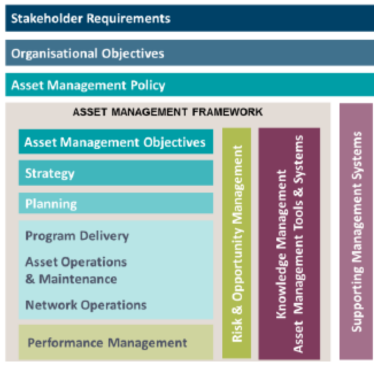
Transmission Line Electrical and Mechanical Design

Design Standard



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Revision Details

Version	Date	Summary of change
0	10/04/2017	Initial release
1	15/05/2020	Minor revisions including changes to conductor tension limits, LiDar survey tolerances, footing resistance requirements, standard conductors and OPGW
2	31/01/2024	AMS format change

1. Introduction

This standard specifies the key design criteria for the design of Western Power's transmission lines. Lines that are designed consistently with these criteria will eliminate the variability in design outcomes and ensure that Western Power complies with its obligation under the Electricity (Network Safety) Regulations 2015.

1.1 Purpose and scope

This standard specifies the loading, material and design (clearance, electromechanical strength and durability) requirements for the elements of supports, conductors and insulators (shaded area of Table 1.1).

Table 1.1: Transmission Line System, Components and Elements

Structural System	Components	Elements
Transmission Line	Supports	Steel, wood, concrete, composite sections and arms
		Plates, bolts, nuts and washers
		Stays and fittings
		Top geometry
		Earthing and Insulation
	Foundations	Anchor bolts, steel piles and cleat angles
		Footings and soil
		Underground Trench
		Earthing systems
	Conductors	Wires
		Joints
		Hardwares/ shackles
	Insulators	Insulator elements
		Brackets, bolts
		Fittings

This standard shall be read in conjunction with other Western Power standards to form a complete design.

1.2 Acronyms

Acronym	Definition
CBL	Calculated breaking load
EDT	Everyday tension
kV	Kilovolt
kN	Kilonewton

OLS	Obstacle Limitation Surface

1.3 Definitions

Term	Definition
Calculated breaking load	In relation to a conductor, means the calculated minimum breaking load determined in accordance with the relevant Australian/New Zealand Standard
Clearance	The shortest distance between two objects that may have a potential difference between them.
Component	One of the different principal parts of the overhead electrical line system having a specified purpose. Typical components are supports, foundations, conductors, insulator strings and hardware.
Conductor	Any bare conductor which is placed above ground, in the open air and is suspended between two or more supports.
Conductor temperature	Means the average conductor temperature.
Corona	Luminous discharge due to ionization of the air surrounding an electrode caused by a voltage gradient exceeding a critical value. Electrodes may be conductors, hardware, accessories or insulators.
Creepage distance	The shortest distance of the insulating surface of an insulator.
Design working life of design life	Assumed period for which a structure, components and elements are to be used for the intended purpose with anticipated routing maintenance but without substantial repair being necessary.
Earth fault current	Current which flows from the main circuit to earth or earthed parts during a fault.
Earth rod	Earth electrode consisting of a metal rod driven into the ground.
Earth wire (Overhead)	A conductor connected to earth at some or all supports, which is suspended usually but not necessarily above the aerial line conductors to provide a degree of protection against lightning strikes.
Earthing	All means and measures for making a proper conductive connection to earth.
Electric field	The electric field is the space surrounding an electric charge and exerts a force on other electrically charged objects. It is expressed in units of volts per metre (V/m).
Element	One of the different parts of a component. For example, the elements of a steel lattice tower are steel angles, plates and bolts.
Failure	State of a structure, component or element whose purpose is terminated, i.e. in which a component has failed by excessive deformation, loss of stability, overturning, collapse, rupture, buckling, etc.
Highest system voltage	Maximum continuous value of phase-to-phase voltage.
Laminar wind	Wind on conductor with a speed between approximately 0.5 m/s and 7 m/s which results in the excitement of Aeolian vibration frequencies on the conductor.
Limit state (electrical)	State beyond which the electrical design performance is no longer satisfied.
Limit state (structural)	State beyond which the structure, components and elements no longer satisfies the design performance requirements.

Loading condition	Likely design actions with defined variable actions and permanent actions for a particular structure analysis.
Magnetic field	Magnetic field generated by current carrying conductor. The magnetic field strength, H, is expressed in amperes per metre (A/m).
Maintenance	Total set of activities performed during the design working life of the system to maintain its purpose.
Maximum operating temperature	Limiting temperature for electrical clearances.
Nominal voltage	Voltage by which the overhead electrical line is designated and to which certain operating characteristics are referred.
Optical ground wire (OPGW)	An earth wire containing optical telecommunication fibres.
Overhead line	Conductors or cables together with associated supports, insulators and apparatus used for the transmission or distribution of electrical energy.
Power frequency flashover distance	Withstand airgap for highest anticipated short-term power frequency voltage and is typically 1.7 per unit voltage.
Radio interference voltage (RIV)	Any effect on the reception of a radio signal due to an unwanted disturbance withing the radio frequency spectrum. Radio interference is primarily of concern for amplitude-modulated systems (AM radio and television video signals) since other forms of modulation (such as frequency modulation (FM) used for VHF radio broadcasting and television audio signals) are generally much less affected by disturbances that emanate from overhead lines.
Reliability (electrical)	Probability that an electrical system performs a given electrical purpose, under a set of conditions, during a reference period.
Reliability (structural)	Probability that an structural system performs a given mechanical purpose, under a set of conditions, during a reference period.
Return period	Mean statistical interval in years between successive recurrences of a climatic action of at least defined magnitude. The inverse of the return period gives the probability of exceeding the action in one year.
Risk	Chance of or exposure to adverse consequences such as loss, injury or death.
Serviceability limit state (electrical)	State beyond which specified service criteria for an electrical performance is no longer met.
Serviceability limit state (structural)	State beyond which specified service criteria for a structure or structural element is no longer met.
Soil resistivity	Volume resistivity of the earth in Ohm metres.
Span length	The centre-line horizontal distance between two adjacent supports.
Support	General term for different structure types that support the conductors of the overhead electrical line.
Support, intermediate	Support for conductors by pin, post or suspension insulators.
Support, suspension	Support for conductors by suspension insulators.
Support, tension or strain	Support for conductors by tension or strain insulators.
Support, terminal (dead-end)	Tension support capable of carrying the total conductor tensile forces in one direction.

Television interference voltage (TIV)	Special case of radio interference for disturbances affecting the frequency ranges used for television broadcasting.
Transmission Line	Overhead line with system voltage of 66 kV and above.
Ultimate limit state (electrical)	State associated with electrical failure, such as electrical flashover.
Ultimate limit state (structural)	State associated with collapse, or with other forms of structural failure. It corresponds generally to the maximum load-carrying resistance of a structure or structural element.
Weight span	For a support, means the length of conductor which gives the vertical component of the conductor load and equals the span between the lowest points on the catenary curve of the conductor on either side of that support.
Wind span	For a support, means the length of conductor which gives the horizontal lateral component of the conductor load caused by wind and equals one half of the sum of the spans on either side of that support.

1.4 References

References which support implementation of this document

Table 1.2 References

Reference No.	Title
ARTC	Requirements for Electric Aerials Crossing ARTC Infrastructure
	Electricity (Network Safety) Regulations 2015
AS 1154.1-2009	Insulator and conductor fittings for overhead power lines – Performance, material, general requirements and dimensions
AS 1154.3-2009	Insulator and conductor fittings for overhead power lines - Performance and general requirements for helical fittings
AS/NZS 1170.2:2021	Structural Design Actions – Wind Actions
AS 1222.1-1992	Bare overhead – Galvanised (SC/GZ) optical fibre and cable
AS 1222.2-1992	Bare overhead - Aluminium Clad (SC/AC)
AS 1531-1991	Conductors - Bare overhead - Aluminium and Aluminium Alloy
AS 2344:2016	Limits of electromagnetic interference from overhead a.c. powerlines and high voltage equipment installations in the frequency range 0.15 MHz to 3000 MHz
AS/NZS 2947.1-1999	Insulators - Porcelain and glass for overhead power lines - Voltages greater than 1000 V a.c. - Test methods - Insulator units
AS/NZS 2947.4-1999	Insulators - Porcelain and glass for overhead power lines - Voltages greater than 1000 V a.c. - Test methods - Insulator strings and insulator sets
AS/NZS 3007:2013	Electrical installations – Surface mines and associated processing plant.
AS 3607-1989	Conductors - Bare overhead, aluminium and aluminium alloy – Steel reinforced
AS 3822-2002	Test methods for bare overhead conductors
AS 3891.1-2021	Permanent marking of overhead cables and their supporting structures for other than planned low-flying
AS 3891.2-2018	Marking of overhead cables for planned low-level flying operations

AS 5804.1-2010	High Voltage Live Working, Part 1: General
AS 5804.3-2010	High Voltage Live Working, Part 3: Stick Work
AS 5804.4-2010	High Voltage Live Working, Part 4: Barehand
AS 6947-2009	Crossing of waterways by electricity infrastructure
AS 60120-2022	Dimensions of ball and socket couplings of string insulator units
AS 60305-2007	Insulators for overhead lines with a nominal voltage above 1000 V – Ceramic or glass insulator units for a.c. systems – Characteristics of insulator units of the cap and pin type
AS 60372-2022	Locking devices for ball and socket couplings of string insulator units – Dimensions and tests
AS/NZS 7000:2016	Overhead Line Design – Detailed Procedures
ESAA D(b)5-1998	Current Ratings of Bare Overhead Line Conductors
IEEE Std 516-2021	Guide for Maintenance Methods on Energized Power Lines
IEC 60104-1987	Aluminium-magnesium-silicon alloy wire for overhead line conductors
IEC 60793-1-40:2019	Optical fibres – Part 1-40: Measurement and Test Procedures – Attenuation
IEC 61109-2008	Insulators for overhead lines – Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1000 V – Definitions, test methods and acceptance criteria
IEC 61232-1993	Aluminium-clad steel wires for electrical purposes
IEC TR 61328-2017	Live Working – Guidelines for the installation of transmission line conductors and earthwires – Stringing equipment and accessory items
IEC 61394 Ed. 1.0 - 2011	Overhead lines - Requirements for greases for aluminium, aluminium alloy and steel bare conductors
IEC 61952-2008	Insulators for overhead lines – Composite line post insulators for a.c. systems with a nominal voltage greater than 1000 V – Definitions, test methods and acceptance criteria
ICNIRP	ICNIRP 2010 guidelines for limiting exposure to time-varying Electric and magnetic fields (1 hz to 100 khz)
ITU-T G.652	Characteristics of a single-mode optical fibre and cable
PTA	Procedure for High Voltage Power Lines Crossing PTA Infrastructure in the Perth Urban Area
TIA-598	Optical Fibre Cable Colour Coding

2. Symbols

For the purpose of this Standard, the following symbols shall apply.

Ø	Strength Factor
R_n	Nominal Strength of Component
W_n	Ultimate Wind Load
W_d	Serviceable Wind Load
W_m	Maintenance Wind Load
G_S	Vertical loads on insulator and fittings plus the mass of all ancillaries and attachments
G_C	Vertical loads on conductors and attachments such as marker balls, spacers and dampers

F_{tw}	Horizontal conductor tensions in the direction of the line when subject to wind
F_{tm}	Horizontal conductor tensions in the direction of the line when subject to maintenance condition
F_{te}	Horizontal conductor tensions in the direction of the line under no wind

3. Safety in Design

The transmission line electrical and mechanical design must consider all safety aspects that can arise from the construction, operation, maintenance and decommissioning of the transmission line and other activities within the line corridor.

The Transmission Line Electrical and Mechanical Design Hazard Management Register (HMR)[1] captures and document what risks have been controlled by this standard, and what residual risks may remain that should be considered at the project design stages and construction.

Every design is required to have its own project specific Hazard Management Register.

4. Compliance

Western Power is obligated under the Electricity (Network Safety) Regulations 2015 to comply with AS/NZS 7000 for design of overhead powerlines.

Where AS/NZS 7000 makes reference to, and requires compliance with other standards/documents, then Western Power must comply with those other standards/documents.

4.1 Applicability of Standard

Complying with Clause 1.1 of AS/NZS 7000 this standard is only applicable to new overhead lines and is not intended to be retrospectively applied to the routine maintenance, and ongoing life extension of existing overhead lines constructed prior to the issue of this standard. Such maintenance and life extension work ensures that lines continue to comply with the original design standards and remain safe and fit for purpose.

However, where existing overhead lines are proposed to be altered such that elements of the overhead line may be overloaded or overstressed to the original design standard, then the overhead line shall be required to comply with the provisions of this standard.

5. Functional Requirements

The primary objective of a transmission line is to transfer electrical power between terminals, terminals and zone substations, between zone substations and occasionally from Western Power's network to a customer's substation.

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1 See Western Power internal document.

The transmission line is intended to be highly reliable with a low maintenance requirement, a high level of community safety and minimal impact on the properties along the route.

The performance of the line shall be available for the design life of the line.

The functional requirements of the line will be met if it is designed to comply with the performance criteria and design parameters set out in this document.

6. Design Philosophies

6.1 Basic Requirements

For the purpose of assessing the mechanical loadings and strength requirements on conductors, insulators and line hardware, the minimum design return period shall be in accordance with those specified in the *Transmission Line Loadings and Support Structure Design Standard*[2].

6.2 Limit State Design

The limit state concept shall be used for determining the conductor, insulator and line hardware strength requirements (mechanical).

For electrical structure clearances, three serviceability states are defined and shall be considered:

(a) Low wind or still air

(b) Moderate wind

(c) High wind

6.3 Design Site Wind Speed and Pressure

The design site wind speed, V_z, and pressure, q_z, shall be calculated in accordance with AS/NZS 7000.

Unless otherwise modelled, the height (z) used to determine the terrain/height multiplier shall be determined as per Table 6.1.

Table 6.1: Value for Height (z)

Conductor	Height (z)
Phase	average height of the top conductor is the attachment height at the insulator (live end) minus two third of the sag at 15 °C, no wind
Earthwire	average height of earthwire is the attachment height minus two third of the sag at 15 °C, no wind

[2] See Western Power internal document.

6.4 Design Temperatures

The recommended design temperatures used in design of overhead lines are given in Table 6.2, unless more accurate information is available for a particular location.

Table 6.2: Design Temperatures

Condition	Design Temperature
Everyday -Design condition and fatigue endurance	15 °C
Electrical Serviceability - Low, Moderate and High Wind	15 °C
Ultimate Wind	15 °C
Maintenance and Construction	15 °C
Failure Containment	15 °C
Cold	0 °C
Hot	Maximum conductor operating temperature
Conductor Blowout - Easement and Clearances	40 °C
Midspan Clearance	50 °C
Maximum Ambient Temperature	Refer to A.1

7. Conductors

Conductor selection/design shall consider the following:

(a) Electrical Requirements

(b) Mechanical Requirements

(c) Environmental Requirements (Corrosion and Lightning Damage)

(d) Economic Considerations

7.1 Conductor Selection

Regardless of the historical use of other various conductor types and dimensions, where practicable, conductors used on all new sections of transmission overhead line shall be from the following.

Table 7.1: Standard Conductors for Transmission Lines[3]

AAC	AAAC/1120	ACSR/AC
Neptune 19/3.25	Krypton 19/3.25	Cricket 30/7/2.50[4]
Saturn 37/3.00	Nitrogen 37/3.00	Darts 30/7/3.00
Triton 37/3.75	Phosphorous 37/3.75	Diving 30/7/3.50
Venus 61/3.75	Sulfur 61/3.75	Golf 54/7/3.00
		Lacrosse 54/3.75+19/2.225

Phase conductors shall have a minimum conductor diameter of 21 mm.

AAC conductors are typically used for urban environment whereas ASCR/AC conductors are used for rural applications.

Non-conventional conductors (eg. high temperature low sag) will require approval from Western Power.

7.2 Electrical Requirements

7.2.1 Steady State Thermal Current Rating

The steady state thermal current rating shall be determined by the methodology outlined in the *ESAA D(b)5* publication.

The conductor ratings are based on the following parameters.

Table 7.2: Steady State Thermal Current Rating Parameters

Parameters	Values
Ambient Temperature	Summer: Refer to A.1 Winter : 25 ^{o}C
Wind speed	1.0 m/s
Wind direction	90 ° to the line
Direct Solar Radiation	1000 W/m^2

3 For lines with voltages above 132 kV, cost implications may dictate the selection of other conductor types. Seek Western Power approval.

4 Preferably to only be used on country wooden pole lines to maximise span length for matching of legacy country wood pole lines.

Diffuse Solar Radiation	100 W/m^2
Emissivity	0.5
Absorptivity	0.5
Ground Reflectance	0.20

7.2.2 Short-Circuit Thermal Current Rating

The permissible short-circuit rating of phase conductors and earthwires shall be calculated using equation[5]:

$$J^2 t = \frac{DC_{20}\left[1 + A_c\left(\frac{T_1+T_2}{2} - 20\right)\right]}{A_r R} \ln\left[\frac{T_2 - 20 + \frac{1}{A_r}}{T_1 - 20 + \frac{1}{A_r}}\right]$$

where

T_2 final temperature in ^oC

T_1 initial temperature in ^oC

A_r temperature coefficient of resistance in $^oC^{-1}$

R resistivity in Ω.mm at 20 ^oC

D density in g/mm^3 or kg/cm^3

J current density in A/mm^2

t duration in seconds (includes reclosure times)

C_{20} specific heat at 20 ^oC in J.g^{-1}. $^oC^{-1}$

A_c temperature coefficient of specific heat

The initial temperature (T_1) shall be taken as per Table 7.3.

Table 7.3: Short circuit analysis initial conductor temperature

Conductor	Initial Temperature (T_1)
Phase	50 ^oC
Earthwire	40 ^oC

The minimum short-circuit rating of all conductors shall be as per Table 7.4.

[5] AS/NZS 7000 – Appendix Z

Table 7.4: Short circuit thermal current rating requirements[6]

System Voltage		Terminal Stations				Zone Substations		
		500 kV	330 kV	220 kV	132 kV	132 kV		66 kV
						Metro	Country	
Short-circuit current (kA)		TBA	56	27	56	45	27	27
Short-circuit duration (ms)	Phase conductor (new equipment[7])	TBA	270	270	115	115	115	115
	Phase conductor (existing equipment)	N/A	370	370	150	150	150	150
	Earthwire (new equipment)	TBA	100	100	115	115	115	115
	Earthwire (existing equipment	N/A	120	120	150	150	150	150

A fault current distribution analysis shall be carried out:

- To determine the fault level variation along the length where it is required to transition to a smaller sized conductor.
- When two dissimilar earthwires are used

For new lines, the earthwire must be the same for the entire length.

For network augmentation/minor relocation works, where it is not practical to size the earthwire to the ultimate fault levels, power system planners need to be consulted to determine a suitable fault current to size the earthwire taking into consideration cost and possible future requirement.

7.2.3 Corona

The surface voltage gradient on the conductor shall be limited to less than 16 kV/cm to limit generation of corona discharges. Under this circumstance, corona loss will be neglible compared to joule losses.

Alternatively, if the conductor surface irregularity factor (m) can be determined from historical corona performance of an existing line, then a new line operating in a similar environment can be designed such that the conductor operating voltage gradient is less than the conductor corona onset voltage gradient.

The maximum phase to earth voltage used to calculate the surface voltage gradient shall be taken as 1.1 pu in the absence of more accurate figures. However, it shall be noted that the maximum voltage 1.1 pu may

[6] See Western Power internal document.
[7] Equipment refers to protection equipment.

not be reached in practice and hence where results are marginal a sensitivity analysis shall be conducted to take into consideration the economics of selecting a larger conductor size.

7.2.4 Audible Noise (AN)

The audible noise shall be limited to the noise levels as stipulated by the Western Australian Environmental Protection (Noise) Regulations 1997.

7.2.5 Radio Interference Voltage (RIV)

The Radio Interference Voltage (RIV) shall be limited to the allowable levels given in AS 2344.

7.2.6 Maximum Design Operating Temperatures

To limit the level of permanent loss of tensile strength (annealing) of the conductor, the maximum allowable design operating temperatures shall be limited to 100 °C. The design operating temperature is typically determined by the electrical load requirement.

Where requested, metropolitan 132 kV lines may be designed for an emergency rating of 120 °C cumulatively for a period of 300 hours.

For non-conventional overhead line conductors (eg. high temperature low sag conductors), the manufacturer shall be consulted for the conductor temperature operating range.

Conductors operating above 120 °C shall be analysed using a non-linear bimetallic conductor model assuming that aluminium does not take compression at high temperature.

Metropolitan lines are identified in accordance with A.2.

7.3 Mechanical Requirements

7.3.1 Limit States – Conductor Strength

The serviceability limit state (damage) and ultimate limit state (failure) of conductors shall be in accordance with Table 7.5.

Table 7.5: Damage and Failure Limits of Conductors and Fittings[8]

Conductor and tensions fittings	Damage (serviceability) limit	Failure (strength) limit
Bare	Lowest of: • Vibration limit • Clearance violation	0.9 conductor CBL
OPGW	Lowest of: • Vibration limit • Maximum tension corresponding to the optical fibre strain free condition	Optical fibre failure (rupture) 0.9 conductor CBL

[8] AS/NZS 7000 – table 4.1

ADSS	Lowest of: • Manufacturer's recommendation • Maximum tension corresponding to the optical fibre strain free condition	Optical fibre failure (rupture) Optical tensile stress (rupture)

The maximum allowable conductor tension shall be checked under the ultimate wind and cold condition.

For conductor run-out and pre-tension, the maximum tension allowed under no wind shall be the base case horizontal tension indicated in table Y1 of AS/NZS 7000.

7.3.2 Everyday Tension (EDT) – Vibration Limit

The maximum everyday load horizontal tension shall be based on table Y1 of AS/NZS 7000 but with a 3% CBL safety margin applied (deduct 3% from the recommended maximum horizontal tension).

For an undamped conductor, a 1.5% CBL safety margin shall be applied.

7.3.3 Conductor Permanent Elongation

The design and or construction allowance for conductor permanent elongation of new conductors shall include the following method:

1. Conductor prestressing
2. Temperature compensation allowance
3. Sag allowance (refer to section 9.4.8)

This will yield a practical approach and result in a best overall long term predictability of conductor behaviour.

Temperature compensation for creep based on empirical guidelines must be included in the linear conductor model to check for clearances and the support structure's capacity at initial condition.

Typical temperature allowances for a range of conductors are shown in Table 7.6.

Table 7.6: Typical creep temperature compensation[9]

Conductor Tension	AAC Conductor	AAAC Conductor	ACSR Conductor
< 5% CBL	0	0	0
5% CBL < and < 10% CBL	5 to 10	5 to 10	0 to 5
10% CBL < and < 20% CBL	10 to 20	10 to 20	5 to 10
> 5% CBL	20 or higher	20 or higher	10 to 15

If available from the manufacturer, a non-linear conductor model based on laboratory test results where the stress strain curve is described by a polynomial shall be used.

[9] SA/NZS HB 331-2020 – this assumes new conductor and no pre-tensioning.

7.4 Environmental Requirements

7.4.1 Conductor Type Selection

The conductor selection for differing polluted environment shall be determined in accordance with Table 7.7.

Table 7.7: Conductor Selection for Differing Environments

Conductor Type	Salt spray pollution		Industrial pollution	
	50 km from coast north of Moora and 10 km from the coast elsewhere	**Bays, inlets and salt lakes**	**Acidic**	**Alkaline**
AAC	Good	Good	Good	Poor
AAAC/6201	Good	Good	Average	Poor
AAAC/1120	Good	Good	Good	Poor
ACSR/GZ	Poor	Poor	Average	Poor
ACSR/AZ	Average	Good	Average	Poor
ACSR/AC	Good	Good	Average	Poor
SC/GZ	Poor	Poor	Poor	Average
SC/ZC	Good	Good	Good	Poor
OPGW	Good	Good	Average	Poor
HDCu	Good	Good	Average	Poor

For an OPGW, the fibre optics shall be housed in either an aluminium tube or aluminium clad stainless steel tube for all environment.

7.4.2 Protective Greases

The requirements and tests of greases shall be in accordance with IEC 61394.

When using ACSR conductors, all conductor strands shall be greased excluding the outer strands.

The drop point temperature of the protective grease shall be more than the maximum operating temperature of the conductor.

7.4.3 Lightning Damage

Where a line is protected by an earthwire or OPGW, its outer strand diameters shall not be less 2.5 mm, but preferably equal or more than 2.75 mm for steel and 3.0 mm for aluminium. In this instance, no further requirement is required for the phase conductors.

However, if the line is not protected from direct lightning strikes, the phase conductors' outer strand diameter shall be at least 3.00 mm or larger.

7.4.4 Computer Modelling of Wire System

In general, the ruling span method (RS) modelling is applicable to the majority of line design situations. However, under the following situations, finite element (FE) modelling shall be used instead:

- Where it is required to study the slack re-allocation due to moving a conductor attachment point or cutting/adding some wire length in an existing span.
- Inserting, raising or moving a structure without re-sagging the conductors.
- Modelling of an existing line where unequal tensions have been surveyed in various spans of a given tension section.
- Modelling of a new line with unequal wind span and/or an undulating terrain.

7.5 Standards

7.5.1 Bare Overhead Conductor

The design, manufacturing and testing of conductors shall comply with the following Australian Standards:

- AS 1222.1: Bare overhead – Galvanised (SC/GZ)
- AS 1222.2: Bare overhead - Aluminium Clad (SC/AC)
- AS 1531: Conductors - Bare overhead - Aluminium and Aluminium Alloy
- AS 3607: Conductors - Bare overhead, aluminium and aluminium alloy – Steel reinforced
- AS 3822: Test methods for bare overhead conductors

7.5.2 OPGW

The design, manufacturing and testing of OPGW shall comply with the following International Standards and recommendations:

- IEC 60104: Aluminium-magnesium-silicon alloy wire for overhead line conductors
- IEC 60793-1-20: Optical fibres – Part 1-20: Measurement and Test Procedures – Fibre geometry
- IEC 60793-1-40: Optical fibres – Part 1-40: Measurement and Test Procedures – Attenuation
- IEC 60793-1-42: Optical fibres – Part 1-40: Measurement and Test Procedures – Chromatic Dispersion
- IEC 60793-1-44: Optical fibres – Part 1-40: Measurement and Test Procedures – Cut-off wavelength
- IEC 60793-1-45: Optical fibres – Part 1-40: Measurement and Test Procedures – mode field diameter
- IEC 60794-4-10: Optical fibre cables – Part 4-10: Aerial optical cables along electrical power lines – Family specification for OPGW (Optical Ground Wires)
- IEC 61232: Aluminium-clad steel wires for electrical purposes
- ITU-T G.652: Characteristics of a single-mode optical fibre and cable
- TIA-598: Optical Fibre Cable Colour Coding

8. Insulators

Insulator selection/design shall consider the following:

- Electrical Requirements
- Pollution Requirements
- Material Selection
- Mechanical Requirements

8.1 Electrical Requirements

Insulators shall meet the following minimum electrical requirement as per Table 8.1.

Table 8.1: Insulator Electrical Requirements

Condition	Voltage
Power Frequency	1.1 pu continuous voltage
	1.4 pu dynamic overvoltage
Impulse	3.0 pu switching overvoltage

When high speed auto-reclosing is installed, overvoltage can exceed 3.0 pu and shall be determined using system modelling.

The minimum impulse withstand shall be in accordance with Table 8.2.

Table 8.2: Insulator Minimum Impulse Withstand Voltage[10]

System Voltage (kV)	Short Duration (1-minute) Power Frequency Withstand (kVrms)	Lightning impulse withstand voltage (kVpeak)
1166	140	325
132	275	650
220	460	1050
330	520	1175
500	TBA	TBA

When using porcelain disc insulators, an additional disc shall be installed in the strain position to ensure that any flashover on tension structures are across the suspension/bridging string.

[10] See Western Power internal document.

8.2 Material Selection

In general, the insulator material selected should preferably be in accordance with Table 8.3.

Table 8.3: Insulator Material Selection

Nominal System Voltage kV_{rms}	Insulator Material
≤ 132	Composite – Metropolitan
	Composite or Porcelain – Country
> 132	Porcelain
	Composite – Horizontal Vee

Constructability, life cycle cost, environment, mechanical strength and maintenance may also dictate the use of certain type of insulator material.

Where composite insulators are selected, it shall be of Silicone type.

8.3 Grading Rings for Composite Insulators

At 132 kV, grading rings shall be provided on all longrod composite insulators unless the manufacturer can demonstrate under 3D electric field modelling the following:

- The electric field on the end metal fittings shall not exceed 1.8 kV/mm.
- The electric field along the insulator sheath shall not exceed 0.42 kV/mm over a distance of 10 mm.
- The electric field on the end-fitting seal shall not exceed 0.35 kV/mm.

The third criterion is not applicable to insulator design where the sealing portion is concealed and not exposed.

Grading rings shall be applied to all composite insulators at 220 kV and above.

8.4 Pollution Performance – Creepage Distance

The minimum creepage distance for insulators shall be as per Table 8.4.

Table 8.4: Insulator Minimum Creepage Distance Requirements

Location	Minimum Creepage
Inland	22 mm/kV for 330 kV 20 mm/kV for other lower voltages
Coastal - 30 km from the South-West coast	25 mm/kV
Up to 50 km from the South-West coast north of Moora	31 mm/kV

Where local environment experiences a higher level of pollution, the insulator shall be selected based on the worst case.

8.5 Mechanical Design

The three states for mechanical design of insulators which need to be considered are:

(a) Everyday load

(b) Serviceable wind load

(c) Ultimate load or Failure Containment Load

The insulator loading criteria shall be as per Table 8.5.

Table 8.5: Insulator Loading Conditions

State	Tension Insulator	Suspension and Vee String Insulator	Post Insulator
Everyday	N/A	Weight span, 0 Pa Wind	Weight span, 0 Pa Wind
Serviceable – Working Wind	N/A	Resultant load at 500 Pa transverse wind	Resultant load at 500 Pa transverse wind + longitudinal unbalance load
Serviceable – Maintenance	construction and maintenance loads	Resultant load for construction and maintenance	Resultant load for construction and maintenance
Ultimate Load	Ultimate Load	Resultant load for ultimate conductor wind transverse load or failure containment	Resultant load for ultimate conductor wind transverse load + longitudinal unbalance load

8.5.1 Tension Insulator – Load Factors

The following load factor factors shall be applied for tension insulators.

Table 8.6: Tension Insulator Load Factors

State	Load Factors	Condition
Serviceable – Maintenance	$ØR_n > W_m + 1.1G_s + 1.5G_c + 1.5F_{tm}$	100 Pa Wind
Ultimate Load – Maximum Wind	$ØR_n > W_n + 1.1G_s + 1.25G_c + 1.25F_{tw}$	Ultimate Wind Maximum Weight Span

8.5.2 Suspension and Vee String Insulator – Load Factors

The following load factors shall be applied for suspension and vee string insulators.

Table 8.7: Suspension and Vee String Insulator Load Factors

State	Load Factors	Condition
Everyday	$ØR_n > 1.1G_s + 1.25G_c + 1.1F_{te}$	0 Pa Wind Maximum Weight Span
Serviceable – Working Wind	$ØR_n > W_d + 1.1G_s + 1.1G_c + 1.0F_{tw}$	500 Pa Wind Maximum Weight Span
Serviceable – Maintenance	$ØR_n > W_m + 1.1G_s + 1.5G_c + 1.5F_{tm}$	100 Pa Wind
Ultimate Load – Maximum Wind	$ØR_n > W_n + 1.1_{Gs} + 1.25_{Gc} + 1.25F_{tw}$	Ultimate Wind Maximum Weight Span
Ultimate Load – Failure Containment	$ØR_n > 0.25W_n + 1.1_{Gs} + 1.25_{Gc} + 1.25F_b$	0.25 x Ultimate Wind RSL (refer to Table 8.8) 0.5 x Maximum Weight Span

In the absence of more detailed numerical assessment, the residual static load (RSL) shall be calculated as per table Table 8.8.

Table 8.8: RSL Tension

State	RSL
Suspension (≥ 1.0 m length of free swing insulator, bracket system or arm)	$F_b = 0.7 \times F_{tw}$
All other insulator	$F_b = 1.0 \times F_{tw}$

8.5.3 Post Insulator – Load Factors

The following load factor factors shall be applied for post insulators.

Table 8.9: Post Insulator Load Factors

State	Load Factors	Condition
Everyday	$ØR_n > 1.1G_s + 1.25G_c + 1.1F_{te}$	0 Pa Wind Maximum Weight Span
Serviceable – Working Wind	$ØR_n > W_d + 1.1G_s + 1.1G_c + 1.0F_{tw}$	500 Pa Wind Maximum Weight Span
Serviceable – Maintenance	$ØR_n > W_m + 1.1G_s + 2.0G_c + 2.0F_{tm}$	100 Pa Wind
Ultimate Load – Maximum Wind	$ØR_n > W_n + 1.1_{Gs} + 1.25_{Gc} + 1.25F_{tw}$	Ultimate Wind Maximum Weight Span

The manufacturer's combined load curve, taking into consideration the horizontal, vertical and transverse loads, shall be used for determining the mechanical strength of a line post insulator.

The deflection of the line post shall not cause any electrical clearance infringement.

Failure Containment case is not required to be considered for post insulators. However, stop structure placement in accordance with *Transmission Line Loadings and Support Structure Design Standard*[11] shall be applied to new lines.

8.5.4 Strength Reduction Factor

The strength reduction factor (Ø) to be applied to insulators shall be as per table 6.2 of AS/NZS 7000.

8.6 Insulation of Stay Wires

Stay wires shall have insulators installed to limit the chance of an energised stay wire coming into contact with the public or staff due to conductor failure or broken stay wire.

The stay wire insulator shall be placed so that:

1. Its lowest point is not less than 2.4 m above the ground
2. It is lower than the lowest conductor, excluding any underslung earthwire

More than one stay wire insulator shall be installed if a failed stay wire can fall onto live conductors and bring an energised stay wire closer than 2.4 m in height from the ground.

8.7 Standards

8.7.1 Porcelain Disc Insulator

The design, manufacturing and testing of porcelain disc insulators shall comply with the following Australian Standards:

- AS/NZS 2947: Porcelain and glass for overhead power lines – Voltages greater than 1000 V a.c.
- AS 60120: Dimensions of ball and socket couplings of string insulator units
- AS 60305: Insulators for overhead lines with a nominal voltage above 1000 V – Ceramic or glass insulator units for a.c. systems – Characteristics of insulator units of the cap and pin type
- AS 60372: Locking devices for ball and socket couplings of string insulator units – Dimensions and tests

8.7.2 Composite Insulator

The design, manufacturing and testing of composite insulators shall comply with the following Australian Standards:

- IEC 61109: Insulators for overhead lines – Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1000 V – Definitions, test methods and acceptance criteria
- IEC 61952: Insulators for overhead lines – Composite line post insulators for a.c. systems with a nominal voltage greater than 1000 V – Definitions, test methods and acceptance criteria

[11] See Western Power internal document.

9. Electrical Clearances

The electrical clearances which are outlined in this standard set the minimum acceptable standards required. The clearances to be considered are:

(a) Clearance at the structure

(b) Clearance for inspection and maintenance

(c) Mid span and vertical separation

(d) Ground Clearance

(e) Phase conductor to objects

(f) Circuit to circuit

9.1 Clearance at the Structure – Internal Clearances

In addition to the still air (no wind) condition, the three serviceability electrical clearance states and their corresponding wind pressure shall be in accordance with Table 9.1.

Table 9.1: Electrical Clearance Serviceability States

Electrical Serviceability State	Wind Pressure	Conductor Condition
Low Wind	100 Pa	Creep
Moderate Wind	300 Pa	Creep
High Wind	500 Pa	Creep
Note: 1. The serviceability high wind is only applicable for lines built in Region A (all terrain categories) and Region B (terrain category 1 and 2 only). For other regions and terrain categories, the serviceability high wind shall be calculated. 2. A lower moderate wind pressure can be selected (minimum 100 Pa) only if the wind pressure has been used on a past design in Western Power which resulted in an acceptable level of reliability or where a lower level of reliability is acceptable.		

The minimum electrical internal clearances shall be in accordance with Table 9.2.

Table 9.2: Minimum Electrical Internal Clearances

<table>
<tr><th>Electrical Serviceability State</th><th>Clearance Condition</th><th>Criteria Requirement</th></tr>
<tr><td rowspan="3">Still air / low wind</td><td>Lightning/switching impulse</td><td>AS/NZS 7000: Table 3.4</td></tr>
<tr><td>Climbing – hand reach
Pole: 1200 mm to the left/right of climber and 1700 mm to the rear of the climber.
Tower: 1700 mm from face of tower</td><td>AS/NZS 7000: Table 3.4
Power Frequency Withstand</td></tr>
<tr><td>Maintenance Approach for Climbing</td><td>Electrical System Safety Rules (ESSR)</td></tr>
</table>

	Live Line Working	AS 5801.1 AS 5801.3 AS 5801.4
Moderate wind	Lightning/switching impulse	AS/NZS 7000: Table 3.4
High wind	Power Frequency	AS/NZS 7000: Table 3.4

Notes:

1. The minimum approach distance envelope for climbing shall not infringe the climbing corridor where climbing facilities are required. This is not required on poles unless it is inaccessible by use of an elevated work platform (EWP).

2. The climbing corridor, if required, shall be 1 m x 1 m.

3. The requirement for live line clearances shall be in accordance with the project sponsor's requirement.

9.2 Live Line Helicopter Maintenance

If required, adequate vertical phase to phase separation for lines with bundled conductors must be allowed for live maintenance on spacers.

Live line helicopter maintenance does not apply to construction of supporting assets or conductor stringing.

For clearances, refer to IEEE Std 516, with the following input parameters:

- Voltage impulse level for 330 kV 3.0 p.u
- Helicopter height 3.0 m
- Helicopter rotor blade diameter 8.0 m
- Helicopter position from support location 40.0 m

9.3 De-energised Maintenance

All double circuit lines shall be designed such that one circuit can be maintained in a de-energised state using an elevated work platform (EWP) with the adjacent circuit live.

For suspension structures equipped with suspension strings on crossarms, no extra clearances are required.

For suspension structures equipped with horizontal line post insulators, the distance (X) from the face of the pole to the conductor attachment shall be greater than the minimum approach distance for mobile plant (refer to ESSR) - Figure 9.1.

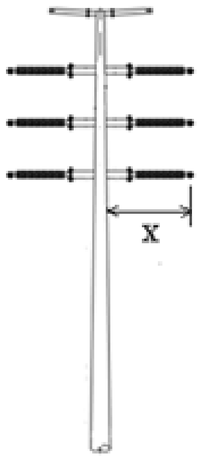

Figure 9.1: Suspension Structure De-energised Maintenance using EWP

For strain structures, the closest distance (X) from the insulator attachment point to any part of the adjacent live circuit shall be greater than 2.2 m plus the minimum approach distance for mobile plant (refer to ESSR) - Figure 9.2.

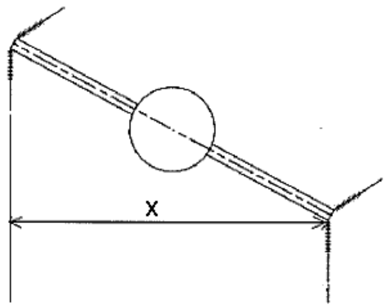

Figure 9.2: Strain Structure De-energised Maintenance using EWP

9.4 Clearances to Ground, Railways and Waterways

9.4.1 Clearances to Ground

The minimum clearances (still air or conductor movement due to wind) to level or sloping ground at maximum operating temperature shall be in accordance with Table 3.5 of AS/NZS 7000.

9.4.2 Wheat-belt Region

An additional 2.3m shall be added to Table 3.5 of AS/NZS 7000 for lines traversing a wheat-belt region. This additional clearance will not be required if the area is not traversable by farming vehicles.

9.4.3 Surface Mines

For lines traversing a surface mine, AS/NZS 3007 shall be used to determine the minimum clearance for the movement of vehicles and machinery under and in the vicinity of overhead lines.

9.4.4 Heavy Haulage and High Wide Load Roads

Roads classified as heavy haulage shall refer to ENA NENS 04:2003, Table 5 to determine the minimum clearance for the movement of vehicles under and in the vicinity of overhead lines.

Main Roads Western Australia (MRWA) shall be consulted on the dimensions of a high wide load (HWL) corridor as it may vary depending upon the height and width intended to use the corridor.

9.4.5 Waterways

Clearances to waterways shall be in accordance with AS 6947, table 3.1.

9.4.6 Railway Tracks

For railways operated by PTA (urban area), the minimum electrical clearance shall comply with the latest version of PTA's "*Procedure for High Voltage Power Lines Crossing PTA Infrastructure in the Perth Urban Area*".

For railways operated by ARTC, the minimum electrical clearance shall comply with the latest version of ARTC's "*Requirements for Electric Aerials Crossing ARTC Infrastructure*".

For railways not controlled by either the PTA or ARTC, agreement on the clearance with the operator of that particular railway line shall be required.

9.4.7 Aerodromes

Where the transmission line is to be installed near an aerodrome, the aerodrome operator must be consulted to identify the Obstacle Limitation Surface (OLS) to ensure the transmission line does not penetrate the OLS at any point.

9.4.8 Ground Clearances Tolerances

In addition to the regulatory requirements, extra tolerances shall be added to the minimum clearance to cater for survey errors, modelling errors and construction errors.

Table 9.3: Ground Clearance Tolerances for New Conductors

Voltage	Tolerance (m)
66 kV and 132 kV	0.8
220 kV and 330 kV	1.0

For AAC conductor emergency operation of 120 °C, an additional tolerance due to elongation caused by elevated temperatures on the conductor shall be added[12].

Table 9.4: Ground Clearance Tolerances for Existing Conductors

Situation	Tolerance (m)
LiDAR survey	0.15
Ground profile survey	0.5
Survey at specific location (eg. middle of road to conductor above)	0.3

An accuracy tolerance of +/- 300 mm for surveys to map ground contours has been included in the ground clearance tolerances. Where more accurate survey tolerances have been specified, the ground clearance tolerances may be reduced accordingly.

9.5 Clearances to Non-Electrical Structure

The minimum clearance from electrical conductors to any non electrical infrastructure such as buildings shall comply with Table 3.7 of AS/NZS 7000. The position to which a conductor in an overhead line may swing under the influence of 500 Pa wind at 40 ^{0}C shall be taken into consideration.

The serviceable wind pressure of 500 Pa only applies to areas in Region A (all terrain categories) and Region B (terrain category 1 and 2 only). For other regions and terrain categories, the serviceable wind pressure shall be calculated.

9.6 Circuit to Circuit Clearance

9.6.1 Different Circuit on Same Support – Attached Crossings

In general, attached crossings on transmission structures are not permitted.

However, should circumstance arise where it is not possible to avoid attached crossings, then the conductors of a higher voltage shall be placed above a lower voltage circuit and the minimum vertical separation required to prevent circuit to circuit flashover shall not be less than the values specified in AS/NZS 7000, table 3.3 (No allowance has been made for safe approach distances)

These clearances are based on the lower circuit conductors attached to post insulators. Additional clearance is required to allow for conductor movement, if the lower circuit is attached by suspension of strain insulators.

9.6.2 Different Circuit on Different Support – Unattached Crossings

Where two circuits of different voltage cross each other, conductors of a higher voltage should be placed above the lower voltage circuit.

The vertical separation between any conductor of the higher circuit and any conductor of the lower circuit shall satisfy the requirements shown in Table 9.5 to prevent circuit to circuit flashover, under both normal operating and fault conditions.

[12] In the absence of more accurate data, an elongation of 738 mm/km may be assumed

Table 9.5: Conditions for Determining Clearances for Unattached Crossings

Condition	Upper Conductor	Lower Conductor	Clearance
No wind on both circuit	Hot	40 ^{o}C	AS/NZS 7000, table 3.1 – No wind
No wind on both circuit	40 ^{o}C	Cold	AS/NZS 7000, table 3.1 – No wind
No wind displacement on upper circuit Low wind (100 Pa) on lower circuit	15 ^{o}C	15 ^{o}C	AS/NZS 7000, table 3.1 – Wind
No wind displacement on upper circuit High wind (500 Pa) on lower circuit	15 ^{o}C	15 ^{o}C	Power Frequency 0.5 m – 132 kV 0.7 m – 220 kV 1.0 m – 330 kV
Note: The upper circuit conductors is assumed to have the wind direction along the span – conductors not displaced by wind			

For situations where there is a likelihood of vegetation falling on the bottom circuit, an additional dynamic loading clearance check shall be performed where the vertical separation at the crossing point shall be twice the sag of the lower circuit at the crossing point when both conductors are at its maximum operating temperature (refer to figure 3.3 of AS/NZS 7000).

9.6.3 Different Circuit on Different Alignment – Adjacent Circuit

The minimum required electrical clearance (Table 3.7 of AS/NZS 7000) shall be maintained when conductors on one circuit blow-out towards structures or phases on the adjacent circuit (to be taken at still air condition).

In addition, the separation between two adjacent circuits shall also consider the space needed for construction/maintenance purposes.

9.7 Mid Span and Vertical Separation

The mid span separation shall be calculated as per equation in AS/NZS 7000 and with the *k* constant equal to 0.6.

$$\sqrt{X^2 + (1.2Y)^2} \geq \frac{U}{150} + k\sqrt{D + l_i}$$

Where

X is the projected horizontal distance in metres between the conductors at mid span; (X = (X1 + X2)/2) where X1 is the projected horizontal distance between the conductors at one support and X2 is the projected horizontal distance between the conductors at the other support in the same span

Y is the projected vertical distance in metres between the conductors at mid span; (Y = (Y1 + Y2)/2) where Y1 is the projected vertical distance between the conductors at one support and Y2 is the projected vertical distance between the conductors at the other support in the same span

U is the r.m.s. vector difference in potential (kV) between the two conductors when each is operating at its nominal voltage. In determining the potential between conductors of different circuits or between an earthwire and an aerial phase conductor, regard shall be paid to any phase differences in the nominal voltages

K is a constant = 0.6

D is the greater of the two conductor sags in metres at the centre of an equivalent level span and at a conductor temperature with electrical load (50°C in still air). This may be higher for high temperature conductors

l_i is the length in metres of any free swing suspension insulator associated with either conductor. Zero for pin and post insulators

For stacked circuits (ie. one circuit above the other), the minimum conductor separation at any point in the span (other than the support structure) shall be calculated as per AS/NZS 7000 with *q* = 0.01.

Vertical separation (m) ≥ 0.38 + q(U-11)

9.8 Vegetation Clearances

Vegetation clearances shall include allowance for blow out of the conductors and the potential of growth of the species of trees. It must meet the clearance specified in *Transmission Easement Strategy – Requirements and Typical Challenges*[13].

10. Lightning Performance

Where practicable, all new overhead lines shall be built with at least one overhead earthwire or OPGW.

The lightning performance of an overhead line shall consider the following:

(a) Shielding Failure

(b) Backflashover

(c) Induced Voltage caused by indirect strike – Not considered for transmission lines

[13] See Western Power internal document.

10.1 Shielding Failure Flashover Rate

The shielding failure flashover rate shall be limited to 0.05 failures/100 km/year for lines serving critical loads (terminal stations, generators, critical/strategic customers) and 0.2 failures/100km/year for lines connecting zone substations and non-critical loads[14].

The average annual thunder days and lightning ground flash density in Australia is shown in A.3 and A.4 respectively.

10.2 Backflashover

The backflashover rate shall be limited such that the overall lightning performance (shielding failure flashover plus backflashover) of a line is within the limits shown in Table 10.1.

Table 10.1: Minimum Lightning Outage Rate

Voltage	Outages/100 km/year
66 kV and 132 kV	2
220 kV and 330 kV	0.5
500 kV	TBA

For lines supplying a customer, the minimum lightning outage rate may need to be reduced to comply with their operational requirements as significant costs can be incurred as a result of line outages.

10.3 Footing Resistance

Notwithstanding the extra requirement needed to address any touch and step potential hazard, the recommended footing resistance distribution on a line for lightning performance is[15]:

(a) Steel structures: on average 10 Ω or less for the line

(b) Wood pole: no structure to be more than 30 Ω with the aim to try and achieve 10 Ω where practicable

The values recommended will be subject to soil resistivity, practical considerations and economic reasons. Deviations from this recommendation are permissible when qualified by detailed calculation to determine the lightning outage rate.

10.4 Position of Overhead Earthwire

The overhead earthwire position shall be located to achieve a desirable shielding failure flashover rate.

In addition, midspan clearances shall be checked for possible clashing of conductors.

[14] See Western Power internal document.

[15] These values only apply to new earths and may not be representative of existing earths in the network. Where it is critical to know the existing earth resistance value, testing may be required.

In general, the sag of the earthwire at EDT shall be 90% of phase conductors' sag if it is within allowable strength requirements.

10.5 Existing Lines without Shielding Earthwire – Substation Cut-in

In general, an overhead shielding earthwire is to be retrofitted on each resulting line for a minimum distance of 500 m from the end where the line emanates from the substation[10].

A shorter earthwire length is permissible when qualified by detailed calculation to determine an acceptable level of insulation coordination.

10.6 Underground to Overhead Transition Structure

For an underground to overhead transition structure, a minimum of 3 adjacent spans needs to be fitted with an overhead shielding earthwire. The transition structure, including the 3 adjacent support structures must have a footing resistance of 10 Ω or less.

Deviation to this requirement is allowable with an insulation coordination study.

11. Earthing System

For transmission line earthing requirements, refer to *Transmission Lines Earthing Design Standard*[16].

12. Electric and Magnetic Fields

12.1 Electric and Magnetic Fields

The electric and magnetic fields shall be limited to the values stipulated in ICNIRP 2010 guidelines for limiting exposure to time-varying electric and magnetic fields (1 hz to 100 khz).

The actual current used for the calculation shall be based on the long term average loading on the line, which in the absence of more detailed information, shall be taken as 75% of the continuous current rating (not emergency rating).

The voltage shall be based on the nominal system voltage.

12.2 Induction for Conductor Stringing

Induce voltages may be present when stringing (or removing conductors) in parallel to an existing energised line. Where required, the requirements in IEC TR 61328 shall be implemented during all subsequent works to protect personnel safety exposed to hazardous voltage conditions.

12.3 Electrostatic Induction

Electrostatic induction caused by electric fields surrounding the powerline and inducing charges on nearby metallic objects shall be limited to 5 mA.

This shall be determined for voltages above 200 kV and where the line is in close proximity to large bulky metallic objects. This may influence the minimum ground clearance over parking areas.

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[16] See Western Power internal document.

13. Overhead Line Fittings

The design life of overhead line fittings shall be based on the design working life of the line.

13.1 Rules of Mating

The general rules of mating are:

- Balls mate with sockets (two axes of freedom)
- Tongues mate with clevis (one axis of freedom)
- Eyes mate with eyes and bow shackles (two axes of freedom)
- Y-clevis mates with eyes or bow shackles (two axes of freedom)

The following are not recommended:

- Eyes mate with bolts
- Clevis with Clevis
- Clevis with Bow Shackle
- Eye with Ball
- Y-clevis with tongue

13.2 Electrical Requirements

All current carrying fittings directly connected to the conductor shall be able to withstand the maximum load current and short-circuit currents.

The voltage drop across the fittings shall not be greater than the voltage drop across an equivalent conductor length.

13.3 Mechanical Requirements

Conductor termination fittings and all components in insulator suspension assemblies shall be capable of transferring the maximum design load from the load combinations described in Clause **Error! Reference source not found.**.

Fittings shall be selected based on the following strength rating:

(i) 70 kN

(ii) 120 kN

(iii) 160 kN

(iv) 210 kN

13.4 Strength Reduction Factor

The strength reduction factor (Ø) to be applied to fittings shall be in accordance with table 6.2 of AS/NZS 7000.

13.5 Deadend Tension Fittings

The application of deadend tension fittings shall be selected in accordance with Table 13.1.

Table 13.1: Selection of Deadend Tension Fittings

Deadend Fitting	Max Operating Temp	Conductor Type	Support Structure Type
Helical	100 °C	AAC and AAAC only (not applicable for use ACSR)	Preferably on wood pole only
Compression	120 °C[17]	All type (including ACSR)	All type (including steel structures)

13.6 Spacers for Bundled Conductors

The separation of bundled conductors using spacers shall be determined using the a/d ratio (separation to conductor diameter).

Table 13.2: Separation of Bundled Conductors

Conductor	a/d ratio
Two and three conductor bundles	16 - 18
Four	20

The following three standard size spacers shall be used:

(i) 380 mm

(ii) 460 mm

(iii) 520 mm

The spacer size shall be the closest separation required from the a/d ratio.

The compressive strength of the spacer shall be greater than the peak forces encountered during faults when sub-conductors are attracted towards each other.

13.7 Vibration Dampers

Vibration dampers must be installed to limit conductor fatigue when higher tensions specified in Table Y1 of AS/NZS 7000 are used. Vibration dampers shall be installed in quantities and locations specified by the damper manufacturer.

For quad conductor arrangements, a combination of spacer dampers and end span damping is recommended. The use of spacer dampers only (without end span damping) is not acceptable.

[17] Continuous maximum operating temperature of 100 °C and an emergency operation of 120 °C for 300 hours cumulatively.

13.8 OPGW Downlead Clamps and Joint Enclosures

The installation of OPGW downlead clamps and joint enclosure shall be in accordance with Table 13.3.

Table 13.3: OPGW Downlead and Joint Enclosure Installation

Item	Installation Requirement
OPGW Downlead Clamps	Intervals not exceeding 1.5 m
Splice Enclosure	Tower – above anti-climbing device Pole – minimum 5 m above ground

13.9 Aerial Warning Spheres

Aerial warning spheres shall be installed in accordance with AS 3891 for the following situation:

- Conductor heights in excess of 90 m from any road, railway or navigable water
- Conductor heights in excess of 90 m continuously for 50 m above any ground not containing a road, railway or navigable water
- Within the approach and take-off slopes of aerodromes
- Areas with low-flying operations such as mustering, power, pipeline and railway aerial inspection

The interval between the warning spheres shall be positioned as per Table 13.4.

Table 13.4: Aerial Warning Sphere Spacing Intervals

Diameter	Interval
Less than 600 mm	25 – 30 m
600 mm to 800 mm	30 – 35 m
Greater than 800 mm	35 – 40 m

Where aerial warning spheres are required to be installed on the phase conductors, consideration on the operating temperature of the conductors is required to ensure adequately rated warning spheres has been selected.

High intensity obstacle lights shall be installed where:

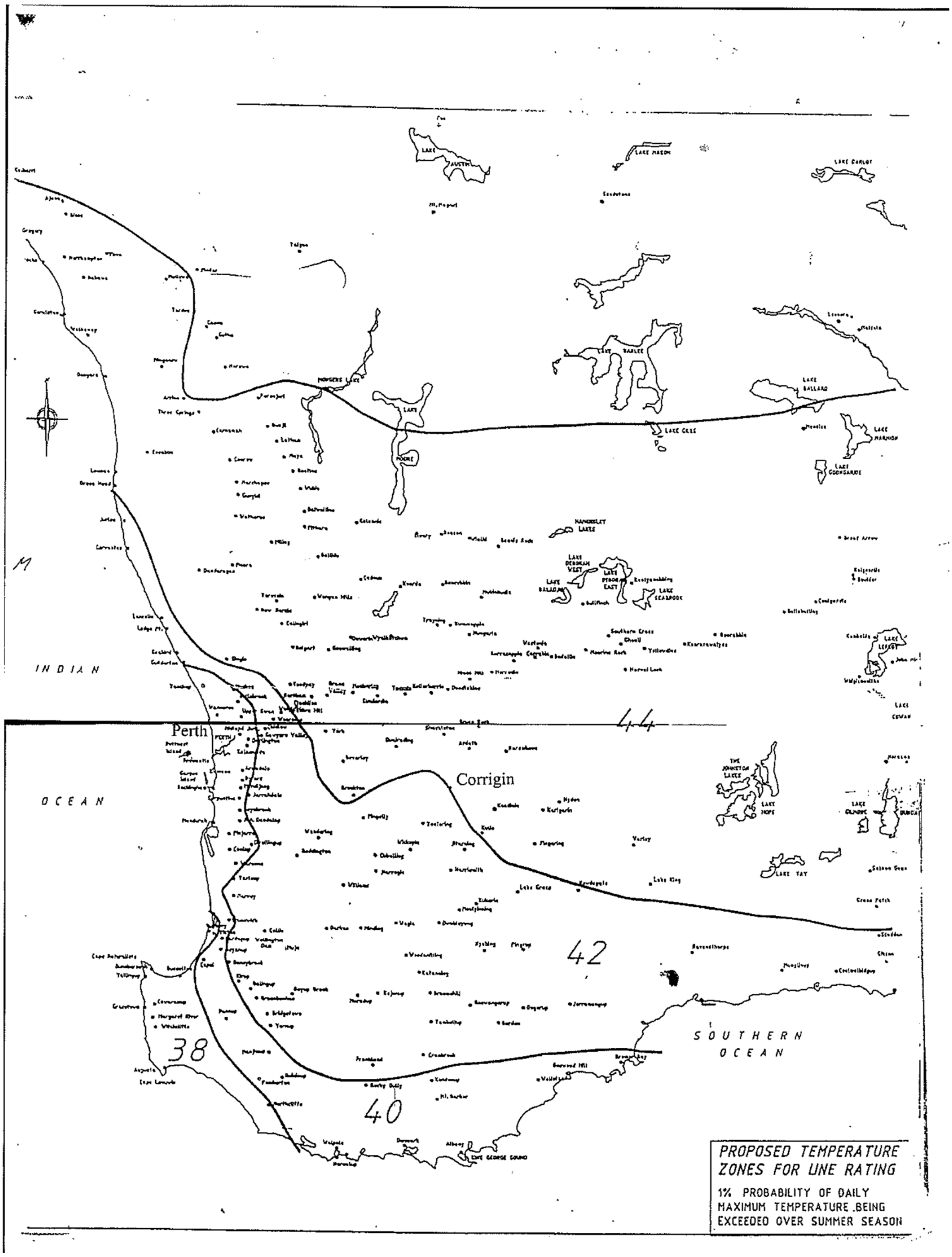
- Conductor heights in excess of 150 m
- Conductor heights above 90 m and a span length exceeding 1500 m

13.10 Standards

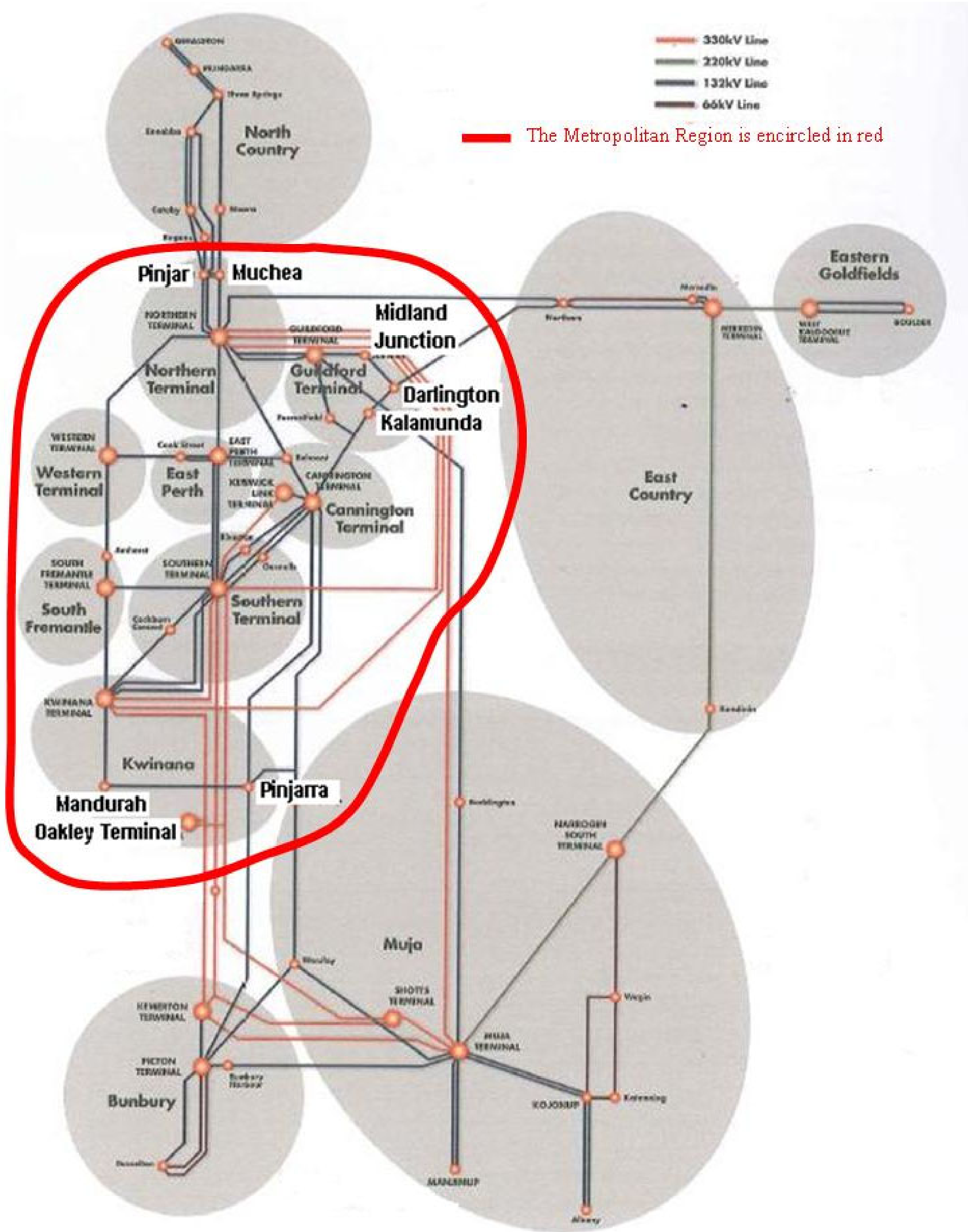
The design, manufacturing and testing of overhead line fittings shall comply with the AS 1154: Insulator and conductor fittings for overhead power lines.

Appendices

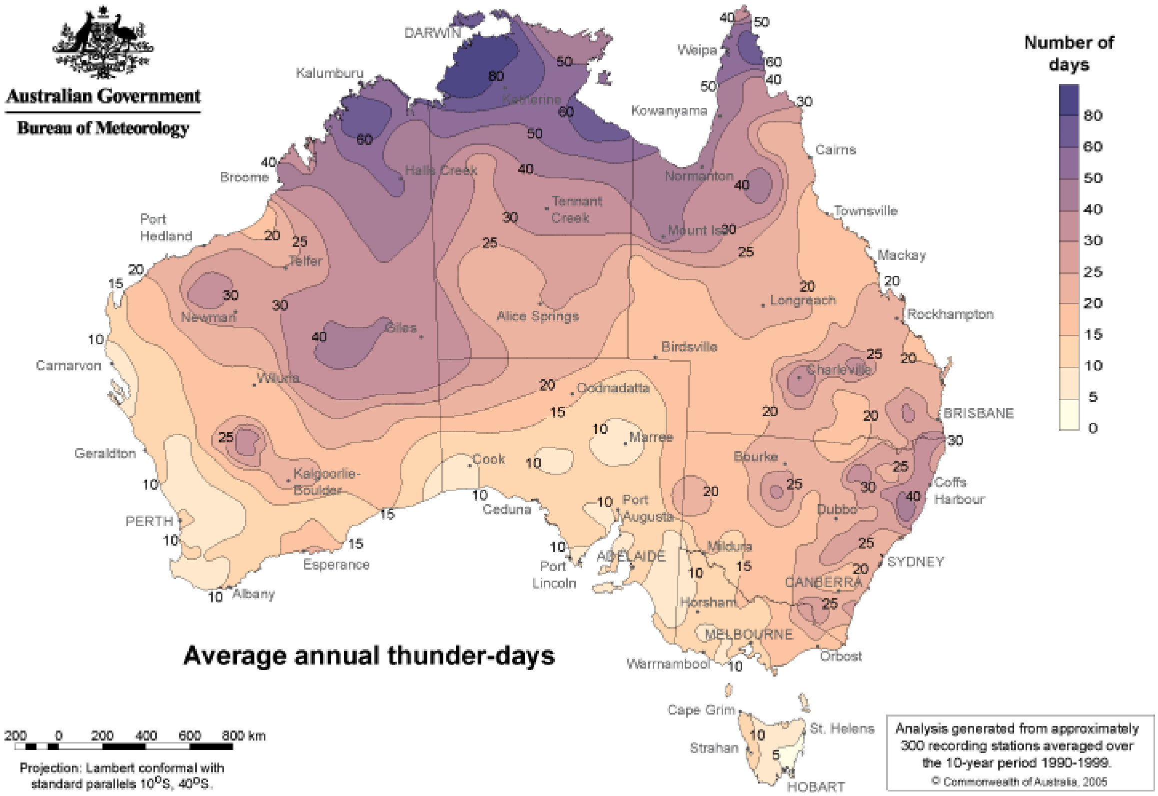
A.1 Maximum Ambient Temperature



A.2 Metropolitan Lines



A.3 Average Annual Thunder Days



A.4 Lightning Ground Flash Density