

Overhead electrical lines exceeding AC 45 kV —

Part 1: General requirements — Common specifications

ICS 29.240.20

National foreword

This British Standard is the UK implementation of EN 50341-1:2001+A1:2009. It supersedes BS EN 50341-1:2001 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/11, Overhead lines.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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30 April 2010	Implementation of CENELEC amendment A1:2009, which is appended at the back of this document

Overhead electrical lines exceeding AC 45 kV
Part 1: General requirements -
Common specifications

Lignes électriques aériennes dépassant
AC 45 kV
Partie 1: Règles générales -
Spécifications communes

Freileitungen über AC 45 kV
Teil 1: Allgemeine Anforderungen -
Gemeinsame Festlegungen

This European Standard was approved by CENELEC on 2001-01-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 11, Overhead electrical lines exceeding AC 1 kV (DC 1,5 kV).

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Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, annexes E, G, J & K are normative and annexes A, B, C, D, F, H, L, M, N, P, Q & R are informative.

As far as the overhead lines towers are concerned, the designer may refer to ENV 1993-3-1, as prepared by TC 250 of CEN, if considered appropriate.

Foreword to amendment A1

This amendment was prepared by the Technical Committee CENELEC TC 11, Overhead electrical lines exceeding 1 kV a.c. (1,5 kV d.c.).

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Introduction

Detailed structure of the standard

The standard comprises three parts:

Part 1: General requirements - Common specifications

This part, also referred to as the Main Body, includes clauses common to all countries. These clauses have been prepared by Working Groups and approved by CLC/TC 11.

The Main Body is available in English, French and German.

Part 2: Index of National Normative Aspects

This index gives the list of all the National Normative Aspects (NNAs) - see signification and contents of NNAs hereafter under "Part 3: National Normative Aspects".

The index is available in English, French and German.

Part 3: National Normative Aspects

The National Normative Aspects (NNAs) reflect national practices. They generally include A-deviations, special national conditions and national complements.

A-deviations:

A-deviations are required by existing national laws or regulations, which cannot be altered at the time of preparation of the standard.

Reference is made to CENELEC Internal Regulations Part 2, definition 3.1.9.

Special national conditions (snc):

Special national conditions are national characteristics or practices that cannot be changed even over a long period, e.g. those due to climatic conditions, earth resistivity, etc.

Reference is made to CENELEC Internal Regulations, Part 2, definition 3.1.7/ 3.1.9.

National complements (NCPTs):

National complements reflect national practices, which are neither A-deviations, nor special national conditions. It has been agreed within CLC/TC 11 that NCPTs should be gradually adapted to the Main Body, aiming at the usual EN standard structure including only a Main Body, A-deviations and special national conditions.

Rules for the numbering of NNAs:

The NNAs are numbered as follows :

AT	Austria	EN 50341-3-1
BE	Belgium	EN 50341-3-2
CH	Switzerland	EN 50341-3-3
DE	Germany	EN 50341-3-4
DK	Denmark	EN 50341-3-5
ES	Spain	EN 50341-3-6
FI	Finland	EN 50341-3-7
FR	France	EN 50341-3-8
GB	Great Britain	EN 50341-3-9
GR	Greece	EN 50341-3-10
IE	Ireland	EN 50341-3-11
IS	Iceland	EN 50341-3-12
IT	Italy	EN 50341-3-13
LU	Luxembourg	EN 50341-3-14 (non existant)
NL	Netherlands	EN 50341-3-15
NO	Norway	EN 50341-3-16
PT	Portugal	EN 50341-3-17
SE	Sweden	EN 50341-3-18
CZ	Czech Republic	EN 50341-3-19
x	xxxx	EN 50341-3-xx, etc.

Language:

The NNAs are published in English and in the national language(s) of the respective country.

1 Scope

This standard applies to overhead electric lines with rated voltages exceeding 45 kV AC and with rated frequencies below 100 Hz.

This standard specifies the general requirements that shall be met for the design and construction of new overhead lines to ensure that the line is suitable for its purpose with regard to safety of persons, maintenance, operation and environmental considerations.

NOTE 1 The extent of the application of this standard by each country in respect of existing overhead lines is subject to the requirements of the National Normative Aspects (NNA) applicable to that country.

NOTE 2 Design and construction of overhead lines with insulated conductors, where internal and external clearances can be smaller than specified in the standard are not included. All other requirements of the standard may be applied to overhead lines with insulated conductors. When necessary, requirements for clearances can be given in the NNAs.

NOTE 3 This part of the standard is applicable for optical Ground Wires (OPGWs) and optical Conductors (OPCONs). However the standard is not applicable to telecommunication systems which are used on overhead transmission lines either attached to the transmission line conductor/earth wire system (for example wraparound,...) or as separate cables supported by the transmission supports for example All Dielectric Self Supporting (ADSS) or for telecommunication equipment mounted on individual transmission line structures. When necessary, requirements can be given in the NNAs.

This standard does not apply to :

- overhead electric lines inside closed electrical areas as defined in HD 637;
- catenary systems of electrified railways.

2 Definitions, symbols and references

2.1 Definitions

For the purposes of this European Standard, the terms and definitions given in the International Vocabulary (IEC 60050) Chapters 441, 466, 471, 601 and 604 and the following apply.

In order to achieve a better understanding of the definition of certain terms used in this standard, some words in the definitions are written in *italics*. The definitions of these words are also given in this subclause.

2.1.1 action

- a) force (load) applied to the (*mechanical*) system (direct action).

NOTE An action can be *permanent*, *variable* or *accidental*.

- b) an imposed or constrained deformation or an imposed acceleration caused for example, by temperature changes, moisture variation, uneven settlement or earthquakes (indirect action)

2.1.2 accidental action

action, usually of short duration, which is unlikely to occur with a significant magnitude during the *design working life*

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

2.1.3

bonding conductor

conductor providing equipotential bonding

2.1.4

box values

numerical values identified by "box values" are given as indication. Other values may be specified by NCs in NNAs

2.1.5

characteristic resistance

value of mechanical *resistance* calculated using characteristic values of material properties. These values may be obtained from ENV 1992-1-1, ENV 1993-1-1 or ENV 1995-1-1

2.1.6

characteristic value of a material property

value of a material property having a prescribed probability of not being attained in a hypothetical unlimited test series. This value generally corresponds to a specified fraction of the assumed statistical distribution of the particular property of the material. A nominal value is used as the characteristic value in some circumstances

2.1.7

characteristic value of an action

principal representative value of an action. In so far as this characteristic value can be fixed on statistical bases, it is chosen so as to correspond to a prescribed probability of not being exceeded on the unfavourable side during a "*reference period*" taking into account the *design working life* of the *system* and the duration of the *design situation*

2.1.8

clearance

distance between two conductive parts along a string stretched the shortest way between these conductive parts [IEV 441-17-31]

2.1.9

coefficient of variation

ratio of the standard deviation to the mean value

2.1.10

combination of actions

set of *design values of actions* used for the verification of the *structural reliability* for a *limit state* under the *load case*

2.1.11

combination factor for an action

factor used for the determination of the *combination value for an action*

2.1.12

combination value for an action

value associated with the use of *combinations of actions* to take account of a reduced probability of simultaneous occurrence of the most unfavourable values of several independent *actions*. Value obtained by multiplying the *characteristic value of an action* by the *combination factor for an action* or, in special circumstances, by direct determination

2.1.13

component

one of the different principle parts of the overhead electrical line system having a specified *purpose*. Typical components are *supports*, foundations, *conductors*, insulator strings and hardware

2.1.14

conductor (of an overhead line)

one or more aluminium, aluminium alloy, copper, zinc coated or aluminium clad steel wires, or combinations thereof, wrapped together which collectively have the function of conducting an electrical current [IEV 466-01-15: A wire or combination of wires not insulated from one another, suitable for carrying an electric current]

2.1.15

corona

luminous discharge due to ionisation of the air surrounding an electrode caused by a voltage gradient exceeding a certain critical value

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

2.1.16

current to earth

current flowing to earth via the *impedance to earth*

2.1.17

design resistance

structural *resistance* associating all structural properties with the respective *design value of the material properties*

2.1.18

design situation

set of physical conditions representing a *reference period* for which the design will demonstrate that the relevant *limit states* are not exceeded

2.1.19

design value of a material property

value obtained by dividing the *characteristic value of a material property* by the *partial factor for the material property* or, in special circumstances, by direct determination

2.1.20

design value of an action

value obtained by multiplying the *characteristic value of an action* by the *partial factor for an action*

2.1.21

design working life

assumed period for which a *structure* is to be used for its intended *purpose* with anticipated *maintenance* but without substantial repair being necessary

2.1.22

dynamic action

action which causes significant acceleration of the *structure* or structural *elements*

2.1.23

earth

term for the earth as a location as well as for earth as a conductive mass, for example types of soil, humus, loam sand, gravel and stone

2.1.24

earth electrode

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

2.1.25

earth fault

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

2.1.26

earth fault current

current which flows from the main circuit to *earth* or earthed parts if there is only one *earth fault* point at the fault location (*earth fault* location)

2.1.27

earth potential rise

voltage between an *earthing system* and *reference earth*

2.1.28

earth rod

earth electrode which is generally buried or driven in vertically to a greater depth. For example it can consist of a pipe, round bar or other profile material

2.1.29

earth surface potential

voltage between a point on the earth surface and *reference earth*

2.1.30

earthing

all means and measures for making a proper conductive connection to earth

2.1.31

earthing conductor

conductor which connects that part of the installation which has to be earthed to an *earth electrode* as far as it is laid outside of the soil (*earth wire*) or buried in the soil

2.1.32

earthing system

locally limited *electrical system* of conductively connected *earth electrodes* or *earthing conductors* and of *bonding conductors*, [or metal parts effective in the same way, for example tower footings, armourings, metal cable sheaths]

2.1.33

earth wire

a conductor connected to earth at some or all supports, which is suspended usually but not necessarily above the line conductors to provide a degree of protection against lightning strokes [IEV 466-10-25]

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

2.1.34

effective field strength

square root of the sum of the squares of the three root mean square (r.m.s.) mutually orthogonal components of the field

2.1.35

effect of action

effect of *actions* on structural *elements* for example: internal force, moment, stress, and strain. The design value of the effect of *action* is the total effect of the respective *design values of actions*

2.1.36

electric field

the electric field created in the vicinity of a charged *conductor* is the vector quantified by the electric field strength, *E*. This quantity is the force exerted by an electric field on a unit charge and is measured in volts per metre (V/m)

2.1.37

element

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

2.1.38

equipotential bonding

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

2.1.39

exclusion limit probability of a variable

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

2.1.40

external clearances

all *clearances* which are not "*internal clearances*". They include those to the ground plane, roads, buildings and installations (if they are permitted by National Statute) and to objects which can be on any of these

2.1.41

failure (structural)

state of a *structure* whose *purpose* is terminated, i.e. in which a *component* has failed by excessive deformation, loss of stability, overturning, collapse, rupture, buckling, etc.

2.1.42

fixed action

action which has a fixed distribution over the *structure* such that the magnitude and direction of the *action* are determined unambiguously for the whole *structure* if this magnitude and direction are determined at one point on the *structure*

2.1.43

foundation earth electrode

conductor which is embedded in concrete and is in contact with the *earth* via a large surface

2.1.44

free action

action which may have any spatial distribution over the structure within given limits

2.1.45

frequently occupied area

area which people will occupy so frequently that risk of simultaneous *earth fault* must be considered (examples: playgrounds, pavements of public roads, close vicinity of residences, etc.)

NOTE Utilities should define these areas.

2.1.46

highest system voltage

highest (r.m.s.) value of voltage which occurs at any time and at any point of the overhead line under normal operating conditions and for which the overhead electrical line shall be designed

2.1.47

horizontal earth electrode

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

2.1.48

impedance to earth of an earthing system

impedance between the *earthing system* and *reference earth*

2.1.49

internal clearance

clearance between phase *conductors* and earthed parts such as steel *structural elements* and *earth wires* and also those between phase *conductors*. Also included are *clearances* to other circuits on the same *support*

2.1.50

limit state (structural)

state beyond which the *structure* no longer satisfies the design performance requirements

2.1.51

load arrangement

identification of the position, magnitude and direction of a *free action*

2.1.52

load case

compatible *load arrangements*, sets of deformations and imperfections considered simultaneously with defined *variable actions* and *permanent actions* for a particular verification

2.1.53

magnetic field

the magnetic field is a vector quantity. The magnetic field strength, H , is expressed in amperes per metre (A/m)

2.1.54

magnetic flux density

the magnetic flux density, also known as the magnetic induction, is the force exerted on a charge moving in the field and has the unit tesla (T). One tesla is equal to $1 \text{ V}\cdot\text{s}/\text{m}^2$ or 1 weber per square metre (Wb/m^2)

2.1.55

maintenance

total set of activities performed during the *design working life* of the *system* to maintain its *purpose*

2.1.56

nominal voltage

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

2.1.57

optical conductor (OPCON)

conductor containing optical telecommunication fibres

2.1.58

optical groundwire (OPGW)

optical conductor used solely as an *earth wire*. The conductor *component* may be stranded or may be tubular or a combination of both

2.1.59

partial factor for an action

factor depending on the selected *reliability* level, taking in account the possibility of unfavourable deviations from the *characteristic value of actions*, inaccurate modelling and uncertainties in the assessment of the *effects of actions*

2.1.60

partial factor for a material property

factor covering unfavourable deviations from the *characteristic value of material properties*, inaccuracies in applied conversion factors and uncertainties in the geometric properties and the *resistance* model

2.1.61

permanent action

action which is likely to act throughout a given *design situation* and for which the variation in magnitude with time is negligible in relation to the mean value, or for which the variation is always in the same direction (monotonic) until the *action* attains a certain limit value

2.1.62

perturbed/unperturbed electric field

electric field in the vicinity of a conducting object which is "perturbed" by the presence of such object. In this case, for practical purposes, reference may be made to the "unperturbed *electric field*" (i.e., the field that would exist in the absence of the object)

2.1.63

potential grading

influencing of the earth potential, especially the *earth surface potential*, by means of *earth electrodes*

2.1.64

potential grading earth electrode

conductor which due to shape and arrangement is principally used for *potential grading* rather than for establishing a certain resistance to *earth*

2.1.65

project specification

document supplied by the client to the contractor and containing adequate details of all the requirements for materials, design, manufacture and erection for a particular *system* or for a *component* of a line. The Project specification may supplement the requirements of the standard but it shall not relax their technological requirements and it shall not supersede the minimum requirements specified in this standard. It should be reduced to a minimum for each project, i. e. to truly unique or specific details

2.1.66

purpose

function of the *system* (overhead electrical line), i.e. to transmit electrical power between its two ends, or of a part of the system

2.1.67

quasi-static action

dynamic action that can be described by static models in which the dynamic effects are included

2.1.68

radio interference

any effect on the reception of a required radio signal due to an unwanted disturbance within the radio-frequency spectrum. Radio interference is primarily of concern for amplitude-modulated systems (AM radio and television video signals) since other forms of modulation (such as frequency modulation (FM) used for VHF radio broadcasting and television audio signals) are generally much less affected by disturbances that emanate from overhead lines

2.1.69

reduction factor of a three phase line

ratio, r , of the *earth fault current* (or earth return current) over the sum of the zero sequence currents in the phase *conductors* of the main circuit

2.1.70

reference earth (remote earth)

those parts of the *earth* outside the influence area of an *earth electrode* or an *earthing system*, where, between any two points, no perceptible voltages due to the current to earth occur

2.1.71

reference period

period taking into account the *design working life* of the *system* or of one of its *elements* and/or of the *characteristic value of an action*

2.1.72

reliability (electrical)

ability of a system to meet its supply function under stated conditions for a given time interval

2.1.73

reliability (structural)

probability that a *system* performs a given *purpose*, under a set of conditions, during a *reference period*. Reliability is thus a measure of the success of a *system* in accomplishing its *purpose*

2.1.74

resistance (structural)

mechanical property of a *component*, of a cross-section or of an *element* of a *structure*, e.g. bending resistance, buckling resistance. Resistance is the capacity to withstand collapse, or any other form of structural *failure*, which may endanger the *safety* of people or have a deleterious effect on the functioning of the *system*

NOTE Resistance against the following effects may require consideration : - loss of equilibrium of the structure or any part of it, considered as a rigid body, - failure by excessive deformation, rupture, or loss of stability of the structure or any part of it, including supports and foundations.

2.1.75

resistance to earth of an earth electrode

electrical resistance of the *earth* between the *earth electrode* and the *reference earth*. In practice this is a pure resistance

2.1.76

return period

mean interval between successive recurrences of a climatic *action* of at least defined magnitude. The inverse of the return period gives the probability of exceeding the *action* in one year

2.1.77

safety

ability of a *system* not to cause human injuries or loss of lives during its construction, operation and maintenance

2.1.78

security

ability of a *system* to be protected from a major collapse (cascading effect) if a *failure* is triggered in a given *component*. This may be caused by electrical or structural factors

2.1.79

serviceability limit state

state beyond which specified service criteria for a *structure* or structural *element* are no longer met

2.1.80

soil resistivity

specific electrical resistance of the *earth*

2.1.81

sparkover

disruptive discharge

2.1.82

static action

action which does not cause significant acceleration of the *structure* or structural *elements*

2.1.83

step voltage

that part of the *earth potential rise* which can be picked up by a person with a step-width of 1 m, i.e. the current flowing through the human body from foot to foot

2.1.84

strength

mechanical property of a material, usually given in units of stress

2.1.85

structure

organised combination of connected *elements* designed to provide some measure of rigidity

2.1.86

support

general term for different types of *structure* that support the *conductors* of the overhead electrical line

2.1.87

support, angle

suspension or tension support used at an angle point of a line

2.1.88

support, section

tension support with or without a line angle serving additionally as rigid point in a line to limit cascading

2.1.89

support, suspension

support equipped with suspension insulator sets

2.1.90

support, tangent

suspension or tension support used in straight line

2.1.91

support, tension

support equipped with tension insulator sets

2.1.92

support, terminal (dead-end)

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

2.1.93

system (mechanical)

set of *components* connected together to form an overhead electrical line

2.1.94

system (electrical)

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

2.1.95

system with isolated neutral

system (electrical) in which the neutrals of transformers, generators and earthing transformers are not intentionally connected to earth, except for high impedance connections for signalling, measuring or protection purposes

2.1.96

system with low-impedance neutral earthing

system (electrical) in which at least one neutral of a transformer, earthing transformer or generator is earthed directly or via an impedance designed such that due to an *earth fault* at any location the magnitude of the fault current leads to a reliable automatic tripping

2.1.97

system with low-impedance neutral or phase earthing

system (electrical) with isolated neutral or resonant earthing, in which in case of a non-self-extinguishing *earth fault* a neutral or phase *conductor* of the main circuit is earthed directly or via low impedance a few seconds after the occurrence of an *earth fault*

2.1.98

system with resonant earthing

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

2.1.99

television interference

special case of *radio interference* for disturbances affecting the frequency ranges used for television broadcasting

2.1.100

touch voltage

that part of the *earth potential rise* across the human body from hand to feet (assumed to be at a horizontal distance of 1 m from the exposed part of the installation)

2.1.101

transferred potential

potential rise of an *earthing system* caused by a current to *earth* transferred by means of a connected *conductor* (for example cable metal sheath, pipeline, rail) into areas with low or no potential rise to *reference earth*

2.1.102

ultimate limit state

state associated with collapse, or with other forms of structural *failure* which may endanger the safety of people

NOTE It corresponds generally to the maximum load-carrying resistance of a structure or a structural element.

2.1.103

unavailability

inability of a *system* to accomplish its *purpose*. Unavailability of an overhead electrical line results from structural *failure* or insufficient *electrical reliability* as well as from *failure* due to other unforeseeable events such as landslides, impact of objects, sabotage, defects in material, etc.

2.1.104

unreliability (structural)

complement to (*structural*) *reliability* or the probability of (*structural*) *failure*

2.1.105

variable action

action which is unlikely to act throughout a given *design situation* or for which the variation in magnitude with time is neither negligible in relation to mean value nor monotonic

2.1.106

voltage difference

voltage acting as a source voltage in the touching circuit with a limited value that guarantees the safety of a person when using additional known resistances (for example footwear or standing on surface insulating material)

2.2 List of symbols

Symbol	Signification	References
A	Accidental action	3.4.1
A	Area projected on a plane perpendicular to the wind	4.2.2.3
A_K	Characteristic value of an accidental action	3.4.2
A_K	Characteristic residual conductor tension	4.2.7
A_{ins}	Projected area of an insulator set	4.2.2.4.2
A_{pol}	Projected area of a pole	4.2.2.4.4
A_t	Effective area of the elements of a tower panel face	4.2.2.4.3
A_{tc}	Effective area of the elements of the lattice crossarm face	4.2.2.4.3
A_{tn}	Effective area of the elements of lattice tower panel face n	4.2.2.4.3
a_{so}	Straight line distance between live parts and earthed parts	5.3.5.1
a_{som}	Minimum value of a _{so}	5.3.5.1
b₁, b₂	Width of the lattice tower panel	4.2.2.4.3
C_c	Drag factor for conductors	4.2.2.4.1
C_{cl}	Drag factor for ice covered conductors	4.2.4.2
C_{ins}	Drag factor for insulator sets	4.2.2.4.2
C_{pol}	Drag factor for poles	4.2.2.4.4
C_{tc}	Drag factor for lattice crossarms in a wind perpendicular to the crossarm face	4.2.2.4.3
C_{tn}	Drag factor for lattice tower panel face n	4.2.2.4.3
C_x	Drag factor for component	4.2.2.3
D	Equivalent diameter of ice covered conductors	4.2.4.4
D_{el}	Minimum air clearance required to prevent a disruptive discharge between phase conductors and objects at earth potential during fast front or slow front overvoltages. D _{el} may be either internal when considering conductor to tower structure clearances or external when considering conductor to obstacle clearances.	5.3.5.1

Symbol	Signification	References
D_{pp}	Minimum air clearance required to prevent a disruptive discharge between phase conductors during fast front or slow front overvoltages. D_{pp} is an internal clearance	5.3.5.1
$D_{50Hz_p_e}$	Minimum air clearance required to prevent a disruptive discharge at power frequency voltage between a phase conductor and objects at earth potential. $D_{50Hz_p_e}$ is an internal clearance.	5.3.5.1
$D_{50Hz_p_p}$	Minimum air clearance required to prevent a disruptive discharge at power frequency voltage between phase conductors. $D_{50Hz_p_p}$ is an internal clearance.	5.3.5.1
d	Diameter of a conductor	4.2.2.4.1
d	Distance from the top of a pole	7.6.2.2
E	Electric field strength	2.1.36
E	Total value of the effect of actions	-
E_d	Total design value of the effect of actions	3.7.3
F	Action (force or imposed deformation)	3.4.1
F_d	Design value of an action	3.7.2
F_K	Characteristic value of an action	3.4.2
$F_{R,d}$	Design load for the ultimate limit state	7.3.8
$F_{test, R}$	Minimum test load	7.3.8
F_T	Characteristic value of an action with a return period T	3.7.2
G	Permanent action	3.4.1
G_K	Characteristic value of a permanent action	3.4.2
G_K	Characteristic value of self weight of conductors, insulators and supports	4.3.11
G_c	Structural resonance factor for conductors or span factor	4.2.2.4.1
G_{ins}	Structural resonance factor for insulator sets	4.2.2.4.2
G_{pol}	Structural resonance factor for poles	4.2.2.4.4
G_q	Gust response factor	4.2.2.3

Symbol	Signification	References
G_t	Structural resonance factor for lattice tower	4.2.2.4.3
G_x	Structural resonance factor for component	4.2.2.3
g	Peak factor for wind	4.2.2.3
H	Reference altitude for determination of air density	4.2.2.2
H	Magnetic field strength	2.1.53
H	Total length of concrete pole	7.6.4
h	Height above ground	4.2.2.1.4
h	Height of the lattice tower panel	4.2.2.4.3
I	Ice load per unit conductor length	4.2.3.3
I_K	Characteristic ice load per unit conductor length	4.2.3.2
I_R	Reference ice load per unit conductor length	4.2.3.2
K_a	Altitude factor	5.3.4
K_g	Gap factor	5.3.5.2
K_{g_sf}	Switching impulse gap factor for the air gap	5.3.5.2
k_T	Terrain factor	4.2.2.1.5
k_g	Wind speed gust factor	4.2.2.1.4
k_1	Reduction factor for minimum clearance	5.4.3
L	Span length	4.2.2.4.1
L	Length of tower leg	7.7.5.3
L_R	Ruling span	4.2.10.1
L_w	Contribution of the weight span	4.2.3.3
L_n	Span length of span n	4.2.2.4.1
n	Number of variable	3.7.4
Q	Variable action	3.4.1

Symbol	Signification	References
Q_{CK}	Characteristic value of actions resulting from conductor tensile forces	4.3.11
Q_I	Force on conductors from ice loads	4.2.3.3
Q_{IK}	Characteristic value of ice action on conductors	4.2.4.1
Q_K	Characteristic value of a variable action	3.4.2
Q_P	Construction and maintenance loads	4.2.6.1
Q_{PK}	Characteristic value of construction and maintenance loads	4.3.11
Q_{WK}	Characteristic value of wind action	4.2.4.1
Q_{Wc}	Wind force on a tangent support	4.2.2.4.1
Q_{Wins}	Wind force on insulator set	4.2.2.4.2
Q_{Wpol}	Wind force on a pole	4.2.2.4.4
Q_{Wt}	Wind force on a lattice tower panel	4.2.2.4.3
Q_{Wtc}	Wind force on a lattice crossarm	4.2.2.4.3
Q_{Wx}	Wind force on any element of the line	4.2.2.3
Q_n	Variable action n	3.7.4
Q_{nK}	Characteristic value of variable action n	3.7.4
Q_o	Background response part	4.2.2.3
Q_l	Dominant variable action	3.7.4
q	Dynamic wind pressure	4.3.2
q_c	Dynamic wind pressure on conductors	4.3.2
q_h	Dynamic wind pressure at height h above ground	4.2.2.2
q_x	Dynamic wind pressure on any element of the supports or insulator sets	4.3.2
R	Structural resistance	-
R_a	Additional electrical resistance	6.2.4.3
R_b	Backflashover rate	5.3.3.5

Symbol	Signification	References
R_d	Structural design resistance	3.7.3
R_k	Characteristic value of the foundation resistance	8.5.2.1
R_{sf}	Shielding failure flashover rate	5.3.3.5
R_x	Resonant response part	4.2.2.3
r	Reduction factor of a three phase line	2.1.69
T	Return period of a climatic action	3.2.2
T_n	Return period of a variable action n	3.7.4
T_o	Initial horizontal tension in a conductor	4.2.7
T_1	Return period for a dominant variable action	3.7.4
T'	Absolute temperature at a reference altitude H	4.2.2.2
t_F	Duration of the fault current	6.2.4.3
U_D	Voltage difference acting as a source voltage in the touching circuit with a limited value that guarantees the safety of a person when using additional known resistances (e.g. footwear, standing surface insulating material)	6.2.4.2
U_E	Earth potential rise	6.2.4.2
U_T	Touch voltage	6.2.4.2
U_{Tp}	Permissible touch voltage, i.e. the voltage across the human body	6.2.4.2
U_{cw}	Co-ordination withstand voltage	5.3.1
U_{rp}	Representative overvoltage	5.3.1
U_{rw}	Required withstand voltage	5.3.1
U_s	Highest system voltage	5.3.2.2
V	Wind speed	4.2.2.1.1
V_{ih}	Wind speed associated with icing at a height h above ground	4.2.4.3
V_R	Reference wind speed	4.2.2.1.5
$V_{R(II)}$	Reference wind speed at nearby measuring site of category II	4.2.2.1.5

Symbol	Signification	References
V_g	Gust wind speed	4.2.2.1.1
V_h	Wind speed at height h above ground	4.2.2.1.6
V_{mean}	Mean wind speed	4.2.2.1.1
X_K	Characteristic value of a material property	3.7.2
X_d	Design value of a material property	3.7.2
X_{nK}	Characteristic value of a material property n	3.7.3
X_{nd}	Design value of material property n	3.7.3
z_o	Ground roughness parameter	4.2.2.1.4
α	Exponent for the variation of wind speed with height above ground	4.2.2.1.6
α	Reduction factors for ice loads	4.2.10.2
β	Reduction factor for conductor tension	4.2.7
γ	Partial factor	4.2.11
γ_A	Partial factor for an accidental action	3.7.2
γ_C	Partial factor for conductor tensile loads	4.3.11
γ_F	Partial factor for actions	3.7.2
γ_G	Partial factor for a permanent action	3.7.2
γ_I	Partial factor for an ice action	4.2.4.1
γ_M	Partial safety factor for a material property	3.7.2
γ_P	Partial factor for construction and maintenance loads	4.2.11
γ_{Pt}	Partial factor for action on prestressing force	7.6.4
γ_Q	Partial factor for a variable action	3.7.2
γ_{Qn}	Partial factor for a variable action n	3.7.4

Symbol	Signification	References
γ_w	Partial factor for a wind action	4.2.11
ρ	Air density	4.2.2.2
ρ_E	Resistivity of the ground near the surface ($\Omega.m$)	6.2.4.3
ρ_I	Ice density	4.2.4.2
ρ'	Air density corresponding to an absolute temperature T' and a reference altitude H	4.2.2.2
ϕ	Angle of incidence for the critical wind direction	4.2.2.4.1
ϕ	Angle between wind direction and the longitudinal axis of the lattice crossarm	4.2.2.4.3
χ	Solidity ratio of a tower panel	4.2.2.4.3
Ψ	Combination factor for an action	4.2.11
Ψ_I	Combination factor for an ice action	4.2.4.1
Ψ_Q	Combination factor for a variable action	3.4.3
Ψ_{Qn}	Combination factor for variable action n	3.7.4
Ψ_w	Combination factor for a wind action	4.2.4.1

2.3 References

This European Standard incorporates, by either normative or informative reference, provisions from other publications. These references are cited at the appropriate places in the text together with a statement indicating whether the reference is normative in this standard or informative. All references are undated and the latest edition of the publication referred to applies.

The publications are listed hereafter. These references are in accordance with the CEN and CENELEC catalogues and the Catalogue of IEC publications dated 2001.

Reference	Title
EN ISO 1461	Hot dip galvanised coatings on fabricated ferrous products – Specifications and test methods
EN ISO 9001	Quality systems. Model for quality assurance in design, development, production, installation and servicing
EN ISO 9002	Quality systems. Model for quality assurance in production, installation and servicing

Reference	Title
EN ISO 9003	Quality systems. Model for quality assurance in final inspection and test
EN ISO 14713	Protection against corrosion in iron and steel – Zinc and aluminium coatings - Guidelines
EN 10025	Hot rolled products of non alloy structural steels - Technical delivery conditions
EN 10149	Hot-rolled flat products made of high yield strength steels for cold forming
EN 10204	Metallic products. Types of inspection documents
EN 12465	Wood poles for overhead lines – Durability requirements ¹⁾
EN 12479	Wood poles for overhead lines – Sizes – Methods of measurement and permissible deviations
EN 12509	Wood poles for overhead lines – Test methods – Determination of modulus of elasticity, bending strength, density and moisture content ¹⁾
EN 12510	Wood poles for overhead lines – Strength grading criteria ¹⁾
EN 12511	Wood poles for overhead lines – Determination of characteristic values ¹⁾
EN 12843	Precast concrete masts and poles ¹⁾
EN 22063	Metallic and other inorganic coatings - Thermal spraying - Zinc, aluminium and their alloys
EN 50182	Conductors for overhead lines - Round wire concentric lay stranded conductors
EN 50183	Conductors for overhead lines - Aluminium-magnesium-silicon alloy wires
EN 50189	Conductors for overhead lines - Zinc coated steel wires
EN 50326	Conductors for overhead lines - Characteristics of greases ¹⁾
EN 50351	Basic standard for the calculation and measurement methods relating to the influence of electric power supply and traction systems on telecommunication systems ¹⁾
EN 50352	Limits relating to the influence of electric power supply and traction systems on telecommunication systems ¹⁾
EN 60071-1	Insulation co-ordination -- Part 1: Definitions, principles and rules (IEC 60071-1)
EN 60071-2	Insulation co-ordination -- Part 2: Application guide (IEC 60071-2)
EN 60305	Insulators for overhead lines with a nominal voltage above 1 kV - Ceramic or glass insulators for a.c. systems - Characteristics of insulator units of the cap and pin type (IEC 60305)
EN 60383-1	Insulators for overhead lines with a nominal voltage above 1 000 V Part 1: Ceramic or glass insulator units for a.c. systems - Definitions, test methods and acceptance criteria (IEC 60383-1)
EN 60383-2	Insulators for overhead lines with a nominal voltage above 1 000 V Part 2: Insulator strings and insulator sets for a.c. systems - Definitions, test methods and acceptance criteria (IEC 60383-2)

¹⁾ In preparation.

Reference	Title
EN 60433	Insulators for overhead lines with a nominal voltage above 1 000 V - Ceramic insulators for a.c. systems - Characteristics of insulator units of the long rod type (IEC 60433)
EN 60437	Radio interference tests on high-voltage insulators (IEC 60437)
EN 60507	Artificial pollution test on high voltage insulators to be used on a.c. systems (IEC 60507)
EN 60794-1-1	Optical fibre cables -- Part 1-1: Generic specification - General (IEC 60794-1-1)
EN 60794-1-2	Optical fibre cables -- Part 1-2: Generic specification - Basic optical cable test procedures (IEC 60794-1-2)
EN 60865-1	Short circuit currents - Calculation of effects -- Part 1: Definitions and calculation methods (IEC 60865-1)
EN 60889	Hard-drawn aluminium wire for overhead line conductors (IEC 60889)
EN 61232	Aluminium-clad steel wires for electrical purposes (IEC 61232)
EN 61284	Overhead lines - Requirements and tests for fittings (IEC 61284)
EN 61325	Insulators for overhead lines with a nominal voltage above 1 000 V - Ceramic or glass insulator units for d.c. systems - Definitions, test methods and acceptance criteria (IEC 61325)
EN 61395	Overhead electrical conductors - Creep test procedures for stranded conductors (IEC 61395)
EN 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 (IEC 61466-1)
EN 61466-2	Composite string insulator units for overhead lines with a nominal voltage greater than 1 000 V -- Part 2: Dimensional and electrical characteristics (IEC 61466-2)
EN 61773	Overhead lines - Testing of foundations for structures (IEC 61773)
EN 61854	Overhead lines - Requirements and tests for spacers (IEC 61854)
EN 61897	Overhead lines - Requirements and tests for Stockbridge type aeolian vibration dampers (IEC 61897)
EN 187200	Sectional Specification: Optical cables to be used along electrical power lines (OCEPL)
ENV 1090-1	Execution of steel structures. General rules and rules for buildings
EUROCODE 1	ENV 1991 : Basis of design and actions on structures
	ENV 1991-1 : Basis of design
	ENV 1991-2-1 : Actions on structures
	ENV 1991-2-4 : Actions on structures. Wind loads
EUROCODE 2	ENV 1992 : Design of concrete structures
	ENV 1992-1-1 : General rules and rules for buildings
	ENV 1992-1-3 : General rules. Precast concrete elements and structures
	ENV 1992-3 : Design of concrete structures. Concrete foundations

Reference	Title
EUROCODE 3	ENV 1993 : Design of steel structures ENV 1993-1-1 : General rules and rules for buildings ENV 1993-1-3 : Supplementary rules for cold formed thin gauge members and sheeting ENV 1993-5 : Piling
EUROCODE 5	ENV 1995 : Design of timber structures ENV 1995-1-1 : General rules and rules for buildings
EUROCODE 7	ENV 1997 : Geotechnical design ENV 1997-1 : General rules
EUROCODE 8	ENV 1998 : Design provisions for earthquake resistance of structures ENV 1998-5 : Foundations, retaining structures and geotechnical aspects
HD 474 S1	Dimensions of ball and socket couplings of string insulator units (IEC 60120)
HD 637	Power installations exceeding 1 kV a.c.
IEC 60038	IEC standard voltages
IEC 60050-441	International Electrotechnical Vocabulary - Chapter 441 - Switchgear, controlgear and fuses
IEC 60050-466	International Electrotechnical Vocabulary - Chapter 466 - Overhead lines
IEC 60050-471	International Electrotechnical Vocabulary - Chapter 471 - Insulators
IEC 60050-601	International Electrotechnical Vocabulary - Chapter 601 – Generation, transmission and distribution of electricity - General
IEC 60050-604	International Electrotechnical Vocabulary - Chapter 604 – Generation, transmission and distribution of electricity - Operation
IEC 60287-3-1	Electric cables - Calculation of the current rating - Part 3-1: Sections on operating conditions - Reference operating conditions and selection of cable type
IEC 60372	Locking devices for ball and socket couplings of string insulator units: Dimensions and tests
IEC 60471	Dimensions of clevis and tongue couplings of string insulator units
IEC/TR 60479-1	Guide to effects of current on human beings and livestock – Part 1: General aspects
IEC/TR 60575	Thermal-mechanical performance test and mechanical performance test on string insulator units
IEC 60652	Loading tests on overhead line towers
IEC 60720	Characteristics of line post insulators
IEC 60724	Short-circuit temperature limits of electric cables with rated voltages of 1 kV ($U_m = 1,2$ kV) and 3 kV ($U_m = 3,6$ kV)
IEC 60794-4-1	Optical fibre cables -- Part 4-1: Aerial optical cables for high voltage power lines
IEC 60797	Residual strength of string insulator units of glass or ceramic material for overhead lines after mechanical damage of the dielectric
IEC/TR 60815	Guide for the selection of insulators in respect of polluted conditions

Reference	Title
IEC/TR 60826	Loading and strength of overhead transmission lines
IEC 60909	Short-circuit current calculation in three-phase AC systems
IEC 61109	Composite insulators for a.c. overhead lines with a nominal voltage greater than 1 000 V - Definitions, test methods and acceptance criteria
IEC/TR 61211	Insulators of ceramic material or glass for overhead lines with a nominal voltage greater than 1 000 V - Puncture testing
IEC 61467	Insulators for overhead lines with nominal voltage over 1 000 V - AC power arc tests on insulator sets
IEC/TR 61597	Overhead electrical conductors - Calculation methods for stranded bare conductors
IEC/TR 61774	Overhead lines – Meteorological data for assessing climatic loads
IEC 62219	Formed wire concentric lay overhead electrical stranded conductors ¹⁾
CISPR 16-1	Specification for radio disturbance and immunity measuring apparatus and methods Part 1: Radio disturbance and immunity measuring apparatus
CISPR 16-2	Specification for radio disturbance and immunity measuring apparatus and methods Part 2: Methods of measurement of disturbances and immunity
CISPR 18-2	Radio interference characteristics of overhead power lines and high voltage equipment -- Part 2: Methods of measurement and procedure for determining limits
CISPR 18-3	Radio interference characteristics of overhead power lines and high voltage equipment -- Part 3: Code of practice for minimising the penetration of radio interferences

3 Basis of design

3.1 General

This clause of the standard provides the basis and the general principles for the structural, geotechnical and mechanical design of overhead lines exceeding AC 45 kV.

The clause should be read in conjunction with Eurocodes 1, 2, 3, 5, 7 and 8. The provisions in this standard supersede the corresponding clauses in the said Eurocodes.

The general principles of structural design are based on the limit state concept used in conjunction with the partial factor method as described in 3.7.

The values of the partial factor for actions and material properties depend on the degree of uncertainty for the loads, resistances, geometrical quantities and design model, and on the type of structure and the type of limit state. Partial factors can also depend on the coordination of strength envisaged for the line.

¹⁾ In preparation.

In principle there are two approaches used to determine numerical values for actions and for partial factors. The first is on the basis of the statistical evaluation of meteorological and experimental data and field observations. This should be done in the framework of a probabilistic reliability theory as described in IEC 60826. A second approach is on the basis of calibration by a long and successful history of construction of overhead lines. For most of the factors proposed in the Eurocodes mentioned above this is the guiding principle.

In practice, the two approaches are used in combination, see Figure 3.1. In particular, a statistical method requires a sufficient set of data. In many cases additional activities to obtain such data will be valuable. Comparison with the traditional design method can be performed, related to the long standing experience of constructing and operating overhead lines mentioned above. From this point of view, the statistical approach can be considered as giving added value to the more traditional/empirical approach and vice versa.

The Empirical approach given in 4.3 is an alternative to the General approach applied regarding actions in 4.2. The Empirical approach incorporates the above mentioned experience of national high voltage regulations, which have existed in some countries since about 1900. Therefore, these regulations can give a good basis for calibration of the empirical method. A countercheck of certain values with data obtained from a statistical analysis of available information should be carried out to confirm and calibrate the design criteria.

Each individual National Committee shall decide which specific national and/or regional requirements are to be employed in the design of overhead lines and also defines their relevant partial factors, see 4.2.11 and 4.3.11, if and as required. The National Committee can further decide to use the Empirical approach in 4.3. Partial factors along with related requirements are stated in the NNAs, thus being decisive. They may also be specified in a Project Specification.

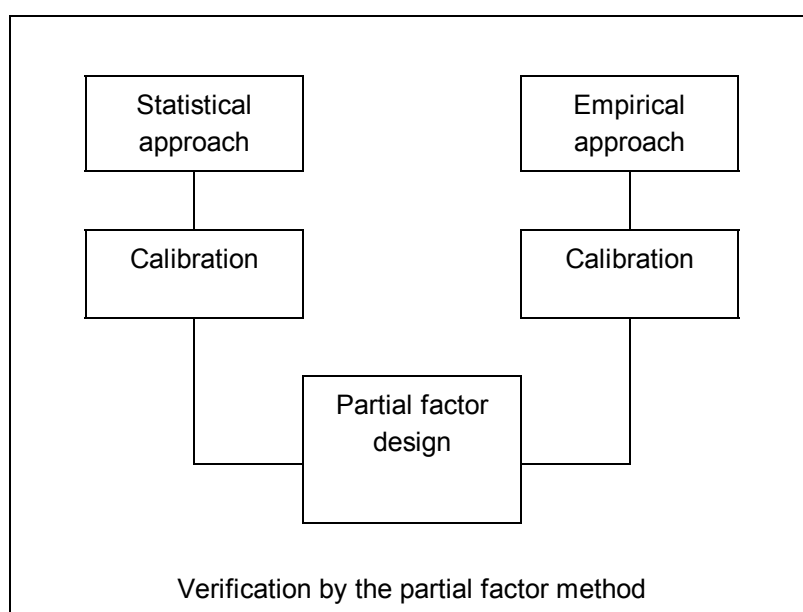


Figure 3.1 - Overview of the determination of partial factors

3.2 Requirements

3.2.1 Basic requirements

An overhead electrical line shall be designed and constructed in such a way that during its intended life,

- it shall perform its purpose under a defined set of conditions, with acceptable levels of reliability and in an economic manner. This refers to aspects of reliability requirements,
- it shall not be liable to a progressive collapse (cascading) if a failure is triggered in a defined component. This refers to aspects of security requirements,
- it shall not be liable to cause human injuries or loss of life during construction and maintenance. This refers to aspects of safety requirements.

An overhead line shall also be designed, constructed and maintained in such a way that due regard is given to safety of the public, durability, robustness, maintainability, environmental considerations and appearance.

The above requirements shall be met by the choice of suitable materials, by appropriate design and detailing, and by specifying control procedures for design, production, construction and use relevant to the particular project.

The selected design situations shall be, by representative load cases, sufficiently severe and varied as to encompass all conditions which can reasonably be foreseen to occur during the construction and the design working life of the overhead line.

3.2.2 Reliability of overhead lines

The reliability required for overhead lines, including all of its components and elements, is achieved by design according to this standard and Eurocodes 1, 2 3, 5, 7 and 8, and appropriate quality assurance measures.

The following a) or b) apply:

- a) In accordance with their national experiences and calibrations carried out National Committees can decide to apply one reliability level, generally corresponding at least to reliability level 1 mentioned below. Exceptions to this shall be given in the NNAs.
- b) When using the statistical approach, three different reliability levels for overhead lines may generally be considered as defined in Table 3.1, each corresponding to a given return period T of the climatic actions.

Table 3.1 – Reliability levels

Reliability level	Return period T of climatic actions Years
1	50
2	150
3	500

Deviations from these levels may be made in accordance with the specific requirements for the project in question. However, the level selected shall at least correspond to reliability level 1 except for temporary constructions and for components installed temporarily.

NOTE The yearly reliability of an overhead line is roughly related to the return period T of the climatic action and is between $1-1/T$ and $1-1/2T$, which can be considered as a minimum value. Further information can be found in IEC 60826.

An absolute reliability of an overhead line will generally be difficult to determine. Therefore, reliability level 1 can be regarded as a reference reliability whereas the higher reliability levels are to be understood as relative to the reference one.

Reliability levels, if decided upon, are given in the NNAs.

3.2.3 *Security requirements*

Security requirements correspond to special loads and/or measures intended to prevent uncontrollable progressive (or cascading) failures.

Should a line fail either due to material defects, unforeseeable events (e.g. impact of an object, landslide, etc.) or an unusual climatic action, it is essential that the failure is contained within or very close to the section where overloads, exceeding the strengths of components, have occurred.

In order to prevent cascading failures, some simulated actions and loading conditions are provided for in this standard as given in clause 4.

A higher level of security may be justified for some overhead lines either due to their importance in the network or because they are subjected to severe climatic loads. In such cases additional measures may be applied for increasing security according to experience and to the type of line to be designed. Insertion of section supports at specified intervals may be adopted to limit a progressive collapse.

3.2.4 *Safety requirements during construction and maintenance*

Safety requirements are intended to ensure that construction and maintenance operations do not pose safety hazards to people. The safety requirements in this standard consist of special loads, as defined in 4.2.6 and 4.3.6, for which line components (mostly supports) have to be designed.

3.2.5 *Coordination of strength*

Regarding an overhead line as a system requires coordination of the strength of the components constituting the line. In this standard specific requirements for strength coordination are referred to in the NNAs.

NOTE Strength coordination is in practice generally obtained by matching the partial factors and/or the loading cases.

Annex A gives details of the concept of strength coordination based on IEC 60826.

3.2.6 *Additional considerations*

Consideration of an overhead line as an element in the environment shall take account of the environmental and legal situations existing in a particular region or country.

Safety of human beings and protection of wild life and livestock, for example birds, cattle, etc. shall be properly considered. Specific requirements may be given in NNAs.

3.2.7 *Design working life*

The design working life is the assumed period for which an overhead line is to be used for its intended purpose with anticipated maintenance but without substantial repair being necessary.

The design working life of overhead lines is generally considered to be 50 years, unless otherwise defined in the Project Specification.

NOTE The operating period will normally be in the range of 30 to 80 years.

3.2.8 *Durability*

The durability of a support or part of it in its environment shall be such that it remains fit for use during the design working life given appropriate maintenance.

The environmental, atmospheric and climatic conditions shall be appraised at the design stage to assess their significance in relation to durability and to enable adequate provisions to be made for protection of the materials.

3.2.9 *Quality assurance*

In order to provide an overhead line corresponding to the requirements and to the assumptions made in the design, appropriate quality assurance measures during design and construction shall be adopted.

NOTE Quality assurance is described in EN ISO 9001.

3.3 Limit states

3.3.1 *General*

Limit states are states beyond which the overhead line no longer satisfies the design performance requirements.

Generally, a distinction is made between ultimate limit states and serviceability limit states.

3.3.2 *Ultimate limit states*

Ultimate limit states are those associated with collapse or with other similar forms of structural failure due to excessive deformation, loss of stability, overturning, rupture, buckling, etc.

Damage states prior to structural collapse, which, for simplicity, are considered in place of the collapse itself are also treated as ultimate limit states.

Ultimate limit states concern:

- the reliability and security of supports, foundations, conductors and equipment;
- the safety of people.

3.3.3 *Serviceability limit states*

Serviceability limit states correspond to certain defined conditions beyond which specified service requirements for an overhead line are no longer met.

The serviceability requirements concern:

- the mechanical functioning of supports, foundations, conductors and equipment;
- the electrical clearances.

Serviceability limit states which may require consideration include:

- deformations and displacements which affect the appearance or effective use of the support including a reduction of electrical clearances;
- vibrations which cause damage to conductors, supports or equipment or which limit their functional effectiveness;
- damage (including cracking) which is likely to affect the durability or the function of the supports, conductors, insulators and line accessories adversely.

Reference should be made to NNAs and the Project Specification for recommendations on serviceability limit states and performance criteria.

3.3.4 *Limit state design*

Limit state design shall be carried out by:

- setting up structural and load models for relevant ultimate and serviceability limit states to be considered in the various design situations and load cases;
- verifying that the limit states are not exceeded when design values for actions, material properties and geometrical data are used in the models.

Design values are generally obtained by using characteristic or combination values (as defined in this standard) in conjunction with partial factors as defined in this standard and Eurocodes 2, 3, 5, 7 and 8.

In some cases, it may be appropriate to determine design values directly. The values should be chosen cautiously and should correspond to at least the same degree of reliability for the various limit states as implied in the partial factors in this standard.

3.4 Actions

3.4.1 Principal classifications

An action, F , is:

- a direct action, i.e. force (load) applied to the supports including foundations, to the conductors, etc.;
- an indirect action, i.e. an imposed or constrained deformation, caused, for example, by temperature changes, ground water variation or uneven settlement, if applicable.

Actions are classified:

a) by their variation in time:

- 1) *permanent action (G)*, i.e. self-weight of supports including foundations, fittings and fixed equipment.

Self-weight of conductors and the effects of the applicable conductor tension at the reference temperature, see clause 4, as well as uneven settlements of supports are regarded as permanent actions.

- 2) *variable actions (Q)*, i.e. wind loads, ice loads or other imposed loads.

Wind loads and ice loads as well as applicable temperatures are climatic conditions which can be assessed by probabilistic methods (reliability concept) or on a deterministic basis.

Conductor tension effects due to wind and ice and temperature deviations from the reference temperature are variable actions.

NOTE The vertical reaction from self-weight of the conductor at the support (in other words the weight span) is affected by deviations from the reference state of the conductor tension due to conductor creep and temperature variations. As mentioned, this variation from the reference state is a variable action. Where critical for the design, especially if no other climatic conditions are present, the uncertainty in such a variation -unfavourable or favourable- should be considered by use of a partial factor on the self-weight (or on the weight span).

Imposed loads arising from conductor stringing, climbing on the structures, etc. are assessed on a deterministic basis and refer to the safety aspect.

- 3) *accidental actions (A)*, i.e. failure containment loads, avalanches, etc. These relate to the security aspect.

Exceptional ice loads including unbalanced ice loads can be treated as accidental actions if the Empirical approach is employed.

b) by their nature and/or the structural response:

- 1) *static actions*, which do not cause significant acceleration of the components or elements
- 2) *dynamic actions*, which cause significant acceleration of the components or elements

It is usually sufficient to consider the equivalent static effect of quasi-static actions, such as wind loads, in the design of overhead line supports (including foundations). Special attention shall be paid to extraordinary high and/or slender supports.

3.4.2 Characteristic values of actions

The characteristic value of an action, F_K , is its main representative value used for limit state verifications.

Permanent actions (G)

The characteristic value of permanent actions in the design of overhead lines can normally be determined as one value, G_K , as the variability of G is very small.

Variable actions (Q)

For variable actions the characteristic value, Q_K , corresponds to:

- either a nominal value used for deterministic based actions and in the Empirical approach;
- or an upper value with an intended probability of not being exceeded (e.g. wind and ice loads) and in the case of, for example, temperatures, a lower value with an intended probability of not being lower, during a reference period of one year. In this standard a value of probability of 0,02 per year is assumed (i.e. a return period of 50 years).

Accidental actions (A)

For accidental actions the representative value is generally a characteristic value A_K corresponding to a specified value.

3.4.3 Combination values of variable actions

Combination values are associated with the use of combinations of actions, to take account of a reduced probability of simultaneous occurrence of the most unfavourable values of several independent actions.

The combination value of a variable action Q is generally represented as a product of a combination factor and a characteristic value, $\Psi_Q \cdot Q_K$, - or directly by an action with a reduced return period or may be directly specified in clause 4. This combination value ($\Psi_Q \cdot Q_K$) is considered to be the design value. Where the occurrence of actions is correlated with each other, this is reflected in the combination factor.

NOTE In this standard the combination factor for a variable action, Ψ_Q , is principally derived on the basis of a reduced return period and, therefore, includes the partial factor used in the Eurocode format as well as any other reduction factors.

3.5 Material properties

A material property is represented by a characteristic value, which corresponds to that value of the material property having a prescribed probability of not being attained in a hypothetical unlimited test series. It generally corresponds for a particular material property to a specified exclusion limit of the assumed statistical distribution of that material property of the material as used in the system.

A material property value shall normally be determined from standardized tests performed under specified conditions. A conversion factor shall be applied where it is necessary to convert the test results into values, which can be assumed to represent the behavior of the material in the overhead line.

NOTE Material properties specified in Eurocodes 2, 3, 5 and 7 and standards referred to herein may generally be applied if not determined otherwise in this standard. Supplementary information on material data given in IEC 60826 may be adopted as applicable in each case.

3.6 Modelling for structural analysis and resistance

3.6.1 General

Calculations shall be performed using appropriate design models involving relevant variables. The models shall be appropriate to predict the structural behaviour and the limit states considered.

Design models should normally be based on established engineering theory and practice verified experimentally, if necessary.

3.6.2 Interactions between support foundations and soil

Special attention shall be paid to the interaction of:

- loads deriving from the support;
- loads resulting from active soil pressures and the permanent weight of foundation and soil;
- buoyancy effects of ground water on soil and foundation. These, together with the reaction forces of the soil strata shall be taken into account in the calculation of the support foundations.

Also, the limit state criteria for:

- acceptable/unacceptable settlement of the foundation including uneven settlement;
- imposed deformations on the support or support members;
- inclinations of the support (especially angle and dead-end supports);

should be defined and taken into consideration.

Provisions regarding the interaction of loads and recommendations on limit states criteria are given in clauses 7 and 8 including annexes.

3.7 Design values and verification method

3.7.1 General

When following this standard reliability is achieved by the application of partial factors or appropriate return periods for climatic actions based on the statistical approach and partial factors for deterministic actions and material properties.

In the partial factor method it is verified that in all relevant design situations the limit states are not reached when design values for actions, material properties and geometrical data are used in the design models. In particular it shall be verified that

- the effects of design actions do not exceed the design resistance of the overhead line at the ultimate limit state,
- the effects of design actions comply with the performance requirements of the overhead line for the serviceability limit state.

Simplified verifications based on the limit state concept may be used by considering only limit states and load combinations which from experience are known to govern the design.

3.7.2 Design values

The design value of an action, F_d , is expressed in general terms as

$$F_d = \gamma_F \cdot F_K$$

The partial factor for actions, γ_F , depends on the selected reliability level and takes account of the possibility of unfavourable deviations of the actions, inaccurate modelling and uncertainties in the assessment of the effects of actions.

NOTE 1 The design values of the different actions G, Q and A classified in 3.4.1 are calculated as $\gamma_G \cdot G_K$, $\gamma_Q \cdot Q_K$ and $\gamma_A \cdot A_K$, respectively.

NOTE 2 Partial factors for actions are generally based on theoretical considerations, experience and calibration by retrospective calculations on existing designs. National values, stated by National Committees as required, appear in the NNAs, see 3.1.

When calculating the effect of the action on the conductor tension, the partial factors are applied to the characteristic values of the action, i.e. directly on the wind and/or ice action acting on the conductor. The computed value of the conductor tension is then the final design value.

For deterministic calculations including security load conditions the partial factor may, however, be applied to the action effect of the characteristic values of the actions, i.e. on the conductor tension, as specifically mentioned in clause 4 regarding actions.

In the statistical approach the design value of an action, F_d , is determined directly by its value for the selected return period T

$$F_d = F_T$$

The design value of a material property, X_d , is generally defined as

$$X_d = X_K / \gamma_M$$

The partial factor for a material property, γ_M , covers unfavourable deviations from the characteristic value X_K of the material property, inaccuracies in applied conversion factors and uncertainties in the geometric properties and the resistance model. Partial factors for line components are specified in this standard. Partial factors stated in the Eurocodes 2, 3, 5, 7 and 8 generally apply, if not specifically amended in this standard or determined otherwise in the NNAs or Project Specification.

3.7.3 Basic design equation

When considering a limit state of rupture or excessive deformation of a component, element or connection, it shall be verified that

$$E_d \leq R_d$$

where

E_d is the total design value of the effect of actions, such as internal force or moment, or a representative vector of several internal forces or moments, see 3.7.4;

R_d is the corresponding structural design resistance, associating all structural properties with the respective design values, X_{nd} , as follows

$$R_d = f \{X_{1d}, X_{2d}, \dots\}$$

or alternatively as defined in each case, the respective characteristic values, X_{nK}

$$R_d = f \{X_{1K}, X_{2K}, \dots\} / \gamma_M$$

3.7.4 Combination of actions

Permanent actions G , the values of variable actions Q_1, Q_2, Q_3 , etc. which occur simultaneously and accidental actions A as relevant are combined in accordance with the design situation considered.

For each critical load case, the design values of the effects of actions, E_d , should be determined as given by the equations (1) and (3) below.

The alternative equations (2) and (4) apply when the variable actions Q_n are determined directly. In equation (2) the dominant variable action Q_1 with the return period T_1 corresponding to the selected reliability level (e.g. 150 years) is combined with variable actions Q_n ($n > 1$) which have reduced return periods T_n (e.g. 3 years). In equation (4) the accidental actions A are combined with variable actions Q_n ($n \geq 1$) which are present, and all of which have reduced return periods T_n .

a) Design situations related to permanent and variable actions

Design value of the dominant variable action, $\gamma_{Q1} \cdot Q_{1K}$, i.e. normally either wind or ice, and the combination value of other variable actions, $\Psi_{Qn} \cdot Q_{nK}$, - or in symbolic forms:

$$E_d = f \{ \sum \gamma_G \cdot G_K, \gamma_{Q1} \cdot Q_{1K}, \sum_{n>1} \Psi_{Qn} \cdot Q_{nK} \} \quad (1)$$

$$E_d = f \{ \sum \gamma_G \cdot G_K, Q_1(T_1), \sum_{n>1} Q_n(T_n) \} \quad (2)$$

b) Design situations related to accidental actions

Design values of accidental actions, $\gamma_A \cdot A_K$, together with defined combination values of variable actions, $\Psi_{Qn} \cdot Q_{nK}$, if any present, - or in symbolic forms:

$$E_d = f \{ \sum \gamma_G \cdot G_K, \gamma_A \cdot A_K, \sum_{n \geq 1} \Psi_{Qn} \cdot Q_{nK} \} \quad (3)$$

$$E_d = f \{ \sum \gamma_G \cdot G_K, \gamma_A \cdot A_K, \sum_{n \geq 1} Q_n(T_n) \} \quad (4)$$

Imposed deformations should be considered where relevant.

4 Actions on lines

4.1 Introduction

The clause on actions on lines is written in two versions in accordance with 3.1 about design methods. The first is called the "General approach" and the second one is called the "Empirical approach".

Each National Committee is responsible for providing climatic data in their NNA which enables the use of one of the two approaches according to 4.2 (General approach) or 4.3 (Empirical approach).

If the NNAs related to 4.2 do not provide sufficient climatic data, the Project Specification shall include such data from available sources to determine a reliable design.

In the case of the Empirical approach, the determination of wind and ice loads and their combinations as given in the NNAs can be assumed to be well established by experience and long-term operation of overhead lines. They constitute a complete design system, especially taking the defined load cases into consideration. Where possible and makes relevant sense, comparisons with the General approach according to 3.1 and 4.2 should be carried out, duly considering the differences in the two approaches.

The General approach is detailed below. For the Empirical approach, see 4.3.

4.2 Actions, General approach

4.2.1 *Permanent loads*

Self-weight of supports, insulator sets and other fixed equipment and of the conductors resulting from the adjacent spans act as permanent loads. Aircraft warning spheres and similar elements are to be considered as permanent dead loads.

4.2.2 *Wind loads*

4.2.2.1 *Wind speeds*

4.2.2.1.1 *Field of application*

This subclause contains rules for determining design wind loads acting on overhead line components, based on meteorological data. The rules cover support heights up to those as specified in the NNAs. If no requirements are stipulated in the NNA, 60 m is generally acceptable.

Wind speed time averaging periods other than those used in this clause may be defined in the NNA. In such a case wind engineering parameters taking into account the specific periods used, apply as given in the NNA.

When designing overhead lines in the ultimate limit state, the gust wind speed is critical. In this standard it is optional to use the mean wind speed V_{mean} or the gust wind speed V_g as a basis for the extreme wind speed in accordance with the practice within each country. In the following text a common symbol V for the wind speed is used for the different parameters when there is no need to distinguish between the two options.

Annex B gives guidelines for the statistical evaluation of wind speed data for determination of the extreme wind speed.

4.2.2.1.2 Mean wind speed V_{mean}

In this standard mean wind speed V_{mean} is defined as the mean wind speed in m/s over a period of 10 min at a height of 10 m above the ground in relatively open terrain (category II, see Table 4.2.1).

4.2.2.1.3 Gust wind speed V_g

The gust wind speed V_g is a characteristic maximum value of the momentary turbulent wind (in this standard based on the average speed measured over a period of 2 s).

4.2.2.1.4 Turbulence, terrain category and gust factor

Turbulence is observed as variations time wise and space wise of the momentary value of the speed about its mean value. The turbulence intensity is dependent on the terrain. In this standard terrain is divided into four categories expressed by the ground roughness parameter z_0 , see Table 4.2.1. A fifth category is added whose wind climate cannot be directly associated with a ground roughness parameter.

The relation between gust wind speed and mean wind speed is expressed by the equation:

$$V_g = k_g \cdot V_{mean}$$

where k_g is the wind speed gust factor. The gust factor is dependent on the measuring periods defined in 4.2.2.1.2 and 4.2.2.1.3 above, the height h above ground and the ground roughness parameter, z_0 . With the measuring periods adopted in this standard, the wind speed gust factor can be calculated as follows:

$$k_g = 1 + 2,28 / \ln \frac{h}{z_0}$$

4.2.2.1.5 Reference wind speed V_R

The reference wind speed V_R is the wind speed to be taken into account 10 m above ground at the site in question.

In countries where the mean wind speed option is used, the reference wind speed V_R at a site of a given terrain category can be evaluated from the reference wind speed $V_R(II)$ at a nearby measuring site of category II using the formula

$$V_R = k_T \cdot \ln \frac{10}{z_0} \cdot V_R(II)$$

The terrain factor k_T and the ground roughness parameter z_0 can be found in Table 4.2.1.

If the gust wind speed option is used, the best choice is to take the reference wind speed equal to the reference wind speed V_R at a nearby measuring site regardless of terrain category.

Reference wind speeds are given in the NNA. However, where reference data for wind speeds appears to be insufficient for a particular project, other data sources should be used for determination of the extreme wind speed at the site in question.

NOTE In most European countries wind speed maps are being developed for different regions. For regions that are not covered in such maps, meteorological assistance should be sought.