

SOUTH AFRICAN NATIONAL STANDARD

Overhead power lines for conditions prevailing in South Africa

Part 1: Safety

WARNING

**This document references other
documents normatively.**

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Table of changes

Change No.	Date	Scope
Amdt 1	2017	Amended to change the designation "SANS 10280-1/NRS 041-1" to read "SANS 10280-1", to update referenced standards, to delete the footnote on the availability of documents, to number definitions, to update the requirements for mechanical design of overhead lines, to update the figures on wind load directions and tower faces, to update the table on conductor tension limits, to delete the notes on shared services on the same structures, and on practical working clearances, to change a cross reference, to update the table on design limits for electric and magnetic field strength, to update the requirements for warning signs and to renumber the subclauses accordingly, and to update the annex on clearances required for power lines that cross services.

Foreword

This South African standard was prepared by National Committee SABS/TC 067/SC 05, *Electricity distribution systems and components – Electricity distribution*, in accordance with procedures of the South African Bureau of Standards, in compliance with annex 3 of the WTO/TBT agreement.

This document was approved for publication in November 2017.

This document supersedes SANS 10280-1:2013 (edition 2).

A vertical line in the margin shows where the text has been technically modified by amendment No. 1.

This document is referenced in the Electrical Machinery Regulations (EMR) (section 44) of the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993).

Compliance with this document cannot confer immunity from legal obligations.

Reference is made in 3.1.29 to "legal requirements". In South Africa this means the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993).

Reference is made in 4.3.5.3.2, 4.4.6.3.2, 10.1.2 and 10.1.5 to the "EMR". In South Africa, this means the Electrical Machinery Regulations of the Occupational Health and Safety Act.

Reference is made in clause 5 (the heading) to the "aviation authority". In South Africa, this is the Commissioner for Civil Aviation of the South African Civil Aviation Authority.

Reference is made in clause 5 to the "Civil Aviation Regulations". In South Africa this means the Civil Aviation Regulations of the Aviation Act, 1962 (Act No. 74 of 1962).

Reference is made in clause 6 (the heading), and in 6.2, 6.3 and 6.4 to the "relevant authority". In South Africa, this is the General Manager of the Division for Maritime Regulation of the Department of Transport.

Reference is made in 9.2.1 to the "machinery authority". In South Africa this means the Chief Inspector of Machinery in accordance with the Machinery Regulations of the Occupational Health and Safety Act.

Reference is made in 12.3 and E.1 to "legislation". In South Africa, this means the Occupational Health and Safety Act.

Reference is made in 10.1.6 and in 10.2.7 to the "railway authority". In South Africa, this is Transnet.

Foreword (*concluded*)

Reference is made in F.1 (the heading), to the "electronic communication network service licensee". In South Africa, this is the person or body to whom an electronic communication network licence has been granted in terms of section 5(2) or 5(4) of the Electronic Communications Act, 2005 (Act No. 36 of 2005).

Reference is made in F.1 to "electronic communication legislation". In South Africa this is the Electronic Communications Act, 2005 (Act No. 36 of 2005) (section 29).

SANS 10280 consists of the following part, under the general title *Overhead power lines for conditions prevailing in South Africa*:

Part 1: Safety.

Annexes E and F form an integral part of this document. Annexes A, B, C and D are for information only.

Introduction

The requirements of this part of SANS 10280 are applicable to new infrastructure, unless otherwise indicated in the relevant clause.

Amdt 1

This part of SANS 10280 has been prepared to enable competent persons to design safe and cost-effective overhead power lines by indicating the current technology and practices applicable in South African conditions.

Amdt 1

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Overhead power lines for conditions prevailing in South Africa

Part 1: Safety

1 Scope

This part of SANS 10280 specifies the mechanical and electrical safety requirements of overhead power lines including requirements for supports, the conductor system, clearances and crossings.

Amdt 1

2 Normative references

The following documents contain provisions which, through reference in this text, constitute provisions of this part of SANS 10280. All documents are subject to revision and, since any reference to a document is deemed to be a reference to the latest edition of that document, parties to agreements based on this specification are encouraged to take steps to ensure the use of the most recent editions of the documents listed below. Information on currently valid national and international standards can be obtained from the South African Bureau of Standards.

Amdt 1

2.1 Standards

ASCE 10-97, *Design of latticed steel transmission structures*.

ASCE 48-11, *Design of steel transmission pole structures*.

IEC 60652, *Loading tests on overhead line structures*.

IEC 60826:2017, *Design criteria of overhead transmission lines*.

Amdt 1

ITU-T K.68, *Operator responsibilities in the management of electromagnetic interference by power systems on telecommunication systems*.

SANS 470, *Concrete poles for telephone, power and lighting purposes*.

SANS 753, *Pine poles, cross-arms and spacers for power distribution, telephone systems and street lighting*.

SANS 754, *Eucalyptus poles, cross-arms and spacers for power distribution and communications systems*.

SANS 61466-1/IEC 61466-1, *Composite string insulator units for overhead lines with a nominal voltage greater than 1 000 V – Part 1: Standard strength classes and end fittings*.

SANS 62110/IEC 62110, *Electric and magnetic field levels generated by AC power systems – Measurement procedures with regard to public exposure*.

2.2 Other publications

Cigré Brochure 273, *Overhead conductor safe design tension with respect to Aeolian vibrations*.

Available from World Wide Web: <<http://www.e-cigre.org>>.

Amdt 1

Cigré Working Group B2.12. Cigré Brochure 299¹⁾. *Guide for selection of weather parameters for bare overhead conductor ratings*. 2006. Available from World Wide Web:

<ELT_144_3 on <http://www.e-cigre.org>>.

Amdt 1

Cigré Working Group SC 22.12. Probabilistic determination of conductor current ratings. *Electra*¹⁾ No. 164, February 1996, pp. 103-119. Available from World Wide Web:

<ELT_164_4 on <http://www.e-cigre.org>>.

Amdt 1

Cigré Working Group SC 22.12. The thermal behaviour of overhead conductors — Section 1 and 2: Mathematical model for evaluation of conductor temperature in the steady state and the application thereof. *Electra* No. 144, October 1992, pp. 107-125. Available from World Wide Web: <ELT_144_3 on <http://www.e-cigre.org>>.

Amdt 1

ICNIRP Guidelines moved to bibliography.

Amdt 1

~~NRS 043, *Joint use of structures for power and telecommunication lines*.~~

Amdt 1

3 Terms, definitions, abbreviations and symbols

For the purposes of this document, the following terms, definitions, abbreviations and symbols apply.

3.1 Terms and definitions

3.1.1

back-stay

temporary cable to stabilize partially strung supports or cross-arms during construction

Amdt 1

3.1.2

characteristic strength

guaranteed strength

R_c

value of material or component strength as determined by appropriate standards correlating to ultimate capacity, usually corresponding to an exclusion limit, from 2 % to 5 %, with 10 % being an upper practical (and conservative) limit

Amdt 1

3.1.3

component

part of an overhead line system that has a specified purpose

NOTE Typical components are towers, foundations, conductors and insulator strings.

Amdt 1

3.1.4

conductor current rating

ampacity

current which will meet the design, security and safety criteria of a particular line on which the conductor is used

[*Electra*, No. 144.]

Amdt 1

Footnote deleted by amendment No. 1.

3.1.5

Amdt 1

cross-rope

chainette

cable, hardware or insulator that supports a multiple phase arrangement

3.1.6

Amdt 1

damage limit (of a component)

serviceability limit state

strength limit of a component that corresponds to a defined limit of permanent (or inelastic)

deformation of this component which leads to damage to the system if it is exceeded

NOTE This limit is also called the "serviceability limit state" in building codes based on limit states design.

3.1.7

Amdt 1

everyday tension

EDT

still air conductor tension at a reference temperature of 15 °C after creep

3.1.8

Amdt 1

exclusion limit $e\%$ value of a variable taken from its distribution function, that corresponds to a probability of $e\%$ of not being exceeded**3.1.9**

Amdt 1

failing load

load equivalent to the characteristic strength of a component

3.1.10

Amdt 1

failure limit

ultimate limit state (of a component)

strength limit of a component that leads to the failure of the system if this limit is exceeded

NOTE If this strength limit is exceeded, the system will reach a state called "ultimate limit state" as defined in building codes based on limit states design.

3.1.11

Amdt 1

guy

permanent anchor cable that supports a structure

3.1.12

Amdt 1

high public exposure area

area where the public frequently gathers

3.1.13

Amdt 1

limit loadclimatic load that corresponds to a return period, T , used for design purposes without additional load factors**3.1.14**

Amdt 1

load factor γ

factor to be multiplied by limit loads in order to design line components

3.1.15

Amdt 1

minimum safety clearance

minimum clearance to any live part of a power line on which a person may encroach, in person or with an object, or on which vegetation may encroach

NOTE This is not the minimum clearance of live parts to earth used in the design of the power line e.g. the clearance across an insulator.

3.1.16

Amdt 1

modulus of rupture

maximum load-carrying capacity of a member (structural timber in the case of this part of SANS 10280), generally used in tests of bending strength to quantify the stress required to cause failure

Amdt 1

NOTE Modulus of rupture is usually reported in megapascal (MPa).

3.1.17

Amdt 1

proven method

method that has been in practice for at least ten years without any known incidents, malfunction, or failure, or a method that uses internationally accepted calculation methods, or a method of test that has been proven by accredited test authorities

3.1.18

Amdt 1

reference wind speed V_R

wind speed at 10 m in height, corresponding to an averaging period of 10 min and having a return period T

NOTE When this wind speed is taken in a terrain type B, which is the most common case in the industry, the reference wind speed is identified as V_{RB} .

3.1.19

Amdt 1

reliability

<structural> probability that a system performs a given task, under a set of operating conditions, during a specified time

NOTE Reliability is thus a measure of the success of a system in accomplishing its task. The complement to reliability is the probability of failure or unreliability.

3.1.20

Amdt 1

residual static load**RSL**

net static conductor tension that follows conductor failure in adjacent span, considering the deflected equilibrium position of all non-rigid support points in all subsequent structures

3.1.21

Amdt 1

return period (of a climatic event)

average occurrence of a climatic event that has a defined intensity

NOTE The inverse of the return period is the yearly frequency which corresponds to the probability of exceeding this climatic event in a given year.

3.1.22

Amdt 1

safety

ability of a system not to cause human injuries or loss of lives

3.1.23

Amdt 1

security

<structural> ability of a system to be protected from a failure event that relates to longitudinal loads in the direction of conductors

NOTE Security loads are further sub-categorized into broken conductor loads (that affect one complete phase at a time) and failure containment loads (that involve sets of phases). Where not catered for, security loads might result in major collapses or cascading structures. Security is a deterministic concept as opposed to reliability, which is a probabilistic concept.

3.1.24

Amdt 1

service load

permanent load that is experienced during everyday tension conditions

NOTE Further definitions that relate to the detailed method, as outlined in 4.4, are contained in IEC 60826.

3.1.25

Amdt 1

shield wire

overhead ground wire or earthwire used for lightning protection and transmittance of fault currents

3.1.26

Amdt 1

step voltage

difference in surface potential experienced by a person bridging a distance of 1 m with the feet without contacting any ground object

3.1.27

Amdt 1

strength factor
 ϕ

factor applied to the characteristic strength of a component

NOTE This factor takes into account the co-ordination of strength, the number of components subjected to maximum load, quality and statistical parameters of components.

3.1.28

Amdt 1

suspension structure

tangent or intermediate structure that is designed for use between bend or terminal points, sometimes catering for minor line deviation angles of up to three degrees

3.1.29

Amdt 1

templating temperature

design temperature

conductor temperature (average) that complies with legal requirements (see foreword) regarding clearance

3.1.30

Amdt 1

touch voltage

potential difference between the ground potential rise (GPR) and the surface potential at the point where a person is standing while at the same time having a hand in contact with a grounded structure

3.1.31

Amdt 1

wire

general term that refers to stranded earth or phase conductors

3.2 Abbreviations

AMSL	above mean sea level
ASCE	American Society of Civil Engineers
BIL	basic insulation level
CAA	Civil Aviation Authority (South African)
EDT	everyday tension
EHV	extra high voltage (the set of nominal voltage levels that are used in power systems for bulk transmission of electricity in the range $220 \text{ kV} \leq U_n \leq 400 \text{ kV}$)
EMR	Electrical Machinery Regulations
GPR	ground potential rise
HV	high voltage (the set of nominal voltage levels that are used in power systems for bulk transmission of electricity in the range $44 \text{ kV} \leq U_n < 220 \text{ kV}$)
IEC	International Electrotechnical Commission
LV	low voltage (the set of nominal voltage levels that are used for the distribution of electricity and the upper limit of which is generally accepted to be an a.c. voltage of 1 kV (or a d.c. voltage of 1,5 kV))
MV	medium voltage (the set of nominal voltages that lie above low voltage and below high voltage in the range $1 \text{ kV} < U_n < 44 \text{ kV}$)
OPGW	optical ground wire
RSL	residual static load (following conductor failure)
UHV	ultra high voltage (the set of nominal voltage levels that are used in power systems for bulk transmission of electricity in the range $U_n > 400 \text{ kV}$)
UTS	ultimate tensile strength of conductors and ground wires

3.3 Symbols

A_c	wind force on the conductor and hardware assemblies support point (acting in the direction of the wind) (N)
A_t	wind force on a tower (acting in the direction of the wind) (N)
A_{tc}	wind force on the poles (acting in the direction of the wind) (N)
C	catenary constant, usually at a reference temperature of 15 °C (m)
d	conductor diameter (m)
D_c	vertical dead load that results from the conductors and attachments (N)
D_{tc}	vertical dead load including all attachments and fittings (other than hardware) (N)

d_t	average pole diameter (m)
EDT	everyday tension (N)
g_c	unit weight of the conductor (N/m)
H	horizontal component of conductor tension (N)
l_e	pole height above ground (m)
L	wind span (m)
L_a	distance from the axis of rotation to the centroid of conductors (m)
L_h	in-span spacing of attached hardware (m)
L_w	design weight span for the structure (m)
Q	calculated load on the supports (N)
q_c	wind pressure on conductor and cylindrical poles and assemblies (Pa)
q_r	wind pressure on supports or objects of rectangular cross-section (Pa)
q_t	wind pressure on lattice towers of rectangular cross-section – applied to the face of the structure (Pa)
R_c	characteristic strength of the component (N)
S_i	maximum wind area of the assembly (m ²)
S_{t1}	transverse windward surface area of lattice members (m ²)
S_{t2}	longitudinal windward surface area of lattice members (m ²)
T_b	resultant conductor tension from a broken conductor condition (N)
T_c	conductor tension (N)
T_f	failure containment conductor tension (N)
V_R	reference speed
W_a	allowable wind span (m)
W_d	design wind span (m)
w_h	weight of attached hardware per conductor in the bundle (N)
z_c	mean conductor height (m)
$z_{1,2}$	conductor attachment heights at supports on either side of the span (m)
z_{cmin}	minimum conductor heights above ground (m)
γQ_f	factored load due to failure containment (N)

- γQ_m factored load due to construction and maintenance (N)
- γQ_t factored load to wind on lattice towers (N)
- γQ_{tc} factored load to wind on poles (N)
- γQ_c factored load due to wind on conductors and hardware assemblies (N)
- γQ_b factored load due to broken conductors (N)
- Ω angle between the wind direction and the conductor (degrees)
- ω_t wind span reduction factor due to the erection of structures in category A terrain, or spans that traverse significant ridges, valleys or escarpments
- θ angle between the wind direction and the tower cross-arm orientation (degrees)
- Φ strength factor, based on strength variance of components (Φ_c) and failure sequencing (Φ_s)
- γ factor, based on a minimum reliability level (linked to a return period), safety implications or variability of loads

4 Mechanical design of overhead lines

4.1 General

4.1.1 In this part of SANS 10280 the mechanical and structural designs of overhead lines, which consist of a system of inter-related components, are conducted using reliability based design concepts, as proposed by the majority of leading internationally accepted mechanical design standards. **Amdt 1**

4.1.2 This part of SANS 10280 proposes a unified approach, appropriate for a wider range of voltage classes, but with the option of simplified calculations for lower voltages. **Amdt 1**

4.1.3 Loads on the supports of lines of operating voltages 132 kV and lower may be determined by using either the simplified method in 4.3 or the detailed method in 4.4. In the case of lines of operating voltage exceeding 132 kV, the detailed method shall be used.

4.1.4 All formulae required by the simplified method are presented in this part of SANS 10280. The detailed method requires reference to IEC 60826. **Amdt 1**

4.1.5 In the case of both simplified and detailed methods, the following loads shall be determined:

- a) wind loads;
- b) ice loads;
- c) construction and maintenance (safety) loads; and
- d) security loads.

4.2 Reliability based design concepts

4.2.1 General

Both the simplified and detailed methods are based on reliability based design (RBD) concepts, in which the load on supports, modified by a load factor, is used to determine the minimum required strength of components, which may be modified by a strength factor, as follows:

$$\Phi R_c \geq \gamma Q$$

where

Φ is the strength factor, based on the strength variance of components (Φ_c) and failure sequencing (Φ_s);

R_c is the characteristic strength of the component;

γ is the load factor, based on a minimum reliability level (linked to a return period), safety implications or variability of loads;

Q is the calculated load.

4.2.2 Strength factors

4.2.2.1 Strength factors (Φ_c) that relate to the characteristic strength of components shall be applied to various material types in accordance with table 1.

Table 1 — Strength factors to be applied

1	2	3	4
Component	Characteristic strength (R_c) determined by	Strength factor Φ_c	
		Strength verified by full-scale testing	Strength not verified by full-scale testing
Steel lattice structures and cross-arms	Yield stress of steel	1,0	0,8
Fabricated tubular steel poles and members	Yield stress of steel or deflection limit	1,0	0,9
Reinforced or pre-stressed concrete structures and members	Crack width or deflection limit ^a	1,0	0,85
Wood structures, poles or members under ultimate loading	Modulus of rupture	0,8	0,7
Wood structures, poles or members under EDT conditions	Modulus of rupture	0,3	0,3
Line fittings, forged or fabricated	Yield stress of steel	1,0	
Line fittings, cast	Failing load	0,7	
Synthetic composite, porcelain or glass insulators	Failing load	1,0 ^b	
Conductors	UTS	0,7	
NOTE Use of materials not covered in this table should be supported by relevant tests and industry standards.			
^a See SANS 470 for deflection limits and permissible crack widths.			
^b Provided that service loads should not exceed 0,5 of the failing load of the insulator.			

4.2.2.2 In addition to the above, strength factors in table 2 (Φ_s) are required (in the detailed method only) to co-ordinate the strength between various components, to facilitate a more predictable failure sequence and to minimize reconstruction implications.

Table 2 — Strength factors for failure sequencing

1	2	3
Component	Characteristic strength (R_c) determined by	Strength factor application (Φ_s)
Superstructures		
Suspension, angle strain ^a or terminal structures	Yield stress of steel ^b	1,0
Hardware^c		
Hardware and insulation – Strain assemblies	UTS of conductor bundle ^d	1,0
Hardware and insulation – Suspension assemblies	Maximum load that results in the collapse of a superstructure ^e	0,8 (or less)
Guy wires and guy fittings	Maximum guy tension of all load cases	0,83
Foundations		
Planted pole foundations or caisson	Maximum overturning capacity of footing	1,0
Foundations in compression only	Maximum compressive load capacity of footing	0,9
Foundations for self-supporting structures (in overturning, compression and tension)	Maximum compressive or tensile load capacity of footing	0,83
Guy anchor foundations for guyed monopoles and guyed vee structures	Maximum tension capacity of footing	0,75
Inclined piles in guyed structures ^f	Maximum tension capacity of footing	0,7
Permanently loaded guy anchor foundations on strain towers	Maximum tension capacity of footing	0,65
^a Strain structures are expected to perform at higher reliability levels than suspension towers. However, due to the low probability that strain towers are utilized to their maximum deviation angle and design spans, the strength factor may be assumed to be equal to that of suspension structures. ^b Plastic failure in cross-arms and post insulator connections may be assumed in conjunction with security loads, in which case the ultimate stress may be used to calculate strength. However, appropriate temporary strengthening during construction and maintenance operations may be required. ^c The strength selection of hardware and insulation shall be in accordance with the strength for insulators in SANS 61466-1. ^d Strain assembly strength is to be at least equal to conductor bundle UTS. However, the actual strength of the conductor when fitted with compression hardware may be reduced by up to 5 %. ^e The load that causes the collapse of a superstructure in this case is defined as the maximum tension in the insulator string for all load cases divided by the maximum member utilization (if available) percentage for that load case. ^f For specialist piles such as continuous flight augured, precast driven, and piles with shaped under reams or bulbs – use $\Phi = 0,75$.		

4.2.3 Determination of member capacity and mechanical testing requirements

4.2.3.1 The recommended design codes to be used in conjunction with the provisions of clause 4 are given in table 3. Other design codes may be used, provided that full-scale load testing has been conducted to verify the adequacy of such codes, and that calculated member capacity complies with or exceeds the requirements of the standards listed below.

Table 3 — Recommended design codes for structure types

1	2
Structure type	Design code
Lattice towers	ASCE 10-97, <i>Design of latticed steel transmission structures</i>
Steel poles	ASCE 48-11, <i>Design of steel transmission pole structures</i>
Concrete poles	SANS 470, <i>Concrete poles for telephone, power and lighting purposes</i>
Wood poles	SANS 753, <i>Pine poles, cross-arms and spacers for power distribution, telephone systems and street lighting</i> SANS 754, <i>Eucalyptus poles, cross-arms and spacers for power distribution and communications systems</i>

4.2.3.2 In the case of lattice and concrete structures, full-scale load testing is recommended for the tallest version of each structure type in a family.

4.2.3.3 It is recommended that testing of towers be undertaken in accordance with IEC 60652.

4.2.3.4 Where full-scale load testing is not undertaken, a strength reduction factor (Φ_c) for untested structures, as stated in table 1, will apply.

4.2.3.5 Where structures utilize composite components which are under permanent loading (for example composite insulators), or critical components which utilize compression fittings where failure would lead to collapse of the structure (for example cross-ropes), non-destructive proof load testing (typically to 0,5 of failing load) is recommended for 100 % of such components.

4.2.3.6 Where compression fittings are used on current-carrying conductors, it is recommended to test to failure a sample fitted with a mid-span joint and dead end compression fittings. This should be undertaken at the outset of each project to ensure adequacy of the jointing procedure and compression system. The minimum failing load to be achieved should be $0,95 \times R_c$ (UTS) of conductor.

4.3 Simplified method

4.3.1 General

The simplified method aims to produce more realistic load case scenarios than those generated by earlier deterministic methods.

The simplified method was derived by applying conservative approximations in the detailed method assuming weather data with a 50 year return period will thus yield slightly higher design loads than those obtained in the detailed method for this return period.

4.3.2 Wind loads

4.3.2.1 Load cases

4.3.2.1.1 Wind loads are applied in two load cases, as illustrated in figure 1:

- a) W1: Wind at 0° to the bisector, applied at the maximum line deviation angle; and
- b) W2 and W3: Wind at 90° to the longer span, applied at the minimum and maximum line deviation angles (only required for angle and terminal structures).

Amdt 1

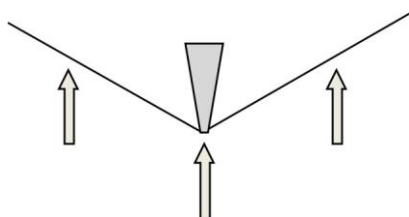


Figure 1(a) — Load case W1

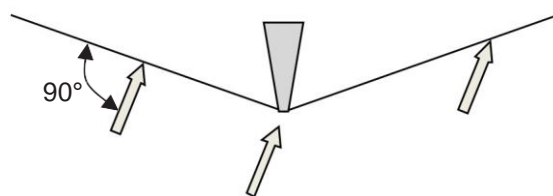


Figure 1(b) — Load cases W2 and W3

Drg.724g

Figure 1 — Wind load directions

Amdt 1

4.3.2.1.2 Wind loads that act simultaneously on conductors, assemblies and structures shall be calculated.

4.3.2.1.3 The ultimate wind pressures applied to the components are given in table 4. These pressures include all load factors and drag force coefficients.

Table 4 — Wind pressure

1	2
Structure or component	Wind pressure (q) Pa
Wind pressure on conductor and cylindrical poles and assemblies (q_c)	1 050
Wind pressure on supports or objects of rectangular cross-section (q_r)	2 400
Wind pressure on lattice towers of rectangular cross-section (q_t) – applied to the face of the structure	3 500

4.3.2.2 Conductor and assembly wind loads

The required resistance due to wind load from conductors and hardware assemblies is given by:

$$\Phi_c \cdot R_c \geq \gamma Q_c = f(A_c, T_c, 1,1D_c)^{2)}$$

NOTE See annex A for the calculation of wind force on conductors using the simplified method.

2) The minimum strength for a component may be also be expressed as $= \gamma Q_r / \Phi$. It is considered good practice to calculate the required design load γQ_r , and to apply the strength factor Φ to the characteristic strength R_c when support components are designed or selected.

where

Φ_c is the appropriate strength factor, given in table 1, which takes into account variability of material, workmanship, etc.;

γQ_c is the factored load due to wind on conductors and hardware assemblies (in N);

A_c is the wind force (in N) on the conductor and hardware assemblies support point (acting in the direction of the wind).

$$A_c = q_c \cdot (d \cdot L + 2 \cdot S_i) \sin^2 \Omega^3)$$

where

d is the conductor diameter (m);

L is the wind span (m);

S_i is the maximum wind area of the assembly (m²);

Ω is the angle between the wind direction and the conductor (degrees).

T_c is the resultant conductor tension

$$T_c = \gamma_c \cdot EDT$$

NOTE The calculated value of T_c shall not exceed 70 % of the conductor ultimate tensile strength (UTS).

$$EDT = g_c \cdot C$$

where

EDT is the everyday tension (N);

g_c is the unit weight of the conductor (N/m);

C is the catenary constant (in m), at a reference temperature of 15 °C;

$$\gamma_c = 0,9 + (q_c \sin^2 \Omega \cdot L^{0,54}) / (6\,450 \, g_c^{0,5})$$

where

γ_c is the load factor applied to EDT to account for incident wind pressure.

$$D_c = 1,1 \cdot g_c \cdot L_w$$

3) NOTE The assembly area has been included in the conductor area and increased by a factor of 2 to account for increased drag on flat components.

where

D_c is the vertical dead load that results from the conductors and attachments (N);

L_w is the design weight span for the structure (m).

NOTE Deleted by amendment No. 1.

4.3.2.3 Wind loads on poles

Wind loads on wood, concrete and steel poles are determined as follows:

$$\gamma Q_{tc} = f(A_{tc}, 1, 1 D_{tc})$$

where

γQ_{tc} is the factored load to wind on poles (N);

D_{tc} is the vertical dead load including the load of all attachments and fittings (other than hardware), (N), multiplied by a load factor of 1,1.

$$A_{tc} = q_c \cdot d_t \cdot l_e$$

where

A_{tc} is the wind force on the poles (that acts in the direction of the wind) (N), which may be considered to act at half of the pole's height above ground;

d_t is the average pole diameter (m);

l_e is the pole height above ground (m).

4.3.2.4 Wind loads on lattice towers

Wind loads on towers utilizing flat or angular members are determined as follows:⁴⁾

$$\gamma Q_t = f(A_t, 1, 1 D_t)$$

where

γQ_t is the factored load to wind on lattice towers (N);

D_t is the vertical dead load including the load of all attachments and fittings (other than hardware), (N), multiplied by a load factor of 1,1.

$$A_t = q_t (1 + 0,2 \sin^2 2\theta) (S_{t1} \cos^2 \theta + S_{t2} \sin^2 \theta)$$

where

A_t is the wind force on a tower (that acts in the direction of the wind) (N);⁵⁾

4) For wind loads on lattice work that consists of tubular members, see the detailed method.

5) During the modelling of lattice towers, it is preferable to specify the effective pressure q_t that acts on the tower face. For the purpose of tower testing, the point loads that result from wind pressure onto the tower body need to be positioned at appropriate locations over the tower length to prevent local overstressing.

- θ is the angle between the wind direction and the tower cross-arm orientation (degrees), as illustrated in figure 2;
- S_{t1} is the transverse windward surface area of lattice members (m^2);
- S_{t2} is the longitudinal windward surface area of lattice members (m^2).

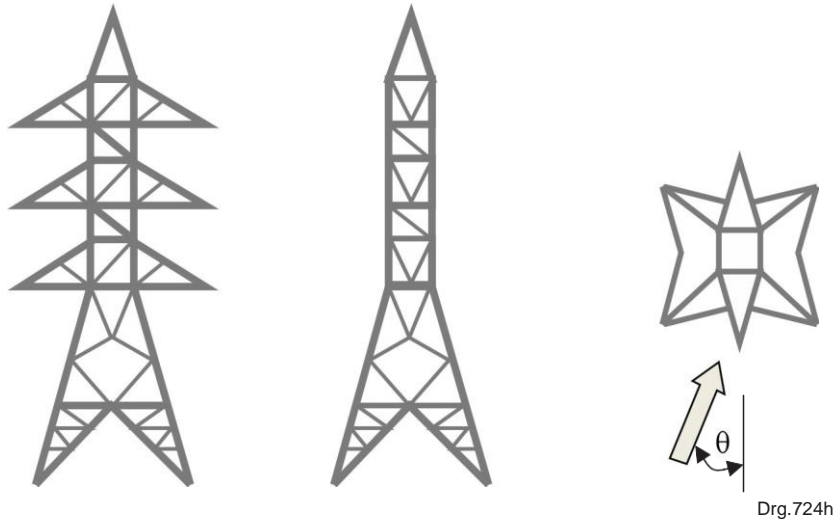


Figure 2(a) — Face 1

Figure 2(b) — Face 2

Figure 2 — Tower faces

Amdt 1

4.3.3 Ice loads

Ice and snow accretion on conductors and structures is not often experienced in South Africa; these conditions are associated with the high altitude areas of the country. Designers shall be aware of these areas (see figure 5) and investigate unbalanced loads produced by ice that forms on conductors owing to local terrain topography (line sections with large adjacent span ratios in hilly terrains).

In such instances the guidelines set out in the detailed method may be followed.

4.3.4 Construction and maintenance loads

4.3.4.1 The structural components of an overhead line shall be designed for the joint, simultaneous effect of the following load combination:

$$\Phi_c R_c \geq \gamma Q_m = f (1,1 D_t, 1,5 D_c, 1,5 Q_i, 1,5 T_c)$$

where

γQ_m is the factored load due to construction and maintenance (N);

D_t is the vertical dead load including the load of all attachments and fittings (other than that of hardware), (N); which is multiplied by a load factor of 1,1;

D_c is the vertical dead load that results from the conductors and attachments (N);

$$= 1,5 \cdot g_c \cdot L_w$$

Q_i is a linesman construction and maintenance load (N), which is multiplied by a load factor of 1,5, and applied at the attachment points of insulator assemblies, where

$Q_i = 1\,000\text{ N}$ for the cross-arms of intermediate and angle suspension structures,

$Q_i = 2\,000\text{ N}$ for all other types of structure.

T_c is the resultant conductor tension (N);

$$= 1,5 \cdot EDT$$

EDT is the everyday tension (N);

$$= g_c \cdot C$$

4.3.4.2 The factor of 1,5 applied to the conductor weight and tension is valid where loads are well controlled and reasonably well defined. This factor shall be increased to 2 if the loads are dynamic or variable or not well defined.⁶⁾

4.3.4.3 In the case of step bolts, ladders, and all members that can be climbed and that are inclined at an angle less than 30° to the horizontal, a construction load of 1,0 kN shall be taken as acting vertically at a statically unfavourable position or in the centre of the member.

4.3.4.4 Any other aspects that can arise from operations, maintenance, project specific or construction practices, which affect the load Q_m , shall be identified by the designer and addressed using the detailed method.

4.3.5 Security loads

4.3.5.1 General

4.3.5.1.1 Security loads are defined as loads produced by conductor bundle or structure failure that have predominantly longitudinal impact load on supports adjacent to the failure event.

4.3.5.1.2 Two types of security load are considered, i.e.

- a) S1: failure containment loads (applied to complete phase sets simultaneously); and
- b) S2: broken conductor loads (applied to one complete phase at a time).

4.3.5.2 Failure containment loads

4.3.5.2.1 The object of designing for failure containment is to reduce the risk of longitudinal cascading failures over a series of sequential structures. The assumption is that the full impact load of all phases can only partially be absorbed, implying that one or a few structures might collapse or be permanently deformed before the cascading failure is contained.

4.3.5.2.2 Structures that support conductors of 132 kV and lower (reliability level 1) need not be designed for failure containment. For such lines, angle strain structures capable of use at a minimum line deviation angle of 10° shall be placed at intervals not exceeding 10 km. For more important sub-transmission lines (e.g. radial feed or double-circuit lines), or where there is a concern that cascading failure impacts are higher (e.g. in remote areas or ice loading risk areas), the designer shall consider failure containment loads for intermediate structures, as defined in the detailed method. Where strain structures for level 1 reliability are not designed for failure containment, these shall be subject to a minimum longitudinal to transverse strength ratio of 1:3. All other cascade resistant structures should be designed considering failure containment loads. Appropriately stayed or axi-symmetric strain towers designed for line angles of 35° or more may be regarded as sufficiently capable.

Amdt 1

⁶⁾ Loads produced during tension stringing may be considered well controlled.

4.3.5.3 Broken conductor loads

4.3.5.3.1 These load cases are relevant to broken hardware, insulator failure, conductor theft, or cross-arm failure, which can typically affect one phase at a time, producing an impact load on one side of the structure. The assumption is that the span on one side of the structure will be under full tension, while zero tension on the other side produces a torsional load on the structure.

4.3.5.3.2 The EMR (see foreword) specifically requires structures that support a crossing span to be designed in such a manner that the structure will be able to withstand the loads that may be imposed upon it should a breakage of any phase conductor or earth conductor occur. It follows that all new structures would normally be designed for broken conductor conditions unless a prohibition which prevents their use next to crossings is expressly stated.

4.3.5.3.3 Both suspension and strain structures should be modelled for broken conductors. The load from broken conductors will be modelled with all phases in place, and one shield wire or one conductor broken on the same side of the structure, so that the maximum torsional load results. The broken conductor condition will typically be considered for the longest cross-arm on the highest phase attachment point, as illustrated in figure 3. However, all support points shall be capable of withstanding a broken conductor condition.

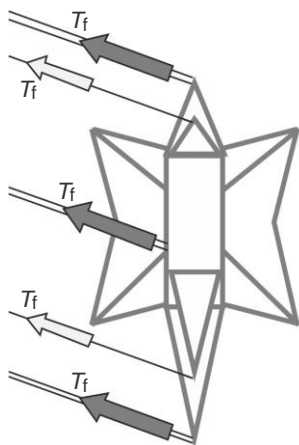
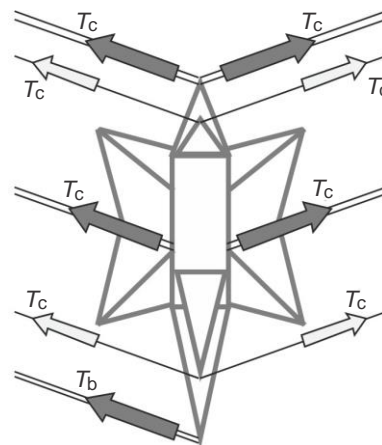


Figure 3(a) — Failure containment loads



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Figure 3(b) — Broken conductor loads

Figure 3 — Typical security load cases

4.3.5.3.4 The factored load due to broken conductors can be calculated as follows:

$$\gamma Q_b = f(1,1 D_t, 1,1 D_c, 1,0 T_c, \gamma_b \cdot T_b)$$

where

γQ_b is the factored load due to broken conductors (N);

D_t is the vertical dead load including the load of all attachments and fittings (other than that of the hardware), (N); which is multiplied by a load factor of 1,1;

D_c is the vertical dead load that results from the conductors and attachments (N);

$$= 1,1 \cdot g_c \cdot L_w$$

T_c is the resultant conductor tension in a healthy conductor (N);

$$= \gamma_f \cdot EDT$$

T_b is the resultant conductor tension from a broken conductor condition (N);

$$= \gamma_f \cdot EDT$$

EDT is the everyday tension (N);

$$= g_c \cdot C$$

$\gamma_b = 1,2$ for suspended assemblies or post insulators semi-rigid in the conductor direction;

$\gamma_b = 1,5$ for strain assemblies.

4.3.6 Coincident tension and vertical loads

Wire tension and vertical load factors applicable to various load cases in the simplified method are summarized in table 5.

Table 5 — Summary of wire tension and vertical load factors used in the simplified method

1	2	3	4
Load case number	Load case description	Wire tension load factor	Vertical load factor
W1-2	Wind loads	Calculate γ_c based on incident pressure	1,1
I1	Ice loads	See detailed method	
	Construction and maintenance loads		
C1	Conductors	$1,5 \times EDT$	1,5
	Security loads		
S1	Broken conductor: suspension towers	$1,2 \times EDT$	1,1
S1	Broken conductor: strain towers	$1,5 \times EDT$	1,1

4.4 Detailed method

4.4.1 General

4.4.1.1 Loads shall be determined in accordance with IEC 60826. The requirements specified in 4.4 are intended to clarify and detail input requirements stipulated in IEC 60826. For this reason this part of SANS 10280 shall be read in conjunction with IEC 60826. **Amdt 1**

4.4.1.2 Certain deviations, simplifications and additions to IEC 60826 are reflected in the requirements in this clause, and shall take precedence over IEC 60826. In particular, attention should be drawn to the information in (a) to (c) when IEC 60826 is used.

a) Clauses 1 to 5 contain essential information that details the IEC loading philosophy and should be reviewed by first time users.

b) Subclause 6.4 (combined wind and ice loadings) is not required by this part of SANS 10280 as ice loads are generally not critical in most parts of South-Africa. **Amdt 1**

c) Simplified requirements are presented in this part of SANS 10280 for the requirements in 6.5 (construction and maintenance loads), in 6.6 (failure containment) and in clause 7 (strength of components). **Amdt 1**

4.4.2 Reliability requirements

4.4.2.1 The reliability levels of lines, selected in accordance with 5.1.2.1 in IEC 60826:2017 shall be in accordance with table 6. **Amdt 1**

Table 6 — Minimum reliability levels

1	2	3	4	5
Voltage	Minimum reliability level	Return period, years	Load factor for wind speed $\gamma_{TW}^{7)}$	Load factor for wind pressure
≤ 132 kV	1	50	1,0	1,0
>132 kV to ≤ 400 kV	2	150	1,1	1,21
> 400 kV ^a	3	500	1,2	1,44
^a Optional, non-mandatory				

Amdt 1

4.4.2.2 Strategically important lines, lines that form the principle source of supply, or long distance links (exceeding 500 km) may be upgraded to the next higher reliability level. Higher levels of reliability than suggested here may be used when line length and strategic importance are being considered. In such instances, interpolated values between the minimum and next reliability level may also be considered.

NOTE The requirements in 4.4.2 do not apply to the design of temporary structures used for emergencies. See 4.5.

7) If statistics of wind are available, the wind speed that corresponds to each reliability level can be directly deduced from these statistics. If statistics of wind are not available, the load factors γ_{TW} can be used.

4.4.3 Wind loads

4.4.3.1 Design of supports

The design of new supports shall take into consideration the wind load cases specified in 4.4.3.2 (for terrain category B). During the tower spotting process, allowable wind spans for a given tower may require adjustment due to specific terrain conditions in accordance with 4.4.3.4.

4.4.3.2 Wind loads on supports

4.4.3.2.1 Wind loads shall be applied in various directions to the supports in accordance with the wind load cases given in table 7 and figure 4.

4.4.3.2.2 In each of these wind load cases, wind loads on insulator strings (see 6.2.10.3 in IEC 60826:2017) and wind loads on supports (see 6.2.10.4 in IEC 60826:2017) shall be combined with wind loads on conductors (see 6.2.10.1 of IEC 60826:2017). **Amdt 1**

4.4.3.2.3 For general conditions in South Africa, the wind load input parameters in table 8 shall be assumed.

4.4.3.2.4 The load cases in table 7 represent a minimum set of wind loads to be applied to standard structures. Non-standard structures may require additional wind load cases. Reverse wind load cases are to be applied where necessary, particularly in the case of non-symmetrical structures and structures located at line angles.

Table 7 — Wind load cases

1	2	3
Type of tower	Wind load case	Description
Suspension tower	W1	Wind at 0° to bisector
	W2	Wind at 15° to bisector
	W3	Wind at 45° to bisector
	W4	Narrow wind at most onerous angle (usually 45°) to the structure
Strain tower	W5	Wind at 90° to the longest span
	W6	Wind at 0° to the shortest span
<p>NOTE 1 See figure 4 for an illustration of the wind load cases.</p> <p>NOTE 2 The wind load cases for strain towers are applied in addition to those for suspension towers.</p> <p>NOTE 3 Additional load cases may be applicable when considering the most onerous conditions applicable considering various combinations of minimum and maximum line deviation angles, minimum and maximum weight spans, minimum and maximum wind spans, maximum wind span combined with the minimum allowed weight span, various distributions of wind and weight spans in the head and back spans of square based cross-arms of dead end towers, different body and leg extension lengths, and orientation of cross-arms.</p> <p>NOTE 4 With the exception of terminal structures, wind loads at the maximum wind span may be determined assuming equal spans on either side of the tower.</p>		

Table 8 — Wind load input parameters

1	2	3
Parameter	Input value	Reference in IEC 60826:2017
Terrain category	B (Open country with few obstacles)	6.2.3
Reference (10 min) wind speed (V_{RB}) at 10 m of height	29 m/s	6.2.4
Combination of wind speed and temperature	Only consider high wind speed and reference temperature of 15 °C	6.2.7
Altitude	0 m AMSL	6.2.9

Amdt 1

NOTE The reference wind speed of 29 m/s applies to all areas in South Africa. An analysis of wind speeds, undertaken by the South African Weather Service, has revealed that the magnitude of 3 s gusts over the central parts of South Africa is both less extreme and more evenly distributed than suggested by previous wind speed maps. This is supported by operational experience.

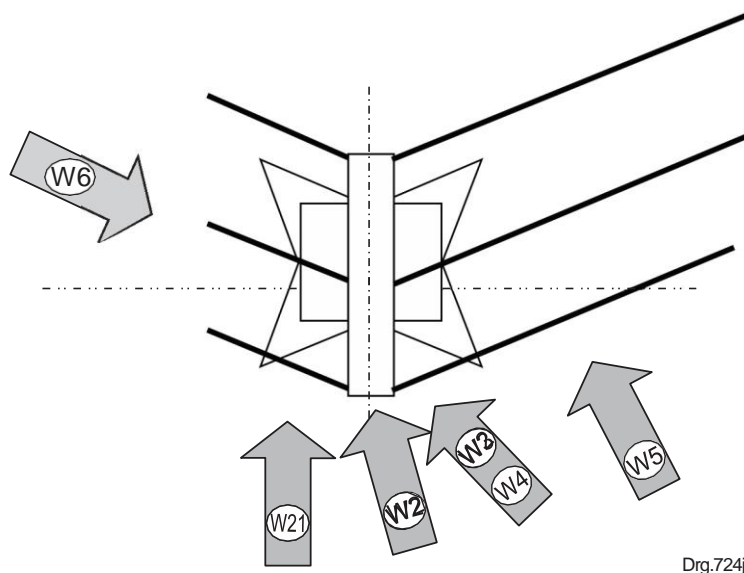


Figure 4 — Incidence of wind loads

4.4.3.2.5 The wind pressure on conductors shall be calculated at a height equal to the mean conductor height (z_c):

$$z_c = \frac{z_i + z_{cmin}}{2}$$

where

z_i is the conductor attachment heights at supports on either side of the span (m);

z_{cmin} is the minimum conductor heights above ground (m).

NOTE In the case of structures with multiple tiers of conductors, z_c may be taken as equal to the z_i of the highest phase conductor.

4.4.3.2.6 The wind pressure on supports may be calculated at a height equal to 0,75 of the structure height.⁸⁾

4.4.3.3 Narrow wind loads

Structures shall be capable of resisting a narrow wind load equivalent to the upper speed range of an F1 category tornado. These loads are simulated by applying the corresponding wind speed, applied to the tower at the most onerous angle (usually 45° to the bisector). Pressure shall be calculated in accordance with 6.2.10.4 of IEC 60826:2017. Co-incident wind pressure on the conductor may be ignored, however, everyday conductor tensions and weight shall be considered. The basic 10 min wind speed (V_{RB}) considered in this load case is 37 m/s (derived from a gust speed of 50 m/s), to be adjusted to 75 % of the structure height, with a wind load factor of 1,0.

Amdt 1

NOTE The narrow wind load case might not effectively yield a tornado-resistant tower, since failure during such climatic events is often caused by impact loads from wind-borne objects. In most structures, this load case should not be dominant.

4.4.3.4 Terrain-specific modification of wind span

4.4.3.4.1 Allowable wind spans of structures, which were designed in accordance with the wind load cases given in 4.4.3 (for terrain category B) require adjustment for certain terrain conditions. Calculate the allowable wind span W_a as follows:

$$W_a = W_d \cdot \omega_t$$

where

W_a is the allowable wind span (m);

W_d is the design wind span (m);

ω_t is the wind span reduction factor due to the erection of structures in category A terrain, or spans that traverse significant ridges, valleys or escarpments.

4.4.3.4.2 Since failures of overhead lines are also attributed to local terrain influences, the following location-specific wind span reduction factors are required where lines traverse the following areas:

- a) wind spans that traverse category A terrain (a large stretch of water upwind, flat coastal area or flat desert):

$$\omega_t = 0,9$$

- b) where conductors are aligned parallel to prominent ridges or cross the crest of larger hills (greater than twice the structure height), further wind speed acceleration due to topographical effects is likely. In such instances, it is recommended to apply a topographical multiplier.

Amdt 1

4.4.4 Ice loads

4.4.4.1 Considering the low frequency of overhead line failures due to wind plus icing in South Africa, the calculation of ice loads shall be done in accordance with a simplified method based on 6.3 in IEC 60826:2017, but with the addition of a low wind pressure of 120 Pa oriented at 0° to the line angle bisector (applied to the increased conductor diameter). The temperature is assumed to be -5 °C.

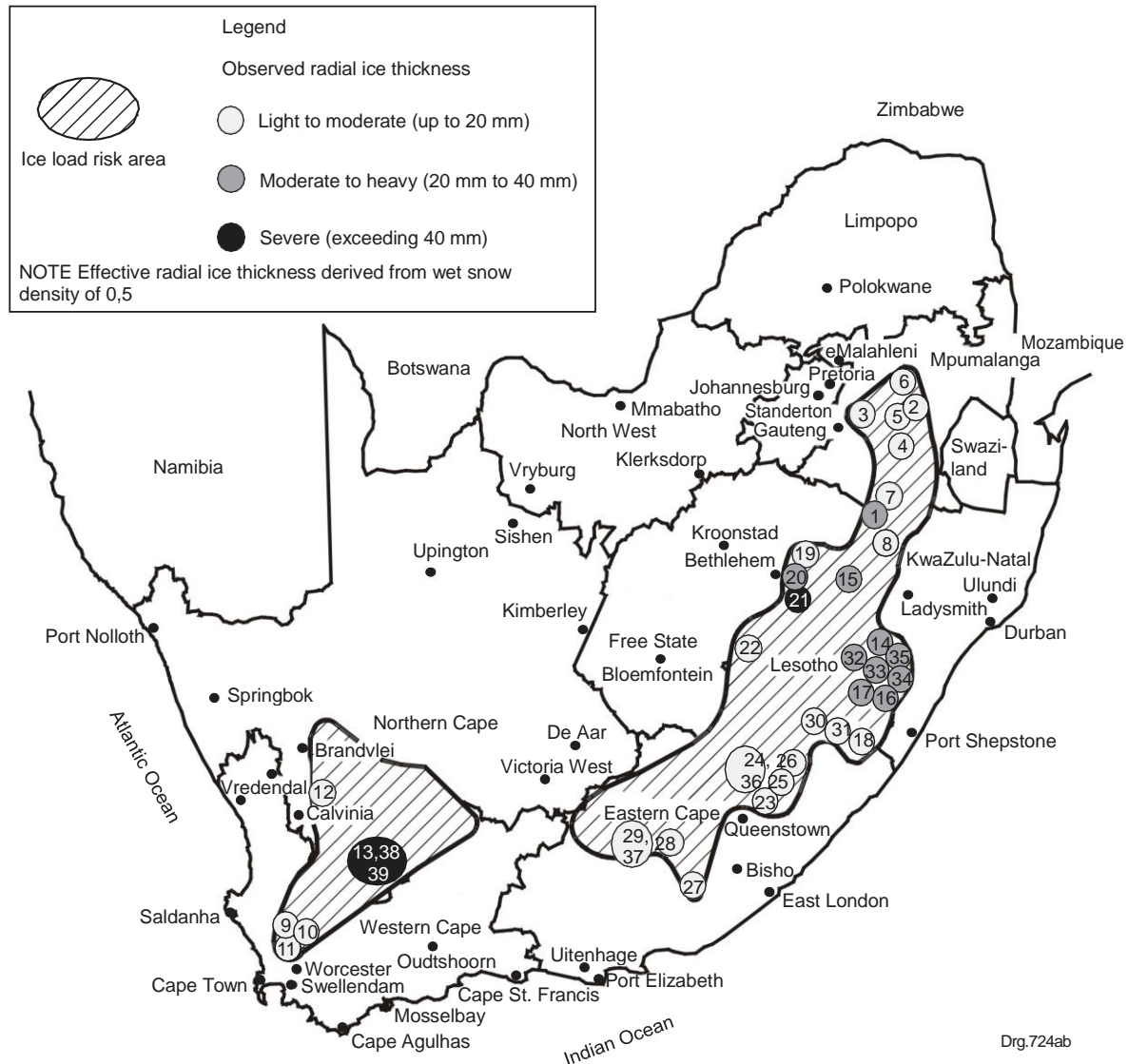
Amdt 1

⁸⁾ Note that some software (e.g. PLS-CADD) automatically takes into account the calculation of conductor heights, span factor, gust response factor, etc. in accordance with IEC 60826, which is considered acceptable.

4.4.4.2 Where overhead lines traverse the ice load risk areas indicated in figure 5, a nominal additional load of 10 mm of radial ice with a density of 0,9 shall be applied to higher lying areas within the risk areas (see 6.3.2 in IEC 60826:2017). This load shall be added to the dead load of the un-factored conductor self-weight.

Amdt 1

4.4.4.3 Where overhead lines traverse terrain where there has been a known incidence of ice load failure, radial ice thickness may be applied in accordance with observations. In such cases, the information given in table B.1 shall be considered. The recommended average load applied to such high risk areas is 30 mm of radial ice with a relative density of 0,9.



NOTE See table B.1 for incident details corresponding to circled numbers above.

Figure 5 — Ice load risk areas in South Africa

4.4.4.4 Thus, towers can be designed for specific ice loads. However, it might also be deemed practicable to design structures for no ice or nominal (10 mm) ices loads, and determine the net reduction in allowable weight span for heavier icing, which is applied during the tower spotting process.

4.4.5 Construction and maintenance loads

4.4.5.1 General

4.4.5.1.1 The construction and maintenance load cases are relevant in the construction phase, when the safety of workers is the main consideration.

4.4.5.1.2 Loads are calculated

- a) during stringing, when conductors pass through running blocks and do not transmit direct longitudinal loads to the structure, and
- b) during regulation (or sagging), where back-stayed and non-back-stayed structures can experience vertical and longitudinal loads.

4.4.5.1.3 As a minimum requirement, construction and maintenance load cases under the following scenarios shall be determined:

- a) C1 stringing: the most onerous conditions for moving and landed conductors;
- b) C2 regulation: induced loads on back-stayed strain and terminal structures; and
- c) C3 maintenance and erection loads to temporary lifting points on the structure.

4.4.5.1.4 No wind pressure shall be considered during stringing (see 6.5.3.3 of IEC 60826:2017).

Amdt 1

4.4.5.2 Stringing loads

4.4.5.2.1 Where conductors pass from ground based stringing equipment through running blocks, the minimum distance between the tower and such equipment is four times the conductor attachment height.

4.4.5.2.2 A conductor tension factor of $2,0 \times$ everyday tension (EDT) for conductors being moved and $1,5 \times$ EDT for all conductors in place shall be applied (see 6.5.3.1 of IEC 60826:2017).

Amdt 1

NOTE In the case of stringing load cases, the increase in tensions will only translate in increased transverse loads on strain towers and will have no effect on suspension structures. Induced longitudinal loads from differences in vertical departure angles are therefore assumed to be negligible.

4.4.5.2.3 In conjunction with the stringing tensions, a vertical load factor of 2,0 and 1,5 for moving and landed conductors respectively, shall be applied to the dead weight of all conductors (including spacers, conductor hardware and insulation).

4.4.5.2.4 The most onerous load combination of one moving phase and landed phases will be considered. In most structures this will imply more than one load case.

4.4.5.3 Regulation loads

4.4.5.3.1 Unless specifically catered for in the design, all strain structures (except terminal structures) from which stringing is initiated on one side, shall be back-stayed during regulation.

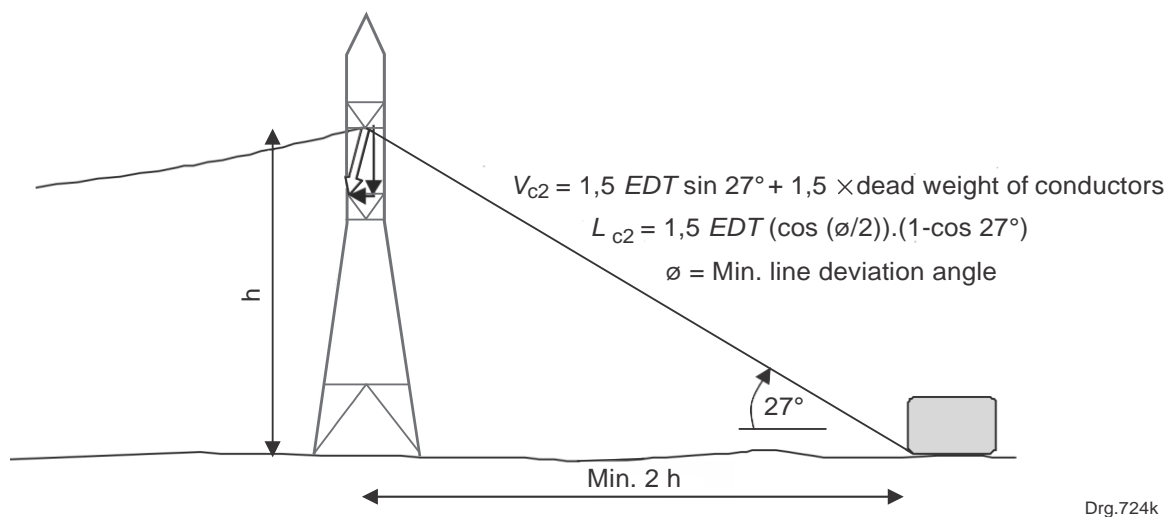
4.4.5.3.2 The minimum angle between the back-stay and the horizontal is 27° (twice the conductor attachment height on level ground). For angle structures, the plan orientation of the stay will be in line with the opposite span, and not induce additional transverse loads on the structure. Where this is not possible, the back stay may be aligned with the plan view conductor orientation, provided that the minimum horizontal distance between the tower and the back-stay support is four times the conductor attachment height.

4.4.5.3.3 Unless otherwise specified, the recommended pre-tension on back-stays is $0,7 \times \text{EDT}$ of the conductor. The strength of the back-stay arrangement (including the anchor point) shall be capable of withstanding $1,2 \times \text{EDT}$ of the conductor. The sequence of back-staying and pre-tensioning shall minimize the loads. The impact of these loads on the tower shall be checked by calculations.

4.4.5.3.4 The induced vertical and longitudinal loads from the back-stayed conductor are calculated assuming a tension of $1,5 \times \text{EDT}$ and $1,5 \times$ the dead weight of conductors.

4.4.5.3.5 The induced vertical and longitudinal loads from this condition may be assumed from the simplified equations given in figure 6.

4.4.5.3.6 For terminal structures, the longitudinal loads on un-stayed cross-arms is calculated assuming the minimum line deviation angle and a tension of $1,5 \times \text{EDT}$ and $1,5 \times$ the dead weight of conductors.



Legend

V_{c2} is the vertical load on the cross-arm resulting from load case C2.

L_{c2} is the longitudinal load on the cross-arm resulting from load case C2.

Figure 6 — Induced vertical and longitudinal loads on back-stayed cross-arm

4.4.5.4 Maintenance and erection loads

As stated in 6.5.2 and 6.5.4 of IEC 60826:2017, the strength of all erection lifting points and maintenance load lifting points shall resist at least twice the static loads produced by the proposed erection method. A tension of $1,1 \times \text{EDT}$ applies in this case.

Amdt 1

4.4.6 Security loads

4.4.6.1 General

4.4.6.1.1 Security loads are defined as loads produced by conductor bundle or structure failure that has a predominantly longitudinal impact load on supports adjacent to the failure event.

4.4.6.1.2 Two types of security load are considered, i.e.

- a) S1: failure containment loads (applied to complete phase sets simultaneously); and
- b) S2: broken conductor loads (applied to one complete phase at a time).

4.4.6.1.3 Where practical, the corresponding limit state for security loads as defined in table 3 of IEC 60826:2017 may be deemed to be the damage limit, i.e., structural capacity is defined in the same way as for climatic and safety loads. Users may, however, elect to assume that the limit state for security loads corresponds to the failure limit. In this regard any full-scale tests for security loads may be deemed to be satisfactory where components have passed their damage limit but are within the failure limits in accordance with tables 18 to 21 of IEC 60826:2017.

Amdt 1

4.4.6.2 Failure containment loads

4.4.6.2.1 The object of designing for failure containment is to reduce the risk of longitudinal cascading failures over a series of sequential structures. The assumption is that the full impact load of all phases can only partially be absorbed, implying that more than one or a few structures might collapse or be permanently deformed before the cascading failure is contained.

4.4.6.2.2 Suspension structures that support conductors of 132 kV and lower (reliability level 1) need not be designed for failure containment. For such lines, a structure designed for failure containment shall be placed at intervals not exceeding 10 km. For more important sub-transmission lines (for example radial feed or double-circuit lines), or where there is a concern that cascading failure impacts are higher (for example in remote areas or in ice load risk areas), the designer may consider failure containment loads for intermediate structures.

4.4.6.2.3 Where strain structures for all level 1 reliability are not designed for failure containment, these shall be subject to a minimum longitudinal to transverse strength ratio of 1:3. All other cascade resistant structures should be designed considering the failure containment loads.

Amdt 1

4.4.6.2.4 Double-circuit lines for reliability levels greater than level 1 shall be designed assuming the simultaneous failure of one circuit and one earthwire. Single-circuit lines shall be designed assuming the simultaneous failure of all phase conductors and earthwires.

4.4.6.2.5 Residual static loads (RSLs) as defined in 4.4.6.4 and 4.4.6.5 shall be applied at relevant conductor and shield wire attachment points on one longitudinal face of the structure (see figure 4).

4.4.6.2.6 Vertical loads from the broken span side of the structure may be taken as equal to the dead weight of a conductor with length = 2 × the attachment height.

4.4.6.3 Broken conductor loads

4.4.6.3.1 Broken conductor loads are relevant in the case of broken hardware, insulator failure, conductor theft, earth peak or cross-arm failure, which can typically affect one phase at a time, producing an impact load on one side of the structure. The assumption is that the span on one side of the structure will be under full tension, while zero tension on the other side produces a longitudinal or torsional load (or both) on the structure.

4.4.6.3.2 The EMR (see foreword) specifically requires structures that support a crossing span to be designed in such a way that it will be able to withstand the loads that may be imposed upon it should a breakage of any phase conductor or earth conductor occur. It thus follows that all new structures would normally be designed for broken conductor conditions, unless a prohibition, which prevents their use next to crossings, is expressly stated.

4.4.6.3.3 Both suspension and strain structures should be designed for broken conductors. The load from broken conductors will be with one shield wire OR one conductor phase broken on the same side of the structure, so that the maximum torsional load results (see figure 4).

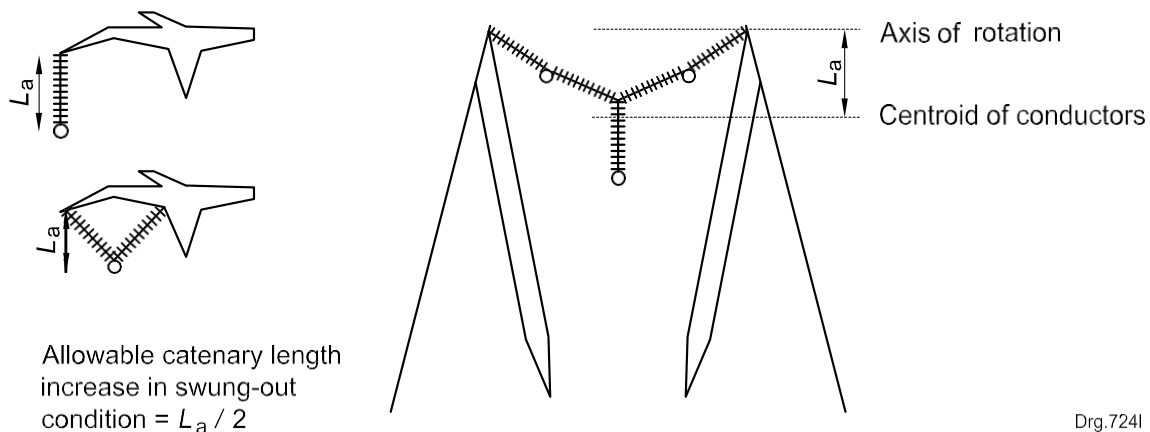
4.4.6.3.4 The resulting tension in the healthy phase opposite to the broken span is assumed to be equal to 1,5 times the residual static load, with no tension or weight assumed in the broken span. The same factors apply to both strain and suspension structures.

4.4.6.4 Calculation of residual static load on suspended or flexible supports

4.4.6.4.1 Suspended or running angle insulator arrangements will, in the event of complete conductor or adjacent structure failure, experience swung-out conditions that will diminish away from the failure point. The net effect of such relaxation in conductor tension (residual static load) may be derived by adding half of the insulator length or estimated support deflection to the span length at everyday tension as illustrated in figure 7.

4.4.6.4.2 The tension reduction on more complex suspension assemblies that carry all phases on a single suspended arrangement (such as suspended delta or chainette configurations), may be derived by adding half of the length from the axis of rotation to the centroid of conductors, to the span length at everyday tension as illustrated in figure 7.

4.4.6.4.3 Suspension structures may be specifically designed to allow for the local failure of cross-arms or post insulator base plates at the tower body attachment, in order to relieve static tension. The net reduction in static tension may be derived by adding half of the post insulator or cross-arm length (in addition to half of the length of suspension assemblies as stipulated above) to the span at everyday tension. The loads shall be applied to the body of the superstructure, which shall be designed to contain the longitudinal load.



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Key

L_a is the distance from the axis of rotation to the centroid of conductors.

Figure 7 — Determination of increase in catenary length for swung-out conditions

4.4.6.4.4 In the case of flexible hardware components, e.g. post insulators, the RSL may be derived assuming half the estimated longitudinal deflection that occurs under EDT applied to one side of the support point. No deflection of the superstructure should be considered in such calculations.

4.4.6.4.5 Structures that utilise a pivoted base configuration will be modelled assuming that the base is restrained against rotation around the vertical axis, unless the base rests on a specifically engineered low friction mounting.

4.4.6.4.6 Calculation methods to determine the RSL are discussed in 4.4.7.

4.4.6.5 Calculation of load from strain assemblies

4.4.6.5.1 In accordance with IEC 60826, strain structures shall have a greater capacity to withstand impact loads. A factor of 1,5 shall be applied to the static everyday tension (EDT).

NOTE It should not be assumed that strain structures designed in accordance with this requirement will fully absorb impact loads.

4.4.6.5.2 Loads are applied at both minimum and maximum line deviation angles.

4.4.6.5.3 Terminal towers need not be checked for failure containment or broken conductors as wind load cases will induce more onerous longitudinal loads.

4.4.7 Coincident tension and vertical loads

4.4.7.1 The everyday tension (*EDT*) that occurs in conductors in load cases with no wind may be determined by the ruling catenary constant and unit weight of the conductor. The effective weight of attached hardware should also be considered in this calculation.

$$EDT = C.(w_c + w_h/L_h)$$

where

C is the catenary constant (m) at a reference temperature of 15 °C;

w_c is the unit weight of the conductor (N/m);

w_h is the weight of attached hardware per conductor in the bundle (N);

L_h is the in-span spacing of attached hardware (m).

4.4.7.2 In the detailed method it is required to calculate with sufficient accuracy, the resultant conductor tension from incident wind pressure, ice loads, temperature changes or deflection of assemblies. Acceptable methods include the use of finite element computer models or other detailed methods (such as the Newton-Rhapson model detailed in annex C), which can be shown to calculate the tension to a minimum accuracy of 5 % compared to a finite element model result.

4.4.7.3 The vertical load factors in table 9 will apply to the dead weight of conductors and hardware for various load cases.

Table 9 — Summary of wire tension and vertical load factors – Detailed method

1	2	3	4
Load case number	Load case	Wire tension load factor (γ_{Lc})	Vertical load factor (γ_{vc})
W1-6	Wind loads	Calculate based on incident pressure	1,1
I1	Ice loads (120 Pa)	Calculate based on ice overload and temperature = -5°C	1,0
	Construction loads		
C1	Stringing: moving wires	$2,0 \times EDT$	2,0
C1	Stringing: landed wires	$1,5 \times EDT$	1,5
C2	Regulation:	$1,5 \times EDT$	1,5
C3	Maintenance and erection	$1,1 \times EDT$	2,0
	Security loads		
S1	Failure containment: strain towers	$1,5 \times EDT$	1,1
S1	Failure containment: suspension towers	$1,0 \times$ residual static load	1,1
S2	Broken conductor and earth wire	$1,5 \times EDT$	1,1

4.5 Design loads for temporary emergency structures

4.5.1 Where temporary line deviations are required for construction purposes, where emergency structures support conductors over road or rail crossings, or where public safety is at risk, an emergency structure shall be designed to reliability level 1.

4.5.2 In the case of other conditions where emergency structures are intended to remain in service for not longer than six months, the load of structures may be as given in table 10.

4.5.3 In the case of all temporary emergency bypasses and structures, appropriate signage should warn the public not to approach the area of reconstruction.

Table 10 — Simplified load cases for emergency structures

1	2
Load case	Requirement
Wind load	800 Pa applied at 90° to the direction of the line with the conductors at everyday tension. Vertical load factor = 1,1.
Construction load	Twice the self-weight of all suspended conductors (including hardware and insulation). Tension = $1,5 \times EDT$. No wind.
Longitudinal load ^a	No stated requirements.
^a Provided public access is restricted to the restoration area, it may be considered preferable to leave conductors in conductive running blocks to prevent any transmission of longitudinal loads to the structure.	

5 Aviation considerations — Application to the aviation authority (see foreword)

The supplier or user of an overhead line shall, in the early planning phase of such a power line route, identify potentially hazardous conditions for aircraft as described in the Civil Aviation Regulations (see foreword) and institute mitigation measures, if necessary, as described in the Civil Aviation Regulations.

6 Waterway considerations — Application to the relevant authority (see foreword)

NOTE Harbours and marinas are considered waterways.

6.1 Where practically possible, the supplier or user of an overhead line shall not make use of overhead lines over waterways and marinas. In the absence of alternative routes, the supplier or user shall identify, in the early planning phase of such a power line route, the potential hazardous conditions for marine craft.

6.2 Where hazards are identified, the supplier or user shall submit an official submission to the relevant authority (see foreword) on the identified hazards. The following documented information shall be included in the submission:

- a) the name of the power line;
- b) a map that indicates the power line route and possible hazards;
- c) a list of co-ordinates of all bend points (latitude and longitude, in degrees, minutes, seconds and tenths of seconds); and
- d) the minimum clearance below the line from the highest expected water level (tide and five year flood line).

6.3 The relevant authority (see foreword) shall evaluate the route and require the supplier or user to mark or re-route those sections of the line (if any), that are considered a danger to marine craft. The relevant authority may require that the supporting structures be marked by the application of a specific marking pattern, or lighted by a combination of low- to high-intensity obstacle lights (or both).

6.4 The relevant authority (see foreword) may also require the supplier or user of the overhead power line to limit approaching marine craft from making contact with the power line by applying overhead barriers.

6.5 Minimum vertical clearance of overhead power lines to rivers and dams that do not form part of waterways shall be in accordance with 10.3.

6.6 The supplier or user of the power line together with the owner of the waterway shall take joint responsibility for ensuring that any marking or barriers are installed and maintained.

7 Aeolian vibration considerations

7.1 Conductors and earthwires are susceptible to aeolian vibration which can cause failure of the conductor or earthwire if not considered and controlled by the designer. One of the contributing factors which can result in aeolian vibration damage is conductor tension or, more specifically, the catenary constant (C) at which the conductor is strung, and can be calculated as follows:

$$C = H/g_c \text{ (in m)}$$

where

H is the horizontal component of conductor tension (N);

g_c is the unit weight of the conductor (N/m).

7.2 It is generally accepted that the higher the C value, the more susceptible the conductor will be to aeolian vibration damage and therefore safe design tensions should be applied to counter this potential damage.

7.3 The recommended safe design tension limits for conductors are given in table 11.

Table 11 — Conductor tension limits — Damped conductors

1	2	3
Conductor condition	Phase conductor	Earthwire
After creep condition at 5 °C	C limit: 2 450 m	C limit: 2 750 m
After creep at <i>EDT</i>	C limit: 1 800 m	C limit: 2 100 m
Ultimate wind/Ice load	70 % of UTS	
NOTE The table does not consider special applications and specialized conductors.		

Amdt 1

7.4 The conductor tension limits for un-damped conductors shall be determined under final (after creep) conditions at a temperature of 15 °C. The C limit is 1 425 m. Where earthwires are present over un-damped conductors, the sag on earthwires should be limited to 90 % of the conductor sag at 15 °C.

Alternatively, conductor tension limits may be determined in accordance with Cigré Brochure 273, which provides guidelines and safe design tensions for both single and bundled conductors of the types AAC, AAAC, ACAR and ACSR. The key guidelines provided in the brochure have been summarized and are given in table D.1 (see annex D). (Copper conductors, steel ground wires and OPGW are not covered in this brochure.)

8 Conductor current rating (ampacity)

8.1 Conductor current ratings (ampacity) can be determined by either assuming the worst case cooling conditions (deterministic method) or by assessing the risk of an unsafe condition that arises (probabilistic method).

8.2 In the case of deterministic ratings, the weather assumptions shall be in accordance with Cigré Brochure 299.

8.3 The deterministic weather parameters are:

- a) wind speed perpendicular to line 0,6 m/s;
- b) absorptivity and emissivity 0,8;
- c) solar radiation (radiant energy) 1 000 W/m²;
- d) ambient temperature 40 °C.

8.4 The deterministic ampacity calculations shall be performed based on the equations found in the article titled *The thermal behaviour of overhead conductors Section 1 and 2: Mathematical model for evaluation of conductor temperature in the steady state and the application thereof*. (Article in the Cigré publication, *Electra*, No. 144.)

8.5 In the case of the deterministic method, the templating or design temperature of the line is the temperature that shall be used in the calculation of the current.

8.6 If the probabilistic method is used, it shall be performed in accordance with the article titled *Probabilistic determination of conductor current ratings*. (Article in the Cigré publication *Electra*, No. 164.)

8.7 The current ratings in different geographical areas with different weather conditions and different load profiles shall not result in the probability of an unsafe condition arising that is higher than the highest probability that already exists in areas in which lines are in operation. Based on current analysis, the probability of an unsafe condition arising shall be not higher than 6×10^{-6} for normal operating conditions.

9 Clearances

9.1 Clearance to ground

9.1.1 The minimum vertical clearance above ground shall be in accordance with the values in column 4 in table E.1. The distances shall be applied taking creep of conductors into consideration. The clearance shall be maintained in a 6 m corridor (3 m either side) below the still air position of the conductor at the templating or design temperature of the conductor but not less than 50 °C. (See figure 8.)

9.1.2 Where conductor positions are blown outside of the 6 m corridor, the vertical clearance shall be maintained for all positions from this point through to the maximum blowout position corresponding to 575 Pa. The 575 Pa wind pressure was conservatively determined to correspond with a 1 in 10 year return period. The vertical clearance outside the 6 m corridor may be checked with a reduced conductor temperature. The suggested value is 50 °C; however, the designer may use the coincident conductor temperature obtained through calculation.

9.1.3 In areas with severe side slopes, the corresponding horizontal clearance applicable to all ground points at the 575 Pa maximum blowout position is the safety clearance given in table E.1, column 8.

9.1.4 Where ice load conditions are applicable, the vertical ground clearance shall be maintained under maximum ice load conditions on the power line conductor at -5 °C and no wind. The ice load thickness will be determined by the designer.

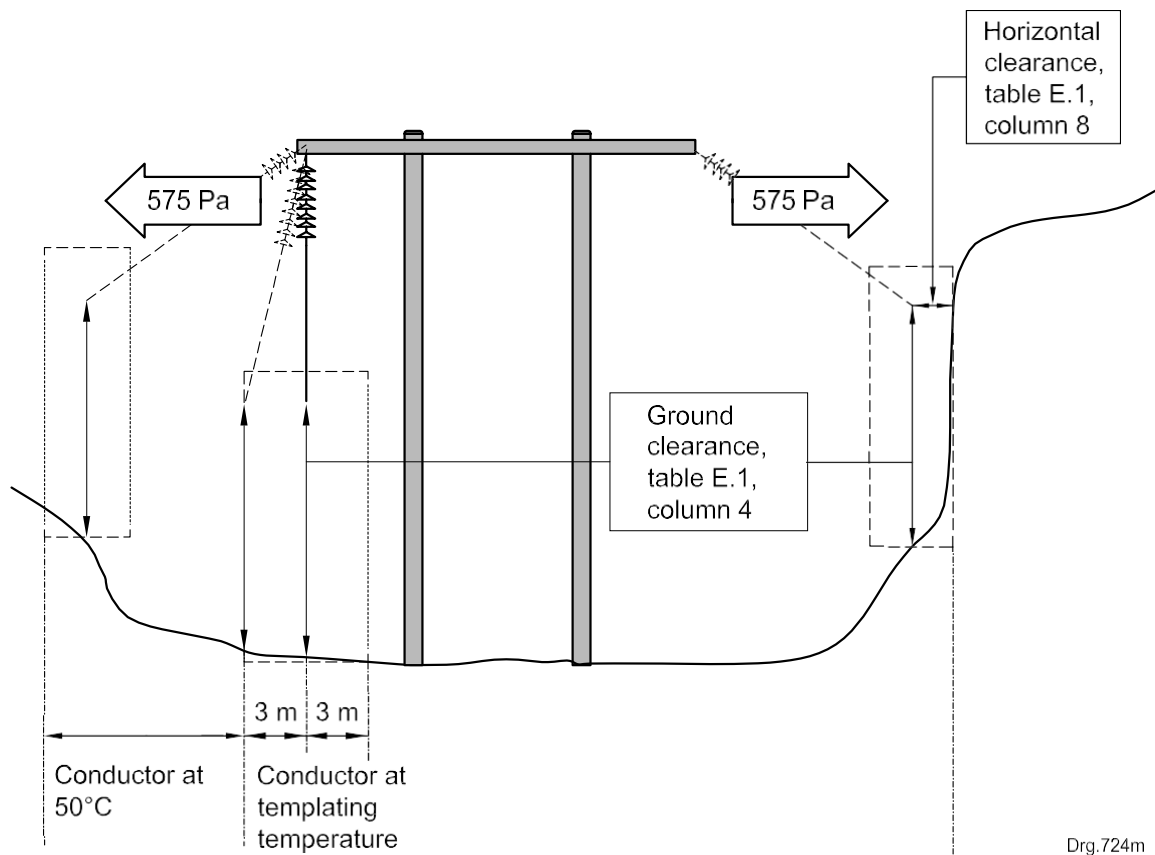


Figure 8 — Clearance of conductors to ground

9.2 Clearances to vegetation, buildings and structures not part of the power line

9.2.1 Except in the case of low-voltage lines of insulated wire of a type approved by the machinery authority (see foreword), the clearances between any live conductor and vegetation, buildings, poles and structures which are not part of power lines shall be in accordance with the values in column 6 in table E.1 in the case of templating or design temperature not less than 50 °C.

9.2.2 This clearance shall be maintained while the conductor is within the 6 m corridor referred to in 9.1.1. In the case of conductor positions outside the 6 m corridor through to the maximum conductor blowout position, the clearance shall be maintained using a suggested conductor temperature of 50 °C. The designer can, however, determine the coincident conductor temperature through calculation. (See figure 9.)

9.2.3 As far as is reasonably practicable, the horizontal distance to objects, including vegetation, likely to fall onto an overhead line conductor, shall be maintained at the height of such object.

9.2.4 At the blowout position that corresponds to 575 Pa, the horizontal clearance applicable to buildings and vegetation shall be maintained in accordance with the values in column 8 in table E.1. Designers may use their discretion in the application of this requirement where such infringements are highly improbable, such as over deep valleys and in rural areas.

9.2.5 The separation of parallel power lines shall be such that a 575 Pa wind pressure from either direction (applied to both lines in the same direction) shall not cause clearance violation (in accordance with column 3 of table E.1) between the power lines. Calculations should be done from the new line to the existing line and vice versa.

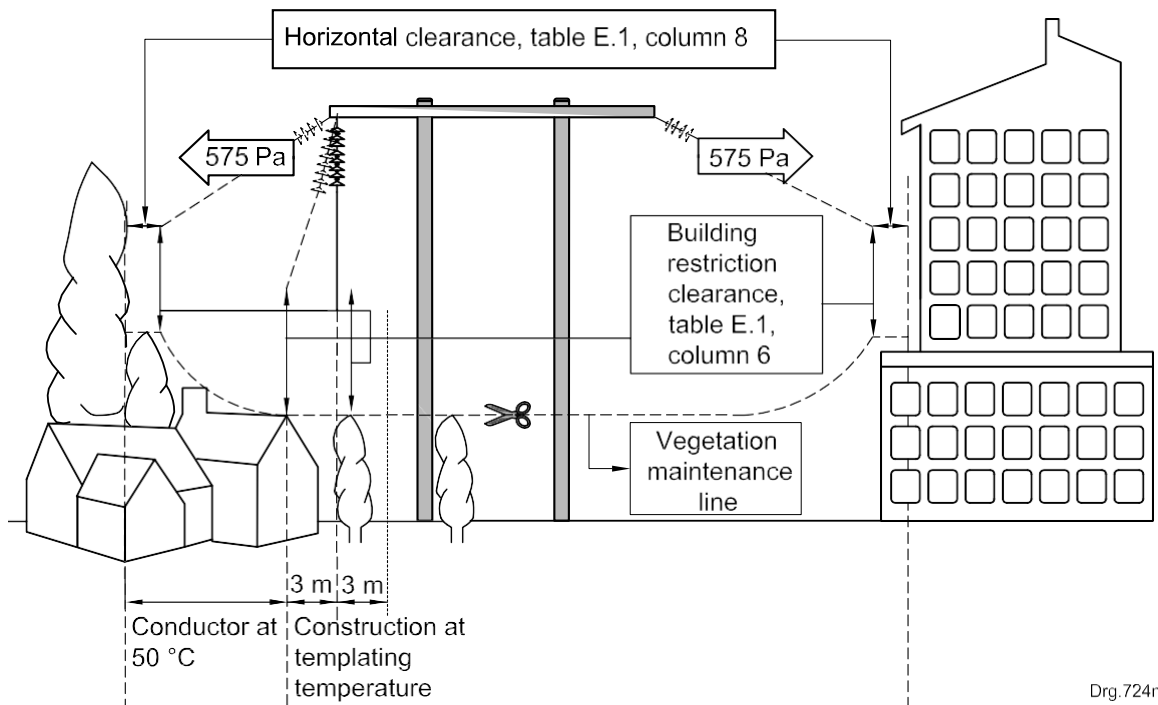


Figure 9 — Clearance of conductors to buildings and vegetation

10 Crossings

10.1 Crossings over roads and railway lines

10.1.1 The line shall be designed to ensure that the likelihood of the conductor or sub-conductor burning off in the event of a flashover in a crossing span is minimized. This can be achieved by the use of arcing horns, or armour rods, or other proven methods (see 3.1).

10.1.2 Conventional armour rods shall not be used where the conductor is secured to a rigid insulator by means of a preformed tie, because in the event of a breakage, the conductor can slide through the ungritted armour rods and the crossing span clearance would consequently be reduced to below the minimum of 4,5 m as required in the EMR (see foreword). To overcome this problem, a full-wrap preformed twin tie shall be used, which, in addition to fixing the conductor securely to the rigid insulator, also protects the conductor against damage in the event of flashover.

10.1.3 The line shall be so designed as to ensure that damage to the line conductors adjacent to the crossing cannot jeopardize the integrity of the crossing span.

10.1.4 If the crossing span is strained off at each end, the crossing will not be affected by damage to the conductors beyond the crossing. It is, therefore, unnecessary to fit arcing horns or armour rods to the live end of insulators on strain or intermediate structures beyond the crossing span. In the crossing span itself, however, arcing horns are required where the conductor could be burnt off in the event of a flashover.

10.1.5 The EMR (see foreword) requires that every structure that supports a crossing span, as far as is reasonably practicable, will be located in such a way that it will not touch the service crossed, should it overturn, and that one of the structures will be placed as close to the point of crossing as is reasonably practicable.

10.1.6 The clearances that shall be maintained over roads and railway track crossings are given in column 5 of table E.1. Railway crossings owned by the railway authority (see foreword) may require clearances additional to those given in column 5.

10.1.7 The clearances to roads and railways shall be verified in the case of the load cases given in (a) and (b).

a) Still air and maximum swing: the clearances shall be maintained under still air conditions through to the maximum conductor blowout positions at conductor templating or design temperatures but not less than 50 °C. The maximum conductor blowout shall be calculated using a wind pressure of 575 Pa.

b) Ice load (where applicable): the clearances shall be maintained under maximum ice load on the power line conductor over the road or railway at -5 °C with no wind.

10.2 Crossings between power lines or power lines and telecommunication lines

10.2.1 In addition to the pertinent requirements specified in 10.1, the requirements in 10.2 shall be adhered to at crossings between power lines and power lines and telecommunication lines.

10.2.2 In the case of line crossings, the line of higher voltage should be above the lower voltage line.

10.2.3 In the absence of an agreement between the power utility and the telecommunications network service licensee on line crossing angles, table F.2 shall be used.

10.2.4 The clearance values to be maintained in all directions between the conductors of crossing lines shall correspond to the values in table E.1 for the clearance of the higher voltage line given in column 7 of table E.1. These values apply in the case of power line conductors that cross over power line earth conductors or over telecommunication conductors.

10.2.5 Clearances shall be maintained under the conductor conditions given in (a), (b) and (c).

a) Vertical clearance

The minimum clearance between power lines as stated in column 7 of table E.1 shall be determined by considering the templating or design temperature of the top line (minimum 50 °C) with the lower line conductor not exceeding 15 °C.

b) Conductor swing

If the orientation of the line crossing is such that blowout of the conductors could cause a reduction in the distance between the conductors of the different lines, the clearances given in column 3 in table E.1 shall be maintained in all positions through to the maximum blowout position of the conductor.

Clearance shall be maintained while one conductor is subjected to a wind pressure of 575 Pa and the other conductor is in still air conditions.

c) Ice loading (where applicable)

Clearances (column 3 in table E.1) shall be maintained under maximum ice loading on the upper conductor at -5 °C with no wind, and on the lower conductor with no ice or wind at -5 °C.

10.2.6 The clearances between conductors provided in column 7 of table E.1 are electrical clearances required to maintain operation of the lines under normal and abnormal operating conditions. Additional clearances may be required for inspection of crossings and during live line maintenance.

10.2.7 Power lines that cross power lines of the railway authority (see foreword) may require additional clearances to those provided in table E.1.

NOTE Deleted by amendment No. 1.

10.3 Crossings over water

10.3.1 In general, normal ground clearances shall be provided. However, where crossings are made over rivers, dams or lakes, which are, or could be, used as recognized sailing waters, a clearance of 2,5 m plus the relevant minimum safety clearance (in accordance with column 3 in table E.1) shall be provided; this clearance covers a distance over the tallest boat mast likely to be encountered on such water under conditions of a normal high-water level and maximum conductor sag. **Amdt 1**

10.3.2 The tallest boat mast to be encountered on inland waters is not likely to exceed 15,5 m. Checks should, however, be carried out for particular stretches of water that are to be crossed.

10.3.3 The clearances in 10.3.1 and 10.3.2 should be maintained in the case of access routes to and in the immediate vicinity of navigable waters.

10.4 In the proximity of and in crossings of LV feeders and service connections with telecommunication services

The minimum separation requirements are given in columns 7 and 8 of table E.1.

NOTE Deleted by amendment No. 1.

11 Earthing of power line towers and poles

11.1 Dangerous step and touch potentials can occur around power line towers and poles under fault conditions. In the case of MV and HV lines these conditions only exist for a short period until the fault is cleared by the protection system. In the case of LV systems certain types of fault may go undetected for extended periods of time.

11.2 LV system protection is not capable of clearing certain types of fault. This can lead to sustained potentially dangerous situations. As a safety measure against this situation it is advised that on LV structures made of insulating or semi-insulating material (such as wood, fibre glass or concrete) use will be made of insulated earth down leads to prevent accidental contact with these earth conductors. This measure shall be applied in high public exposure areas.

The risk in the case of conducting poles such as steel poles is very difficult to avoid and no avoidance measures are recommended.

11.3 HV and MV structures can lead to dangerous voltages under fault conditions for short durations until the fault is cleared by protection. Where such risks exist in areas of high public exposure, measures to guard against step and touch potential hazards or public notices (or both) should be considered.

NOTE Due to the costs involved in achieving safe step and touch potentials around a tower, the requirement in 11.3 is only applicable in high public exposure areas. This means that compliance with safe transferred potentials is practically not possible.

12 Communication lines, fences and pipelines

12.1 Power lines can induce voltages which may be dangerous on nearby communication lines. General rules and criteria for design in this case are given in annex F.

12.2 Power lines can induce voltages which may be dangerous on both fences and pipelines during both steady state and fault conditions. It shall be ensured that these induced voltages are safe when contact is made with the fence or pipeline. Safety measures might involve inclusion of additional earthing or equipotentialization (or both).

12.3 In the case of an existing line, the party that constructed the pipeline shall comply with the safety requirements for induced voltage. The party that constructed the fence shall notify the electricity utility of the construction in writing. The notification and approval of the building of a power line shall be done in accordance with the relevant legislation (see foreword).

NOTE It is recommended that the electricity utility should inform the landowner about the safety of fences in close proximity to power lines and provide technical guidance if necessary.

13 Design limits for electric and magnetic fields

13.1 The design limits for electric and magnetic fields in table 12 shall be observed. These limits are based on the safety levels set by IEEE standard C95.6 and the exposure guidelines provided by the International Commission on Non-Ionising Radiation Protection (ICNIRP) in accordance with the recommendations made by the World Health Organization (WHO). **Amdt 1**

13.2 All measurements shall be performed in accordance with SANS 62110.

NOTE The occupational exposure should be dealt with in appropriate industry standards.

Table 12 — Design limits for electric and magnetic field strength

Amdt 1

1	2	3
Applicable to	Limit	Method of evaluation ^a
General public	5 kV/m at servitude boundary and 10 kV/m maximum inside the servitude	SANS 62110
General public	200 μ T	SANS 62110
NOTE 1 μ T (microtesla) is the unit for magnetic field level.		
NOTE 2 kV/m (kilovolt per metre) is the unit for electric field level.		
^a When measurements are made.		

Amdt 1

14 Warning signs

14.1 All structures should be marked with a label clearly identifying the line and structure number. Structures supporting multiple circuits shall include labelling which identifies each circuit.

14.2 Where line crossings could affect the safety of aerial line inspections, 3 structures on either side of the crossing point should be marked, with a line crossing label. The label should consist of a black "X" not less than 400 mm in height on a reflective background, placed at the highest practical point on the structure.

14.3 Designers shall also consider induction on insulated wires and components that may be within reach of maintenance staff accessing structures, for example on insulated OPGW down-leads. Such conditions should be avoided where possible, and where unavoidable, suitably located warning labels should advise maintenance staff to apply working earths when accessing towers.

Amdt 1

14.4 In high public exposure areas (see 3.1), warning signs (see 14.5) shall be installed on overhead power lines, transformers and auxiliary equipment structures considered to be easily climbable, that do not have anti-climb devices, and are in close proximity to the following areas:

Amdt 1

- a) outdoor public assembly areas including parks, schools, sports grounds, township (electrification) areas, rural pathways; and
- b) specific installations (including installations on private property) adjacent to holiday resorts, game farms, farmhouses, dairies, stores, processing plants, bottle stores and spaza shops.

NOTE Easily climbable structures include the following:

- a) any pole, or structure, or apparatus, particularly lattice structures, that is easy to climb;
- b) any structure that is installed as a strut to a vertical structure;
- c) any structure that is planted less than one metre from another structure;
- d) any structure that has parallel or diverging stay wires attached;
- e) any structure that has a cable or cables installed and are secured by means of strapping at intervals of less than 500 mm;
- f) any structure that has equipment, cables, earthing, bracing or any other component which could cause the equipment to become an effective ladder or means to enable assisted climbing of the structure; and
- g) shared structures.

14.5 The warning signs shall clearly indicate that there is imminent danger in the vicinity. Due to various languages being in use, the signs shall be pictorial in nature, for example a lightning flash.

Amdt 1

Annex A

(informative)

Calculation of wind force on conductors using the simplified method

A1 The subdivision of conductor loads into left and right span loads, and into x- and y-components is detailed in this annex. It is necessary to separate the load into these components, since the wind incidence on the conductor may be different to the left and the right spans, as illustrated in figure A.1.

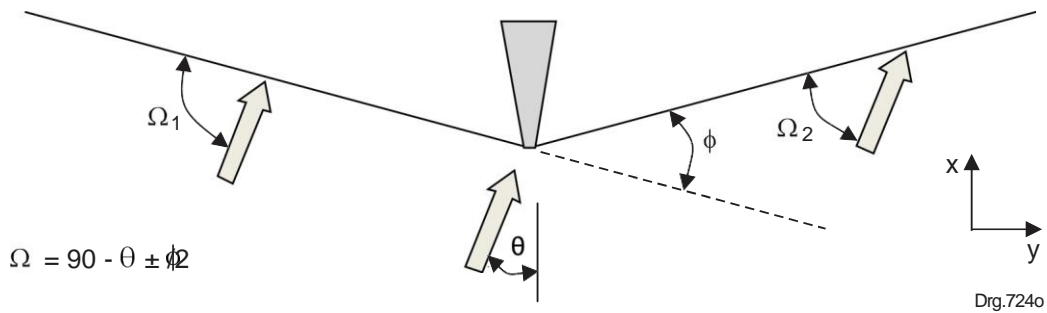


Figure A.1 — Angle between wind direction, conductor, and cross-arm axis (bisector) of the line structure

A2 The factored transverse load from conductors (γQ_{cx}) is given by

$$\gamma Q_{cx} = \gamma Q_{cx1} + \gamma Q_{cx2}$$

where

$\gamma Q_{cx1,2}$ is the transverse load from conductors on the left and the right hand spans, (N);

and, for example

$$\begin{aligned} \gamma Q_{cx2} &= A_{cx2} + T_{cx2} \\ &= A_c \cdot \cos(\phi/2) + T_c \cdot \sin(\phi/2) \\ &= q_c \cdot (d \cdot L_2 + 2 \cdot S_{i2}) \sin^2 \Omega_2 \cdot \cos(\phi/2) + (0,9 + q_c \sin^2 \Omega_2 \cdot L_2^{0,54} / (6450 g_c^{0,5})) \cdot g_c \cdot C \cdot \sin(\phi/2) \end{aligned}$$

where

L_2 is the wind span (m), on the right hand span = 0,5 × right span length;

S_{i2} is the assembly area that supports the right hand span (m^2);

Ω_2 is the wind incidence (degrees), to the right span = $90 - \theta - \phi/2$.

A3 The force from conductors in the longitudinal direction will be equal and opposite only when the wind incidence is 0° (as in load case W1). For load case W2, such as illustrated in figure A.1, the different incident pressures between the left and the right hand spans will induce a net longitudinal load on the structure. Thus the factored longitudinal load from conductors (γQ_{cy}) is given by

$$\gamma Q_{cy} = \gamma Q_{cy1} - \gamma Q_{cy2}$$

where

$\gamma Q_{cy1,2}$ is the longitudinal load from conductors on the left and right hand spans (N);

$$\begin{aligned} \gamma Q_{cy2} &= A_{cy2} + T_{cy2} \\ &= A_c \cdot \sin(\phi/2) + T_c \cdot \cos(\phi/2) \end{aligned}$$

A4 The subdivision of loads x- and y- components for other wind loads (as applied to poles and towers) is performed in a similar way to the way given above.

Annex B
(informative)

**Ice load incidents on overhead lines recorded in South Africa:
1982 to 2009**

The following table was recorded by collating first-hand accounts of operational experience from 1982 to 2009. Radial ice thicknesses refer mostly to wet snow accretion incidents and were not in all instances recorded scientifically.

Table B.1 — Ice load incidents on overhead lines recorded in South Africa: 1982 to 2009

Incident No.	Date of incident	Location indicated on map?	Closest town	Severity of ice load, estimated radial ice thickness (or educated guess)	Type and voltage of affected structures	Estimated number of structures affected	Failure type: mark with X			
							Conductor failure	Earth wire failure	Tower/cross-arm failure	No failure
1	Sept. 2001	Yes	Volksrust	50 mm	400	1			X	
2	Jun. 1996	Yes	Machado-dorp	5 mm	0 kV	0				X
3	Oct. 1982	Yes	eMahlaleneni	10 mm	11 kV	Unknown				X
4	Jul. 1997	Yes	Carolina	5 mm	11 kV	Unknown				X
5	Jul. 1997	Yes	Belfast	5 mm	11 kV	Unknown				X
6	Jul. 1997	Yes	Dullstroom	5 mm	11 kV	Unknown				X
7	Sept. 2001	Yes	Volksrust	30 mm	400	1		X		
8	Sept. 2001	Yes	Newcastle	30 mm	400	1		X		
9	Jun. 2001	Yes	Ceres	10 mm	22 kV	0				X
10	Jul. 2002	Yes	Ceres	10 mm	22 kV	0				X
11	Aug. 2003	Yes	Ceres	5 mm	22 kV	0				X
12	Jul. 2001	Yes	Calvinia	5 mm + wind	22 kV	3	X		X	
13	Jul. 2002	Yes	Sutherland	70 mm	22 kV	20	X		X	
14	Sept. 2001	Yes	Kamberg	50 mm	88 kV	3		X	X	
15	Sept. 2001	Yes	Harrismith	55 mm	11 kV – 22 kV		X			
16	Jul. 1996	Yes	Bulwer	50 mm	88 kV	5			X	

Table B.1 (concluded)

Incident No.	Date of incident	Location indicated on map?	Closest town	Severity of ice load, estimated radial ice thickness (or educated guess)	Type and voltage of affected structures	Estimated number of structures affected	Failure type: mark with X			
							Con-ductor failure	Earth wire failure	Tower/cross-arm failure	No failure
17	Jul. 1996	Yes	Underberg	50 mm	88 kV	2			X	
18	Sept. 2001	Yes	Kokstad	20 mm	22 kV	2	X		X	
19	Jul. 2000	Yes	Reitz	30 mm Trees fell	22 kV		X			
20	Jul. 1996	Yes	Bethlehem	60 mm	11 kV – 22 kV		X			
21	Jul. 1996	Yes	Clarens	65 mm	11 kV – 22 kV	35			X	
22	Jul. 1996	Yes	Ladybrand	30 mm	11 kV		X			
23	Aug. 1995	Yes	Elliot	40 mm	66 kV		X			
24	Aug. 1995	Yes	Barkley East	30 mm	22 kV	4	X		X	
25	Aug. 1995	Yes	Ugie	30 mm	22 kV		X			
26	Aug. 1995	Yes	Maclear	30 mm	22 kV		X			
27	Aug. 2002	Yes	Hogsback	Unknown	22 kV		X			
28	Aug. 2002	Yes	Tarkastad	Unknown	22 kV		X			
29	Aug. 2002	Yes	Cradock	45 mm	22 kV		X		X	
30	Sept. 2001	Yes	Matatiele	20 mm	22 kV				X	
31	Sept. 2001	Yes	Cedarville	20 mm	22 kV				X	
32A	Jul. 1996	Yes	Boston	50 mm	88 kV	3			X	
32B	Jul. 1997	Yes	Boston	50 mm	88 kV	2		X		
33	Jul. 1996	Yes	Elandskop	50 mm+	88 kV	Substation (tripped)				X
34	Jul. 1996	Yes	Taylor's Halt	50 mm+	132 kV	4		X		
35	Jul. 1996	Yes	Nottingham Road	50 mm+	22 kV	Shed roof collapse				X
36	Jul. 2009	Yes	Elliot	30 mm	22 kV	12	X			
37	Jul. 2009	Yes	Cradock	30 mm	22 kV	3	X			
38	Jul. 2008	Yes	Sutherland	50 mm	22 kV	5	X			
39	Jul. 2009	Yes	RD165	30 mm	22 kV	1	X			

Annex C

(informative)

Newton-Rhapson procedure for calculating change in conductor tension due to change of state

The change in conductor tension due to temperature change, ice loads, support displacement and wind pressure may be calculated using the procedure given in this annex.

This procedure requires successive iterations to converge to the solution, and is suited for use in software programs or spreadsheet applications capable of automating the process.

The tension approximation after n iterations (T_n) is calculated by modifying the previous approximation (T_{n-1}) by a differential (F/k), until the two values converge. Thus

$$T_n = T_{n-1} - \frac{F}{k}$$

and

$$F = S + \frac{S^3 M_1^2}{24 T_{n-1}^2} - L_0 \left[1 + \frac{(T_0 - T)}{AE} \right] \frac{(1 + \alpha \Delta T)(S + \Delta L)}{S}$$

$$k = \frac{-0.083 S^3 M_1^2}{24 T_{n-1}^3} - \frac{L_0 (1 + \alpha \Delta T)(S + \Delta L)}{AES}$$

where

S is the chord span length taking in account elevation, in metres (m);
(may be taken = 0,9 design wind span for general conditions);

M_1 is the effective weight due to combined mass and wind loading, in Newtons per metre (N/m);

$$= \sqrt{(M_0 + M_i)^2 + W_i^2}$$

where

M_0 is the conductor unit weight including attached hardware, in Newtons per metre (N/m);

M_i is the overload unit weight onto the conductor, in Newtons per metre (N/m);

W_i is the wind load per unit length = $P_i d$, in Newtons per metre (N/m);

P_i is the incident wind pressure at right angles to the conductor, in Pascals (Pa);

d is the conductor diameter, in metres (m);

L_0 is the initial length of conductor curve, in metres (m);

$$L_0 = S + \frac{S^3 M_0^2}{24 T_0^2}$$

where

T_0 is the input tension = $M_0.C$, in Newtons (N);

ΔL is the displacement of conductor support along the conductor arc, in metres (m);

A is the cross-sectional area of all conductor strands, in millimetres squared (mm^2);

E is Young's modulus (use either initial (unstretched) or final (after creep) values from conductor supplier catalogues, in Newtons per millimetres squared (N/mm^2);

α is the conductor thermal expansion coefficient, in degrees Celsius to the power of minus one ($^{\circ}\text{C}^{-1}$);

ΔT is the change in conductor temperature from reference, in degrees Celsius ($^{\circ}\text{C}$).

Annex D
(informative)

**Recommended conductor safe design tensions with respect to
aeolian vibrations**

D.1 The notes in (a) to (e) should be read in conjunction with table D.1.

- a) Only suspension clamp supports are covered. Pin insulator supports or tie-rods that are used to attach the conductor to the insulator are not covered.
- b) The use of armour rods or special supporting devices such as cushioned clamps and helical elastomeric-bushed suspensions may justify higher design tensions.
- c) Only Stockbridge type dampers are covered in the case of span end-damping. Helical impact type dampers, "Bretelle" and "Festoon" type dampers are not covered.
- d) The recommended C-values used are based on the **initial** horizontal tension, before wind and ice load and **before** creep at the average temperature of the coldest month on the site of the line.

D.2 If cases are encountered which are not covered by Cigré brochure 273, the designer shall satisfy himself by further research, testing, measurement or other means, ensuring that the line design would not suffer from premature failure due to aeolian vibration.

Table D.1 — Summary of safe design tensions (from Cigré brochure 273)

1	2		3		4		5	
Conductor system	Terrain cat. 1		Terrain cat. 2		Terrain cat. 3		Terrain cat. 4	
	H/w m	LD/m m ³ /kg	H/w m	LD/m m ³ /kg	H/w m	LD/m m ³ /kg	H/w m	LD/m m ³ /kg
1 Unclamped single conductor	< 1 000		< 1 125		< 1 225		< 1 425	
2 Single conductor with span-end Stockbridge dampers	<2615(LD/m) ^{0,12}	<15	<2780(LD/m) ^{0,12}	<15	<2860(LD/m) ^{0,12}	<15	<3030(LD/m) ^{0,12}	<15
3 Unclamped, unspaced twin, triple and quad bundled conductors	<1 000		<1 125		<1 125		<1 425	
4 Unspaced twin, triple and quad bundled conductors with span-end Stockbridge dampers	<2615(LD/m) ^{0,12}	<15	<2780(LD/m) ^{0,12}	<15	<2860(LD/m) ^{0,12}	<15	<3030(LD/m) ^{0,12}	<15
5 Twin horizontal bundled conductors with non-damping spacers	<1 725	<15	<1 925	<15	<2 100	<15	<2 450	<15
6 Twin horizontal bundled conductors with non-damping spacers and span-end Stockbridge dampers	<2615(LD/m) ^{0,12}	<15	<2780(LD/m) ^{0,12}	<15	<2860(LD/m) ^{0,12} <2 100	<13 >13; <15	<3030(LD/m) ^{0,12} <2 450	<6 >6; <15
7 Twin horizontal bundled conductors with damping spacers	<1 900		<2 200		<2 500		<2 500	
8 Triple apex-down bundled conductors with non-damping spacers	<1 850	<15	<2 100	<15	<2 275	<15	<2 500	<15
9 Triple apex-down bundled conductors with non-damping spacers and span-end Stockbridge dampers	<2615(LD/m) ^{0,12}	<15	<2780(LD/m) ^{0,12} <2 100	<10 >10; <15	<2860(LD/m) ^{0,12} <2 275	<7 >7; <15	<3030(LD/m) ^{0,12} <2 500	<5 >5; <15
10 Triple apex-down bundled conductors with damping spacers	<2 500		<2 500		<2 500		<2 500	
11 Quad horizontal bundled conductors with non-damping spacers	<1 850	<15	<2 100	<15	<2 275	<15	<2 500	<15
12 Quad horizontal bundled conductors with non-damping spacers and span-end Stockbridge dampers	<2615(LD/m) ^{0,12}	<15	<2780(LD/m) ^{0,12} <2 100	<10 >10; <15	<2860(LD/m) ^{0,12} <2 275	<7 >7; <15	<3030(LD/m) ^{0,12} <2 500	<5 >5; <15
13 Quad horizontal bundled conductors with damping spacers	<2 500		<2 500		<2 500		< 2 500	
Terrain cat. 1: Open, flat, no trees, no obstruction, with snow cover, or near/across large bodies of water or flat desert. Terrain cat. 2: Open, flat, no obstruction, no snow, for example farmland without any obstruction, summer time. Terrain cat. 3: Open, flat or undulating with very few obstacles, for example open grass of farmland with few trees, hedgerows and other barriers, prairie, tundra. Terrain cat. 4: Built-up with some trees and buildings, for example residential suburbs, small towns, woodlands and shrubs. Small fields with bushes, trees and hedges. H: initial horizontal tension; w: conductor weight per unit length; L: actual span length; D: conductor diameter; m: conductor mass per unit length								

Annex E (normative)

Clearances required for power lines that cross services

E.1 Table E.1 shows the minimum clearances required in accordance with legislation (see foreword) (see also clause 9 for the application of clearances in table E.1).

E.2 The safety clearances in column 3 of table E.1 shall not be interpreted as specifying line equipment clearances. The line equipment clearances are based on the equipment insulation level for the appropriate voltage level of the power line, the latter being chosen to ensure a flashover across the insulation of the line rather than from the line to other objects within the basic clearance in the case of an overvoltage.

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Table E.1 — Minimum clearances for power lines

1	2	3	4	5	6	7	8
Highest system r.m.s. voltage kV	System nominal r.m.s. voltage kV	Minimum safety clearance m	Minimum vertical clearances m				Horizontal clearances m
			Ground clearance, all areas	Roads in townships and proclaimed roads, railways ^e	To buildings, poles, structures not part of power lines and vegetation	To tele-communication lines and between power lines	To all ground, buildings, vegetation and structures not part of the power line
<1	–	–	4,9 ^a	6,1 ^a	3,0 ^b	0,6 ^b	3 ^b
7,2	6,6	0,15	5,5	6,2	3,0	0,7	3
12	11	0,20	5,5	6,3	3,0	0,8	3
24	22	0,32	5,5	6,4	3,0	0,9	3
36	33	0,43	5,5	6,5	3,0	1,0	3
48	44	0,54	5,5	6,6	3,0	1,1	3
72	66	0,77	5,7	6,9	3,2	1,4	3
100	88	1,00	5,9	7,1	3,4	1,6	3
145	132	1,45	6,3	7,5	3,8	2,0	3
245	220	2,1	7,0	8,2	4,5	2,7	3
300	275	2,5	7,4	8,6	4,9	3,1	3
362	330	2,9	7,8	9,0	5,3	3,5	3
420	400	3,2	8,1	9,3	5,6	3,8	3,2
800 ^c	765	5,5	10,4	11,6	8,5	6,1	5,5
533d.c. ^d	–	3,7	8,6	9,8	6,1	4,3	3,7

^a For minimum vertical clearance requirements which are applicable to low voltage overhead lines to ground, as well as road and railway crossings – Refer to table E.2.

^b The minimum clearance of electric conductors and other wires of power lines, excluding overhead service connections and line conductors having a voltage not exceeding 1,1 kV r.m.s. consisting of insulated wire of a type which complies with a safety standard incorporated for this purpose in these requirements or SANS 1481-1 and SANS 1418-2 (aerial bundled conductor systems) or SANS 1507-6 (concentric cables) to be not less than the clearances indicated in this table.

^c The clearances provided in this table are intended to ensure the safety of personnel. Increased distances will be required to limit levels of electric fields, magnetic fields and audible noise which are dependent on the system voltage, conductor and bundle spacing, phase configuration and spacing, and the current carried by conductors.

^d Maximum voltage to earth, for which insulation is designed.

^e Certain railway authorities may have more onerous clearance requirements.

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Table E.2 — Minimum vertical clearance requirements applicable to low voltage overhead lines to ground, as well as road and railway crossings <1kV

1	2	3	4
Minimum vertical clearance at 50 °C			
Conductor type	Ground clearance proclaimed roads and railway crossings	Ground clearance other roads, tracks, registered business stand entrances	Ground clearance excluding roads, railway crossings, registered business stand entrances
<1kV LV Bare	6,1	4,9	4,9
<1kV LV ABC	6,1	4,9	3,7
<1kV (Concentric)	6,1	4,7	3

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Annex F (normative)

Directives on power lines and telecommunication circuits

F.1 Notification and approval of the electronic communication network service licensee (see foreword)

In the case of an existing line, the party that constructed the pipeline or fence shall comply with the limits for induced voltages.

The notification and approval of the building of a power line shall be done in accordance with electronic communication legislation (see foreword).

F.2 Telecommunication system induced safety voltage limits

F.2.1 The ITU-T Recommendation K.68 permissible safety levels shall be adopted.

F.2.2 Induced voltages under steady state and fault conditions shall not exceed the values given in table F.1.

Table F.1 — Induced safety voltage limits for telecommunication systems

1	2
Induced duration t s	Induced voltage V_{rms} V
$t < 0,2$	1 030
$0,2 < t < 0,35$	780
$0,35 < t < 0,5$	650
$0,5 < t < 1,0$	430
$t > 1$	60

F.3 Combined and parallel routes

F.3.1 Common structures

Common structures shall comply with the requirements agreed between the relevant power and telecommunication authorities.

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F.3.2 Independent structures

If an overhead telecommunication line and a power line or if two power lines are erected parallel to each other along the same route, the separation between lines shall be such that, with both lines healthy, the clearance between any conductor of the higher-voltage line and any conductor or earth-wire of the lower-voltage line is never less than the minimum phase-to-phase clearance applicable to the higher-voltage line. See table F.1.

This clearance shall be maintained for all conditions up to maximum sag and maximum side swing of the conductors of either line. It is assumed that the other line remains in the template position for still air, and that the maximum side swing occurs at design wind pressure at a conductor temperature of 50 °C below the design temperature but not less than 40 °C.

F.4 Power line and telecommunication line crossings

The power line route should cross the telecommunication line route, as nearly as possible, at right angles. Where this is impracticable, the deviations from a right-angle crossing in table F.2 are permitted.

Table F.2 — Maximum deviation angles on telecommunication line crossings

1	2
Operating voltage of line	Permissible deviation from right angle
Below 48 kV	45°
48 kV and above	30°

Bibliography

British standards

BS 3551, *Specification for alloy steel shackles.*

BS 4429, *Specification for rigging screws and turnbuckles for general engineering, lifting purposes and pipe hanger applications.*

BS 5649-5, *Lighting columns – Part 5: Specification for base compartments and cableways.*

BS 6091-1, *Vulcanized fibre for electrical purposes – Part 1: Specification of general requirements.*

BS 6091-2, *Vulcanized fibre for electrical purposes – Part 2: Methods of test.*

CSIR/Eskom report

CSIR report, Eskom Contract No. 550.22461, November 1990, *Recommendations for transmission line loading.* Available from the Transmission Line Technology Manager, Eskom, Private Bag X13, Halfway House, 1685.

IEC standards

IEC 60038, *IEC standard voltages.*

IEC 60050-466, *International Electrotechnical Vocabulary – Chapter 466: Overhead lines.*

South African specifications and standards

~~NRS 033, *Electricity distribution – Guidelines for the application design, planning and construction of medium voltage overhead power lines up to and including 22 kV, using wooden pole structures and bare conductors.*~~

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~~NRS 034-3, *Electricity distribution – Guidelines for the provision of electrical distribution networks in residential areas – Part 3: Overhead distribution in very low, low and moderate consumption areas, including rural areas and informal settlements.*~~

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~~NRS 044, *Working procedures and standards in respect of the installation of new electrical works and telecommunication facilities, or the extension or modification of such existing works and facilities.*~~

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SANS 182-1, *Conductors for overhead electrical transmission lines – Part 1: Copper wires and stranded copper conductors.*

SANS 182-2, *Conductors for overhead electrical transmission lines – Part 2: Stranded aluminium conductors.*

SANS 182-3, *Conductors for overhead electrical transmission lines – Part 3: Aluminium conductors, steel reinforced.*

SANS 182-5, *Conductors for overhead electrical transmission lines – Part 5: Zinc-coated steel wires for conductors and stays.*

SANS 1019, *Standard voltages, currents and insulation levels for electricity supply.*

SANS 1418-1, *Aerial bundled conductor systems – Part 1: Cores.*

SANS 1418-2, *Aerial bundled conductor systems – Part 2: Assembled insulated conductor bundles.*

SANS 1507-6, *Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1 900/3 300 V) – Part 6: Service cables.*

SANS 61089/IEC 61089, *Round wire concentric lay overhead electrical stranded conductors.*

Other publications

Amdt 1

IEEE C95.6, *IEEE standard for safety levels with respect to human exposure to electromagnetic fields, 0 – 3 kHz.*

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International Commission on Non-Ionizing Radiation Protection. *ICNIRP Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz).* Health Physics; December 2010, Volume 99, Number 6.

World Health Organization (WHO). 2007. *Extremely low frequency fields, environmental health criteria monograph No. 238.* Geneva: WHO.

Amdt 1