

Australian/New Zealand Standard™

Overhead line design



AS/NZS 7000:2016

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Australian/New Zealand Standard™

Overhead line design

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL-052, Electrical Energy Networks, Construction and Operation.

The objective of this Standard is to provide Electricity Industry network owners, overhead line maintenance service providers, design consultants, construction contractors, structure designers, and pole manufacturers with an industry standard that replaces all previously used reference guidelines.

This Standard is one of a series of two documents—

- 1 *Overhead line design Standard*, which is a Standard that sets the detailed design requirements for overhead lines.
- 2 HB 331 *Overhead line design*, is a handbook providing supporting information, commentary, worked examples and supporting software (where applicable) for the design of overhead lines.

Statements expressed in mandatory terms in Notes to Tables and Figures are deemed to be requirements of this Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendices to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

Major changes in the 2016 edition include the following:

- (a) In Table 6.2, Strength Reduction Factor ϕ for Component Strength, a new category ‘Foundations designed to yield before structure’ with a range from 0.8 to 1.0 has been added. It aligns with the current embedment depths for distribution poles;
- (b) In Appendix B, Paragraph B4.2, it is recommended that in region B until more definitive data is available, designers should select one higher level of line security for convective winds to achieve comparable overhead line reliability in all zones.
- (c) Appendix F, Timber poles, has been made normative;
- (d) A new Appendix FF, structural Test for Prototype Poles, has been added;
- (e) The maximum short-circuit temperatures for conductors in Table BB4, Typical Conductor Operating Temperatures, have been revised;
- (f) Additional guidelines for ice loading have been added to Appendix DD, Snow and Ice loads;
- (g) In Appendix EE the hand reach clearances for poles (1200 mm to the left and right and 1700 mm to the rear) have been clarified.
- (h) A number of editorial changes have been made.

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Australian/New Zealand Standard Overhead line design

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE AND GENERAL

This Standard specifies the general requirements that are to be met for the design and construction of new overhead lines to ensure that the line is suitable for its intended purpose, and provides acceptable levels of safety for construction, maintenance and operation, and meets requirements for environmental considerations.

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'.

Where the additional loading does not exceed the foundation or major structural element capacities, it is not necessary to comply with this Standard. Modifications may be made to comply with the Standard applicable to the original design. Major structural elements include poles, lattice tower legs and foundations.

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 is required to be assessed by a competent person for compliance with the provisions of this Standard.

This Standard is applicable to overhead lines supporting telecommunication systems or where they are used on overhead lines either attached to the aerial line conductor/earth wire systems or as separate cables supported by the supports. These telecommunication systems include optical ground wires (OPGWs), optical conductors and all dielectric self supporting (ADSS) cables.

It is also applicable to overhead line structures supporting telecommunications equipment.

The electrical requirements of this standard apply to alternating current (a.c.) systems with a nominal frequency of 50 Hz.

This Standard does not apply to catenary systems of electrified railways.

NOTE: Overhead line design handbook HB 331 complements this Standard providing further information and worked examples.

1.2 USE OF ALTERNATIVE MATERIALS OR METHODS

This Standard shall not be interpreted so to prevent innovation or the use of materials or methods of design or construction not specifically referred to herein.

Alternative methods, dimensions or materials that provide safety and reliability levels equal to, or greater, than this Standard can be used and are deemed to comply with this Standard.

Special studies shall be carried out to demonstrate comprehensive engineering design including a risk management assessment. This study shall include appropriate documentation to show the source of all data in the context of the specific evaluation. It should include the following, where relevant:

- (a) Departures from this Standard and rationale.
- (b) Reference to other national or international Standards.
- (c) Comparison with other data.
- (d) Analytical methods used.

1.3 REFERENCED AND RELATED DOCUMENTS

See Appendix A for a list of documents referenced in this Standard and for a list of related documents.

1.4 DEFINITIONS

For the purpose of this Standard the definitions below apply.

1.4.1 Accidental action

Action, usually of short duration, which has a low probability of occurrence during the design working life.

NOTE: An accidental action can be expected in many cases to cause severe consequences unless special measures are taken.

1.4.2 Action

Set of concentrated or distributed forces acting on a structure (direct action), or deformation imposed on a structure or constrained within it (indirect action).

NOTE: The term load is also often used to describe direct actions. An action can be permanent, variable or accidental.

1.4.3 Aerial bundled cable

Two or more cores twisted together into a single bundled cable assembly. Two types of aerial bundled cable are used—

- (a) low voltage aerial bundled cable (LVABC) means a cable which meets the requirements of either AS/NZS 3560.1 or AS/NZS 3560.2 as applicable; and
- (b) high voltage aerial bundled cable (HVABC) means a cable which meets the requirements of either AS/NZS 3599.1 or AS/NZS 3599.2 as applicable.

1.4.4 Aerial cable

Any insulated or covered conductor or assembly of cores with or without protective covering, which is placed above ground, in the open air and is suspended between two or more supports.

1.4.5 Bonding conductor

Conductor providing equipotential bonding.

1.4.6 Calculated breaking load (CBL)

In relation to a conductor, means the calculated minimum breaking load determined in accordance with the relevant Australian/New Zealand Standard.

1.4.7 Characteristic value of a material property

Value of a material property having a prescribed probability of not being attained in a hypothetical unlimited test series. This value generally corresponds to a specified fraction of the assumed statistical distribution of the particular property of the material.

1.4.8 Clearance

The shortest distance between two objects that may have a potential difference between them.

1.4.9 Coefficient of variation

Ratio of the standard deviation to the mean value.

1.4.10 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.

1.4.11 Conductor

Any bare conductor which is placed above ground, in the open air and is suspended between two or more supports.

1.4.12 Conductor temperature

Means the average conductor temperature.

1.4.13 Corona

Luminous discharge due to ionization of the air surrounding an electrode caused by a voltage gradient exceeding a critical value.

NOTE: Electrodes may be conductors, hardware, accessories or insulators.

1.4.14 Covered conductor

A conductor around which is applied a specified thickness of insulating material. AS/NZS 3675 specifies two types of covered conductor—

- (a) CC—where the nominal covering thickness is independent of working voltage; and
- (b) CCT—where the nominal covering thickness is dependent on the working voltage.

1.4.15 Design working life or design life

Assumed period for which a structure, components and elements are to be used for the intended purpose with anticipated routine maintenance but without substantial repair being necessary.

1.4.16 Earth current

Current that flows from the main circuit to earth or earthed parts at the fault location (earth fault location).

1.4.17 Earth electrode

Conductor which is embedded in the earth and conductively connected to the earth, or a conductor which is embedded in concrete, which is in contact with the earth via a large surface (for example foundation earth electrode).

1.4.18 Earth fault

Conductive connection caused by a fault between an aerial phase conductor of the main circuit and earth or an earthed part. The conductive connection can also occur via an arc. Earth faults of two or several aerial phase conductors of the same electrical system at different locations are designated as double or multiple earth faults.

1.4.19 Earth fault current

Current which flows from the main circuit to earth or earthed parts during a fault.

1.4.20 Earth potential rise (EPR)

Voltage between an earthing system and reference or remote earth.

1.4.21 Earth (Reference/remote)

Part of the earth considered as conductive, the voltage of which is conventionally taken as zero, being outside the zone of influence of the relevant earthing arrangement.

1.4.22 Earth rod

Earth electrode consisting of a metal rod driven into the ground.

1.4.23 Earth surface potential

Voltage between a point on the earth surface and remote earth.

1.4.24 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.

NOTE: An earth wire may also contain non-metallic wires for telecommunication purposes.

1.4.25 Earthing

All means and measures for making a proper conductive connection to earth.

1.4.26 Earthing conductor

Conductor which connects that part of the installation which has to be earthed to an earth electrode.

1.4.27 Earthing system

Electrical system of conductively connected earth electrodes, earthing conductors, bonding conductors, or metal parts effective in the same way, for example tower footings, armourings, metal cable sheaths.

1.4.28 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).

1.4.29 Element

One of the different parts of a component. For example, the elements of a steel lattice tower are steel angles, plates and bolts.

1.4.30 Equipotential bonding

Conductive connection between conductive parts, to reduce the potential differences between these parts.

1.4.31 Exclusion limit probability of a variable

Value of a variable taken from its distribution function and corresponding to an assigned probability of not being exceeded.

1.4.32 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.

1.4.33 Highest system voltage

Maximum continuous value of phase-to-phase voltage.

1.4.34 Horizontal earth electrode

Electrode which is generally buried at a shallow depth. For example it can consist of strip, round bar or stranded conductor and can be carried out as radial, ring or mesh earth electrode or as a combination of these.

1.4.35 Impedance to earth of an earthing system

Impedance between the earthing system and reference or remote earth.

1.4.36 Insulated conductor

A conductor surrounded by a layer of insulation which provides resistance to the passage of current, or to disruptive discharges through or over the surface of the substance at the operating voltage, or injurious leakage of current. For clearance purposes a distinction is made between insulated conductors with and without earthed screens operating at voltages in excess of 1000 V.

1.4.37 Insulated with earthed screen

Includes aerial bundled cable (ABC) complying with either AS/NZS 3599.1 or AS/NZS 3599.2 as applicable.

1.4.38 Insulated without earthed screen

Includes CCT cable complying with AS/NZS 3675.

1.4.39 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.

1.4.40 Limit state (electrical)

State beyond which the electrical design performance is no longer satisfied.

1.4.41 Limit state (structural)

State beyond which the structure, components and elements no longer satisfies the design performance requirements.

1.4.42 Loading condition

Likely design actions with defined variable actions and permanent actions for a particular structure analysis.

1.4.43 Magnetic field

Magnetic field generated by current carrying conductor. The magnetic field strength, H , is expressed in amperes per metre (A/m).

1.4.44 Magnetic flux density

The magnetic flux density, 'B', is the magnetic field per unit area and expressed in the units of milliGauss (mG) or microTesla (μT).

1.4.45 Maintenance

Total set of activities performed during the design working life of the system to maintain its purpose.

1.4.46 Maximum operating temperature

Limiting temperature for electrical clearances.

1.4.47 Nominal voltage

Voltage by which the overhead electrical line is designated and to which certain operating characteristics are referred.

1.4.48 Optical conductor (OPCON)

An electrical phase conductor containing optical telecommunication fibres.

1.4.49 Optical ground wire (OPGW)

An earth wire containing optical telecommunication fibres.

1.4.50 Overhead line

Conductors or cables together with associated supports, insulators and apparatus used for the transmission or distribution of electrical energy.

1.4.51 Overhead service line

An overhead line operating at a voltage less than 1000 V generally located between the electricity utility's overhead line and the point of connection to an electrical installation.

1.4.52 Permanent action

Action that is likely to act continuously and for which variations in magnitude with time are small compared with the mean value.

1.4.53 Potential grading

Influencing the earth surface potential by means of earth (grading) electrodes.

1.4.54 Power frequency flashover distance

Withstand airgap for highest anticipated short-term power frequency voltage and is typically 1.7 per unit voltage.

1.4.55 Prospective step voltage

The prospective or open circuit voltage that may appear between any two points on the surface of the earth spaced one metre apart (measured with two driven electrodes and a high impedance voltmeter).

1.4.56 Prospective touch voltage

The prospective or open circuit voltage (measured with a driven electrode and a high impedance voltmeter) which may appear between any point of contact with uninsulated metalwork located within 2.4 m of the ground and any point on the surface of the ground within a horizontal distance of one metre from the vertical projection of the point of contact with the uninsulated metalwork.

1.4.57 Radio interference voltage (RIV)

Any effect on the reception of a radio signal due to an unwanted disturbance within the radiofrequency 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.

1.4.58 Reliability (electrical)

Probability that an electrical system performs a given electrical 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.

1.4.59 Reliability (structural)

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.

1.4.60 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.

1.4.61 Risk

Chance of or exposure to adverse consequences such as loss, injury or death.

1.4.62 Serviceability limit state (electrical)

State beyond which specified service criteria for an electrical performance is no longer met.

1.4.63 Serviceability limit state (structural)

State beyond which specified service criteria for a structure or structural element are no longer met.

1.4.64 Soil resistivity

Volume resistivity of the earth in Ohm metres.

1.4.65 Span length

The centre-line horizontal distance between two adjacent supports.

1.4.66 Support

General term for different structure types that support the conductors of the overhead electrical line.

1.4.67 Support, intermediate

Support for conductors by pin, post or suspension insulators.

1.4.68 Support, suspension

Support for conductors by suspension insulators.

1.4.69 Support, tension or strain

Support for conductors by tension or strain insulators.

1.4.70 Support, terminal (dead-end)

Tension support capable of carrying the total conductor tensile forces in one direction.

1.4.71 System (electrical)

All items of equipment which are used in combination for the generation, transmission and distribution of electricity.

1.4.72 System (mechanical and structural)

Set of components connected together to form an overhead electrical line.

1.4.73 System that is non-effectively earthed (electrical)

System (electrical) with isolated neutral or resonant earthing.

1.4.74 System that is solidly earthed (electrical)

System (electrical) in which at least one neutral of a transformer, earthing transformer or generator is earthed directly or via a low impedance.

1.4.75 System with resonant earthing (electrical)

System (electrical) in which at least one neutral of a transformer or earthing transformer is earthed via an arc suppression coil and the combined inductance of all arc suppression coils is essentially tuned to the capacitance of the system to earth for the operating frequency.

1.4.76 Television interference voltage (TIV)

Special case of radio interference for disturbances affecting the frequency ranges used for television broadcasting.

1.4.77 Transferred potential

Potential rise of an earthing system caused by a current to earth transferred by means of a connected conductor (for example a metallic cable sheath, protective earthed neutral conductor, pipeline, rail) into areas with low or no potential rise relative to reference earth resulting in a potential difference occurring between the conductor and its surroundings.

NOTE: The definition also applies where a conductor, which is connected to reference earth, leads into the area of the potential rise.

1.4.78 Ultimate limit state (electrical)

State associated with electrical failure, such as electrical flashover.

1.4.79 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 a structural element.

1.4.80 Variable action

A time variable action.

1.4.81 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.

1.4.82 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.

1.5 NOTATION

The quantity symbols used in this Standard shall have the meanings ascribed to them below.

Symbol	Signification
α	= angle of wind to conductor
ϕ	= strength reduction factor which takes into account variability of material, workmanship etc.
η	= shielding factor
δ	= solidity factor
γ	= soil unit weight (kN/m ³)
φ	= soil angle of friction
γ_x	= load factors which take into account variability of loads, importance of structure, safety implications etc.

Symbol	Signification
A	= the projected area of one structure section (panel) under consideration in a vertical plane along the face for square towers (m^2)
A^*	= the projected area of the structure section under consideration in a plane normal to the wind direction (m^2)
A_1, A_3	= projected areas of the longitudinal faces on lattice structures in a vertical plane along the face (m^2)
A_2, A_4	= projected areas of transverse faces on lattice structures in a vertical plane along the face (m^2)
C	= drag coefficient of wire
$\underline{C}$	= soil cohesion (kPa)
C_d	= drag force coefficient for member
COV	= coefficient of variation
CRF	= component reliability factor
$\underline{D}$	= conductor diameter (mm)
D_E	= 'effective diameter' of foundation (m)
E_n	= earthquake load corresponding to an appropriate return period (kN)
F_b	= load on structure due to unbalanced conductor tensions resulting from abnormal conditions e.g. a broken conductor
F_c	= load on structure resulting from wind action on the projected wind area of the conductor (kN)
$F_{s\theta}$	= wind load on tower sections in the direction of the wind (kN)
F_t	= load on the structure due to the intact horizontal component of conductor tension in the direction of the line for the appropriate wind load (kN)
F_{t_w}	= horizontal component of the conductor tensions in the direction of the line when subject to wind (kN)
F_{t_m}	= horizontal component of the conductor tensions in the direction of the line when subject to maintenance conditions (kN)
F_{t_e}	= horizontal component of the conductor tension in the direction of the line under no wind (kN)
G	= vertical dead loads
G_c	= vertical dead load related to conductors (kN)
G_s	= vertical dead loads resulting from non conductor loads (kN)
H	= ground line lateral load (kN)
H_{calc}	= calculated value using recommended method (kN)
H_L	= nominal failure load (kN)
$H_{max.}$	= maximum lateral load (kN)
K_θ	= factor for angle of incidence θ of wind to frames (kN)
K_i	= factor that is function of soil modulus of elasticity and foundation geometry

Symbol	Signification	
K_q, K_c	= factors that are a function of z/D and ϕ	
K_x	= represents factors accounting for aspect ratio, wind direction and shielding of the member	
L	= conductor length under consideration for determining conductor loads due to wind action e.g. the wind span for a structure	(m)
L	= embedment depth or length for structural design	(m)
LR	= line reliability	
M	= bending moment at ground line	(kNm)
M_d	= wind direction multiplier. See AS/NZS 1170.2	
M_{rel}	= reliability based load multiplier for wind loads	
M_t	= topographic multiplier for gust wind speed. Refer to AS/NZS 1170.2	
p	= ultimate soil pressure	(kPa)
P_c	= conductor natural and forced convection cooling	
P_j	= conductor joule heating due to the resistance of the conductor	
P_r	= conductor radiation cooling	
P_s	= conductor solar heat gain	
Q	= maintenance loads	
q_z	= dynamic wind pressure	(kPa)
q_z	= vertical overburden pressure at depth z , $q_z = \gamma z$	(kPa)
Re	= component design strength based on the nominal strength of the component for the required exclusion limit 'e'	(kN)
Rm	= mean strength of the component	(kN)
R_n	= the nominal strength of the component	(kN)
RP	= return period	(years)
S	= snow and ice loads	(kN)
S_γ	= snow and ice loads corresponding to an appropriate return period	
SRF	= span reduction factor to provide for spatial variation in wind	
$TSRF$	= tension section reduction factor to provide for spatial variation in wind	
U	= nominal phase-to-phase voltage	(V)
V_R	= regional wind speed. See AS/NZS 1170.2	(m/s)
$V_{sit,\beta}$	= design site wind velocity. See AS/NZS 1170	(m/s)
W_n	= wind load based on selected wind return period or a specified design wind pressure	(kN)
X	= the applied loads pertinent to each loading condition	(kN)
z	= depth below the ground surface	(m)
z_r	= point of rotation at a depth below the surface	(m)

SECTION 2 DESIGN PHILOSOPHIES

2.1 GENERAL

The design of overhead lines requires that the total system including supports, foundations, conductors, insulators and fittings, has operational characteristics that provide for the safe operation and insulation of the energized components, for a planned design service life, and meets or exceeds design levels of reliability.

The overhead line design process is an iterative one and principles from related design fields (electrical, structural and mechanical) need to be applied whilst incorporating regulatory, environment and maintenance requirements.

The overhead line design shall achieve a number of objectives and some of these may be competing between the related design fields. The objectives which need to be considered are—

- (a) designed to relevant regulations, Australian Standards, New Zealand Standards and other relevant international standards;
- (b) security (minimal structural or component failures);
- (c) reliability (appropriate outage rates);
- (d) meeting of environmental requirements (electromagnetic fields (EMF), visual, RIV, TIV and audible noise);
- (e) whole of life cost;
- (f) practicality to construct;
- (g) ability to be maintained (provide for climbing corridors, access for elevating work platform vehicles, live line, helicopter maintenance);
- (h) meeting of regulations and codes of practice; and
- (i) satisfaction of power transfer rating requirements.

2.2 LIMIT STATE DESIGN

2.2.1 General

The design of overhead lines shall be based on limit state principles for serviceability and strength limit states for the various line components.

Structure limit state design uses a load and resistance format, which separates the effects of component strengths and their variability from the effects of external loadings and their uncertainty.

The state of system and the serviceability and ultimate strength limits are illustrated in Figure 2.1.



FIGURE 2.1 LIMIT STATE DESIGN

An explanation of limit state design is given in IEC 60826.

2.2.2 Limit states on line components

2.2.2.1 General

The overhead line is considered intact when its structure, insulators, conductors and fittings are used at stresses below the damage limit.

2.2.2.2 Structure design limit states

The limit states to be considered in the design of overhead lines are:

- (a) Ultimate strength limit state in which the structure's or component's design capacity exceeds the design load.
- (b) Serviceability limit state in which the performance of the structure or component under commonly occurring loads or conditions will be satisfactory.

Serviceability limit states include support deflections. Exceeding the serviceability design load may cause damage to some components.

NOTE: A structure or part thereof or component may be designed to fail or undergo high deflections under some loading situations in order to relieve loads on other parts of the structural system. When this occurs, serviceability limit states may not be maintained.

2.2.2.3 Conductors (including earthwires) limit states

When the conductor is subjected to increasing loads, conductors may exhibit at some load a permanent deformation particularly if the failure mode is ductile or may exhibit strand fracture when subjected to wind induced Aeolian vibration.

These conditions are defined as the damage or serviceability limit state. If the load is further increased, failure of the conductor and or tension fittings occurs at a level called the failure or ultimate limit state.

2.2.2.4 Insulator limit states

There are three states for the mechanical design of insulators, as follows:

- (a) Everyday.
- (b) Serviceable wind.
- (c) Ultimate load condition.

The serviceable wind state is the maximum load that can be applied without causing damage to the insulator or exceeding the desired deflection limit.

2.2.2.5 Electrical structure clearances limit states

Three serviceability states are defined and shall be considered:

(a) Condition (a)—Low wind

Under low wind conditions the clearance shall be sufficient for maintenance activities. If provision is to be made for live line work, then the clearance shall also be adequate to maintain safe working distances at a recommended wind pressure of 100 Pa (minimum of 50 Pa).

(b) Condition (b)—Moderate wind

Under moderate wind with a recommended pressure of 300 Pa (minimum of 100 Pa) the clearance shall be sufficient to withstand lightning impulse and switching over-voltages.

(c) *Condition (c)—High wind*

Under high wind pressure of 500 Pa and at maximum swing position of the insulators, the clearance shall withstand highest power frequency temporary (dynamic) voltages which are normally taken as between 1.4 (solidly earthed) to 1.7 (non-effectively earthed) times the 'per unit' voltage.

2.3 DESIGN LIFE OF OVERHEAD LINES

The design life, or target nominal service life expectancy, of a structure is dependent on its exposure to a number of variable factors such as solar radiation, temperature, precipitation, wind, ice, and seismic effects.

The service life of an overhead line is the period over which it will continue to serve its intended purpose safely, without excessive maintenance or repair disproportionate to its cost of replacement and without exceeding any specified serviceability criteria. This recognizes that cumulative deterioration of the overhead line will occur over time. Therefore, due maintenance and possible minor repairs will be required from time to time to maintain the structure in a safe and useable condition over its service life.

2.4 ELECTRICAL OPERATIONAL CHARACTERISTICS OF AN OVERHEAD LINE

Each overhead line shall be designed to be capable of transferring a prescribed electrical power, at a selected maximum operating temperature, and with acceptable levels of electrical effects of corona, radio and television interference and electric and magnetic fields. It shall also be capable of safe operation at the serviceability limit states.

2.5 MECHANICAL OPERATIONAL PERFORMANCE OF OVERHEAD LINES

The operational performance of a line is dependant on each component of a line being able to meet its assumed performance criteria and to achieve a target reliability level under the serviceability and ultimate strength limit state conditions.

2.6 RELIABILITY

All overhead lines shall be designed for a selected reliability level relevant to the line's importance to the system (including consideration of system redundancy), its location and exposure to climatic conditions, and with due consideration for public safety.

2.7 COORDINATION OF STRENGTH

Overhead lines should be regarded as a total spatial structural system that has components constituting the line as set out below.

Consideration may be given to the coordination of the relative strength of the components to establish a desired sequence of component failure to minimize overall damage. This approach provides a hierarchical control of the sequence of failure of components within an overhead line system, thereby enabling the designer to coordinate the relative strengths of components and recognizes the fact that an overhead line is a series of components where the failure of any component could lead to the loss of power transmission capability.

The four major components of the overhead line are shown in Table 2.1.

TABLE 2.1
OVERHEAD LINE SYSTEM, COMPONENTS AND ELEMENTS

Structural system	Components	Elements
Overhead line	Supports	Steel sections, poles cross-arms etc.
		Plates, bolts etc.
		Guys and fittings
	Foundations	Anchor bolts, piles, cleats etc.
		Concrete footing
		Soil
	Conductors	Wires
		Joints
		Hardware, shackles etc.
	Insulators	Insulator elements
		Brackets, bolts etc.
		Fittings

2.8 ENVIRONMENTAL CONSIDERATIONS

All overhead lines should be designed and constructed with consideration for their environmental impact.

SECTION 3 ELECTRICAL REQUIREMENTS

3.1 GENERAL CONSIDERATIONS

The electrical design for an overhead line covers the following:

- (a) Design of conductor to minimize losses and meet required voltage drop, corona and RIV, TIV and audible noise levels.

NOTE: See Appendix H.

- (b) Power frequency, switching and lightning overvoltages (see Clause 3.3).
- (c) Determination of current rating to meet power transmission requirements (see Clause 3.2).
- (d) Electrical clearances (see Clause 3.5).
- (e) Selection of insulation (see Clause 3.3).
- (f) Lightning performance (see Clause 3.4).
- (g) Design of earthing system (see Section 10).

NOTE: Appendix T provides guidance on a risk based approach to earthing.

- (h) Electric and magnetic fields (see Clause 3.14).

The electrical clearances in this Standard apply to a.c. systems with a nominal frequency up to 60 Hz.

3.2 CURRENT CONSIDERATIONS

The cross-section of the aerial phase conductors shall be chosen so that the design maximum temperature for the conductor material, determined by grease drop point or annealing considerations, is not exceeded under operating conditions. Once a conductor and its maximum operating temperature have been chosen, the conductor rating can be calculated. Various methods of determining conductor rating are given in Section 4.

The overhead line and the earthing system (See Section 10) shall be designed to withstand the mechanical and thermal effects due to the fault currents and associated fault durations and remain serviceable.

3.3 INSULATION SYSTEM DESIGN

3.3.1 General

Overhead equipment will be subjected to the effects of pollution and lightning. The insulation system comprises air gaps and insulators. All overhead lines shall be designed to coordinate insulation protection schemes to protect sensitive plant and equipment, such as substations, and to provide the desired outage performance rate. These issues are discussed further in the following sections.

NOTE: Reference should be made to Appendix P for guidelines on the design of insulation.

3.3.2 Coordination with substations

Precautions should be taken to ensure that lightning strikes close to the substation are attenuated to levels which do not cause damage to substation equipment.

The principles and rules of insulation co-ordination are described in AS 1824. The procedure for insulation co-ordination consists of the selection of a set of standard withstand voltages which characterize the insulation.

3.4 LIGHTNING PERFORMANCE OF OVERHEAD LINES

In the northern parts of Australia and those parts of New Zealand where there are moderate to high ceramic levels, lightning is a major cause of line outages. The design of the overhead line should incorporate a reliability target for the lightning performance. A procedure for the design for lightning performance is covered in Appendix E.

3.5 ELECTRICAL CLEARANCE DISTANCES TO AVOID FLASHOVER

3.5.1 Introduction

Overhead lines shall be designed with electrical clearances from the energized conductor to surrounding objects to provide safe and reliable operation. These objects can be other energized conductors, structures, constructions, plant, vehicles or vessels (watercraft). The basic approach to electrical clearances is to combine an electrical air gap withstand distance, (G_w) with a safety margin (S_m). G_w is dependent on the electrical breakdown voltage of air (around 300 kV/m for air gaps up to 2 m), relative air density (RAD) and the air gap geometry. S_m is dependent on the type of object, the movement of the object and the exposure of persons in the vicinity of the energized conductor.

The electrical clearances which are outlined in this Standard set the minimum acceptable standards for the safe operation and reliable electrical performance of the overhead line.

The clearances to be considered are as follows:

- (a) Clearance at the structure.
- (b) Clearance for inspection and maintenance.
- (c) Mid span phase conductor to phase conductor.
- (d) Conductor to ground.
- (e) Phase conductor to objects.
- (f) Circuit to circuit (attached to same structure or unattached).

In New Zealand, NZECP 34 Code of Practice for Electrical Safe Distance stipulates electrical clearances for both maintenance and design.

3.5.2 Inspection and maintenance clearances

The designer needs to be aware of the different methods used for line maintenance and the impact this may have on circuit availability, particularly for multi-circuit construction.

Inspection and maintenance activities include the following:

- (a) *Deadline inspection and/or maintenance*—with the line de-energized or earthed for safe access.
- (b) *Live line inspection*—by provision of a safe access corridor on the structure to inspect components. The designer should have regard, in selecting corridor width, to the available freedom or constraint on body movement and the consequence of inadvertent movement in managing risk.
- (c) *Live line maintenance*—this could include stick or bare hand work either from the structure or insulated elevated work platform or helicopter (in-span if clearances are appropriate).

For safe approach and live line clearances refer to Electricity Networks Association (Australia) publications, Electricity Engineers' Association (New Zealand) publications, Australian Standards and New Zealand Codes of Practice.

3.5.3 Live access clearance

During structure access, there is a higher risk of lapse of control than when in the working position. Climbing corridors on structures which are designed to be accessed live shall be dimensioned to as follows:

- (a) To accommodate the natural climbing action without requiring the constrained movement by the climber to maintain safe electrical distances (see climbing space test in Figure 3.1).
- (b) To maintain at least power frequency flashover distance in the event of a momentary lapse of controlled movement by the climber.

NOTE: See hand reach test in Figure 3.1 and application in Appendix EE.

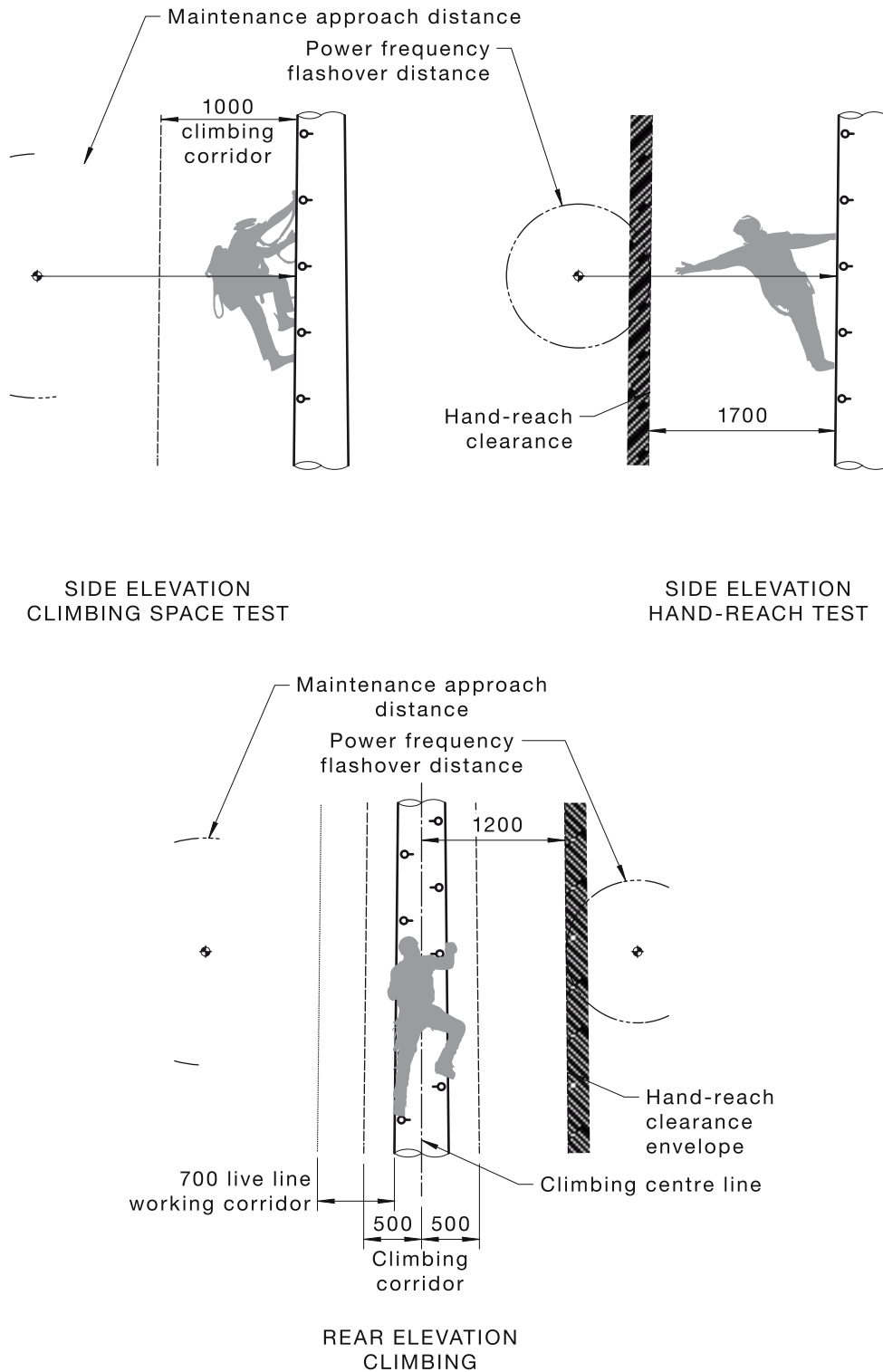


FIGURE 3.1 ACCESS CLEARANCE TEST

3.5.4 States for calculation of clearances

3.5.4.1 Maximum operating temperature

Vertical clearances shall be based on the maximum operating temperature of the conductors.

3.5.4.2 Ice load for determination of electrical clearance

The ice load to be applied shall be specified directly based on regional experience.

3.5.4.3 Combined wind and snow/ice loads

Combined wind and snow/ice loads should be considered in certain regions of Australia and New Zealand, based on regional experience.

NOTE: Appendix DD provides guidance on snow and ice loading.

3.5.4.4 Operating temperature under serviceable wind

The conductor operating temperature under serviceable wind shall be based on the average ambient temperature for the year.

3.5.5 Clearances at the structure

The three serviceability clearance states which shall be considered are as follows:

- (a) Low wind or still air.
- (b) Moderate wind.
- (c) High wind.

3.6 DETERMINATION OF STRUCTURE GEOMETRY

3.6.1 General

Structures shall be designed with adequate air clearances to provide a reliable performance and to allow maintenance to be performed safely. The electrical design determines the structure geometry and shall be coordinated with the structural design.

NOTE: Appendix EE provides guidance on the determination of structure geometry and clearances to structure are given in Clause 3.8.2 and Appendix R.

3.6.2 High wind serviceability state

Power frequency clearance shall be provided for high wind serviceability wind pressure. Insulator swing shall be taken into account when determining the structure geometry.

3.6.3 Moderate wind serviceability state

Switching impulse clearances shall be provided for moderate wind pressure. Insulator swing shall be taken into account when determining the structure geometry.

Lightning impulse clearances should be considered under moderate wind conditions to achieve the desired reliability level.

3.6.4 Maintenance clearances

The method of access to the structure shall be considered and then climbing corridors and work positions defined. The structures shall be designed with consideration given to the types of maintenance activities used, such as climbing patrols, helicopter patrols and live line and bare hand working crews. Adequate clearances between the workers and live equipment shall be provided for the various maintenance activities to be performed safely.

For inspection and maintenance activities, a maintenance approach distance between personnel and live parts shall be provided under low winds.

Clearances are required to be considered for the following cases:

- (a) Maintenance approach distance for climbing and inspection.
- (b) Live line working.
- (c) Hand reach clearance.

For maintenance approach distances see AS 5804.1.

In New Zealand the relevant references are:

- (i) EEA SM-EI.

- (ii) NZECP 34.
- (iii) NZECP 46.

3.7 SPACING OF CONDUCTORS

3.7.1 Conductors of different circuits on different supports (unattached crossing)

3.7.1.1 General

This Clause provides the minimum requirements to minimize the potential for circuit to circuit flashover, under both normal operating and fault conditions, between conductors or cables of different circuits that cross each other and are not attached to the same pole or support at the point of crossing (see Figure 3.2) as follows:

- (a) Where two circuits of different or similar voltage cross each other, conductors of a higher voltage circuit shall be placed above a lower voltage circuit (except for single wire earth return (SWER) lines).
- (b) The vertical separation between any conductor or cable of the higher circuit and any conductor or cable of the lower circuit shall satisfy both of the following conditions:
 - (i) *Normal conditions clearance*—The vertical separation shall be not less than that specified in Table 3.1.
 - (ii) *Dynamic loading clearance*—See Figure 3.3.

If conditions are such that it is likely that the lower circuit can accidentally contact into the higher circuit, the vertical separation at the crossing point shall be twice the sag of the lower circuit at the crossing point when both conductors and cables are at their maximum operating temperature. (This is a simplified calculation method).

NOTE: Dynamic load can be caused by vegetation falling on conductors or ice shedding.

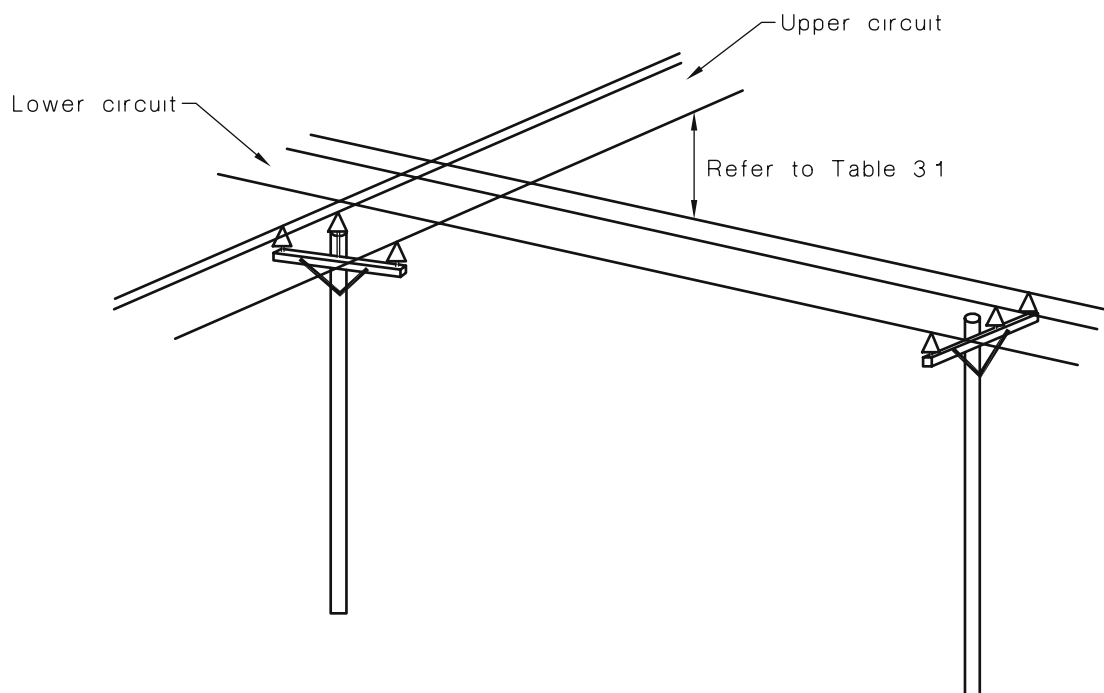
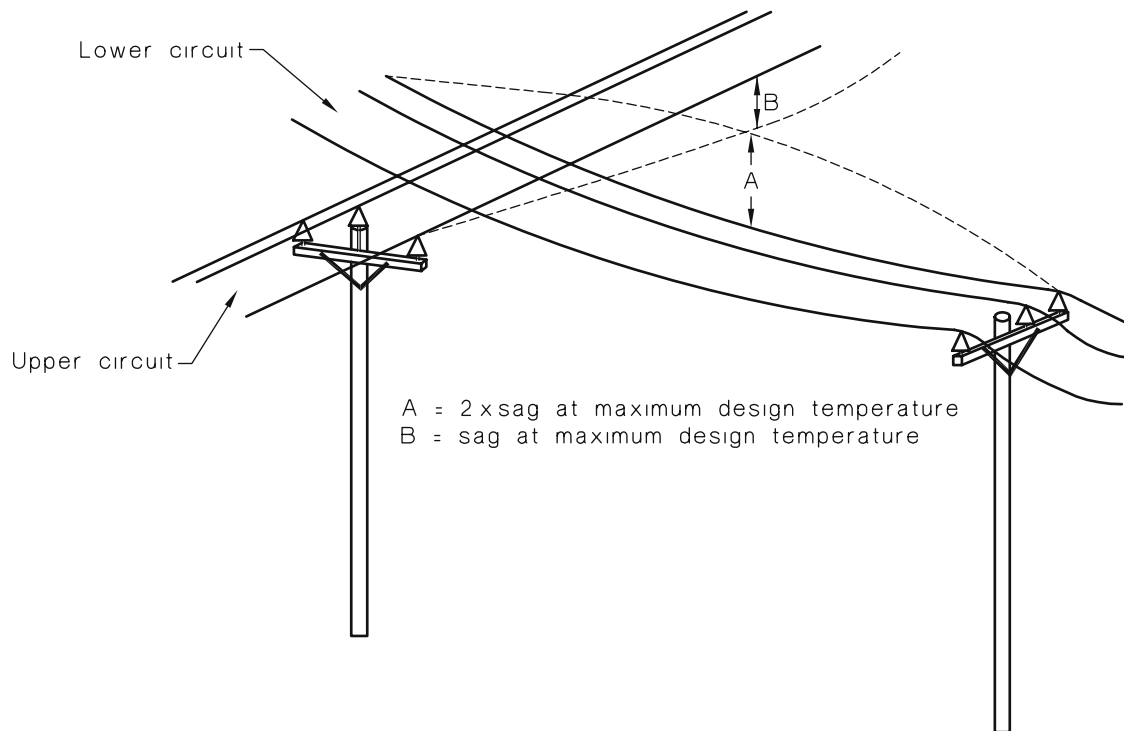


FIGURE 3.2 UNATTACHED CROSSING



NOTE Minimum separation recommended = A

FIGURE 3.3 SIMPLIFIED UNATTACHED CROSSINGS FOR DISTURBANCE CONDITIONS (DOUBLE ENVELOPE METHOD)

TABLE 3.1
MINIMUM VERTICAL SEPARATION FOR UNATTACHED CROSSINGS (IN METRES)

			UPPER CIRCUIT									
			U ≤ 500 kV U > 330 kV Bare	U ≤ 330 kV U > 275 kV Bare	U ≤ 275 kV U > 132 kV Bare	U ≤ 132 kV U > 66 kV Bare	U ≤ 66 kV U > 33 kV Bare	U ≤ 33 kV U > 1000 V Bare or covered	U ≤ 33 kV U > 1000 V Insulated	U < 1000 V Bare, covered and insulated	Other cables (Conductive)	Other cables (Non- conductive)
L O W E R C I R C U I T	330 kV < U ≤ 500 kV Bare	No wind	5.2									
		Wind	3.6									
	275 kV < U ≤ 330 kV Bare	No wind	5.2	3.8								
		Wind	3.6	2.6								
	132 kV < U ≤ 275 kV Bare	No wind	5.2	3.8	2.8							
		Wind	3.6	2.6	2.2							
	66 kV < U ≤ 132 kV Bare	No wind	5.2	3.8	2.8	2.4						
		Wind	3.6	2.6	2.2	1.5						
	33 kV < U ≤ 66 kV Bare	No wind	5.2	3.8	2.8	2.4	1.8					
		Wind	3.6	2.6	2.2	1.5	0.8					
	1000 V < U ≤ 33 kV Bare or covered	No wind	5.2	3.8	2.8	2.4	1.8	1.2				
		Wind	3.6	2.6	2.2	1.5	0.8	0.5				
	1000 V < U ≤ 33 kV Insulated	No wind	5.2	3.8	2.8	2.4	1.8	1.2	0.6			
		Wind	3.6	2.6	2.2	1.5	0.8	0.5	0.4			
	U ≤ 1000 V Bare, covered and insulated	No wind	5.2	3.8	2.8	2.4	1.8	1.2	0.6	0.6		
		Wind	3.6	2.6	2.2	1.5	0.8	0.5	0.4	0.4		
T	Other cables (Conductive)	No wind	5.2	3.8	2.8	2.4	1.8	1.2	0.6	0.6	0.6	0.4
		Wind	3.6	2.6	2.2	1.5	0.8	0.5	0.4	0.4	0.4	0.2
	Other cables (Non conductive)	No wind	5.2	3.8	2.8	2.4	1.8	1.2	0.6	0.6	0.4	0.4
		Wind	3.6	2.6	2.2	1.5	0.8	0.5	0.4	0.4	0.2	0.2

NOTES:

The above clearances may need to be increased due to local factors.

The clearances in this table may need to be increased to account for safe approach distances required for construction, operation and maintenances and for blowout on large spans.

The above clearances are based on the upper circuit being at maximum conductor temperature and the lower circuit at ambient temperature.

These clearances apply to altitudes up to 1000 m. Correction factors at higher altitudes are contained in AS 2650.

The 'wind' condition corresponds to serviceable load conditions.

3.7.1.2 Determination of conductor separation

Vertical separation between circuits is determined by establishing the conductor positions with reference to—

- (a) conductor temperatures of each circuit; and
- (b) wind conditions.

NOTE: Appendix S provides guidance on the measurement of conductor temperature.

The provisions of Clauses 3.7.1.3 and 3.7.1.4 should be used as a guide for selecting appropriate conductor temperatures and wind pressures.

3.7.1.3 Separation in still air

The conductor temperature of the higher circuit should be the maximum operating temperature. The temperature of the lower conductor should be the ambient temperature.

In the case of a bearer wire supporting a conductor bundle (e.g. as in Aerial Control Cable to AS/NZS 2373 or HVABC to AS/NZS 3599) the maximum operating temperature would be the maximum temperature the bearer wire may reach under the influence of ambient temperature of the air, solar radiation and heat transferred to it from the aerial phase conductors, if applicable.

3.7.1.4 Separation under wind

The conductor temperatures for the upper and lower circuits are given in Table 3.2. The upper circuit conductors should be assumed to be hanging in the vertical plane with the wind direction along the span, e.g. conductors not displaced by wind.

The conductor of the lower circuits should be assumed to be displaced by wind pressure (P), i.e. the wind direction is normal to the span.

NOTE: This assumes that the conductor temperatures of both circuits are at the temperature at which wind pressure occurs, e.g. conductors have cooled to the air temperature.

Table 3.2 gives the temperature and electrical conditions for determining the electrical clearances. The ambient temperature is the higher of (a) conductor everyday temperature or (b) the ambient temperature used to determine the maximum design temperature of the upper conductor.

TABLE 3.2
CONDITIONS FOR DETERMINING CLEARANCES

Condition, P	Upper conductor	Lower conductor	Clearance
No wind	Max. operating	Ambient	Table 3.1—No wind
Low wind on lower conductor (100 Pa)	Ambient temp	Ambient temp	Switching impulse or Table 3.1—Wind
High wind on lower conductor (500 Pa)	Ambient temp	Ambient temp	Power frequency

3.7.2 Conductors of different circuits on the same support (attached crossing)

This Clause provides the minimum requirements to prevent circuit to circuit flashover, under operating conditions, between conductors or cables that are attached to the same support and cross each other (see Figure 3.4).

Where two circuits of different or similar voltage cross each other and are attached to the same support, conductors of a higher voltage circuit shall be placed above a lower voltage circuit and the vertical separations between the different circuits at any point on the support under normal working conditions shall not be less than specified in Table 3.3.

NOTE: For voltages in excess of 132 kV separations should be determined by the designer.

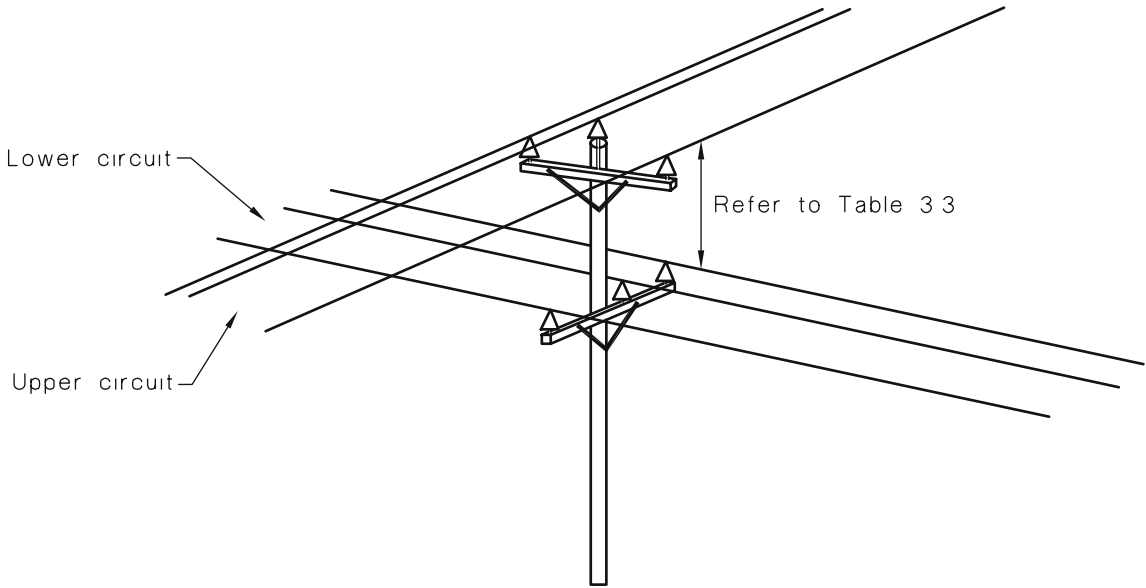


FIGURE 3.4 ATTACHED CROSSINGS

TABLE 3.3
VERTICAL SEPARATION AT SUPPORTS FOR ATTACHED CROSSINGS (IN METRES)

		UPPER CIRCUIT							
		U ≤ 132 kV U > 66 kV Bare	U ≤ 66 kV U > 33 kV Bare	U ≤ 33 kV U > 1000 V Bare or covered	U ≤ 33 kV U > 1000 V Insulated	U < 1000 V Bare and covered	U < 1000 V Insulated	Other cables (Conductive)	Other cables (Non- conductive)
LOW VOLTAGE	66 kV < U ≤ 132 kV Bare	2.4							
	33 kV < U ≤ 66 kV Bare (Note 1)	2.4	1.5						
	1000 V < U ≤ 33 kV Bare or covered	2.4	1.5	0.9	0.9				
	1000 V < U ≤ 33 kV Insulated	2.4	1.5	0.9	0.2				
	U < 1000 V Bare and covered	2.4	1.8	1.2	0.6	0.3	0.3		
	U < 1000 V Insulated	2.4	1.8	1.2	0.6	0.3	0.2	0.3	
	Other cables (Conductive)	2.4	1.8	1.2	0.6	0.3	0.3	0.2	0.2
	Other cables (Non conductive)	2.4	1.8	1.2	0.6	0.3	0.2	0.2	0.2

NOTES:

- 1 The clearances in the table are based on the lower circuit conductors being attached to pin or post insulators. Additional clearance is required to allow for conductor movement, if the lower circuit is attached by suspension or strain insulators.
- 2 The clearances in this table may need to be increased to account for safe approach distances required for construction, operation and maintenances.

3.7.3 Conductors on the same supports (same or different circuits and shared spans)

3.7.3.1 General

This Clause provides the minimum requirements between conductors or cables attached to the same support, and sharing the same span to prevent circuit-to-circuit or phase-to-phase flashover under operating conditions.

Where conductors or cables are carried on the same pole or support as those of a higher voltage the lower voltage conductors shall be placed below the higher voltage conductors, or beside in the case of vertical circuit construction.

Any two bare conductors having a difference in voltage with respect to each other shall have vertical, horizontal or angular separation from each other in accordance with the values required by Clause 3.7.3.2 (See Figure 3.5), provided that the clearance at the support or at any part in the span is not less than the separation nominated in Item (b) (See Figure 3.6).

The separation given by Clause 3.7.3.2 is intended to cater for differential (out of phase and in phase) movement of conductors under wind conditions with minimum turbulence. The separation given by Clause 3.7.3.3 is a minimum under any circumstances.

3.7.3.2 At mid span

The mid span conductor separation for a single circuit can be determined using Equation 3.1 and Figure 3.5.

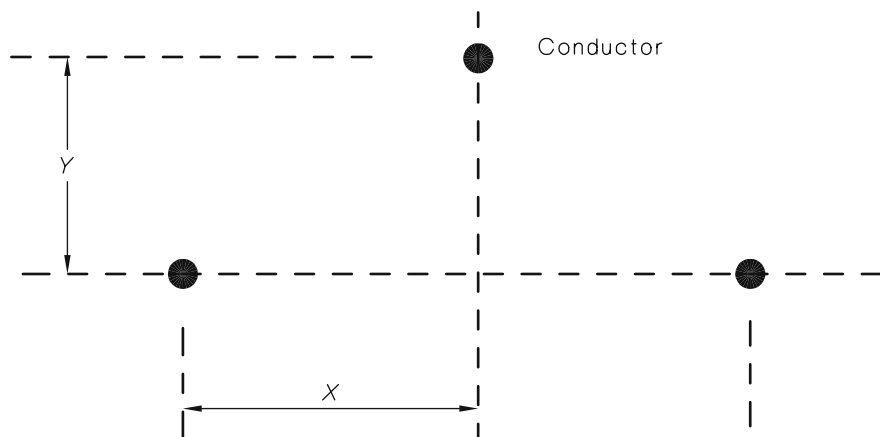


FIGURE 3.5 CONDUCTOR SEPARATION AT MID SPAN (ONE CIRCUIT)

$$\sqrt{X^2 + (1.2Y)^2} \geq \frac{U}{150} + k\sqrt{D+l_i} \quad \dots 3.1$$

where

- X = is the projected horizontal distance in metres between the conductors at mid span; ($X = (X_1 + X_2)/2$) where X_1 is the projected horizontal distance between the conductors at one support and X_2 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; ($Y = (Y_1 + Y_2)/2$) where Y_1 is the projected vertical distance between the conductors at one support and Y_2 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, normally equal to 0.4. Where experience has shown that other values are appropriate, these may be applied. See Note 5 to Figure 3.6.
- 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 (typically 50°C in still air). This may be higher for high temperature conductors
- l = is the length in metres of any free swing suspension insulator associated with either conductor. Zero for pin and post insulators

For the purposes of this Clause an equivalent level span shall mean a span—

- (a) which has the same span length in the horizontal projection as the original span;
- (b) in which conductor attachments at supports are in the same horizontal plane; and
- (c) in which the horizontal component of the conductor tension is the same as in the original span.

As this Equation 3.1 is intended to cater for out-of-phase movement of conductors under wind conditions with minimum turbulence, the conductor sags are calculated at 50°C and the effect of different load currents is ignored (because of the significant cooling effect of the wind in these conditions). The wind is not sufficient to increase the sag, and therefore sag can be calculated assuming still air.

U can be determined by using the formula—

$$U = \sqrt{V_a^2 + V_b^2 - 2 V_a V_b \cos \phi} \quad \dots 3.2$$

where

- V_a = upper circuit nominal voltage phase to earth value (kV)
- V_b = lower circuit nominal voltage phase to earth value (kV)
- ϕ = phase angle difference between circuits (degrees)

3.7.3.3 *At any point in the span (vertical)*

$$\begin{aligned} \text{Where } U \leq 11 \text{ kV} & \dots 0.38 \text{ m} \\ \text{Where } U > 11 \text{ kV} & \dots (0.38 + q (U - 11)) \end{aligned} \quad \dots 3.3$$

where

- q = constant which varies from 0.005 to 0.01 (normal). Where regional service experience has shown that other values are appropriate, these may be applied

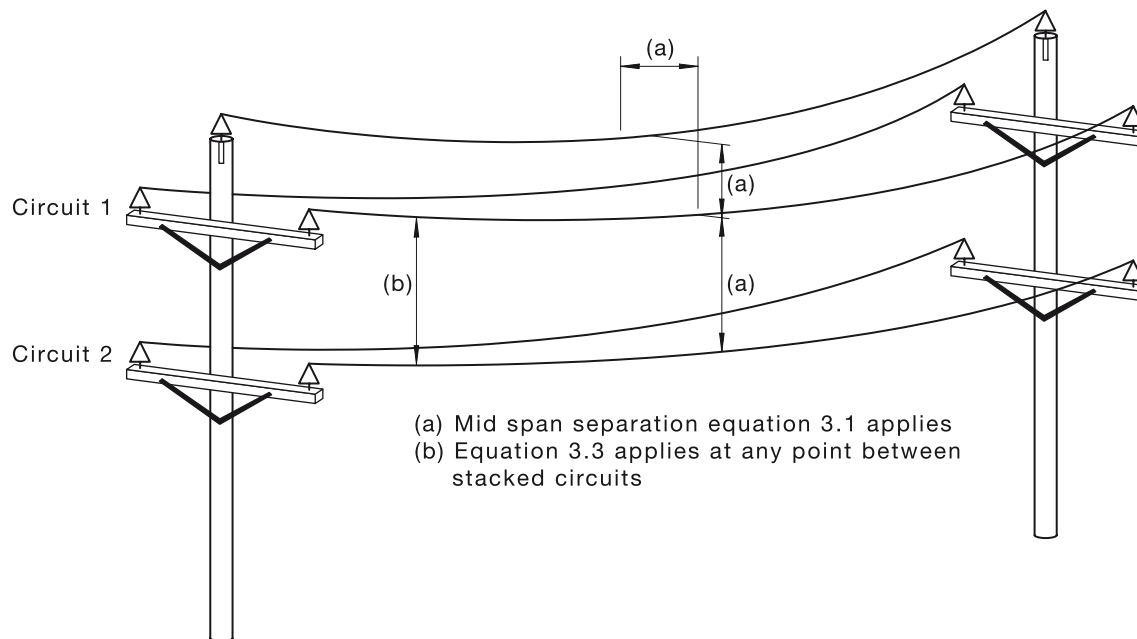


FIGURE 3.6 MINIMUM CONDUCTOR SEPARATION—ATTACHED ON SAME STRUCTURE

NOTES:

- 1 When conductors of different circuits are located vertically one above the other, consideration should be given to the need to prevent clashing of conductors of different circuits under the influence of load current in one or both circuits. (See Figure 3.7).
- 2 This Clause is not intended to apply to insulated conductors (with or without earthed screens) of any voltage.
- 3 The spacing for covered conductors may be reduced provided the covering is adequate to prevent electrical breakdown of the covering when the conductors clash and a risk management strategy is in place to ensure that conductors do not remain entangled for periods beyond what the covering can withstand.
- 4 Where phase spacers are used, separation may be less than those specified. It is suggested that the spacer be taken to be a conductor support for the purpose of calculating conductor spacing.
- 5 Empirical formula 3.1 is intended to minimize the risk of conductor clashing; however, circumstances do arise where it is not practicable to give guidance or predict outcomes. Some of these situations involve—
 - (a) extremely turbulent wind conditions;
 - (b) the different amount of movement of conductors of different size and type under the same wind conditions; and
 - (c) conductors movement under fault conditions (particularly with horizontal construction).

The following k factors are recommended for overhead power lines which have phase-to-phase clearances at 1200 mm or less at midspan:

- (i) Extremely turbulent wind conditions— k to be in range 0.4 to 0.6.
- (ii) High to extreme bushfire prone areas— k to be in range 0.4 to 0.6.
- (iii) Under high phase-to-phase fault conditions— $k = 0.4$ for fault currents up to 4,000 A, 0.5 for fault currents from 4,000 A to 6,000 A and 0.6 for fault currents above 6,000 A.
- (iv) Conductors of different mass/diameter ratios and at different attachment heights— $k = 0.4$ to 0.6.

In all other situations a k factor of 0.4 is recommended.

- 6 Mid span clearances may need to be increased in situations where the conductor transition from horizontal to vertical or where the adjacent conductors are of different characteristics (diameter, weight) which can cause out of phase movement.
- 7 The following situations may also need to be taken into account when considering spacing of conductors but it is not practicable to provide guidance in this document. Knowledge of local conditions would be required to make design decisions. The situations are as follows:
 - (a) Aircraft warning devices.
 - (b) Large birds which may collide with conductors, causing them to come together, or whose wingspan is such as to make contact between bare conductors and conducting cross-arms.
 - (c) Flocks of birds resting on conductors are known to ‘lift off’ simultaneously, causing excessive conductor movement.
 - (d) Ice and snow loading and ice shedding.
 - (e) Terrain factors that may contribute to aerodynamic lift and/or random motion.
 - (f) Spray irrigators.
 - (g) Safety approach clearances for construction, operation and maintenance.
 - (h) Fire prone areas (e.g. burning of sugar cane trash) where ionized air will have a reduced dielectric strength.

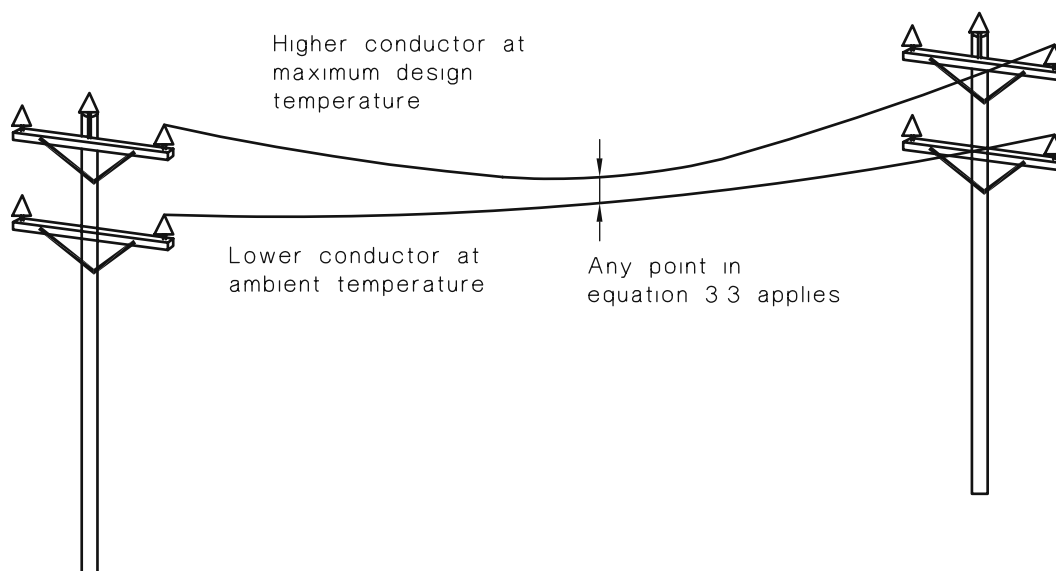


FIGURE 3.7 CONDUCTOR SEPARATION—INFLUENCE OF LOAD CURRENT—
ATTACHED ON SAME STRUCTURE

3.7.4 Minimum clearance to inter-span poles

Poles may be installed in between spans to accommodate street lights or low voltage services and electrical clearance shall be provided for maintenance personnel. The minimum separation between the circuit at maximum operating temperature and inter-span pole for voltages up to 33 kV shall be 1.5 m (see Figure 3.8).

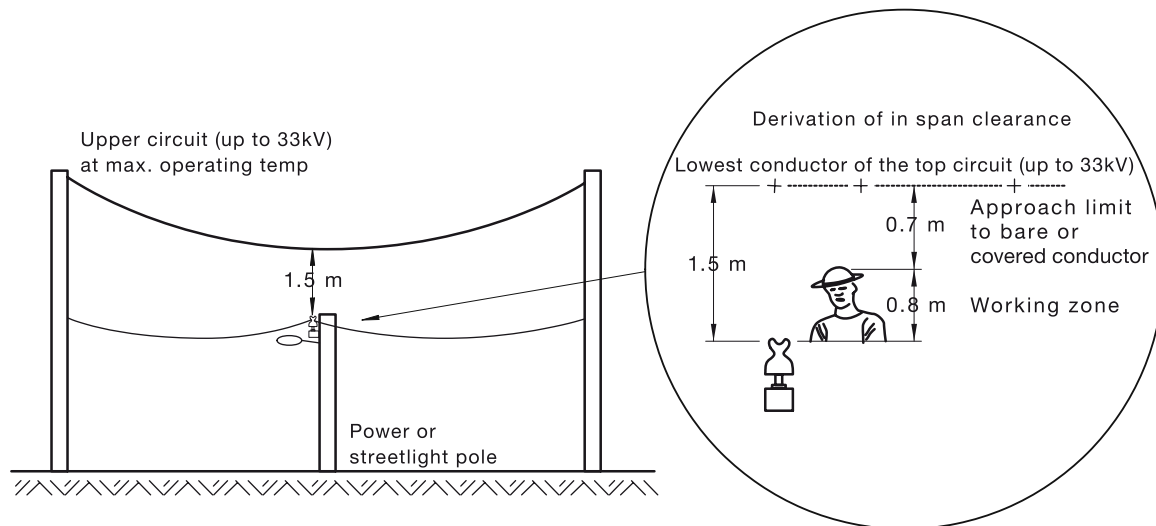


FIGURE 3.8 CLEARANCE TO INTER-SPAN POLES

3.8 INSULATOR AND CONDUCTOR MOVEMENT AT STRUCTURE

3.8.1 General

This Clause provides the minimum requirements for the separation between conductors and any earthed structure to prevent flashover under operating conditions.

This Clause applies to all transmission and distribution lines using bare conductors and suspension insulators. It is intended to provide guidance in the selection of suitable air gap clearances between conductors and the structure. Guidance in the selection of solid insulation levels is not covered here and should be considered separately.

Insulation at the structure is provided by a combination of solid insulators such as porcelain, glass or other composite materials and also by wood cross-arms, air, or a combination of these. This insulation is subjected to electrical stresses resulting from power frequency voltages, switching surges and lightning impulse voltages.

The insulation levels and air gap clearances should be selected to withstand these overvoltages so that the desired operational performance is achieved. A good design should also provide for insulation coordination between the line insulation and terminal station insulation so as to avoid damage to station equipment from overvoltages.

If provision is to be made for live line maintenance, or for access or inspection under live conditions, then the physical distances to access and working positions should be adequate for the safe conduct of this work and to meet any statutory requirements where specified. To the extent practicable, hazards under live conditions should be mitigated by provision of adequate air gap clearances in preference to reliance on procedural precautions. These clearances should encompass the ergonomic and electrical distances necessary to safely provide for both natural and inadvertent movements of persons, together with the movement of conductors possible under the range of working conditions permitted.

With suspension insulator strings, the air gap clearances change as the insulator string swings from its position at rest, due to wind action. Consequently the insulation strength of the air gap also changes. The air breakdown strength at any moment will depend on the physical gap, the shape of the electrodes, atmospheric conditions and altitude. Hence the ability to withstand different overvoltages resulting from power frequency, lightning impulse and switching surges constantly changes.

Thus for a freely suspended conductor, both the air gap and the overvoltages are random variables and probabilistic processes need to be used to determine the optimum coordination. Statistical considerations indicate that lightning or switching impulses combined with high swing angles of the insulator string (i.e. smaller air gaps to the structure) have a very low probability of occurrence. The angle of swing itself depends on several variables such as wind velocity, time and space distribution of wind, wind direction, topography, ratio of the wind to weight span, and conductor deviation angle.

3.8.2 Structure clearances

Based on the operational experience and probabilistic considerations discussed in Clause 3.8.1, a simplified approach consisting of a three envelope system is recommended for the determination of conductor clearances on structures.

The conditions are, Condition (a)—Low wind; Condition (b)—Moderate wind and Condition (c)—High wind.

Table 3.4 provides recommended structure and conductor clearances for conditions (b) and (c) for different system and impulse withstand voltages. For condition (a), consideration of both the live line working distance (as detailed in AS 5804.1 and NZECP46), maintenance approach distance (NENS04 and NZECP34) and the hand reach clearance (Clause 3.5.3) needs to be made. Appendix EE provides further guidance.

Clearances should take into account protrusions from the structure (e.g. step bolts) and the conductor (e.g. corona rings).

See Figure 3.9 for suspension insulator swing angle. These are suitable for most applications. Where unusual or extreme weather and climatic conditions exist, local knowledge and experience should be used to modify the clearances.

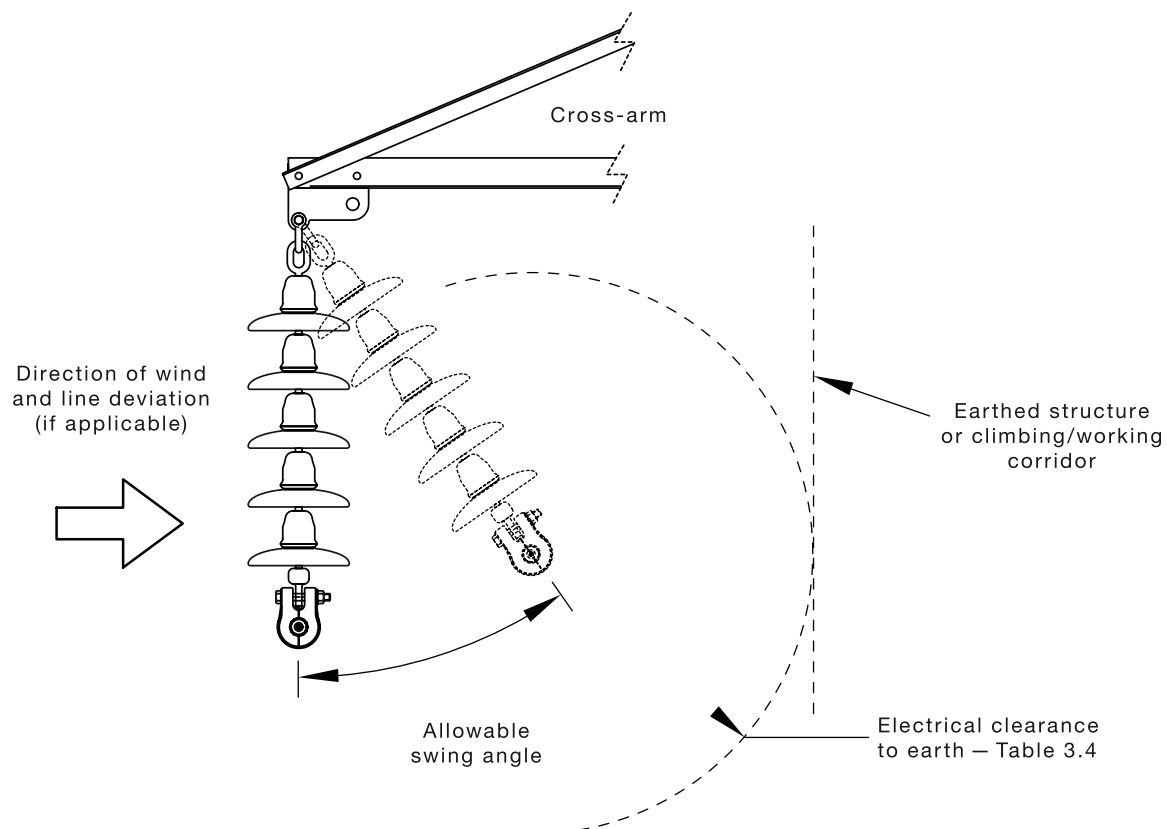


FIGURE 3.9 CLEARANCE TO STRUCTURES SWING ANGLE

TABLE 3.4
MINIMUM CLEARANCES TO EARTHED STRUCTURES (IN METRES)

Nominal system voltage U_n	Lightning/switching impulse withstand voltage	Clearance to earthed structure in metres for altitudes up to 1000 m	
kV (r.m.s.)	kV (peak)	Moderate wind	High wind or maximum swing
		Condition (b)	Condition (c)
11	95	0.16	0.10
22	150	0.28	0.13
33	200	0.38	0.18
66	350	0.69	0.28
110	550	1.1	0.40
132	650	1.3	0.50
220	950	1.9	0.75
275	1050	2.2	0.90
330	1175	2.6	1.10
400	1250	2.8	1.5
500	1300	3.1	1.75
	1550	4.2	1.75

NOTES:

- 1 For structures with line post or pin insulators, the moderate wind distances recommended can be used to establish structure clearances.
- 2 For voltages up to 66 kV, clearances may need to be increased in locations where bridging of insulators by birds or animals is experienced or probable.
- 3 These clearances apply to altitudes up to 1000 m. Correction factors at higher altitudes are contained in AS 2650.
- 4 Condition (b) relates to lightning impulse distance and Condition (c) to power frequency flashover distance.
- 5 These clearances do not apply to rod gaps.

3.8.3 Calculation of swing angles

The conductor tension for insulator swing angle should be based on the relevant reference wind pressure and temperature.

The estimation of swing angles may be made using a simplified deterministic approach or a detailed procedure using meteorological data. The latter method should be used when greater precision is required or where unusual and/or extreme local conditions prevail.

There are other alternative insulator assemblies and appropriate clearances and line actions which need to be considered. These alternative types include—

- (a) bridging insulators;
- (b) strain insulators;
- (c) line post insulators;
- (d) vee strings; and
- (e) horizontal vee assemblies.

The swing angles of suspension insulator strings for low, moderate and high wind conditions can be estimated.

NOTE: Appendix Q provides a method of estimating swing angles.

3.9 LIVE LINE MAINTENANCE CLEARANCES

When live line maintenance is required, structures shall be designed to minimum live line approach clearances as given in AS 5804 and NZECP46.

Reference shall also be made to the provisions set out in Clause 3.6.3.

Other relevant NZ references include EEA *Use of Helicopters in Power Company Work*.

3.10 CLEARANCES TO OBJECTS AND GROUND

The designer shall have regard for State or National-based Electricity Safety Regulations which may specify additional or more onerous clearances than stipulated by this Standard.

Where regulations set line design clearances above road pavement these will typically be based on a minimum electrical clearance (flashover clearance plus margin) plus provision for the maximum likely vehicle height.

The designer should consider the requirement for any over-dimensional vehicle or machinery and make provision, where necessary, for construction of future subsidiary circuits or under crossings of distribution/sub-transmission lines. The resulting clearance will be above the clearance normally accepted for road purposes.

3.11 CLEARANCES TO GROUND AND AREAS REMOTE FROM BUILDING, RAILWAYS AND NAVIGABLE WATERWAYS

3.11.1 Clearances to ground and roads

3.11.1.1 *Lines other than insulated service lines*

This Clause covers all overhead lines except insulated conductors of an overhead service line and facade mounted insulated cable systems.

The conductors or cables of an overhead line shall be located so that the distances to level or sloping ground in any direction from any position to which any part of such conductors may either sag at maximum operating temperature or move as a result of wind pressure, shall not be less than the distances specified in Table 3.5.

Departures from these specified distances are permissible where a comprehensive risk management assessment has been carried out.

In Australia AS 6947 provides guidance on installing power lines across waterways.

In New Zealand, the EEA/Maritime Safety Authority publication *Guide to Safety Management of Power Line Waterway Crossings*, provides guidance to protect waterway users from electrical hazards, as well as protecting power lines and cables from contact by watercraft and the resultant damage.

TABLE 3.5
MINIMUM CLEARANCE FROM GROUND, LINES OTHER
THAN INSULATED SERVICE LINES

Nominal system voltage U	Distance to ground in any direction m		
	Over the carriageway of roads	Over land other than the carriageway of roads	Over land which due to its steepness or swampiness is not traversable by vehicles more than 3 m in height
Bare or insulated conductor or any other cable $U \leq 1000$ V	5.5	5.5	4.5
OR			
Insulated conductor with earthed screen $U > 1000$ V	6.0	5.5	4.5
Insulated conductor without earthed screen $U > 1000$ V			
Bare or covered conductor			
$1000 \text{ V} < U \leq 33 \text{ kV}$	6.7	5.5	4.5
$33 \text{ V} < U \leq 132 \text{ kV}$	6.7	6.7	5.5
$132 \text{ kV} < U \leq 275 \text{ kV}$	7.5	7.5	6.0
$275 \text{ kV} < U \leq 330 \text{ kV}$	8.0	8.0	6.7
$330 \text{ kV} < U \leq 400 \text{ kV}$	9.0	9.0	7.5
$400 \text{ kV} < U \leq 500 \text{ kV}$	9.0	9.0	7.5

NOTES:

- 1 For the purpose of this Clause, the term 'ground' includes any unroofed elevated area accessible to plant or vehicles and the term 'over' means 'across and along'.
- 2 In the case of cliff faces or cuttings the clearances specified in the column headed 'Over land which due to its steepness or swampiness is not traversable by vehicles' shall apply.
- 3 In the case of waterways, flood plains and snowfields, the clearances should be determined having regard to local conditions and requirements.
- 4 Where the usage of land is such that vehicles of unusual height are likely to pass under an overhead line, the clearances given in this Clause may need to be increased.
- 5 The distances specified are final conditions for conductors which have aged. When conductors are first erected, an allowance should be made for 'settling in' and 'conductor creep'. See Appendix R.
- 6 The distances specified are designed to protect supports from damage from impact loads on conductors as well as protecting vehicles from contact with conductors.
- 7 The above values are based on vehicles with a maximum height of 4.6 m.

3.11.1.2 Insulated LV service lines

Insulated conductors of an overhead service line shall be located so that the distance to level or sloping ground in any direction from any position to which any part of such conductors may either sag at maximum operating temperature or move as a result of wind pressure, shall not be less than the distances specified in Table 3.6.

TABLE 3.6
MINIMUM CLEARANCE FROM GROUND,
INSULATED LV SERVICE LINES

Service line location	Distance to ground in any direction m
Over the centre of a formed road	5.5
Over any other part of a road	4.6
Over a footway or land which is likely to be used by vehicles	3.0
Elsewhere	2.7

NOTES:

- 1 For the purpose of this Clause, the term 'ground' includes any unroofed elevated area accessible to plant or vehicles.
- 2 In the case of waterways, flood plains and snowfields, the clearances should be determined having regard to local conditions and requirements.
- 3 Where the usage of land is such that vehicles of unusual height are likely to pass under an insulated overhead service line, the clearances given in this Clause may need to be increased.
- 4 The clearances specified in Table 3.6 are final conditions for conductors that have aged. When conductors are first erected, an allowance should be made for 'settling in' and 'conductor creep'. See Appendix R.
- 5 This Table does not apply where there are local rules and regulations.

3.11.2 Clearances to buildings, other lines and recreational areas

3.11.2.1 Structures and buildings

This Clause specifies the minimum clearance from electrical conductors to any non-electrical infrastructure such as structures and buildings. The position to which a conductor in an overhead line may swing under the influence of wind shall be taken into consideration. See Appendix R for conductor swing angle calculations.

NOTES:

- 1 The clearances to be maintained at the outer extremities of those parts on any structure on which a person can stand are defined by an arc of radius A or B as appropriate (see Figure 3.10). This arc has its centre at the outer extremity of the structure and extends outward to its intersection with a vertical line that is located at a horizontal distance specified in C, from the outer extremities of those parts of any structure on which a person can stand.
- 2 Table 3.7 does not apply to cable systems supported along the facade of a building.
- 3 Figure 3.10 illustrates the application of Table 3.7 to a particular building. The letters A to D refer to distances A to D as set out in Table 3.7. The letter G refers to distance to ground.

3.11.2.2 Easements

When considering the width of an easement to provide clearance from structures, the position of the conductors or cables under the influence of wind at any point along the span should be taken into account. A safety clearance should also be included. (See Figure 3.11.)

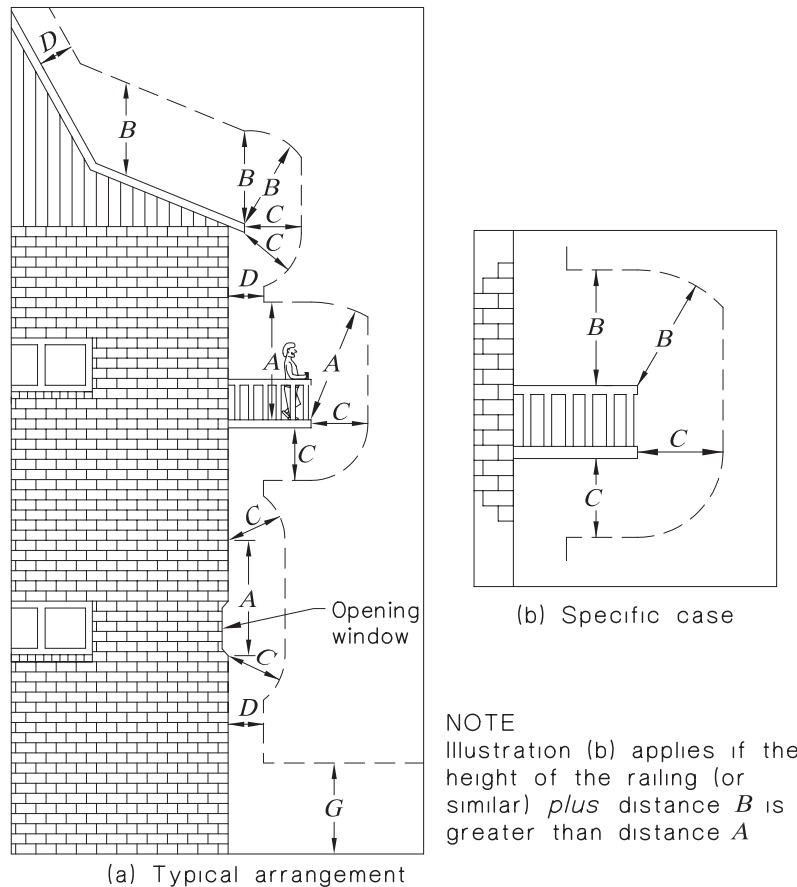


FIGURE 3.10 STRUCTURE CLEARANCES FOR TABLE 3.7

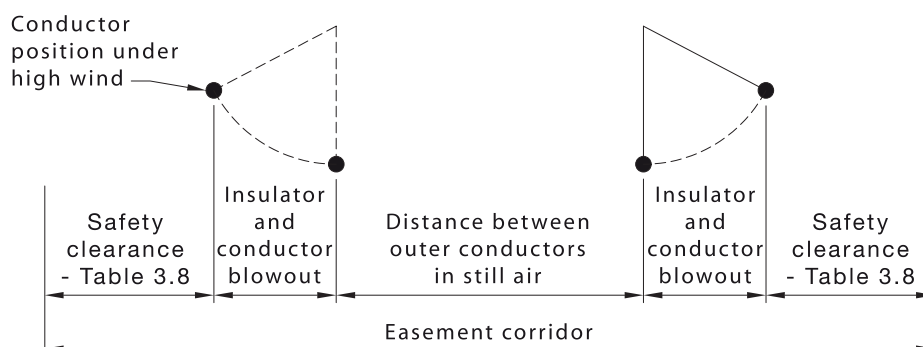


FIGURE 3.11 EASEMENT CLEARANCES

TABLE 3.7
CLEARANCES FROM STRUCTURES

Clearance	U ≤ 1000 V			U > 1000 V		1000 V < U ≤ 33 kV	33 kV < U ≤ 132 kV	132 kV < U ≤ 275 kV	275 kV < U ≤ 330 kV	330 kV < U ≤ 500 kV
	Insulated	Bare neutral	Bare active	Insulated with earthed screen	Insulated without earthed screen	Bare or covered	Bare	Bare	Bare	Bare
	m	m	m	m	m	m	m	m	m	m
A	2.7	2.7	3.7	2.7	3.7	4.5	5.0	6.5	7.0	8.0
Vertically ⁽¹⁾ above those parts of any structure normally accessible to persons										
B	2.0	2.7	2.7	2.7	2.7	3.7	4.5	6.0	6.5	7.5
Vertically ⁽¹⁾ above those parts of any structure not normally accessible to persons but on which a person can stand										
C	1.0	0.9	1.5	1.5	1.5	2.1	3.0	4.5	5.0	6.0
In any direction (other than vertically above) from those parts of any structure normally accessible to persons, or from any part not normally accessible to persons but on which a person can stand										
D	0.1 ⁽²⁾	0.3 ⁽²⁾	0.6 ⁽²⁾	0.1	0.6	1.5	2.5	3.5	4.0	5.0
In any direction from those parts of any structure not normally accessible to persons										
G	See Table 3.5			See Table 3.5		See Table 3.5				
In any direction from ground										

⁽¹⁾ This should not be taken as meaning only the literal vertical. The actual clearance may also extend outwards in an arc until it intersects with the relevant 'C' dimension clearance, as indicated on Figure 3.10. See also Note 1 in Clause 3.11.2.1.

⁽²⁾ This clearance can be further reduced to allow for termination at the point of attachment.

NOTES:

- 1 The interpretation/confirmation of clearances that apply for different situations outlined in this Table may in some instances only be made following reference to Figure 3.10 to determine an actual clearance that is relevant for a particular application.
- 2 Clearances in this Table do not apply where there are local rules and regulations. In New Zealand, applicable clearances are given in NZECP34.

3.12 POWER LINE EASEMENTS

An easement is legally described as an encumbrance on the title of land limited in width and height above or below the land conferring a right to construct, operate and maintain an electricity power line, cable, or apparatus.

Easements are usually obtained or created to ensure electricity utilities can gain ready access to assets for maintenance, repair and upgrading the power lines and for the safety of persons living, working or playing near overhead lines.

An easement width can be established to accommodate an overhead energized line asset which ensures adequate safe electrical and mechanical spatial clearances are provided.

The easement width may be influenced by other factors such as audible noise, radio and television interference, or electric and magnetic fields.

NOTE: Appendix CC provides typical easement widths for a range of voltages.

3.13 CORONA EFFECT

3.13.1 General

The surface voltage gradient on the conductor should be limited to less than 16 kV/cm to limit the generation of corona discharges. For higher surface voltage gradients, all surfaces on hardware should be smooth and the corners rounded. At the higher voltage levels, the use of corona rings should be considered around the hardware to reduce corona.

3.13.2 Radio and television interference

Corona generates interference over a wide band of frequencies.

The degree of annoyance caused by radio and television interference is determined by the 'signal-to-noise ratio' at the receiving installation. When establishing limits for the emission of radio noise, the radio and television signal strengths to be protected have to be determined.

The allowable levels of Radio Interference Voltage (RIV) and Television Interference (TVI) are given in AS/NZS 2344. For New Zealand, the applicable Standard is NZS 6869.

3.13.3 Audible noise

The most common form of audible noise is a hissing or frying sound (broadband crackle) audible in wet weather. During fair weather, a constant low frequency (100 Hz) hum may also be heard.

Designers need to ensure that audible noise levels comply with relevant EPA, government authority or local council regulations. The total random audible noise consisting of both broadband and 100 Hz hum needs to be addressed in the design process.

3.13.4 Corona loss

In cases where the surface voltage gradient is very high there can be a power loss along the conductor due to corona emission. On overhead power lines, corona loss is expressed in watts per metre (W/m) or kilowatts per kilometre (kW/km). The power loss due to corona is typically less than a few kilowatts/kilometre in fair weather but it can amount to tens of kilowatts/kilometre during heavy rain and up to one hundred kilowatts/kilometre during frost.

In general if the surface voltage gradient is kept below 16 kV/cm, corona loss will be negligible compared to joule losses.

3.14 ELECTRIC AND MAGNETIC FIELDS

3.14.1 Electric and magnetic fields under a line

The design of overhead lines can be influenced by the necessity to limit power frequency electric and magnetic fields produced by energized conductors.

Limit values for electric and magnetic fields are not provided in this Standard. For such limits, reference shall be made, where relevant, to the following:

- (a) *For Australia*—refer to ARPANSA for the current Standard for Radiation Protection Standard for Exposure Limits to Electrical and Magnetic Fields 0 Hz–3 kHz.
- (b) *For New Zealand*—to ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (Up to 300 GHz).

3.14.2 Electric and magnetic field induction

Electric and magnetic fields near an overhead line may induce currents in and voltages on adjacent conductive objects such as long metal structures (e.g. communication installations, fences, lines or pipes) or bulky objects (e.g. conductive roofs, tanks or large vehicles) in proximity to power lines.

Mitigation measures should be considered to reduce these effects to acceptable levels contained in relevant Standards and Codes. Relevant Standards and Codes are HB 102 (CJC 6), and AS/NZS 4853.

3.14.3 Interference with telecommunication circuits

Telecommunication circuits can suffer electrical interference from power lines.

For interference calculations and measures to be taken to eliminate the effects or reduce them to acceptable levels, reference shall be made to relevant International and National Standards and/or to qualified Codes of Practice (i.e. ITU Directives (CCITT) Vol. VI and/or to particular agreements between the parties concerned. Relevant standards and codes are HB 102 (CJC 6) and NZCCPTS *Noise Investigation Guide*.

3.14.4 Electrostatic induction

Electrostatic induction is caused by the electric field surrounding the powerline and these fields can induce charges on nearby metallic objects. This effect is generally only significant at voltages above 200 kV and may influence the minimum ground clearance over parking areas.

For a person, the thresholds for perception are given in Appendix H.

3.15 SINGLE WIRE EARTH RETURN (SWER) POWERLINES

3.15.1 General

Single wire earth return (SWER) are distribution powerlines that utilize the earth as a return circuit instead of a conventional conductor.

These distribution lines are economical to construct in rural areas where long spans can be constructed.

A more detailed discussion on SWER distribution systems is found in The Electricity Authority of New South Wales document, *High Voltage Earth Return for Rural Areas*, and in NZECP 41 *New Zealand Code of Practice for Single Wire Earth Return Systems*.

3.15.2 Types of SWER distribution systems

The ‘isolated’ single wire system is the most common form. This type of SWER distribution system consists of an isolating supply transformer with the secondary winding connected to a medium voltage single wire pole line and earth. Local customer supply pole-type transformers are connected between the single conductor line and earth. The primary winding of the isolating transformer is connected to a conventional medium voltage distribution system.

SWER distribution systems are utilized in the following arrangements:

- (a) The ‘isolated’ single wire system as described above. This is the most common SWER distribution system.
- (b) The ‘duplex’ system that uses an isolating transformer with the secondary earthed at the centre tap. The transformer supplies a two-wire backbone line to which single phase tee-offs are connected.
- (c) The ‘un-isolated’ system that uses a conventional 3-phase backbone from which single wire tee-off lines emanate.

The design issues to be considered for SWER systems are as follows:

- (i) Earthing systems need to be designed to take into account broken or poor earth conductor connections.
- (ii) Limited capacity due to the low conductivity of the conductor commonly used as well as the limited sizes of isolating and customer transformers.
- (iii) Interference with Telecommunications Circuits—there is a limit of 8 A earth current as stipulated in various Codes of Practice for Telecommunications including NZECP 41.
- (iv) Interference with railway telecommunications and signalling circuits [see HB88 (CJC 2)].
- (v) Harmonics caused by customer’s equipment overloading SWER system and some 3-phase converting devices.
- (vi) Reduced visibility to low flying aircraft (which may be involved in crop dusting or fire fighting).
- (vii) Low earth fault currents and the difficulty protecting these schemes.

SECTION 4 CONDUCTORS AND OVERHEAD EARTH WIRES (GROUND WIRES) WITH OR WITHOUT TELECOMMUNICATION CIRCUITS

4.1 ELECTRICAL REQUIREMENTS

4.1.1 D.C. resistance

The conductor d.c. resistance is a function of the conductor construction and stranding, material properties and temperature. The resistance shall be determined from either—

- (a) a mathematical determination using the known properties of the conductor materials and construction as described in relevant Australian and New Zealand Standards on conductors; or
- (b) published values in relevant Australian and New Zealand Standards on conductors.

4.1.2 A.C. resistance

The conductor a.c. resistance is a function of the conductor d.c. resistance, construction and stranding, material properties, temperature, frequency and magnitude of the current. The resistance shall be determined from mathematical determination using the known properties of the conductor materials and construction as described in relevant Australian and New Zealand Standards on conductors. A recommended method and guidance to determine the AC resistance is given in IEC TR 61597.

NOTE: Appendices AA and BB provide guidance on conductor maximum operating temperature.

4.1.3 Steady state thermal current rating

The steady state thermal current rating of a conductor is the maximum current inducing the maximum steady state temperature for a given ambient condition and is based on the conductor heat balance equation—

$$P_j + P_s = P_r + P_c \quad \dots 4.1$$

where the heat gain terms are P_j which is the joule heating due to the resistance of the conductor and P_s is the solar heat gain. The heat loss terms are P_c which is natural and forced convective cooling and P_r is the radiant cooling. The heat gain for cyclic magnetic flux, which is caused by eddy currents, hysteresis and magnetic viscosity; and corona heat gain are not considered. The evaporative cooling is also not considered.

A recommended methodology to establish the steady state thermal ratings for bare conductors is given in IEC TR 61597. For insulated conductors, the steady state thermal rating shall be in accordance with the appropriate Australian and New Zealand Standards. The steady state thermal current rating shall be determined for coincident wind velocity and incident angle, daily solar radiation, ambient temperature and conductor surface condition.

4.1.4 Short time thermal current rating

The short time thermal current rating of a conductor is the maximum current inducing the maximum steady state temperature for a given ambient condition and occurs when a step change in current flow results in a short-term conductor temperature change and the

$$\text{conductor stored heat} = \text{heat gain} - \text{heat loss}$$

The time constant for short time ratings is generally less than 20 min and meteorological conditions other than solar heat gain will generally not have a significant influence on final conductor temperature. Initial conductor conditions shall be assumed and include initial conductor operating temperature. Short time current and associated conductor temperature rise is illustrated in Figure 4.1.

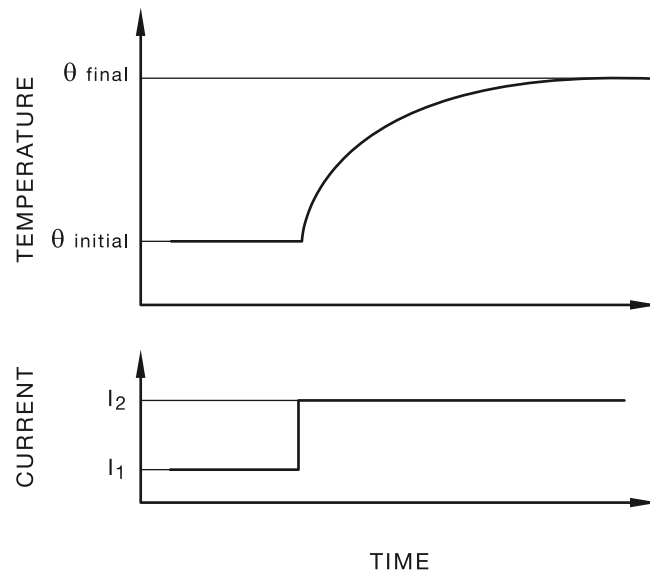


FIGURE 4.1 SHORT TIME CURRENT RATING AND TEMPERATURE

The final conductor temperature shall not exceed the maximum operating temperature defined in Clause 1.4.46.

NOTE: See Appendix Z for guidance on establishing the short time thermal current rating for bare conductors.

Appendix Z provides guidance on establishing the short time thermal current rating for bare conductors. For covered and insulated conductor the maximum short-term thermal rating shall be in accordance with the relevant Australian and New Zealand Standards.

4.1.5 Short-circuit thermal current rating

The short-circuit thermal current rating shall be based on adiabatic heating, that is due to the transient nature of the current flow. The conductor heat gain and loss at the surface of the conductor shall be ignored. The rating is a function of the conductor cross-sectional area, the thermal conductivity of the conductor, the specific heat capacity of the conductor, the conductor resistivity, the conductor temperature coefficient of resistance, the duration of the transient current, the conductor initial temperature, the magnitude of the current and maximum permissible temperature.

In determining the rating for circuits where—

- (a) the reactance to resistance ratio is greater than 10 then the d.c. asymmetrical heating component of the current shall be taken into account; and
- (b) auto reclose protection is employed then the short-circuit duration shall be the sum of the initial fault duration and the successive auto reclose fault durations and the combined conductor heating shall be cumulative,

the conductor short-circuit thermal rating shall not result in exceeding—

- (i) any specified permissible temperature rating of the conductor including appropriate consideration of differential expansion of dissimilar materials (known as birdcaging);
- (ii) for covered and or insulated conductors, the insulation temperature rating as specified in the appropriate Australian and New Zealand Standards;
- (iii) the temperature rating of fibre optic cores;
- (iv) the permissible loss of strength due to annealing.

NOTE: See Appendix AA.