

BS EN 50341-1:2012



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Overhead electrical lines exceeding AC 1 kV -

Part 1: General requirements — Common
specifications

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National foreword

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AC 1 kV -
Partie 1: Règles générales -
Spécifications communes

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

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Foreword

This document (EN 50341-1:2012) has been prepared by CLC/TC 11 "Overhead electrical lines exceeding 1 kV a.c. (1,5 kV d.c.)".

The following dates are fixed:

- latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2013-11-19
- latest date by which the national standards conflicting with this document have to be withdrawn (dow) 2016-11-19

This document supersedes EN 50341-1:2001 + A1:2009 and EN 50423-1:2005.

The most significant technical changes that have been made are:

- EN 50341-1 takes into account distribution and transmission overhead lines by merging EN 50341-1:2001 + A1:2009 and EN 50423-1;
- EN 50341-1 is consistent with recent editions of Eurocodes;
- one unique method is described concerning the determination of actions on line;
- new design methods and new developments are included.

EN 50341 is divided into the following parts:

- EN 50341-1, Overhead electrical lines exceeding AC 1 kV — Part 1: General requirements — Common specifications
- EN 50341-2, Overhead electrical lines exceeding AC 1 kV — Part 2: National Normative Aspects

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

0 Introduction

0.1 Detailed structure of the standard

The standard comprises two parts, numbered Part 1 and Part 2.

0.2 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.

0.3 Part 2: National Normative Aspects

The index lists the existing National Normative Aspects (NNAs) related to the different countries; a NNA for a country is normative in that country and informative in other countries.

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

0.4 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 2.17.

0.5 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 2.15.

0.6 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.

0.7 Language

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

1 Scope

1.1 General

This European Standard applies to new overhead electric lines with nominal system voltages exceeding AC 1 kV and with rated frequencies below 100 Hz.

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.

The specific definition as to the meaning and extent of a “new overhead line” is to be identified by each National Committee (NC) within their own NNA. At the least, it shall mean a totally new line between two points, A and B.

1.2 Field of application

This European Standard also applies to covered conductor overhead lines and overhead insulated cable systems with nominal system voltage exceeding AC 1 kV up to and including AC 45 kV and with rated frequencies below 100 Hz. Additional requirements and simplifications are specified that apply only for this voltage range.

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 for lines exceeding 45 kV. Other requirements of the Standard may be applicable, and where necessary NNAs should be consulted.

This European 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 (e.g. wraparound, etc.) 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 such cases are necessary, requirements can be given in the NNAs.

This European Standard does not apply to:

- overhead electric lines inside closed electrical areas as defined in EN 61936-1;
- catenary systems of electrified railways, unless explicitly required by another standard.

1.3 Structure of the European Standard EN 50341-1

Normative references, definitions and symbols with their significations are listed in Clause 2 below.

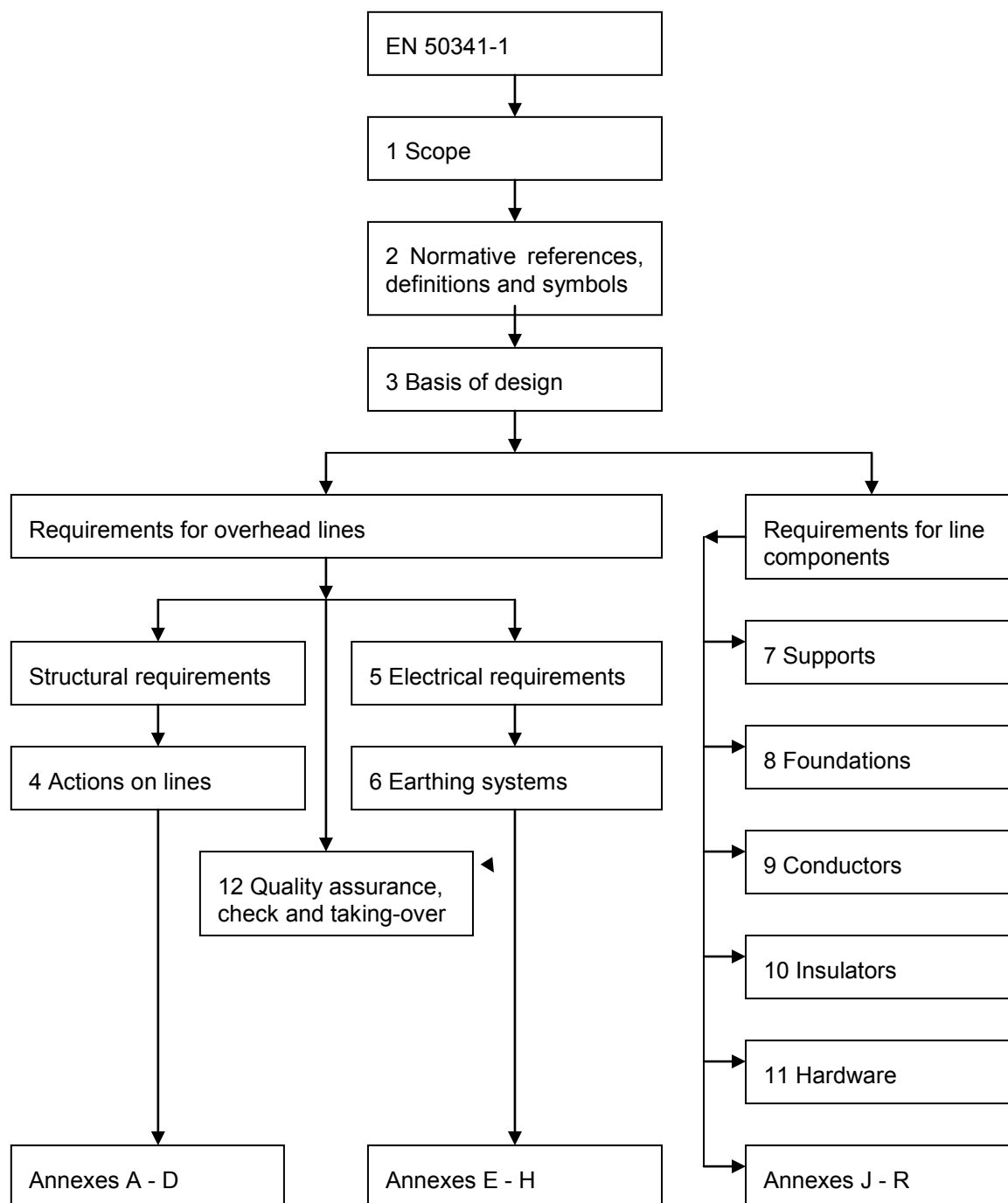
In Clause 3, the basis of design according to this standard is given.

The standard specifies in Clauses 4 to 6 the general requirements that shall be met for the structural and electrical design of overhead lines to ensure that the line is suitable for its purpose with due consideration given to safety of public, construction, operation, maintenance and environmental issues.

Clauses 7 to 11 of this standard consider the structural and electrical requirements that shall be met for the design, installation and testing of overhead line components including supports, foundations, conductors, insulator strings and hardware as determined by the relevant design parameters of the line.

Finally, Clause 12 considers the quality assurance requirements during design, manufacturing and construction.

Flowchart 1.1 summarises the structure of the European Standard EN 50341-1, its Clauses 1 to 12 and its Annexes A to R.



Flowchart 1.1 — Structure of the European Standard EN 50341-1

2 Normative references, definitions and symbols

2.1 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Eurocodes:

Reference	Title
EN 1990:2002	<i>Eurocode — Basis of structural design</i>
EN 1991-1-4:2005	<i>Eurocode 1: Actions on structures — Part 1-4: General actions — Wind actions</i>
EN 1991-1-6:2005	<i>Eurocode 1 — Actions on structures Part 1-6: General actions — Actions during execution</i>
EN 1992-1-1:2004	<i>Eurocode 2: Design of concrete structures — Part 1-1: General rules and rules for buildings</i>
EN 1993-1-1:2005	<i>Eurocode 3: Design of steel structures — Part 1-1: General rules and rules for buildings</i>
EN 1993-1-3:2006	<i>Eurocode 3: Design of steel structures — Part 1-3: General rules — Supplementary rules for cold-formed members and sheeting</i>
EN 1993-1-5:2006	<i>Eurocode 3: Design of steel structures — Part 1-5: Plated structural elements</i>
EN 1993-1-8:2005	<i>Eurocode 3: Design of steel structure — Part 1-8: Design of joints</i>
EN 1993-1-11:2006	<i>Eurocode 3 — Design of steel structures — Part 1-11: Design of structures with tension components</i>
EN 1993-3-1:2006	<i>Eurocode 3 — Design of steel structures — Part 3-1: Towers, masts and chimneys — Towers and masts</i>
EN 1995-1-1:2004	<i>Eurocode 5: Design of timber structures — Part 1-1: General — Common rules and rules for buildings</i>
EN 1997-1:2004	<i>Eurocode 7: Geotechnical design — Part 1: General rules</i>
EN 1997-2:2007	<i>Eurocode 7: Geotechnical design — Part 2: Ground investigation and testing</i>
EN 1998-6:2005	<i>Eurocode 8: Design of structures for earthquake resistance — Part 6: Towers, masts and chimneys</i>

Other European Standards:

Reference	Title
EN ISO 1461:2009	<i>Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods (ISO 1461:2009)</i>
EN ISO 2063	<i>Thermal spraying — Metallic and other inorganic coatings — Zinc, aluminium and their alloys (ISO 2063)</i>
EN ISO 9001	<i>Quality management systems — Requirements (ISO 9001)</i>

Reference	Title
EN ISO 14713 (all parts)	<i>Zinc coatings — Guidelines and recommendations for the protection against corrosion of iron and steel in structures (ISO 14713, all parts)</i>
EN 1090-1	<i>Execution of steel structures and aluminium structures — Part 1: Requirements for conformity assessment of structural components</i>
EN 12385 (all parts)	<i>Steel wire ropes — Safety</i>
EN 12843	<i>Precast concrete products — Masts and poles</i>
EN 14229	<i>Structural timber — Wood poles for overhead lines</i>
EN 50182:2001	<i>Conductors for overhead lines — Round wire concentric lay stranded conductors</i>
EN 50183	<i>Conductors for overhead lines — Aluminium-magnesium-silicon alloy wires</i>
EN 50189	<i>Conductors for overhead lines — Zinc coated steel wires</i>
EN 50326	<i>Conductors for overhead lines — Characteristics of greases</i>
EN 50397-1	<i>Covered conductors for overhead lines and the related accessories for rated voltages above 1 kV a.c. and not exceeding 36 kV a.c. — Part 1: Covered conductors</i>
EN 50522:2010	<i>Earthing of power installations exceeding 1 kV a.c.</i>
EN 55016-1-1	<i>Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-1: Radio disturbance and immunity measuring apparatus — Measuring apparatus</i>
EN 60038	<i>CENELEC standard voltages (IEC 60038)</i>
EN 60071-1	<i>Insulation co-ordination — Part 1: Definitions, principles and rules (IEC 60071-1)</i>
EN 60071-2:1997	<i>Insulation co-ordination — Part 2: Application guide (IEC 60071-2:1996)</i>
EN 60305	<i>Insulators for overhead lines with a nominal voltage above 1 kV — Ceramic or glass insulator units for a.c. systems — Characteristics of insulator units of the cap and pin type (IEC 60305)</i>
EN 60372	<i>Locking devices for ball and socket couplings of string insulator units — Dimensions and tests (IEC 60372)</i>
EN 60383-1	<i>Insulators for overhead lines with a nominal voltage above 1 kV — Part 1: Ceramic or glass insulator units for a.c. systems — Definitions, test methods and acceptance criteria (IEC 60383-1)</i>

Reference	Title
EN 60383-2	<i>Insulators for overhead lines with a nominal voltage above 1 kV — Part 2: Insulator strings and insulator sets for a.c. systems — Definitions, test methods and acceptance criteria (IEC 60383-2)</i>
EN 60433	<i>Insulators for overhead lines with a nominal voltage above 1 kV — Ceramic insulators for a.c. systems — Characteristics of insulator units of the long rod type (IEC 60433)</i>
EN 60437	<i>Radio interference tests on high-voltage insulators (IEC 60437)</i>
EN 60507	<i>Artificial pollution tests on high-voltage insulators to be used on a.c. systems (IEC 60507)</i>
EN 60652	<i>Loading tests on overhead line structures (IEC 60652)</i>
EN 60794-1-1	<i>Optical fibre cables — Part 1-1: Generic specification - General (IEC 60794-1-1)</i>
EN 60794-1-2	<i>Optical fibre cables — Part 1-2: Generic specification — Basic optical cable test procedures (IEC 60794-1-2)</i>
EN 60794-4:2003	<i>Optical fibre cables — Part 4: Sectional specification — Aerial optical cables along electrical power lines (IEC 60794-4)</i>
EN 60794-4-10	<i>Optical fibre cables — Part 4-10: Aerial optical cables along electrical power lines — Family specification for OPGW (Optical Ground Wires) (IEC 60794-4-10)</i>
EN 60865-1	<i>Short circuit currents — Calculation of effects — Part 1: Definitions and calculation methods (IEC 60865-1)</i>
EN 60889	<i>Hard-drawn aluminium wire for overhead line conductors (IEC 60889)</i>
EN 60909-0	<i>Short circuit currents in three-phase a.c. systems — Part 0: Calculation of currents (IEC 60909-0)</i>
EN 61109	<i>Insulators for overhead lines — Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1 000V — Definitions, test methods and acceptance criteria (IEC 61109)</i>
EN 61211	<i>Insulators of ceramic material or glass for overhead lines with a nominal voltage greater than 1 000V — Impulse puncture testing in air (IEC 61211)</i>
EN 61232	<i>Aluminium-clad steel wires for electrical purposes (IEC 61232)</i>
EN 61284	<i>Overhead lines — Requirements and tests for fittings (IEC 61284)</i>
EN 61325	<i>Insulators for overhead lines with a nominal voltage above 1 kV — Ceramic or glass insulator units for d.c. systems — Definitions, test methods and acceptance criteria (IEC 61325)</i>

Reference	Title
EN 61395	<i>Overhead electrical conductors — Creep test procedures for stranded conductors (IEC 61395)</i>
EN 61466-1	<i>Composite string insulator units for overhead lines with a nominal voltage greater than 1 kV — Part 1: Standard strength classes and end fittings (IEC 61466-1)</i>
EN 61466-2	<i>Composite string insulator units for overhead lines with a nominal voltage greater than 1 kV — Part 2: Dimensional and electrical characteristics (IEC 61466-2)</i>
EN 61467	<i>Insulators for overhead lines — Insulator strings and sets for lines with a nominal voltage greater than 1 000 V — AC power arc tests (IEC 61647)</i>
EN 61472	<i>Live working — Minimum approach distances for a.c. systems in the voltage range 72,5 kV to 800 kV — A method of calculation (IEC 61472)</i>
EN 61773	<i>Overhead lines — Testing of foundations for structures (IEC 61773)</i>
EN 61854	<i>Overhead lines — Requirements and tests for spacers (IEC 61854)</i>
EN 61897	<i>Overhead lines — Requirements and tests for Stockbridge type aeolian vibration dampers (IEC 61897)</i>
EN 61936-1	<i>Power installations exceeding 1 kV a.c. — Part 1: Common rules (IEC 61936-1)</i>
EN 61952	<i>Insulators for overhead lines — Composite line post insulators for A.C. systems with a nominal voltage greater than 1 000V — Definitions, test methods and acceptance criteria (IEC 61952)</i>
EN 62004	<i>Thermal-resistant aluminium alloy wire for overhead line conductor (IEC 62004)</i>
EN 62219	<i>Overhead electrical conductors — Formed wire, concentric lay, stranded conductors (IEC 62219)</i>
HD 474 S1	<i>Dimensions of ball and socket couplings of string insulator units (IEC 60120)</i>

Other publications:

Reference	Title
ICAO Regulations-annex 14	<i>Volume 1 — Aerodrome Design and Operations Chapter 6 — Visual aids for denoting obstacles</i>
IEC 60050-441	<i>International Electrotechnical Vocabulary. Switchgear, controlgear and fuses</i>
IEC 60050-466	<i>International Electrotechnical Vocabulary. Chapter 466: Overhead lines</i>

Reference	Title
IEC 60050-471	<i>International Electrotechnical Vocabulary — Part 471: Insulators</i>
IEC 60050-601	<i>International Electrotechnical Vocabulary. Chapter 601: Generation, transmission and distribution of electricity — General</i>
IEC 60050-604	<i>International Electrotechnical Vocabulary. Chapter 604: Generation, transmission and distribution of electricity — Operation</i>
IEC 60287-3-1	<i>Electric cables — Calculation of the current rating — Part 3-1: Sections on operating conditions — Reference operating conditions and selection of cable type</i>
IEC 60471	<i>Dimensions of clevis and tongue couplings of string insulator units</i>
IEC/TS 60479-1:2005	<i>Effects of current on human beings and livestock — Part 1: General aspects</i>
IEC/TR 60575	<i>Thermal-mechanical performance test and mechanical performance test on string insulator units</i>
IEC 60720	<i>Characteristics of line post insulators</i>
IEC 60724	<i>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)</i>
IEC 60797	<i>Residual strength of string insulator units of glass or ceramic material for overhead lines after mechanical damage of the dielectric</i>
IEC/TS 60815-1	<i>Selection and dimensioning of high-voltage insulators intended for use in polluted conditions — Part 1: Definitions, information and general principles</i>
IEC/TS 60815-2	<i>Selection and dimensioning of high-voltage insulators intended for use in polluted conditions — Part 2: Ceramic and glass insulators for a.c. systems</i>
IEC/TS 60815-3	<i>Selection and dimensioning of high-voltage insulators intended for use in polluted conditions — Part 3: Polymer insulators for a.c. systems</i>
IEC 60826	<i>Design criteria of overhead transmission lines</i>
IEC/TR 61597	<i>Overhead electrical conductors — Calculation methods for stranded bare conductors</i>
IEC/TR 61774	<i>Overhead lines — Meteorological data for assessing climatic loads</i>
ISO 12494	<i>Atmospheric icing of structures</i>
CISPR/TR 18-2	<i>Radio interference characteristics of overhead power lines and high-voltage equipment — Part 2: Methods of measurement and procedure for determining limits</i>

Reference	Title
CISPR/TR 18-3	<i>Radio interference characteristics of overhead power lines and high voltage equipment — Part 3: Code of practice for minimizing the generation of radio noise</i>

2.2 Definitions

For the purposes of this European Standard, the terms and definitions given in the International Vocabulary (IEC 60050) Chapters 441, 466, 471, 601, 604, in the Eurocodes (EN 1990 to EN 1999) and the following apply.

2.2.1

action

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

Note 1 to entry: An action can be permanent, variable or accidental.

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

2.2.2

accidental action

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

Note 1 to entry: An accidental action can be expected in many cases to cause severe consequences unless special measures are taken.

2.2.3

anti-cascading tower

tension or suspension tower specially designed with higher strength to avoid cascade failures and installed at a nominated frequency of towers to limit damage and permit quick restoration of failed towers and conductor(s)

2.2.4

bonding conductor

conductor providing equipotential bonding

2.2.5

box values

numerical values identified by "box values" are given as indication

Note 1 to entry: Other values may be specified by NCs in NNAs.

2.2.6

characteristic resistance

value of mechanical resistance calculated using characteristic values of material properties and which may be obtained from EN 1992-1-1, EN 1993-1-1 or EN 1995-1-1

2.2.7

characteristic value of a material property

value of a material property which has a prescribed probability of not being attained in a hypothetical unlimited test series and which generally corresponds to a specified fraction of the assumed statistical distribution of the particular property of the material

Note 1 to entry: A nominal value is used as the characteristic value in some circumstances.

2.2.8

characteristic value of an action

principal representative value of an action which, insofar as this characteristic value can be fixed on statistical bases, 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

2.2.9

clearance

distance between two conductive parts along a string stretched the shortest way between these conductive parts

[SOURCE: IEC 441-17-31]

2.2.10

coefficient of variation

ratio of the standard deviation to the mean value

2.2.11

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

2.2.12

combination factor for an action

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

2.2.13

combination value for an action

value which is 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, and which is obtained by multiplying the characteristic value of an action by the combination factor for an action or, in special circumstances, by direct determination

2.2.14

component

one of the different principle parts of the overhead electrical line system having a specified purpose

Note 1 to entry: Typical components are supports, foundations, conductors, insulator strings and hardware.

2.2.15

composite insulator

insulator made of at least two insulating parts, namely a core and a housing equipped with end fittings

Note 1 to entry: Composite insulators, can consist for example either of individual sheds mounted on the core, with or without an intermediate sheath, or alternatively, of a housing directly moulded or cast in one or several pieces onto the core.

2.2.16

conductor (of an overhead line)

a wire or combination of wires not insulated from one another, suitable for carrying an electric current

Note 1 to entry: 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 electric current.

[SOURCE: IEC 466-01-15]

2.2.16.1

covered conductor

conductor surrounded by a covering made of insulating material to protect against accidental contact between other covered conductors and with earthed parts

Note 1 to entry: Due to being unscreened, covered conductors are not sufficiently insulated to be touch-proof.

2.2.16.2

overhead insulated cable system

system in which each conductor is surrounded by a covering made of insulating material, which fully protects against all leakage currents phase to phase or to earthed parts

Note 1 to entry: In the majority of cases, each phase conductor will have a core screen.

EXAMPLE Examples of such overhead insulated cable system include: aerial bundled conductors (ABC); self-supporting and lashed underground cable; and "Universal" cable systems.

2.2.17

corona

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

Note 1 to entry: Electrodes may be conductors, hardware, accessories or insulators.

2.2.18

current to earth

current flowing to earth via the impedance to earth

2.2.19

design resistance

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

2.2.20

design situation

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

2.2.21

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

2.2.22

design value of an action

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

2.2.23

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

2.2.24

dynamic action

action which causes significant acceleration of the structure or structural elements

2.2.25

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

2.2.26

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)

2.2.27

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

Note 1 to entry: Earth faults of two or several phase conductors of the same electrical system at different locations are designated as double or multiple earth faults.

2.2.28

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)

2.2.29

earth potential rise

voltage between an earthing system and reference earth

2.2.30

earth rod

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

2.2.31

earth surface potential

voltage between a point on the earth surface and reference earth

2.2.32

earthing

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

2.2.33

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

2.2.34

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

2.2.35

earth wire

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

[SOURCE: IEC 466-10-25]

Note 1 to entry: An earth wire may also contain metallic wires for telecommunication purposes.

2.2.36

effective field strength

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

2.2.37

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

2.2.38

electric field

constituent of an electromagnetic field which is characterised by the electric field strength E together with the electric flux density D

[SOURCE: IEC 121-11-67]

2.2.39

element

one of the different parts of a component

Note 1 to entry: For example, the elements of a steel lattice tower are steel angles, plates and bolts.

2.2.40

equipotential bonding

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

2.2.41

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

2.2.42

external clearances

all clearances which are not "internal clearances" and which 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

2.2.43

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.

2.2.44

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

2.2.45

foundation earth electrode

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

2.2.46

free action

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

2.2.47

frequently occupied area

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

Note 1 to entry: Utilities should define these areas.

2.2.48

glu-lam wood poles

abbreviation for glued laminated wood poles and which as a term refers to wood poles manufactured from such glued laminations in contrast to naturally grown timber poles

2.2.49

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

2.2.50

horizontal earth electrode

electrode which is generally buried at a low depth and which, for example, 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

2.2.51

impedance to earth of an earthing system

impedance between the earthing system and reference earth

2.2.52

internal clearance

clearance between phase conductors and earthed parts such as steel structural elements and earth wires and also those between phase conductors

Note 1 to entry: Also included are clearances to other circuits on the same support.

2.2.53

limit state (structural)

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

2.2.54

load arrangement

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

2.2.55

load case

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

2.2.56

magnetic field

constituent of an electromagnetic field which is characterised by the magnetic field strength H together with the magnetic flux density B

[SOURCE: IEC 121-11-69]

2.2.57

magnetic flux density

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)

Note 1 to entry: One tesla is equal to 1 Vs/m², or 1 weber per square metre (Wb/m²).

2.2.58

maintenance

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

2.2.59

nominal system voltage

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

2.2.60

optical conductor

OPCON

conductor containing optical telecommunication fibres

2.2.61

optical groundwire

OPGW

optical conductor used solely as an earth wire

Note 1 to entry: The conductor component may be stranded or may be tubular or a combination of both.

2.2.62

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

2.2.63

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

2.2.64

permanent action

action which is likely to be present 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

2.2.65

potential grading

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

2.2.66

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

2.2.67

Project Specification

document which is 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, which may supplement the requirements of the standard, but shall not relax their technological requirements, which shall not supersede the minimum requirements specified in this standard and which shall be reduced to a minimum for each project, i. e. to truly unique or specific details

2.2.68

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

2.2.69

quasi-static action

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

2.2.70

radio interference

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

2.2.71

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

2.2.72

reference earth (remote earth)

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

2.2.73

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

2.2.74

reliability (electrical)

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

2.2.75

reliability (structural)

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

2.2.76

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 1 to entry: 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.

2.2.77

resistance to earth of an earth electrode

electrical resistance of the earth between the earth electrode and the reference earth which, in practice, is a pure resistance

2.2.78

return period

mean interval between successive recurrences of a climatic action of at least defined magnitude

Note 1 to entry: The inverse of the return period gives the probability of exceeding the action in one year.

2.2.79

safety

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

2.2.80

security

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

2.2.81

serviceability limit state

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

2.2.82

soil resistivity

specific electrical resistance of the earth

2.2.83

sparkover

disruptive discharge

2.2.84

static action

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

2.2.85

step voltage

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

2.2.86

strength

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

2.2.87

structure

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

2.2.88

support

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

2.2.89

support, angle

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

2.2.90

support, section

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

2.2.91

support, suspension

support equipped with suspension insulator sets

2.2.92

support, tangent

suspension or tension support used in straight line

2.2.93

support, tension

support equipped with tension insulator sets

2.2.94

support, terminal (dead-end)

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

2.2.95

system (mechanical)

set of components connected together to form an overhead electrical line

2.2.96

system (electrical)

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

2.2.97

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

2.2.98

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

2.2.99

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

2.2.100

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

2.2.101

television interference

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

2.2.102

temporary line

line that is installed for a short duration, no more than one year

Note 1 to entry: Temporary lines can have the function of Emergency Restoration Systems.

2.2.103

touch voltage

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)

2.2.104

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

2.2.105

ultimate limit state

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

Note 1 to entry: It corresponds generally to the maximum load-carrying resistance of a structure or a structural element.

2.2.106

unavailability

inability of a system to accomplish its purpose, and unavailability of an overhead electrical line that 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.

2.2.107

unreliability (structural)

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

2.2.108

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

2.2.109

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)

2.3 Symbols

Symbol	Signification	Reference
A	Accidental action	3.4.2
A_K	Characteristic value of an accidental action	3.5.1.4
A_K	Characteristic residual conductor tension	4.8.4
A_{ins}	Projected area of an insulator set	4.4.2
A_m	Effective area of a tower member	4.4.3.3
A_{pol}	Projected area of a pole	4.4.4
A_t	Effective area of the elements of a lattice tower panel face	4.4.3.2
A_{tc}	Effective area of the elements of a lattice crossarm face	4.4.3.2
A_{tn}	Effective area of the elements of lattice tower panel face, n	4.4.3.2
A_x	Area of any line component, projected on a plane perpendicular to the wind direction	4.3.5
a	Spacing of two poles at half structure height	4.4.4
a_{som}	Minimum discharge gap between live parts and earthed parts	4.5.3

Symbol	Signification	Reference
B^2	Background factor	4.4.1.2
B_I	Reduction factor of wind velocity associated with icing	4.6.6
b_1, b_2	Width of a lattice tower panel	4.4.3.2
C_{Ic}	Drag factor for ice covered conductors	4.6.2
C_T	Conversion factor for wind velocity or ice load	3.2.2
C_c	Drag factor for conductors	4.4.1.1
C_{ins}	Drag factor for insulator sets	4.4.2
C_m	Drag factor for tower members	4.4.3.3
C_n	Chord length of span n of a line section	4.12.1
C_{pol}	Drag factor for poles	4.4.4
C_{tc}	Drag factor for lattice crossarms in a wind perpendicular to the crossarm face	4.4.3.2
C_{tn}	Drag factor for lattice tower panel face, n	4.4.3.2
C_x	Drag factor (or force coefficient) for any line component	4.3.5
C_{dir}	Wind directional factor	4.3.2
c_0	Orography factor	4.3.2
C_{season}	Seasonal coefficient	3.2.2
D	Equivalent diameter of ice covered conductor	4.6.4
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	5.5.1
D_{pp}	Minimum air clearance required to prevent a disruptive discharge between phase conductors during fast-front or slow-front overvoltages	5.5.1
$D_{50Hz_p_e}$	Minimum air clearance required to prevent a disruptive discharge at power frequency voltage between a phase conductor and objects at earth potential	5.5.1

Symbol	Signification	Reference
$D_{50Hz_p_p}$	Minimum air clearance required to prevent a disruptive discharge at power frequency voltage between phase conductors	5.5.1
d	Diameter of a conductor	4.4.1.1
d	Clearance distance of the air gap necessary to obtain the required withstand voltage	5.3
d	Distance from the top of a pole	7.6.2.2
d_m	Average of the mean diameters from two separate poles	4.4.4
E	Electric field strength	2.2.38
E_d	Total design value of the effect of actions	3.7.2
F	Action (force or imposed deformation)	3.4.1
F_K	Characteristic value of an action	3.5.1.1
$F_{R,d}$	Design load for the ultimate limit state	7.3.8
F_d	Design value of an action	3.6.2
$F_{test, R}$	Minimum test load	7.3.8
G	Permanent action	3.4.2
G_K	Characteristic value of a permanent action	3.5.1.2
G_c	Structural factor for conductors or span factor	4.4.1.1
G_{ins}	Structural factor for insulator sets	4.4.2
G_m	Structural factor for tower members	4.4.3.3
G_{pol}	Structural factor for poles	4.4.4
G_t	Structural factor for lattice towers	4.4.3.2
G_{tc}	Structural factor for lattice cross-arms	4.4.3.2
G_x	Structural factor for any line component	4.3.5
H	Reference altitude for determination of air density	4.3.3
H	Magnetic field strength	2.2.56

Symbol	Signification	Reference
H	Total length of concrete pole	7.6.5
H_t	Total height of a lattice tower	4.4.3.2
h	Reference height above ground	4.3.2
I	Ice load per conductor length	4.5.2
I_T	Ice load per conductor length with return period, T	3.2.2
I_v	Turbulence intensity	4.3.4
I_3	Nominal (or high probability) ice load per conductor length with return period of 3 years	4.6.1
I_{50}	Extreme (or low probability) ice load per conductor length with reference return period of 50 years	3.2.2
K_g	Gap factor	5.5.2
k_a	Atmospheric factor	5.4.3
k_p	Peak factor	4.4.1.2
k_r	Terrain factor	4.3.2
L	Turbulent length scale	4.4.1.2
L	Length of tower leg	7.7.4.3
L_R	Ruling span	4.12.1
L_m	Mean value of two adjacent span lengths	4.4.1.2
L_n	Span length of span, n	4.4.1.1
L_{wn}	Weight length of span, n	4.5.2
n	Number of variable	3.7.3.1
Q	Variable action	3.4.2
Q_i	Vertical ice force on a support from each sub-conductor	4.5.2
Q_K	Characteristic value of a variable action	3.5.1.3
Q_P	Construction and maintenance load	4.9.1

Symbol	Signification	Reference
Q_{Wic}	Wind force on ice covered conductor	4.6.5
Q_{WK}	Characteristic value of a wind action	4.6.1
Q_{WT}	Wind force with return period, T and a 10 minutes mean wind velocity for the determination of minimum air clearances	4.3.5
Q_{Wc}	Wind force on conductor	4.4.1.1
Q_{Wins}	Wind force on insulator set	4.4.2
Q_{Wm}	Wind force on a tower member	4.4.3.3
Q_{Wpol}	Wind force on a pole	4.4.4
Q_{Wt}	Wind force on a lattice tower panel	4.4.3.2
Q_{Wtc}	Wind force on a lattice crossarm	4.4.3.2
Q_{Wx}	Wind force on any line component	4.3.5
Q_{W3}	Nominal wind load with a 10 minutes mean wind velocity for the determination of minimum air clearances with return period of 3 years	4.3.5
Q_{W50}	Extreme wind load with a 10 minutes mean wind velocity for the determination of minimum air clearances with reference return period of 50 years	4.3.5
Q_n	Variable action, n	3.7.3.1
Q_{nK}	Characteristic value of variable action, n	3.7.3.2
Q_1	Dominant variable action	3.7.3.1
q_{lh}	Mean wind pressure associated with icing at reference height, h above ground	4.6.3
q_{lp}	Peak wind pressure associated with icing at reference height, h above ground	4.6.3
q_h	Mean wind pressure at reference height, h above ground	4.3.3
q_p	Peak wind pressure at reference height, h above ground	4.3.4
R_a	Additional electrical resistance	6.4.2
R_b	Backflashover rate	5.4.5

Symbol	Signification	Reference
R_d	Structural design resistance	3.7.2
R_{sf}	Shielding failure flashover rate	5.4.5
R^2	Resonance response factor	4.4.1.2
Re	Reynolds number	4.4.1.3
r	Reduction factor of a three phase line	2.2.72
T	Return period of a climatic action	3.2.2
T_n	Return period of variable action, n	3.7.3.1
T_o	Initial horizontal tension in a conductor	4.8.4
T_1	Return period for a dominant variable action	3.7.3.1
T'	Absolute temperature at a reference altitude, H	4.3.3
t_F	Duration of the fault current	6.4.2
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)	6.4.2
U_E	Earth potential rise	6.4.3
U_T	Touch voltage	6.4.3
U_{Tp}	Permissible touch voltage, i.e. the voltage across the human body	6.4.3
U_{cw}	Co-ordination withstand voltage	5.3
U_m	Highest voltage for equipment	5.4.2
U_n	Nominal system voltage	5.3
U_{rp}	Representative overvoltage	5.3
U_{rw}	Required withstand voltage	5.3
U_s	Highest system voltage	5.4.2
V_{IH}	High probability wind velocity associated with icing	4.6.1

Symbol	Signification	Reference
V_{IL}	Low probability wind velocity associated with icing	4.6.1
V_{Ih}	Mean wind velocity associated with icing at a reference height, h above ground	4.6.3
V_T	Wind velocity with return period, T	3.2.2
$V_{b,0}$	Basic wind velocity	4.3.1
V_h	Mean wind velocity at reference height, h above ground	4.3.2
V_3	Nominal wind velocity with return period of 3 years	4.3.5
V_{50}	Extreme wind velocity with reference return period of 50 years	3.2.2
X_K	Characteristic value of a material property	3.6.3
X_d	Design value of a material property	3.6.3
X_{nK}	Characteristic value of material property, n	3.7.4
X_{nd}	Design value of material property, n	3.7.4
z_0	Roughness length	4.3.2
α	Reduction factor for ice loads	4.12.2
β	Reduction factor for conductor tension	4.8.4
γ	Partial factor	4.13
γ_A	Partial factor for an accidental action	3.6.2
γ_F	Partial factor for an action	3.6.2
γ_G	Partial factor for a permanent action	3.6.2
γ_I	Partial factor for an ice action	4.6.6.1
γ_M	Partial factor for a material property	3.6.3
γ_P	Partial factor for construction and maintenance loads	4.13
γ_{Pt}	Partial factor for action on prestressing force	7.6.5
γ_Q	Partial factor for a variable action	3.6.2

Symbol	Signification	Reference
γ_{Q1}	Partial factor for a dominant variable action	3.7.3.2
γ_w	Partial factor for a wind action	4.6.6.2
θ	Angle of line direction change	4.4.1.1
ν	Kinematic viscosity of the air	4.4.1.3
ρ	Air density	4.3.3
ρ_E	Resistivity of the ground near the surface	6.4.2
ρ_i	Ice density	4.6.2
ρ'	Air density corresponding to an absolute temperature, T' and a reference altitude, H	4.3.3
ϕ	Angle between wind direction and the longitudinal axis of the cross-arm	4.4.1.1
ϕ_m	Angle between the wind direction and the normal axis plane of member m	4.4.3.3
χ	Solidity ratio of a tower panel	4.4.3.2
Ψ	Combination factor for an action	4.13
Ψ_i	Combination factor for an ice action	4.6.6.2
Ψ_Q	Combination factor for a variable action	3.6.4
Ψ_{Qn}	Combination factor for variable action, n	3.7.3.2
Ψ_w	Combination factor for a wind action	4.6.6.1

3 Basis of design

3.1 Introduction

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

The clause shall 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.

Subclause 3.2 gives an overview of the general requirements for overhead lines, including the basic requirements regarding reliability, security and safety. The reliability levels for wind and ice actions correspond to a given theoretical return period of the climatic actions.

Subclause 3.3 declares the distinction between ultimate and serviceability limit states.

Subclause 3.4 distinguishes actions according they are permanent, variable or accidental. An action is defined as either a load or a deformation.

Subclause 3.5 introduces the characteristic value for an action and for a material property.

Subclause 3.6 shows how a design value for an action and for a material property can be developed by using the characteristic value in conjunction with a partial factor.

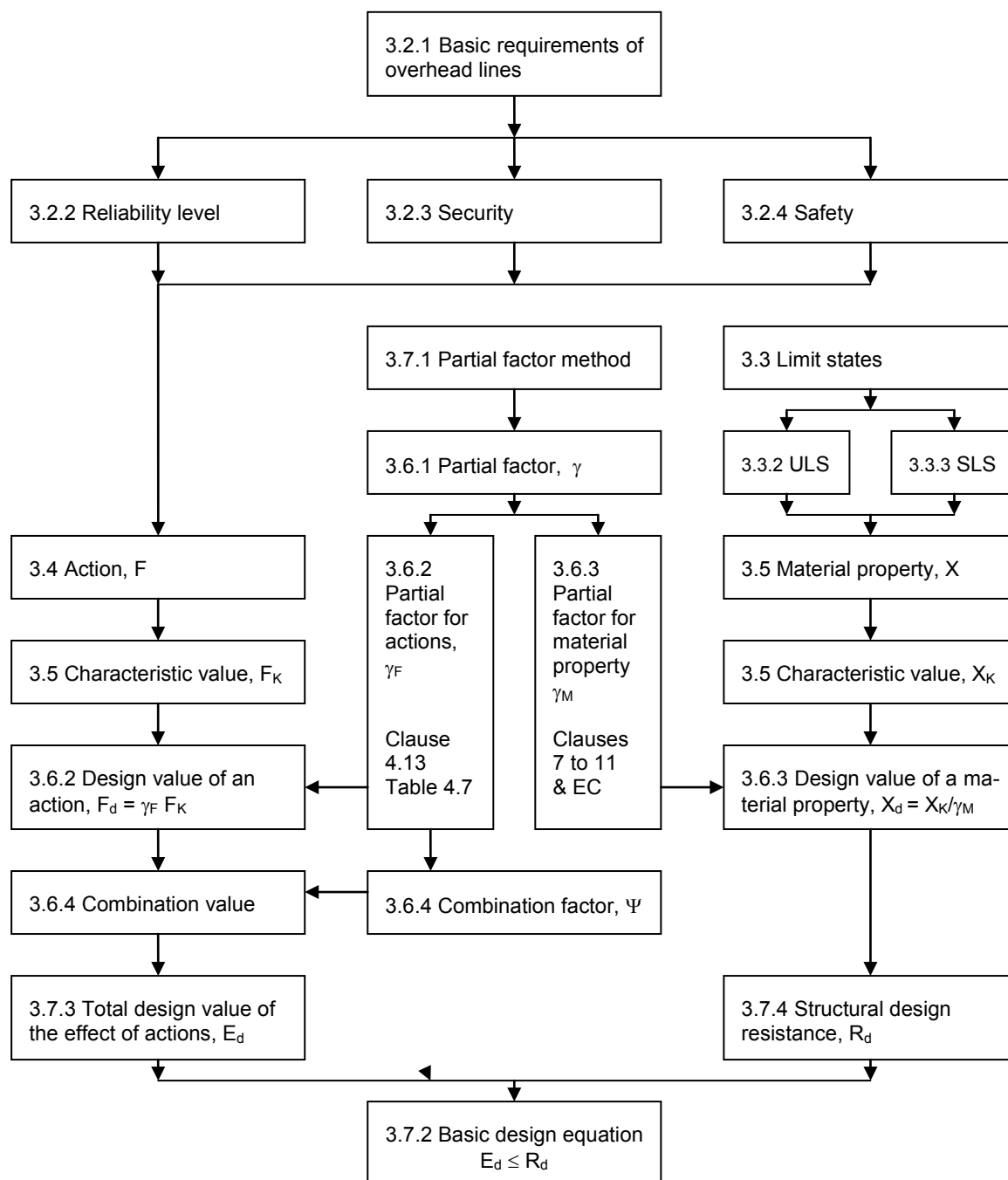
Finally, subclause 3.7 provides the basic design formula following the partial factor method. The total design value of the effect of actions which occur simultaneously, as well as the corresponding structural design resistance, are given.

These subclauses are valid for bare overhead lines exceeding AC 1 kV.

They also apply to:

- covered conductor overhead lines;
- overhead insulated cable systems exceeding AC 1 kV up to and including AC 45 kV.

Flowchart 3.1 summarises the structure of this Clause 3.



Flowchart 3.1 — Structure of Clause 3 on the Basis of Design

3.2 Requirements of overhead lines

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 be designed to avoid a progressive collapse (cascading) if a failure is triggered in a defined component. This refers to aspects of security requirements;
- it shall be designed to avoid 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 appropriate design and detailing, by the choice of suitable materials and by specifying control procedures for design, manufacturing and construction relevant to the particular project.

The selected design scenarios, represented by differing load cases, shall be 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 requirements

The reliability level 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.

Three different reliability levels for overhead lines may generally be considered as defined in Table 3.1, each corresponding to a given theoretical return period T of the climatic actions.

Table 3.1 — Reliability levels

Reliability level	Theoretical return period T of climatic actions [Year]
1 (reference)	50
2	150
3	500

Overhead line supports shall be classified as structures of class 1 according to EN 1990 for safety issues. These three reliability levels, used for service continuity issues, shall be considered as three sub-classes of class 1 according to EN 1990.

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 line components installed temporarily.

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

Due to the lower height of lower voltage electrical overhead lines, the applied loadings on these structures will vary due to ground roughness, line height and accidental action factors (falling trees). These factors should be varied as the topography dictates, however minimum reliability level of the lines shall not be less than 1.

NOTE 1 The relationship between reliability levels given in Table 3.1 and partial factors for actions given in 4.13, Table 4.7 are also explained in B.2 for wind velocities and in B.3 for ice loads.

NOTE 2 For temporary lines, the return period of the climatic actions can be reduced due to the reduced design life exposure as indicated in the following table, which is an extract from EN 1991-1-6:

Table 3.2 — Return period for temporary lines

Duration	Return periods (years)
≤ 3 days	2
≤ 3 months (but > 3 days)	5
≤ 1 year (but > 3 months)	10

For lines installed less than 3 months, it is also possible to take seasonal or current climatic conditions into account: loading assumptions, based on statistical meteorological data, may be defined in the NNAs. For instance:

- a seasonal coefficient c_{season} , as defined in the National Annex of EN 1991-1-4, may be used to reduce wind loads;
- for seasons, where ice accretion does not occur, the ice load need not be considered. This period of the year should be defined in the NNAs, if relevant.

If the extreme wind velocity for the reference 50 years return period, V_{50} , is known, the extreme wind velocity for a theoretical return period of T years, V_T , can be determined by using the conversion factor, C_T , as developed in Annex B.2 and Table B.1. For reduced return periods, the term nominal wind velocity is used.

Similarly, if the extreme ice load per conductor length for the reference 50 years return period, I_{50} , is known, the extreme ice load per conductor length for a theoretical return period of T years, I_T , can be determined by using the conversion factor, C_T , as developed in Annex B.3 and Table B.2. For reduced return periods, the term nominal ice load is used.

Reliability levels for wind and ice actions are given in the NNAs.

It is important to note that increasing the reliability level is not the only way to improve continuity of service of an overhead line. The reference reliability level is generally regarded as providing an acceptable reliability level in respect of continuity of service and safety, but in fact a designer should also consider the following two aspects:

Safety of the public: the reference return period of 50 years gives a high level of reliability. The probability of failure is acceptable in respect of public safety, because the combined probability resulting in human injury is very low. Moreover, as components are designed as complete systems rather than individually in isolation, and because they are usually designed prior to specific knowledge of the real line parameters (e.g. span length), the use factor has a positive influence on actual line reliability.

Continuity of service: it is possible to increase the reliability by increasing the return period but it is not the only solution. It is also possible to increase the service life by creating redundancy, constructing other overhead lines, or having more lines radiating from substations thereby improving design by strength coordination, limiting damage, installing anti-cascading towers, and by setting an emergency restoration plan to repair damage very quickly.

Overall costs are not only determined by the probability of failure, but mostly by the possible consequence of failure, including the uncontrollable propagation of failure and this may extend well beyond the initial failure. Such consequences can be reduced significantly by the following cost-effective measures such as: strength coordination, design of supports to resist torsional and longitudinal security loadings, load control devices, de-icing methods, anti-cascading towers, and construction of other overhead lines, etc. (i.e. proactive solutions); emergency restoration structures, training of linemen, etc. (i.e. reactive solutions).

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 line section where overloads, exceeding the strength of line components, have occurred.

In order to prevent cascade failures, some simulated actions and loading condition provisions are detailed in 4.8.

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 with reference 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

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 4.9, for which line components (mostly supports) have to be designed.

3.2.5 Strength coordination

Regarding an overhead line as a system, requires coordination of the strength of its individual components. 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, (e.g. 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 years to 80 years.

3.2.8 Durability

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

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.

A severe damage state prior to structural collapse, may for simplicity, be treated in the same manner as an ultimate limit state.

Ultimate limit states concern the selected loading conditions determined by reliability, security and safety requirements, likely to affect the resistance of overhead line components such as supports, foundations, conductors, insulator strings and hardware.

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.

Serviceability limit states, which may require consideration include:

- unacceptable frequency and duration of electrical flashovers, occurring either at the support or due to the proximity of conductors in mid span;
- excessive deformations and displacements of supports, which would affect the appearance or effective use of the supports or cause infringements of electrical clearance limits;
- levels of vibration, which would cause damage to conductors, supports or equipment or limit their functional effectiveness;
- damage to surface finishes or surface cracking of concrete, 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.

3.4 Actions

3.4.1 Principal classifications

An action, F , is:

- a direct action, i.e. a force or a load applied to the overhead line components such as supports, foundations, conductors, insulator strings and hardware;
- 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:

- by their variation in time (see 3.4.2);
- by their nature and/or the structural response (see 3.4.3).

3.4.2 Classification of actions 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 applying the reliability concept;
- or on a deterministic basis.

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

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, and especially if no other climatic conditions are present, a partial factor on the conductor mass (or weight span) should be considered due to the uncertainty in such a variation (whether unfavourable or favourable).

Imposed loads arising from conductor stringing, climbing on the structures, etc. are assessed on a deterministic basis and relate to the safety of construction personnel.

- 3) accidental actions, (A), i.e. failure containment loads, avalanches, etc. which relate to the security of the whole line.