33.6	39	
2000	9.5	10.4	11.2	12.0	12.7	13.4	14.1	14.7	15.3	15.9	16.4	35.4	37	
Conductor Type	**Approximate Tension (% NBL)**													
AAC	17	21	24	28	31									
AAAC/1120	12	14	17	19	21	24	26	28	31					

Table 22.3.3 - Damper Selection for AAC and AAAC Conductors

	Catenary Constant (m) at Vibration Weather Case											Approx. Diameter (mm)	Frequency (Hz) at 7 m/s
	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000		

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Conductor Mass (kg/km)	Mass (kg) of Loop Length at 2 m/s Wind												Wind	Colour Legend
100	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	6.9	187	SVD
200	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	9.8	133	SVD + 1.4 kg
300	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	12.0	108	1.4 kg
400	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	13.8	94	2.5kg
500	1.0	1.1	1.2	1.3	1.4	1.5	1.5	1.6	1.7	1.7	1.8	15.5	84	4.7 kg
600	1.3	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.2	2.3	16.6	78	5.5 kg
700	1.7	1.8	2.0	2.1	2.3	2.4	2.5	2.6	2.7	2.8	2.9	17.9	72	
800	2.1	2.3	2.4	2.6	2.8	2.9	3.0	3.2	3.3	3.4	3.6	19.2	67	
900	2.5	2.7	2.9	3.1	3.3	3.5	3.6	3.8	4.0	4.1	4.2	20.3	64	
1000	2.9	3.1	3.4	3.6	3.9	4.1	4.3	4.4	4.6	4.8	5.0	21.4	60	
1200	3.8	4.1	4.5	4.8	5.1	5.3	5.6	5.8	6.1	6.3	6.5	23.5	55	
1400	5.0	5.5	6.0	6.4	6.7	7.1	7.5	7.8	8.1	8.4	8.7	26.8	48	
1600	6.1	6.7	7.3	7.8	8.2	8.7	9.1	9.5	9.9	10.3	10.6	28.7	45	
1800	7.3	8.0	8.7	9.3	9.8	10.4	10.9	11.4	11.8	12.3	12.7	30.4	43	
2000	8.6	9.4	10.2	10.9	11.5	12.1	12.7	13.3	13.8	14.4	14.9	32.1	40	
Conductor Type	**Approximate Tension (% NBL)**													
ACSR 54/7	12	15	17	19	22	24	27	29						
ACSR 6/1	11	14	16	18	20	23	25	27	29					
ACSR 30/7	11	13	15	17	19	21	23	25	28	30				
ACSR 4/3	8	10	12	13	15	17	19	20	22	24	25			
ACSR 3/4	8	9	11	12	14	15	17	18	20	21	23			

Table 22.3.4 - Damper Selection for ACSR and OPGW Conductors

Catenary Constant (m) at Vibration Weather Case											Approx. Diameter (mm)	Frequency (Hz) at 7 m/s
1000	**1200**	**1400**	**1600**	**1800**	**2000**	**2200**	**2400**	**2600**	**2800**	**3000**		

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Conductor Mass (kg/km)	Mass (kg) of Loop Length at 2 m/s Wind												Wind
100	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	4.6	283
200	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	6.5	200
300	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6	7.9	163
400	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	9.2	141
500	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.2	10.2	126
600	0.9	1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.5	1.6	11.2	115
700	1.1	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9	1.9	2.0	12.3	106
800	1.4	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3	2.4	13.1	99
900	1.7	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.7	2.8	2.9	13.9	93
1000	2.0	2.1	2.3	2.5	2.6	2.8	2.9	3.0	3.2	3.3	3.4	14.7	88
1200	2.6	2.8	3.1	3.3	3.5	3.6	3.8	4.0	4.2	4.3	4.5	16.1	81
Conductor Type	**Approximate Tension (% NBL)**												
SC/GZ	6	8	9	10	11	13	14	15	16	18	19		
SC/AC	5	7	8	9	10	11	12	13	14	15	16		

Colour Legend
SVD
SVD + 1.4 kg
1.4 kg
2.5kg

Table 22.3.5 - Damper Selection for SC/GZ and SC/AC Conductors

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22.4 Mass Dampers – Placement

	Number of Dampers per Span			
Span Type	**1**	**2**	**3**	**4**
Suspension to Suspension (Figure 1)	A or D	A & D	(A, B) & D or A & (C, D)	(A, B) & (C, D)
Suspension to Dead-end (Figure 2)	A	(A, B) or (G, H)	A & (G, H)	(A, B) & (G, H)
Dead-end to Dead-end (Figure 3)	N/A	(E, F) or (G, H)	N/A	(E, F) & (G, H)

Table 22.4.1 - Mass Damper Placement

Legend:

(A, B) - the pair of dampers A and B at the same end of the span

N/A - one of the dampers is ineffective for the full frequency spectrum

Figure 22.4.1 - Suspension to Suspension

Figure 22.4.2 - Suspension to Dead-end

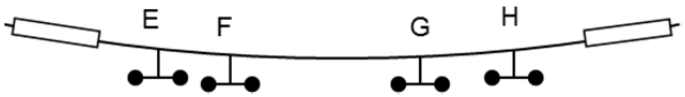

Figure 22.4.3 - Dead-end to Dead-end

Two dampers are required next to strain insulators in accordance with the table above. This is because of the obscure mechanical impedance of the termination and the difficulty of locating a single damper at the ideal location. The two dampers shall be separated by a distance less than the loop length of the highest anticipated vibration frequency i.e. at the highest anticipated laminar wind velocity. If the damper weights touch at this separation, then one damper shall be inverted.

For asymmetrical mass dampers (i.e. a large and a small weight), the orientation of the damper does not affect their performance.

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If dampers of different masses are used together (e.g. A & B or G & H) to protect against a broad range of frequencies, then the lighter mass damper (higher frequency, shorter loop length) shall be located closer to the span end (e.g. mass A lighter than mass B; mass H lighter than mass G).

	Catenary Constant (m) at Vibration Weather Case											Forced Excitation Frequency (Hz)	
	1000	**1200**	**1400**	**1600**	**1800**	**2000**	**2200**	**2400**	**2600**	**2800**	**3000**		
Cond. Diam. (mm)	**Damper Position Z (m) - 75% of Shortest Loop Length**											2 m/s Wind	7 m/s Wind
10	0.29	0.31	0.34	0.36	0.38	0.41	0.43	0.44	0.46	0.48	0.50	37	130
12	0.34	0.38	0.41	0.44	0.46	0.49	0.51	0.53	0.55	0.58	0.60	31	108
14	0.40	0.44	0.48	0.51	0.54	0.57	0.60	0.62	0.65	0.67	0.70	26	93
16	0.46	0.50	0.54	0.58	0.62	0.65	0.68	0.71	0.74	0.77	0.79	23	81
18	0.52	0.57	0.61	0.65	0.69	0.73	0.77	0.80	0.83	0.86	0.89	21	72
20	0.57	0.63	0.68	0.73	0.77	0.81	0.85	0.89	0.92	0.96	0.99	19	65
22	0.63	0.69	0.75	0.80	0.85	0.89	0.94	0.98	1.02	1.06	1.09	17	59
24	0.69	0.75	0.81	0.87	0.92	0.97	1.02	1.07	1.11	1.15	1.19	15	54
26	0.75	0.82	0.88	0.94	1.00	1.05	1.11	1.16	1.20	1.25	1.29	14	50
28	0.80	0.88	0.95	1.02	1.08	1.14	1.19	1.24	1.29	1.34	1.39	13	46
30	0.86	0.94	1.02	1.09	1.15	1.22	1.28	1.33	1.39	1.44	1.49	12	43
32	0.92	1.01	1.09	1.16	1.23	1.30	1.36	1.42	1.48	1.54	1.59	12	40
34	0.98	1.07	1.15	1.23	1.31	1.38	1.45	1.51	1.57	1.63	1.69	11	38

Table 22.4.2 – Damper Location

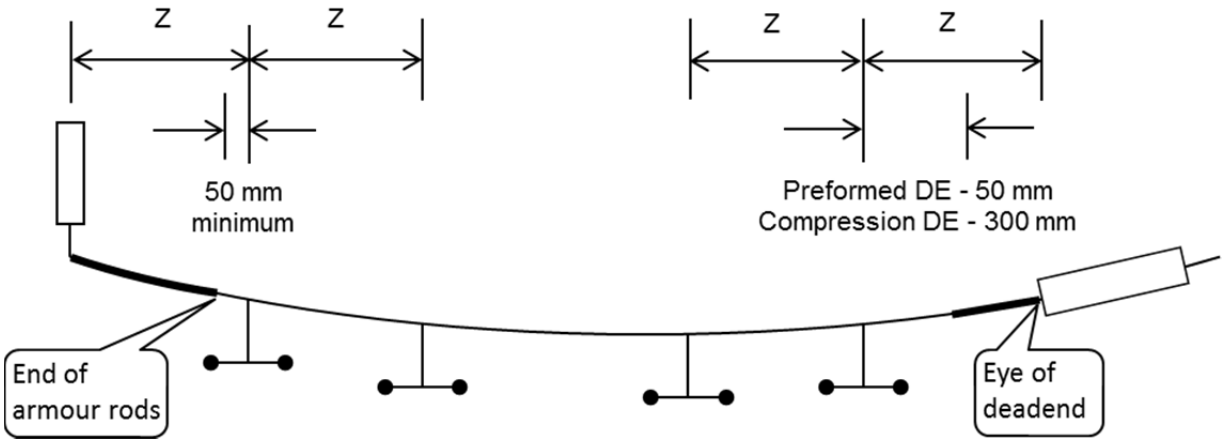

Figure 22.4.4 – Damper Location

Example

19/3.75 AAAC/1120 Neon conductor is to be used at Kingaroy where the average daily mean temperature is between 12 and 15°C. The terrain varies from numerous closely spaced trees having heights generally from 3 to 10m (terrain category 3) to open grassland with well scattered trees (terrain category 2). The conductor is designed to be 22% NBL at 15°C after creep. The ruling span is 300m, the maximum span length is 380m and the minimum span length is 250m.

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The final tension at 12°C is 10.76 kN. Therefore the catenary constant is 1904 m. Neon has a mass of 576 kg/km.

From Table A5 the damper size is borderline between a 1.4 kg and a 2.5 kg mass damper.

From Figure A1 the protectable span length is approximately 220m per damper for terrain category 2. The number of dampers required for the minimum span is 250/220 = 1.1 and 380/220 = 1.7 for the maximum span. Therefore two mass dampers per span are required. Use one 1.4 kg and one 2.5kg mass damper per span. From Table A8 use dampers A & D for suspension to suspension arrangements; (A 1.4kg, B 2.5kg) for suspension to strain arrangements; and (E 1.4kg, F 2.5kg) or (G 2.5kg, H 1.4kg) for strain to strain arrangements.

From Table A8 the damper location dimension Z is about 740 mm. The dampers are positioned in accordance with Figure A5. The length of armour rods for Neon is 1450±100 mm so the end of the armour rods is 725±50mm from the centre of the AGSU. Most likely the dampers will be positioned 50mm from the end of the armour rods. The length of a preformed deadend for Neon is 1240±50 mm therefore the damper is placed 50mm beyond the end of the preformed deadend and not over the rods.

Figure A6 shows the first damper location to be effective for laminar winds from 2.3 to 7 m/s. The second damper is only used when one end of the span is terminated. Alone, the second damper is ineffective over the range of wind speeds from 3.5 to 5.8 m/s. However if one damper is situated at a node (at any wind speed between 2.3 and 7 m/s) then the other damper (separated 740mm apart) is between 25% and 75% of the loop length (i.e. effectively damped provided that the damper is efficient at that frequency).

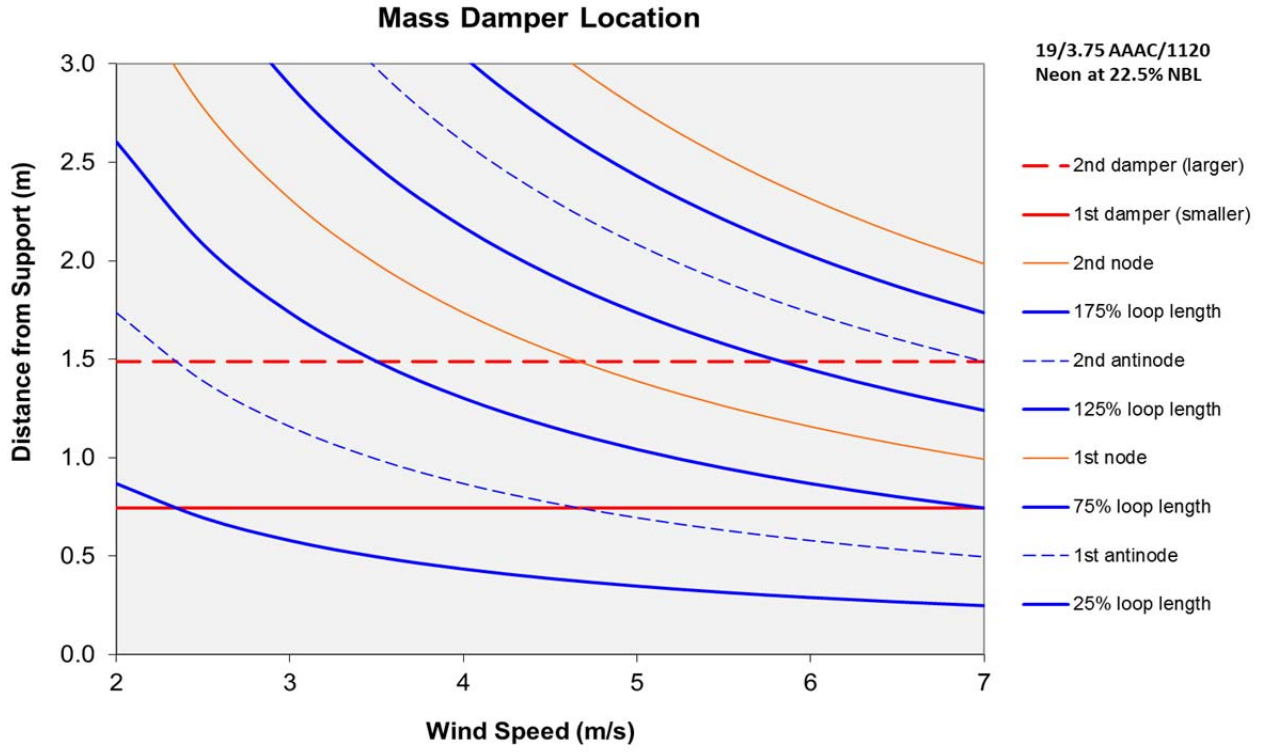

Figure 22.4.5 – Damper Location Effectiveness for all Laminar Wind Speeds

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23 ANNEX H – ELECTRICAL: CLEARANCES

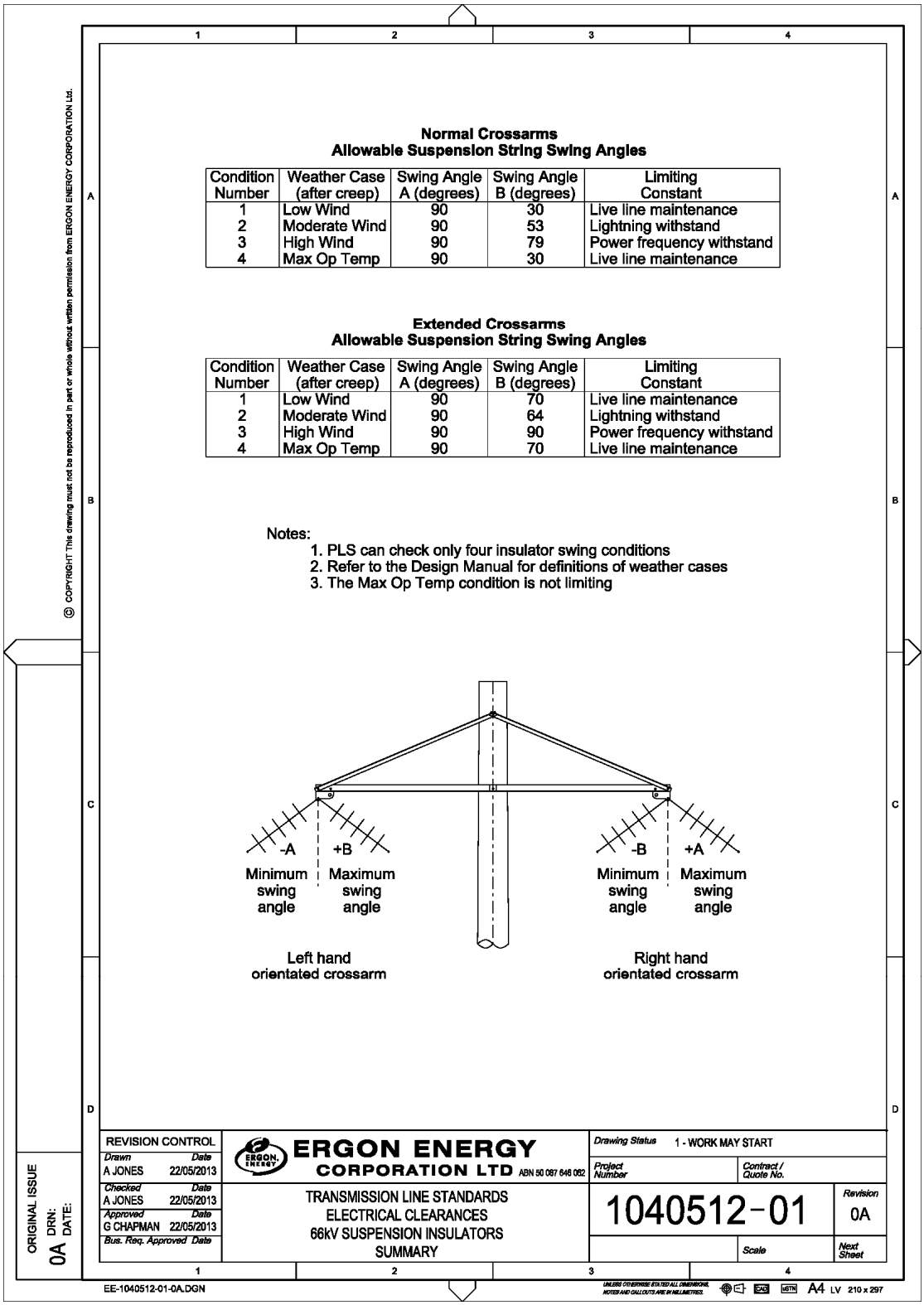

Figure 23.1 – Electrical Clearances - 66kV Suspension Insulators - Summary

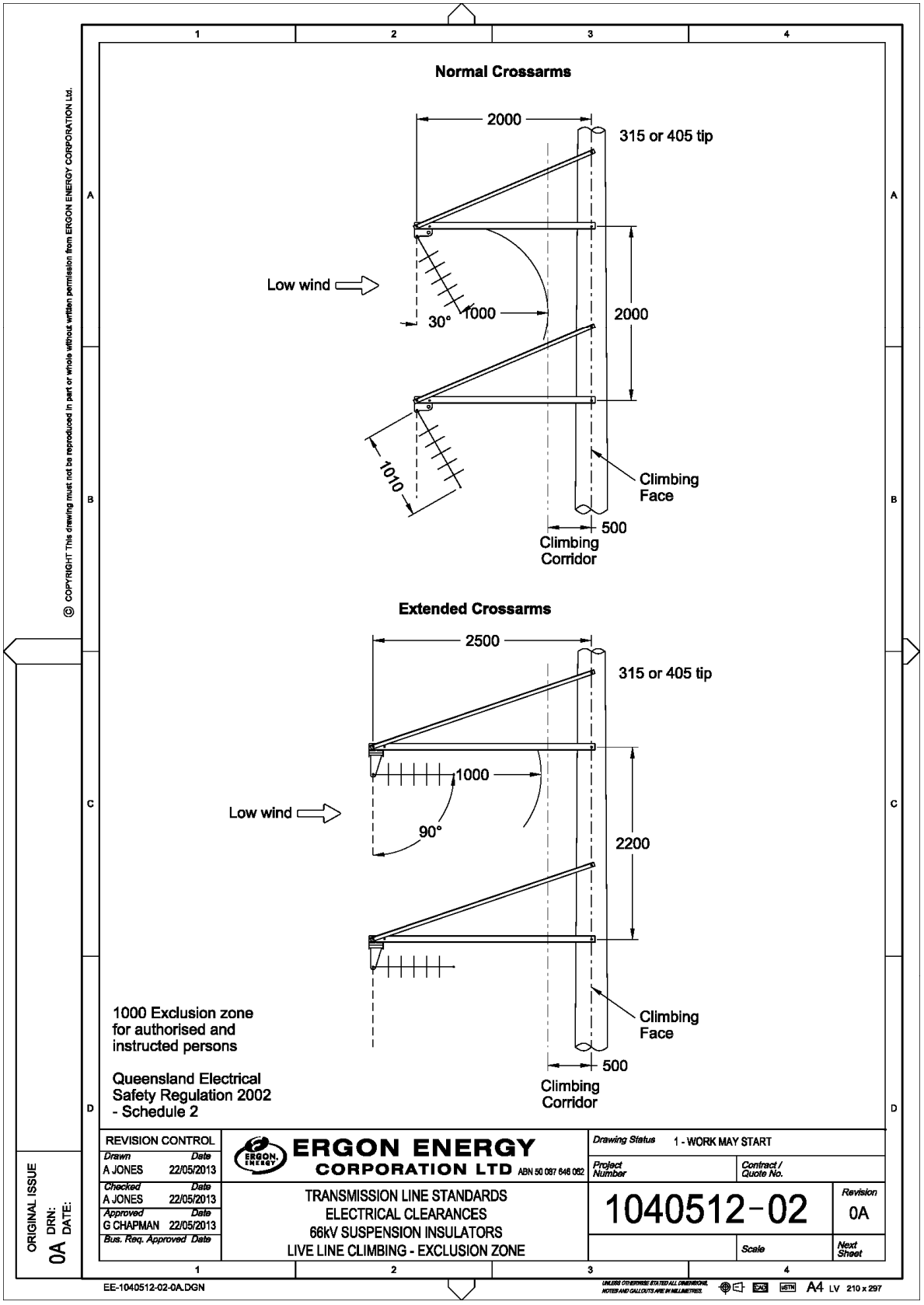

Figure 23.2–Electrical Clearances-Live Line Climbing Corridor–66kV Suspension Insulators

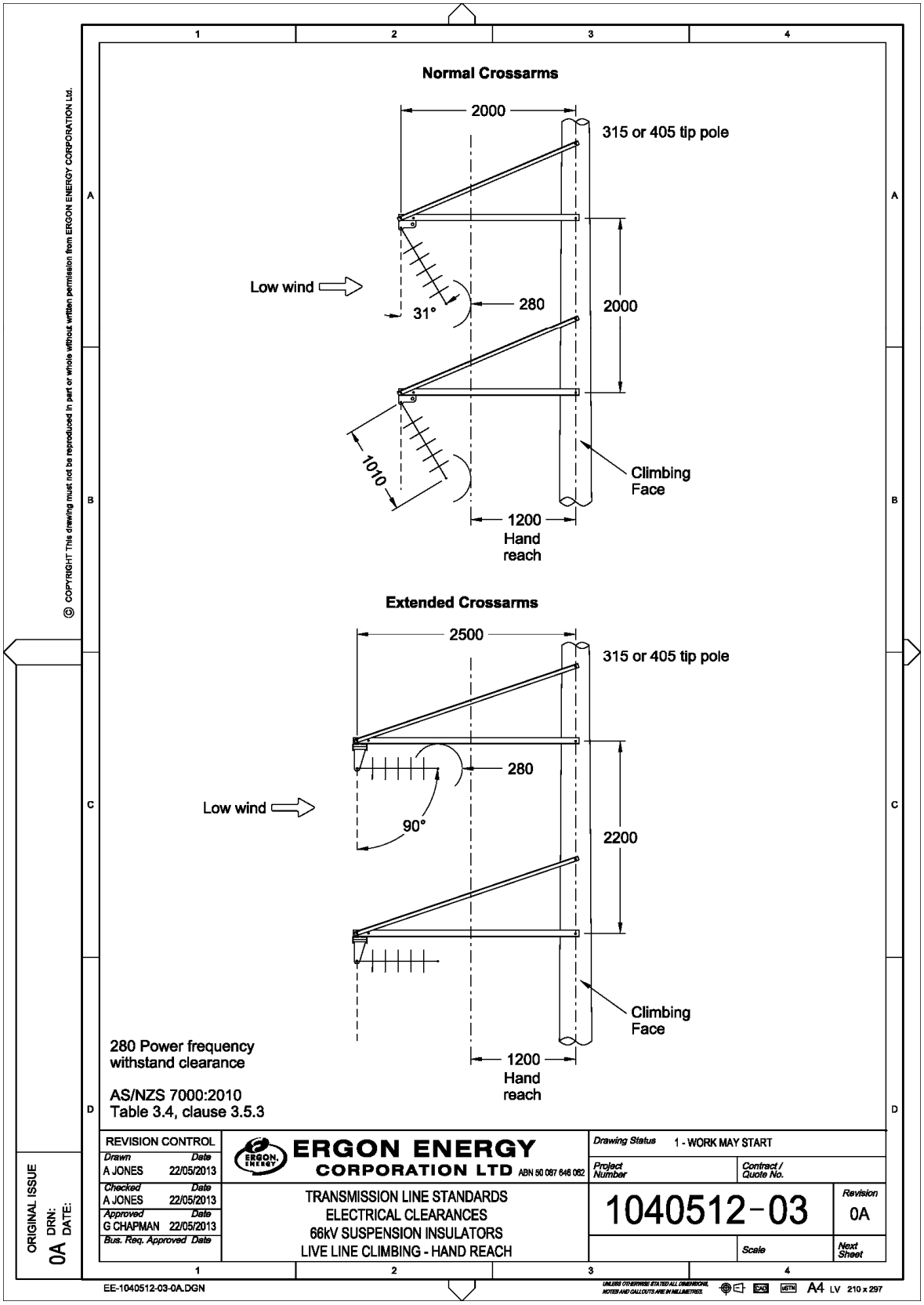

Figure 23.3 – Electrical Clearances - Hand Reach Test– 66kV Suspension Insulators

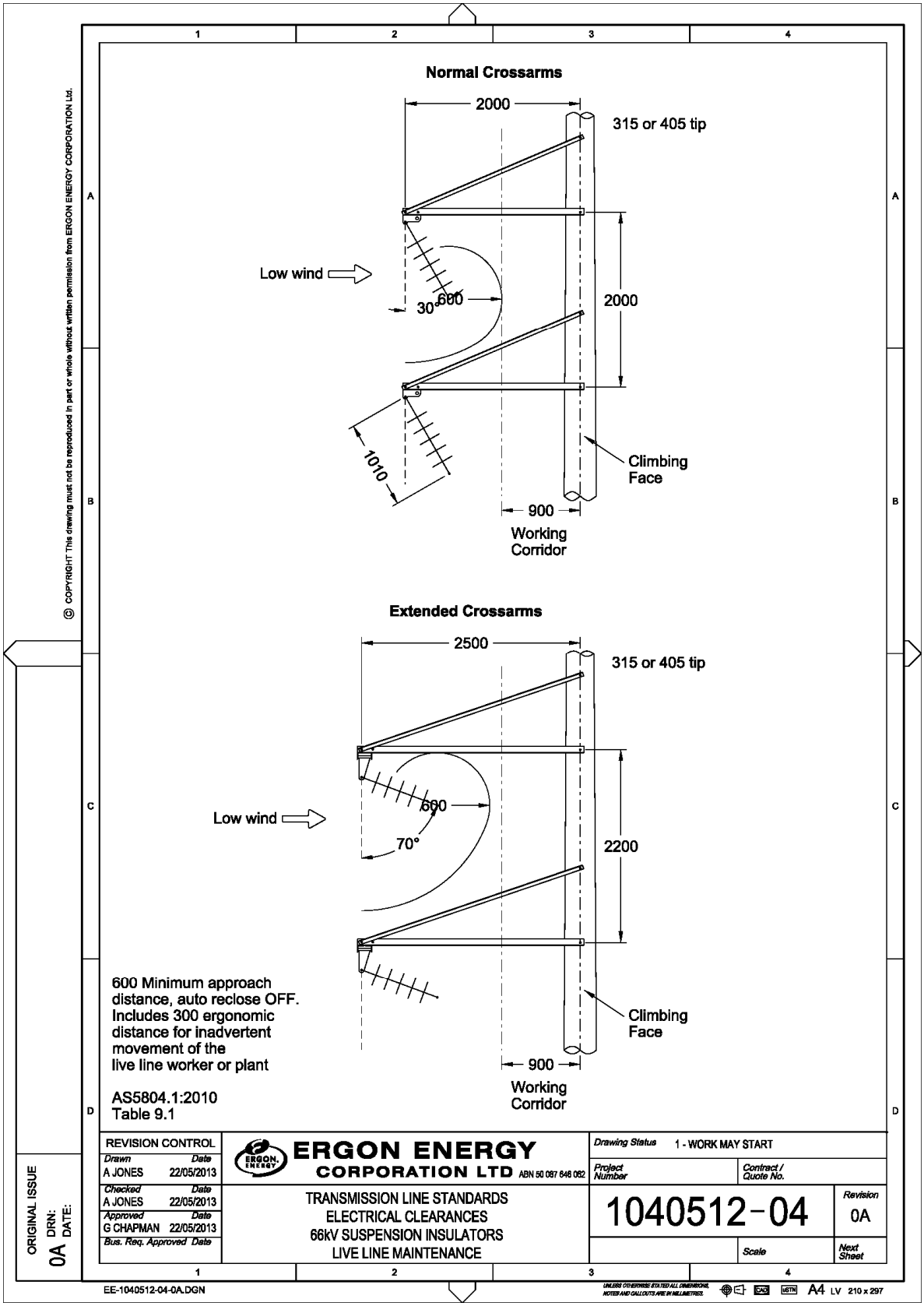

Figure 23.4 – Electrical Clearances - Live Line Maintenance– 66kV Suspension Insulators

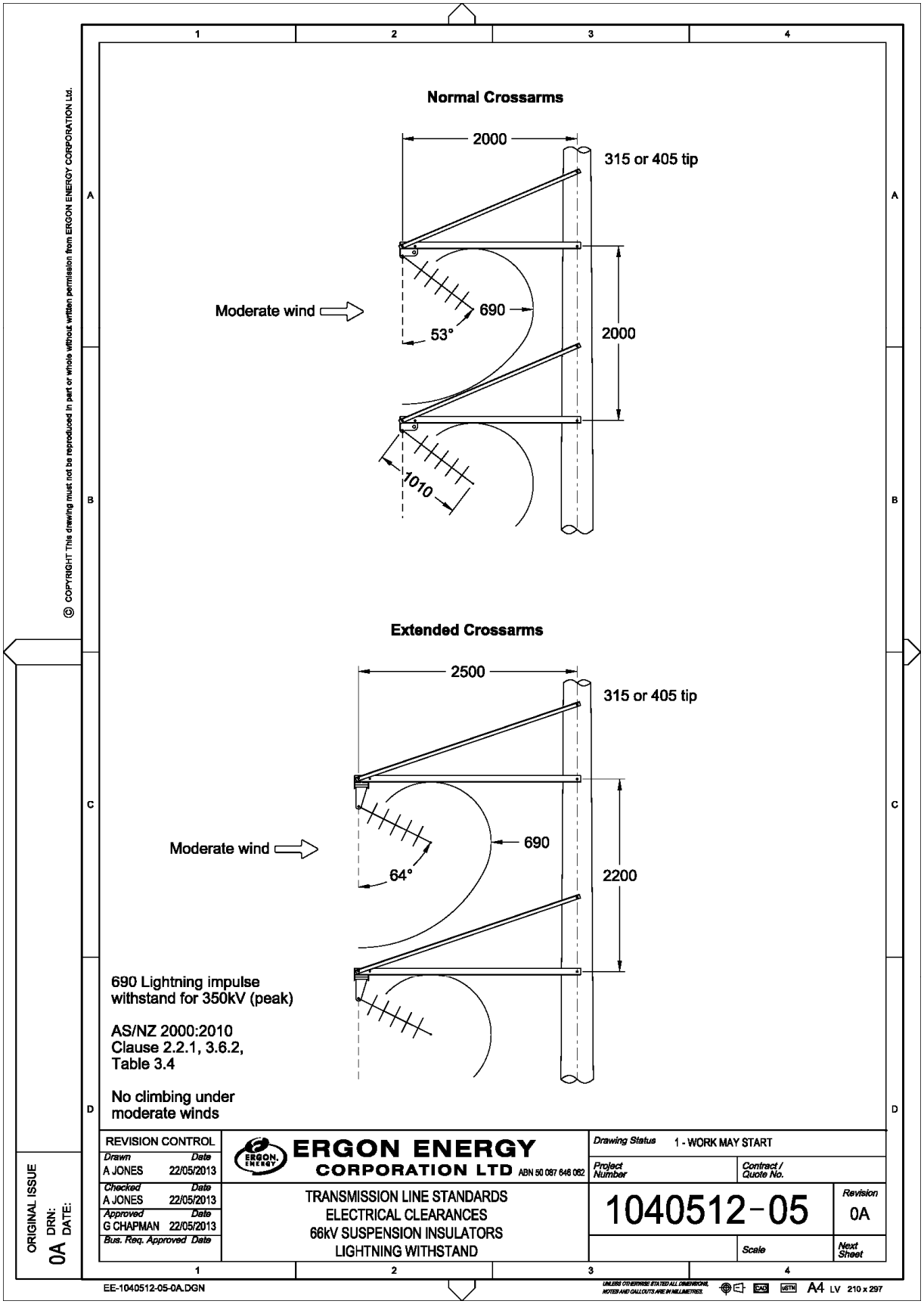

Figure 23.5 – Electrical Clearances – Lightening Withstand – 66kV Suspension Insulators

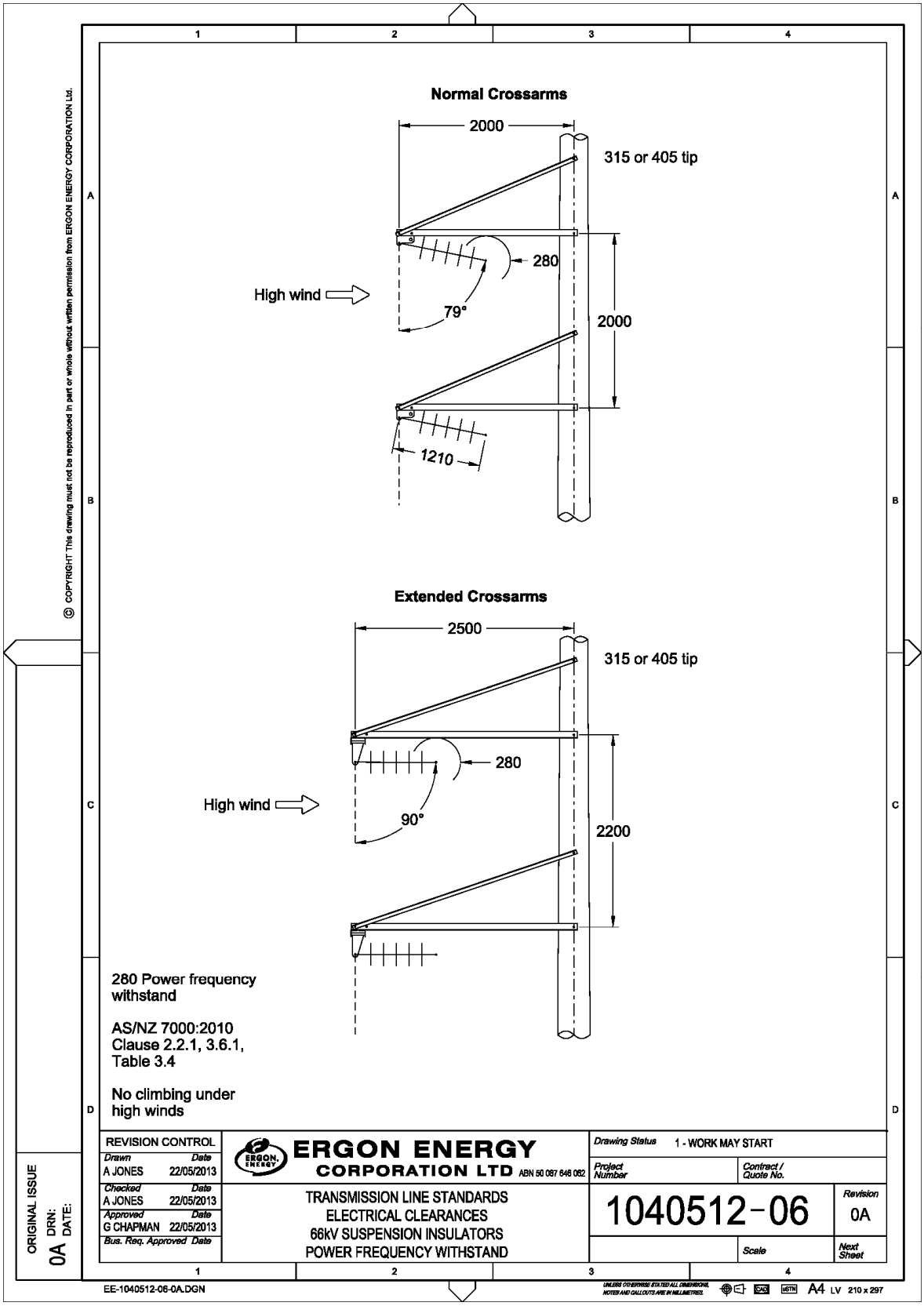

Figure 23.6 – Electrical Clearances – Power Frequency Withstand – 66kV Suspension Insulators

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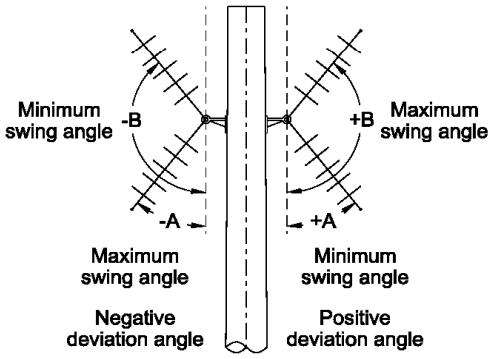
Flying Angle
Allowable String Swing Angles

Condition Number	Weather Case (after creep)	Swing Angle A (degrees)	Swing Angle B (degrees)	Limiting Constant
1	Low Wind	58	122	Live climbing - exclusion zone
2	Moderate Wind	33	147	Lightning withstand
3	High Wind	6	175	Power frequency withstand
4	Max Op Temp	58	122	Live climbing - exclusion zone

Notes:
1. PLS can check only four insulator swing conditions.
   Not all of the weather cases listed on subsequent sheets can be checked.
   The tabulated weather cases will provide sufficient automated checking.
2. Refer to the Design Manual for definitions of weather cases.



REVISION CONTROL			ERGON ENERGY CORPORATION LTD ABN 50 087 646 062	Drawing Status: 1 - WORK MAY START	
Drawn	A JONES	22/05/2013		Project Number	Contract / Quote No.
Checked	A JONES	22/05/2013	TRANSMISSION LINE STANDARDS ELECTRICAL CLEARANCES 66kV FLYING ANGLE WITHOUT CROSSARMS SUMMARY	1040522-01	Revision 0A
Approved	G CHAPMAN	22/05/2013			Next Sheet
Bus. Req. Approved		Date		Scale	

ORIGINAL ISSUE 0A DRN: DATE:

EE-1040522-01-0A.DGN

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Figure 23.7 – Electrical Clearances - Summary – 66kV Flying Angle without Crossarms

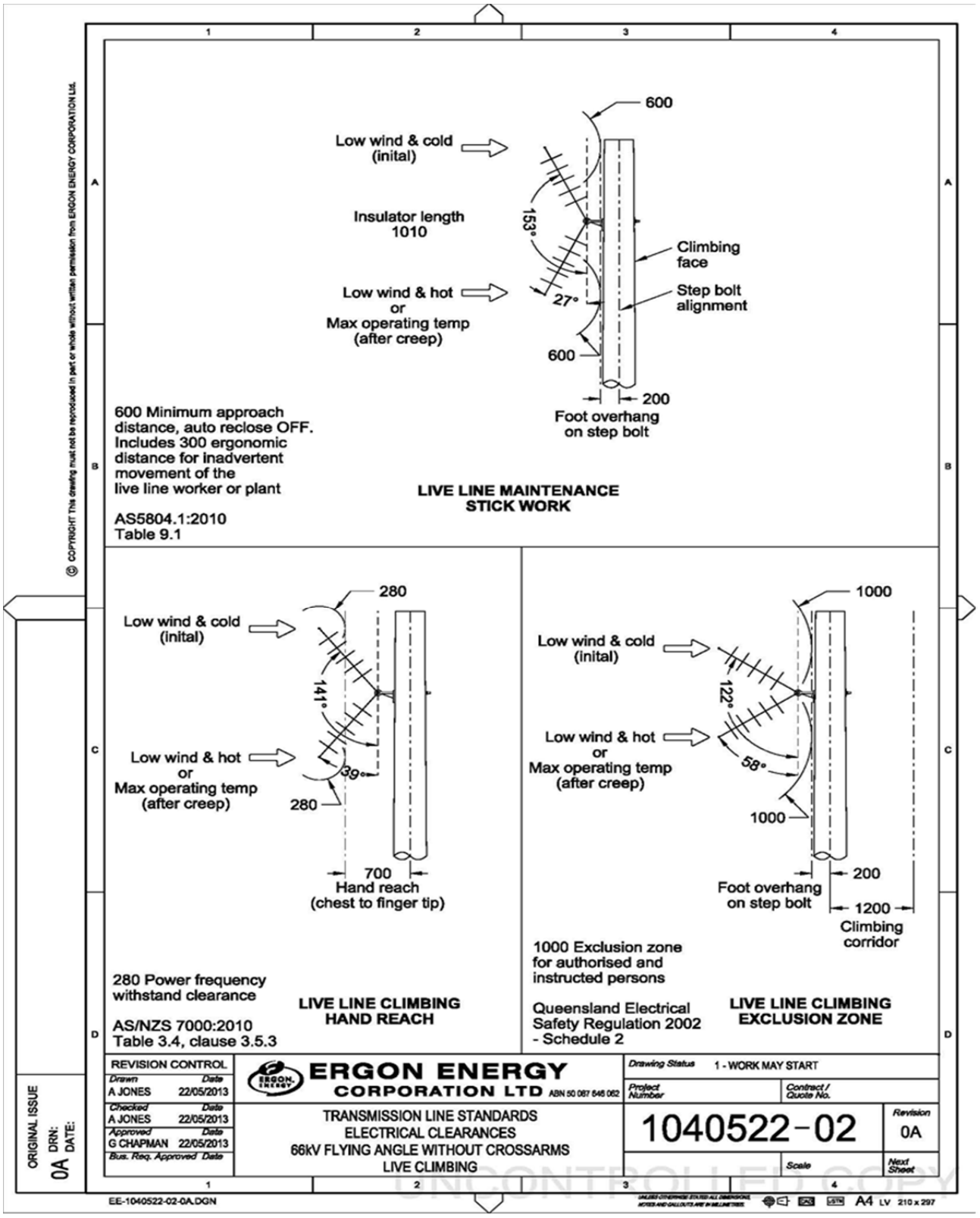

Figure 23.8 – Electrical Clearances – Live Line Climbing – 66kV Flying Angle without Crossarms

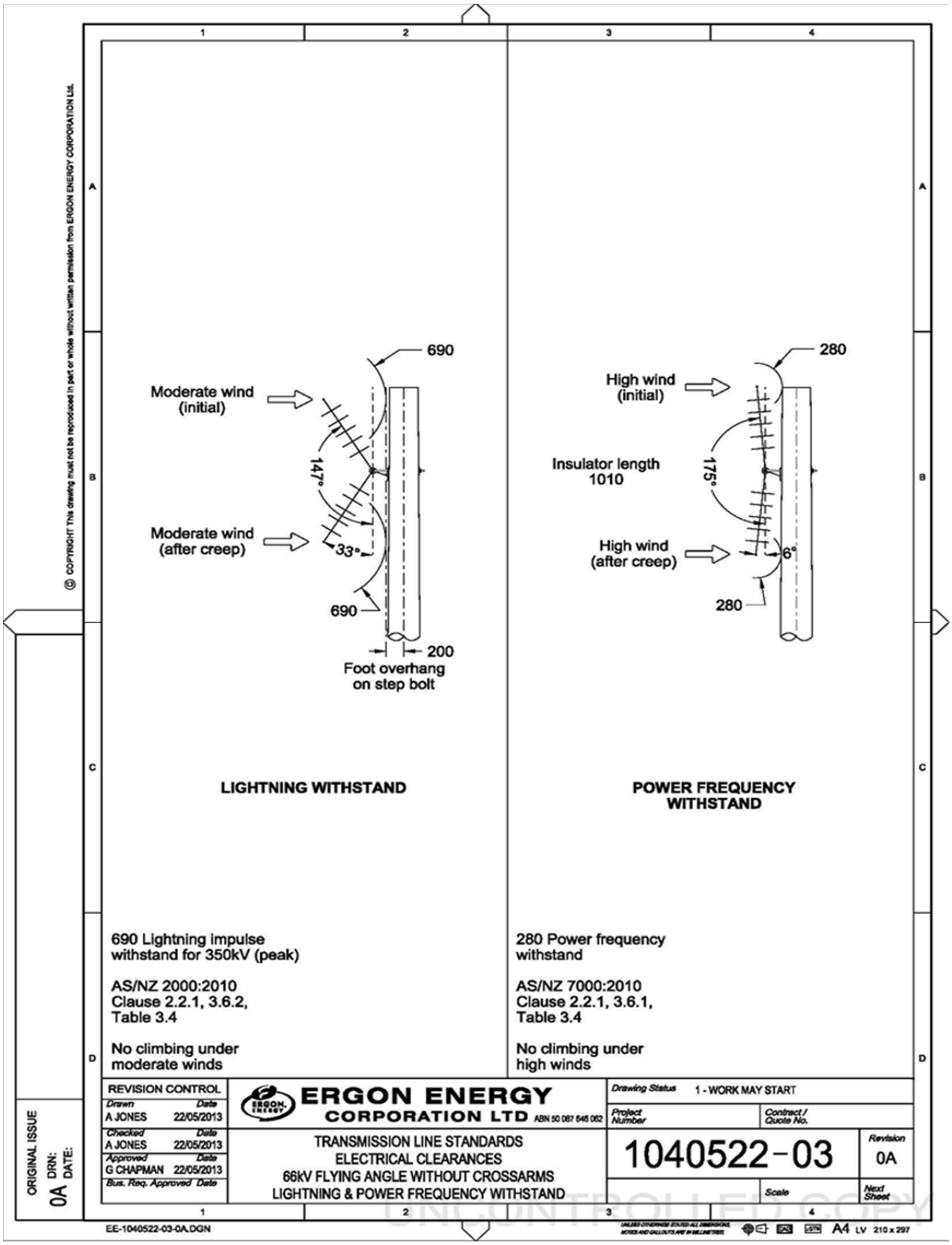

Figure 23.9 – Electrical Clearances – Lightening & Power Frequency Withstand – 66kV Flying Angle without Crossarms

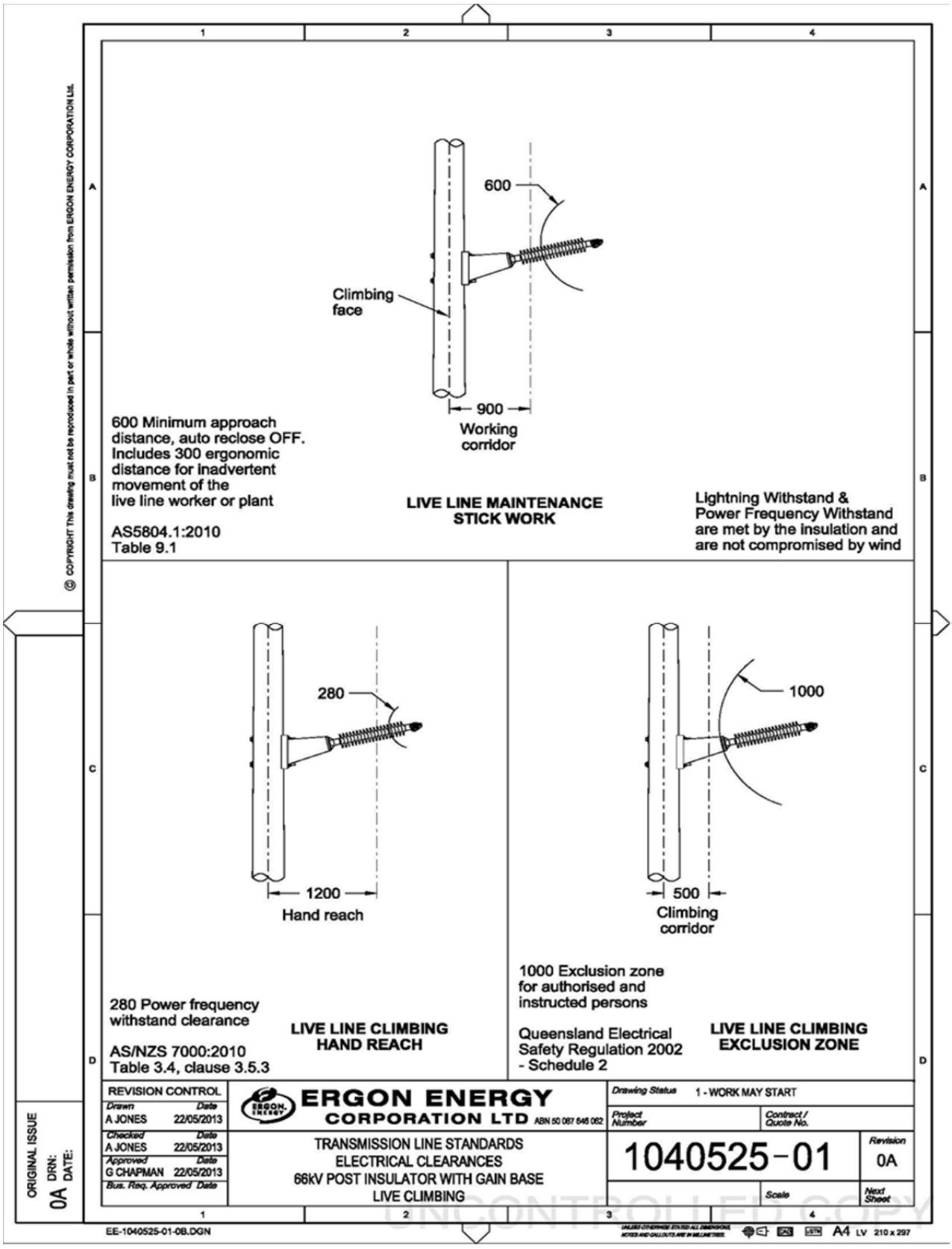

Figure 23.10 – Electrical Clearances – Live Line Climbing – 66kV Post Insulator W/Gainbase

24 ANNEX J – LIMIT STATE CONCRETE POLE CAPACITY TABLES

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30kN 18m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	25
0.5	30	108	25
1	30	111	25
2	60	117	25
3	90	123	25
4	120	129	50
5	150	135	50
6	180	141	50
7	210	147	50
8	240	153	50
9	270	159	50
10	300	165	50
11	330	171	50
12	360	177	50
13	390	183	50
14	420	189	50
15	450	320	50
16	420	320	50
17	380	320	50
18	0	320	50

30kN 21m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	25
0.5	30	108	25
1	30	111	25
2	60	117	25
3	90	123	25
4	120	129	50
5	150	135	50
6	180	141	50
7	210	147	50
8	240	153	50
9	270	159	50
10	300	165	50
11	330	171	50
12	360	177	50
13	390	183	50
14	420	189	50
15	450	195	50
16	480	201	50
17	510	207	50
18	540	360	50
19	500	360	50
20	460	360	50
21	0	360	50

30kN 24m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	25
0.5	30	108	25
1	30	111	25
2	60	117	25
3	90	123	25
4	120	129	50
5	150	135	50
6	180	141	50
7	210	147	50
8	240	153	50
9	270	159	50
10	300	165	50
11	330	171	50
12	360	177	50
13	390	183	50
14	420	189	50
15	450	195	50
16	480	201	50
17	510	207	50
18	540	213	50
19	570	219	50
20	600	400	50
21	570	400	50
22	540	400	50
23	510	400	50
24	0	400	50

30kN 27m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	25
0.5	30	109	25
1	30	113	25
2	60	121	25
3	90	129	25
4	120	137	50
5	150	145	50
6	180	153	50
7	210	161	50
8	240	169	50
9	270	177	50
10	300	185	50
11	330	193	50
12	360	201	50
13	390	209	50
14	420	217	50
15	450	225	50
16	480	233	50
17	510	241	50
18	540	249	50
19	570	257	50
20	600	265	50
21	630	273	50
22	660	281	50
23	690	460	50
24	660	460	50
25	620	460	50
26	590	460	50
27	0	460	50

30kN 30m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	25
0.5	30	109	25
1	30	113	25
2	60	121	25
3	90	129	25
4	120	137	50
5	150	145	50
6	180	153	50
7	210	161	50
8	240	169	50
9	270	177	50
10	300	185	50
11	330	193	50
12	360	201	50
13	390	209	50
14	420	217	50
15	450	225	50
16	480	233	50
17	510	241	50
18	540	249	50
19	570	257	50
20	600	265	50
21	630	273	50
22	660	281	50
23	690	289	50
24	720	297	50
25	750	305	50
26	780	500	50
27	740	500	50
28	700	500	50
29	660	500	50
30	0	500	50

Pole Design Notes:

1. Pole has a Strength Limit State Tip Transverse Load Capacity of 30kN in any direction.
2. Load combinations
   a) If Torsion T* = 0, then M* <= Mu and V* <= Vu
   b) Torsion is applied at crossarms with 50% of M* and 30kN (max) V* shear. (above ground line)
   c) Torsion is applied with 80% of M* and 80% V* shear. (below ground line)
   d) For unstayed poles which act as a cantilever, V* (max) applied at the tip shall be no greater that the stated strength limit state tip transverse load capacity for that pole. If torsion is applied see notes b and c.

REVISION CONTROL		
Drawn	T BORG	26/05/2015
Checked	R MARGANI	16/06/2015
Approved	P DE SOUSA R[illegible]	[illegible]2015
Bus. Req. Approved	Date	

ERGON ENERGY CORPORATION LTD ABN 50 087 646 062

OVERHEAD SUB-TRANSMISSION
CONCRETE POLE DESIGN
STRENGTH LOADINGS - 30kN

Drawing Status	RELEASED STANDARD
Project Number	Contract / Quote No.
EELS-10552-01	Revision 0A
Scale	Next Sheet

ORIGINAL ISSUE
0A DRN:
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40kN 18m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	25
0.5	40	108	25
1	40	111	25
2	80	117	25
3	120	123	25
4	160	129	50
5	200	135	50
6	240	141	50
7	280	147	50
8	320	153	50
9	360	159	50
10	400	165	50
11	440	171	50
12	480	177	50
13	520	183	50
14	560	390	50
15	530	390	50
16	500	390	50
17	470	390	50
18	0	390	50

40kN 21m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	25
0.5	40	108	25
1	40	111	25
2	80	117	25
3	120	123	25
4	160	129	50
5	200	135	50
6	240	141	50
7	280	147	50
8	320	153	50
9	360	159	50
10	400	165	50
11	440	171	50
12	480	177	50
13	520	183	50
14	560	189	50
15	600	195	50
16	640	201	50
17	680	430	50
18	650	430	50
19	610	430	50
20	580	430	50
21	0	430	50

40kN 24m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	25
0.5	40	108	25
1	40	111	25
2	80	117	25
3	120	123	25
4	160	129	50
5	200	135	50
6	240	141	50
7	280	147	50
8	320	153	50
9	360	159	50
10	400	165	50
11	440	171	50
12	480	177	50
13	520	183	50
14	560	189	50
15	600	195	50
16	640	201	50
17	680	207	50
18	720	213	50
19	760	219	50
20	800	470	50
21	760	470	50
22	720	470	50
23	680	470	50
24	0	470	50

40kN 27m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	25
0.5	40	109	25
1	40	113	25
2	80	121	25
3	120	129	25
4	160	137	50
5	200	145	50
6	240	153	50
7	280	161	50
8	320	169	50
9	360	177	50
10	400	185	50
11	440	193	50
12	480	201	50
13	520	209	50
14	560	217	50
15	600	225	50
16	640	233	50
17	680	241	50
18	720	249	50
19	760	257	50
20	800	265	50
21	840	273	50
22	880	281	50
23	920	530	50
24	870	530	50
25	820	530	50
26	780	530	50
27	0	530	50

40kN 30m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	25
0.5	40	109	25
1	40	113	25
2	80	121	25
3	120	129	25
4	160	137	50
5	200	145	50
6	240	153	50
7	280	161	50
8	320	169	50
9	360	177	50
10	400	185	50
11	440	193	50
12	480	201	50
13	520	209	50
14	560	217	50
15	600	225	50
16	640	233	50
17	680	241	50
18	720	249	50
19	760	257	50
20	800	265	50
21	840	273	50
22	880	281	50
23	920	289	50
24	960	297	50
25	1000	305	50
26	1040	570	50
27	980	570	50
28	930	570	50
29	880	570	50
30	0	570	50

Pole Design Notes:

1. Pole has a Strength Limit State Tip Transverse Load Capacity of 40kN in any direction.
2. Load combinations
   a) If Torsion T* = 0, then M* <= Mu and V* <= Vu
   b) Torsion is applied at crossarms with 50% of M* and 40kN (max) V* shear. (above ground line)
   c) Torsion is applied with 80% of M* and 80% V* shear. (below ground line)
   d) For unstayed poles which act as a cantilever, V* (max) applied at the tip shall be no greater that the stated strength limit state tip transverse load capacity for that pole.
   If torsion is applied see notes b and c.

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OVERHEAD SUB-TRANSMISSION
CONCRETE POLE DESIGN
STRENGTH LOADINGS - 40kN

Drawing Status: RELEASED STANDARD
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50kN 18m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	30
0.5	50	108	30
1	50	111	30
2	100	117	30
3	150	123	30
4	200	129	50
5	250	135	50
6	300	141	50
7	350	147	50
8	400	153	50
9	450	159	50
10	500	165	50
11	550	171	50
12	600	177	50
13	650	183	50
14	700	450	50
15	660	450	50
16	620	450	50
17	590	450	50
18	0	450	50

50kN 21m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	30
0.5	50	108	30
1	50	111	30
2	100	117	30
3	150	123	30
4	200	129	50
5	250	135	50
6	300	141	50
7	350	147	50
8	400	153	50
9	450	159	50
10	500	165	50
11	550	171	50
12	600	177	50
13	650	183	50
14	700	189	50
15	750	195	50
16	800	201	50
17	850	500	50
18	810	500	50
19	760	500	50
20	720	500	50
21	0	500	50

50kN 24m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	30
0.5	50	108	30
1	50	111	30
2	100	117	30
3	150	123	30
4	200	129	50
5	250	135	50
6	300	141	50
7	350	147	50
8	400	153	50
9	450	159	50
10	500	165	50
11	550	171	50
12	600	177	50
13	650	183	50
14	700	189	50
15	750	195	50
16	800	201	50
17	850	207	50
18	900	213	50
19	950	219	50
20	1000	550	50
21	950	550	50
22	900	550	50
23	850	550	50
24	0	550	50

50kN 27m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	30
0.5	50	109	30
1	50	113	30
2	100	121	30
3	150	129	30
4	200	137	50
5	250	145	50
6	300	153	50
7	350	161	50
8	400	169	50
9	450	177	50
10	500	185	50
11	550	193	50
12	600	201	50
13	650	209	50
14	700	217	50
15	750	225	50
16	800	233	50
17	850	241	50
18	900	249	50
19	950	257	50
20	1000	265	50
21	1050	273	50
22	1100	600	50
23	1060	600	50
24	1020	600	50
25	980	600	50
26	940	600	50
27	0	600	50

50kN 30m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	0	105	30
0.5	50	109	30
1	50	113	30
2	100	121	30
3	150	129	30
4	200	137	50
5	250	145	50
6	300	153	50
7	350	161	50
8	400	169	50
9	450	177	50
10	500	185	50
11	550	193	50
12	600	201	50
13	650	209	50
14	700	217	50
15	750	225	50
16	800	233	50
17	850	241	50
18	900	249	50
19	950	257	50
20	1000	265	50
21	1050	273	50
22	1100	281	50
23	1150	289	50
24	1200	297	50
25	1250	650	50
26	1200	650	50
27	1150	650	50
28	1110	650	50
29	1060	650	50
30	0	650	50

Pole Design Notes:

1. Pole has a Strength Limit State Tip Transverse Load Capacity of 50kN in any direction.
2. Load combinations
   a) If Torsion T* = 0, then M* <= Mu and V* <= Vu
   b) Torsion is applied at crossarms with 50% of M* and 40kN (max) V* shear. (above ground line)
   c) Torsion is applied with 80% of M* and 80% V* shear. (below ground line)
   d) For unstayed poles which act as a cantilever, V* (max) applied at the tip shall be no greater that the stated strength limit state tip transverse load capacity for that pole. If torsion is applied see notes b and c.

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CONCRETE POLE DESIGN
STRENGTH LOADINGS - 50kN

Drawing Status	RELEASED STANDARD
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60kN 18m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	100	125	50
0.5	100	152	50
1	100	180	50
2	120	180	50
3	180	180	50
4	240	180	80
5	300	180	80
6	360	250	80
7	420	250	80
8	480	250	80
9	540	250	80
10	600	250	80
11	660	250	80
12	720	250	80
13	780	250	80
14	840	510	80
15	800	510	80
16	730	510	80
17	710	510	80
18	0	510	80

60kN 21m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	100	125	50
0.5	100	152	50
1	100	180	50
2	120	180	50
3	180	180	50
4	240	180	80
5	300	180	80
6	360	250	80
7	420	250	80
8	480	250	80
9	540	250	80
10	600	250	80
11	660	250	80
12	720	250	80
13	780	250	80
14	840	250	80
15	900	250	80
16	960	550	80
17	920	550	80
18	890	550	80
19	850	550	80
20	820	550	80
21	0	550	80

60kN 24m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	100	125	50
0.5	100	152	50
1	100	180	50
2	120	180	50
3	180	180	50
4	240	180	80
5	300	180	80
6	360	250	80
7	420	250	80
8	480	250	80
9	540	250	80
10	600	250	80
11	660	250	80
12	720	250	80
13	780	250	80
14	840	250	80
15	900	250	80
16	960	250	80
17	1020	250	80
18	1080	250	80
19	1140	590	80
20	1100	590	80
21	1050	590	80
22	1010	590	80
23	970	590	80
24	0	590	80

60kN 27m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	100	125	50
0.5	100	152	50
1	100	180	50
2	120	180	50
3	180	180	50
4	240	180	80
5	300	180	80
6	360	250	80
7	420	250	80
8	480	250	80
9	540	250	80
10	600	250	80
11	660	250	80
12	720	250	80
13	780	250	80
14	840	250	80
15	900	250	80
16	960	250	80
17	1020	250	80
18	1080	250	80
19	1140	250	80
20	1200	250	80
21	1260	250	80
22	1320	650	80
23	1270	650	80
24	1220	650	80
25	1170	650	80
26	1120	650	80
27	0	650	80

60kN 30m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	100	125	50
0.5	100	152	50
1	100	180	50
2	120	180	50
3	180	180	50
4	240	180	80
5	300	180	80
6	360	250	80
7	420	250	80
8	480	250	80
9	540	250	80
10	600	250	80
11	660	250	80
12	720	250	80
13	780	250	80
14	840	250	80
15	900	250	80
16	960	250	80
17	1020	250	80
18	1080	250	80
19	1140	250	80
20	1200	250	80
21	1260	250	80
22	1320	250	80
23	1380	250	80
24	1440	250	80
25	1500	700	80
26	1440	700	80
27	1380	700	80
28	1320	700	80
29	1260	700	80
30	0	700	80

Pole Design Notes:

1. Pole has a Strength Limit State Tip Transverse Load Capacity of 60kN in any direction.
2. Load combinations
   a) If Torsion T* = 0, then M* <= Mu and V* <= Vu
   b) Torsion is applied at crossarms with 50% of M* and 40kN (max) V* shear. (above ground line)
   c) Torsion is applied with 80% of M* and 80% V* shear. (below ground line)
   d) For unstayed poles which act as a cantilever, V* (max) applied at the tip shall be no greater that the stated strength limit state tip transverse load capacity for that pole. If torsion is applied see notes b and c.

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CONCRETE POLE DESIGN
STRENGTH LOADINGS - 60kN

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80kN 18m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	100	125	50
0.5	100	152	50
1	100	180	50
2	160	180	50
3	240	180	50
4	320	180	80
5	400	180	80
6	480	250	80
7	560	250	80
8	640	250	80
9	720	250	80
10	800	250	80
11	880	250	80
12	960	250	80
13	1040	600	80
14	1000	600	80
15	960	600	80
16	920	600	80
17	880	600	80
18	0	600	80

80kN 21m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	100	125	50
0.5	100	152	50
1	100	180	50
2	160	180	50
3	240	180	50
4	320	180	80
5	400	180	80
6	480	250	80
7	560	250	80
8	640	250	80
9	720	250	80
10	800	250	80
11	880	250	80
12	960	250	80
13	1040	250	80
14	1120	250	80
15	1200	250	80
16	1280	650	80
17	1230	650	80
18	1180	650	80
19	1130	650	80
20	1080	650	80
21	0	650	80

80kN 24m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	100	125	50
0.5	100	152	50
1	100	180	50
2	160	180	50
3	240	180	50
4	320	180	80
5	400	180	80
6	480	250	80
7	560	250	80
8	640	250	80
9	720	250	80
10	800	250	80
11	880	250	80
12	960	250	80
13	1040	250	80
14	1120	250	80
15	1200	250	80
16	1280	250	80
17	1360	250	80
18	1440	250	80
19	1520	700	80
20	1460	700	80
21	1420	700	80
22	1370	700	80
23	1290	700	80
24	0	700	80

80kN 27m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	100	125	50
0.5	100	152	50
1	100	180	50
2	160	180	50
3	240	180	50
4	320	180	80
5	400	180	80
6	480	250	80
7	560	250	80
8	640	250	80
9	720	250	80
10	800	250	80
11	880	250	80
12	960	250	80
13	1040	250	80
14	1120	250	80
15	1200	250	80
16	1280	250	80
17	1360	250	80
18	1440	250	80
19	1520	250	80
20	1600	250	80
21	1680	750	80
22	1630	750	80
23	1580	750	80
24	1530	750	80
25	1480	750	80
26	1430	750	80
27	0	750	80

80kN 30m

STRENGTH LIMIT STATE DESIGN LOAD			
DISTANCE FROM POLE TIP (m)	BENDING MOMENT M* KNm	SHEAR V* KN	TORSION ± T* KNm
0	100	125	50
0.5	100	152	50
1	100	180	50
2	160	180	50
3	240	180	50
4	320	180	80
5	400	180	80
6	480	250	80
7	560	250	80
8	640	250	80
9	720	250	80
10	800	250	80
11	880	250	80
12	960	250	80
13	1040	250	80
14	1120	250	80
15	1200	250	80
16	1280	250	80
17	1360	250	80
18	1440	250	80
19	1520	250	80
20	1600	250	80
21	1680	250	80
22	1760	250	80
23	1840	250	80
24	1920	800	80
25	1860	800	80
26	1800	800	80
27	1740	800	80
28	1680	800	80
29	1620	800	80
30	0	800	80

Pole Design Notes:

1. Pole has a Strength Limit State Tip Transverse Load Capacity of 80kN in any direction.
2. Load combinations
   a) If Torsion T* = 0, then M* <= Mu and V* <= Vu
   b) Torsion is applied at crossarms with 50% of M* and 40kN (max) V* shear. (above ground line)
   c) Torsion is applied with 80% of M* and 80% V* shear. (below ground line)
   d) For unstayed poles which act as a cantilever, V* (max) applied at the tip shall be no greater that the stated strength limit state tip transverse load capacity for that pole.
   If torsion is applied see notes b and c.

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CONCRETE POLE DESIGN
STRENGTH LOADINGS - 80kN

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