

BS EN 61936-1:2010+A1:2014

Incorporating corrigenda March 2011, March 2012 and February 2013



BSI Standards Publication

Power installations exceeding 1 kV a.c.

Part 1: Common rules

bsi.

...making excellence a habit.
AVA Documents™
Document Sharing Hub

National foreword

This British Standard is the UK implementation of EN 61936-1:2010+A1:2014, incorporating CENELEC corrigenda March 2011, March 2012 and February 2013. It is derived from IEC 61936-1:2010, incorporating IEC corrigendum March 2011 and amendment 1:2014. It supersedes BS EN 61936-1:2010, which is withdrawn.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by IEC corrigendum March 2011 is indicated in the text by AC1 AC1.

The CENELEC common modifications have been implemented at the appropriate places in the text. The start and finish of each common modification is indicated in the text by tags C C.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by A1 A1.

CENELEC corrigendum March 2011 adds correct DOR, DOP and DOW values to the EN Foreword. CENELEC corrigendum March 2012 adds special national conditions for Iceland to Annex ZA. CENELEC corrigendum February 2013 adds further special national conditions for Iceland to Annex ZA.

The UK participation in the preparation of EN 61936-1:2010 was entrusted to Technical Committee PEL/99, Erection and operation of power installations. Preparation of this national foreword was entrusted to PEL/99 with assistance from Technical Committee GEL/600, Earthing.

A list of organizations represented on these committees can be obtained on request to their secretaries.

NOTE To ensure wide participation in the process, GEL/600, in particular, has strengthened its membership to include more representation from the UK Electricity Supply industry (TSOs and DNOs) and an earth test equipment manufacturer. Furthermore, detailed consultation has been carried out with The Energy Networks Association (ENA) through its Earthing Co-ordination Group.

Background and developments to IEC/CENELEC documents

In recent years, two documents have existed side-by-side covering, among other things, the earthing of high voltage installations. The first was HD 637 S1, Power installations exceeding 1kV, published in 1999 while the other was IEC 61936-1, of the same title, published in 2002. These documents were produced by working groups of the committees CENELEC TC/99X and IEC TC/99, respectively. As these documents were not published at the same time and the composition of the working groups was to some extent different, a situation arose such that significant discrepancies existed between these two documents, notably, concerning the fundamental safety criterion of allowable human body current and body impedance values under step and touch voltage conditions. This situation was not ideal, and an initiative was taken to develop a revision to IEC 61936-1 under maintenance team IEC TC/99 MT4 and to release it as a European standard. At the same time, a working group CENELEC TC/99X WG1 was formed to extract the earthing content of HD 637 S1 and bring to publication a new European standard on earthing (EN 50522). Parallel voting of EN 61936-1

and EN 50522 was arranged, in order to achieve harmonization of the adopted electrocution safety criteria and both documents were published in 2010.

Differences in the UK approach to earthing design

The differences in the UK approach to earthing are covered in the National Annexes of BS EN 50522 and relate to:

1) Recognition of the probabilistic nature of electrical system safety

A new additional approach to earthing system design, based on probabilistic methods, is outlined and developed in the National Annexes to BS EN 50522.

2) Deviations of UK safety limits compared to IEC/CENELEC limits

As a result of advice obtained from the UK Health and Safety Executive (HSE), consensus was reached between PEL/99 and GEL/600 that UK HV earthing systems have to be designed according to tolerable voltages based on body impedances not exceeded for 5% of the population, as given in DD IEC/TS 60479-1:2005, Table 1 (Column 2) rather than the 50% values (Column 3). The UK obtained a variation to the new CENELEC and IEC standards which has been recognized in the foreword of BS EN 61936-1:2010 and BS EN 50522:2010, Annex Q (A-Deviations). Hence, these documents specify the required difference in approach to earthing design in the UK, based on the 5 % body impedance values. The new UK tolerable touch voltage figures are given in BS EN 50522, National Annex NA.

3) Additional guidance on assessing fault current distribution, earth potential rise, design and testing of earthing systems

4) Recognition of the use of computer-aided earthing design tools

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

© The British Standards Institution 2014.

Published by BSI Standards Limited 2014

ISBN 978 0 580 81261 3

ICS 29.020; 29.080.01

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2012.

Amendments/corrigenda issued since publication

Date	Text affected
31 January 2014	Implementation of CEN correction notice 8 January 2014: Title revised
31 July 2014	Implementation of IEC amendment 1:2014 with CENELEC endorsement A1:2014. Annex ZC amended

This page deliberately left blank

**Power installations exceeding 1 kV a.c. -
Part 1: Common rules
(IEC 61936-1:2010, modified)**

Installations électriques en courant
alternatif de puissance supérieure à 1 kV -
Partie 1: Règles communes
(CEI 61936-1:2010, modifiée)

Starkstromanlagen mit
Nennwechselspannungen über 1 kV -
Teil 1: Allgemeine Bestimmungen
(IEC 61936-1:2010, modifiziert)

This European Standard was approved by CENELEC on 2010-11-01. 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.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

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

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Foreword

The text of document 99/95/FDIS, future edition 2 of IEC 61936-1, prepared by IEC TC 99, System engineering and erection of electrical power installations in systems with nominal voltages above 1 kV a.c. and 1,5 kV d.c., particularly concerning safety aspects, was submitted to the IEC-CENELEC parallel vote.

A draft amendment was prepared by the Technical Committee CENELEC TC 99X, Power installations exceeding 1 kV a.c. (1,5 kV d.c.) and was submitted to formal vote.

The combined texts were approved by CENELEC as EN 61936-1 on 2010-11-01.

This European Standard partially supersedes HD 637 S1:1999.

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

The following dates were fixed:

- | | | |
|--|-------|------------|
| – latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement | (dop) | 2011-11-01 |
| – latest date by which the national standards conflicting
with the EN have to be withdrawn | (dow) | 2013-11-01 |

Annexes ZA, ZB and ZC have been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61936-1:2010 was approved by CENELEC as a European Standard without with agreed common modifications as given below.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

[5] IEC 60044-6	NOTE	Harmonized as EN 60044-6.
[16] IEC 60068 series	NOTE	Harmonized in EN 60068 series (not modified).
[17] IEC 60364-4-41	NOTE	Harmonized as EN 60364-4-41.
[18] IEC 60480	NOTE	Harmonized as EN 60480.
[19] IEC 60664-1	NOTE	Harmonized as EN 60664-1.
[23] IEC 62271-100	NOTE	Harmonized as EN 62271-100.
[24] IEC 62271-102	NOTE	Harmonized as EN 62271-102.
[25] IEC 62271-103	NOTE	Harmonized as EN 62271-103.
[26] IEC 62271-104	NOTE	Harmonized as EN 62271-104.
[27] IEC 62271-105	NOTE	Harmonized as EN 62271-105.

Foreword to amendment A1

The text of document 99/129/FDIS, future IEC 61936-1:2010/A1, prepared by technical committee 99 IEC/TC 99 "System engineering and erection of electrical power installations in systems with nominal voltages above 1 kV a.c. and 1,5 kV d.c., particularly concerning safety aspects" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61936-1:2010/A1:2014.

The following dates are fixed:

- latest date by which the document has to be (dop) 2015-01-02
implemented at national level by
publication of an identical national
standard or by endorsement
- latest date by which the national (dow) 2017-04-02
standards conflicting with the
document have to be withdrawn

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.

Endorsement notice

The text of the International Standard IEC 61936-1:2010/A1:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

Add the following references to the existing list

IEC 60092 (Series)	NOTE	Harmonised as EN 60092 (Series) (not modified).
IEC 61892 (Series)	NOTE	Harmonised as EN 61892 (Series) (not modified).

CONTENTS

INTRODUCTION.....	9
1 Scope.....	10
2 Normative references.....	11
3 Terms and definitions	13
3.1 General definitions.....	13
3.2 Definitions concerning installations	15
3.3 Definitions concerning types of installations	16
3.4 Definitions concerning safety measures against electric shock	16
3.5 Definitions concerning clearances.....	17
3.6 Definitions concerning control and protection	18
3.7 Definitions concerning earthing	18
4 Fundamental requirements	22
4.1 General	22
4.1.1 General requirements	22
4.1.2 Agreements between supplier (manufacturer) and user	23
4.2 Electrical requirements	24
4.2.1 Methods of neutral earthing.....	24
4.2.2 Voltage classification	24
4.2.3 Current in normal operation.....	24
4.2.4 Short-circuit current	24
4.2.5 Rated frequency	25
4.2.6 Corona	25
4.2.7 Electric and magnetic fields	25
4.2.8 Overvoltages	25
4.2.9 Harmonics	26
4.3 Mechanical requirements	26
4.3.1 Equipment and supporting structures	26
4.3.2 Tension load.....	26
4.3.3 Erection load	26
4.3.4 Ice load	27
4.3.5 Wind load	27
4.3.6 Switching forces	27
4.3.7 Short-circuit forces.....	27
4.3.8 Loss of conductor tension	27
4.3.9 A_1 Seismic loads A_1	27
4.3.10 Dimensioning of supporting structures.....	27
4.4 Climatic and environmental conditions	27
4.4.1 General	27
4.4.2 Normal conditions	28
4.4.3 Special conditions.....	29
4.5 Special requirements	30
4.5.1 Effects of small animals and micro-organisms.....	30
4.5.2 Noise level.....	30
4.5.3 Transport.....	30
5 Insulation.....	31
5.1 General.....	31

5.2	Selection of insulation level.....	31
5.2.1	Consideration of methods of neutral earthing	31
5.2.2	Consideration of rated withstand voltages	31
5.3	Verification of withstand values	31
5.4	Minimum clearances of live parts	32
5.4.1	General	32
5.4.2	Minimum clearances in voltage range I.....	32
5.4.3	Minimum clearances in voltage range II.....	32
5.5	Minimum clearances between parts under special conditions	34
5.6	Tested connection zones	35
6	Equipment	35
6.1	General requirements	35
6.1.1	Selection	35
6.1.2	Compliance	35
6.1.3	Personnel safety	35
6.2	Specific requirements	35
6.2.1	Switching devices	35
6.2.2	Power transformers and reactors	36
6.2.3	Prefabricated type-tested switchgear.....	37
6.2.4	Instrument transformers.....	37
6.2.5	Surge arresters.....	38
6.2.6	Capacitors	38
6.2.7	Line traps	38
6.2.8	Insulators.....	38
6.2.9	Insulated cables.....	38
6.2.10	Conductors and accessories	41
6.2.11	Rotating electrical machines	41
6.2.12	Generating units	42
6.2.13	Generating unit main connections	42
6.2.14	Static converters.....	42
6.2.15	Fuses	43
6.2.16	Electrical and mechanical Interlocking.....	43
7	Installations	43
7.1	General requirements	43
7.1.1	Circuit arrangement	43
7.1.2	Documentation.....	44
7.1.3	Transport routes	44
7.1.4	Aisles and access areas	45
7.1.5	Lighting	45
7.1.6	Operational safety.....	45
7.1.7	Labelling.....	45
7.2	Outdoor installations of open design	45
7.2.1	Protective barrier clearances.....	46
7.2.2	Protective obstacle clearances.....	46
7.2.3	Boundary clearances	46
7.2.4	Minimum height over access area	46
7.2.5	Clearances to buildings.....	47
7.2.6	External fences or walls and access doors	47
7.3	Indoor installations of open design.....	

7.4	Installation of prefabricated type-tested switchgear	48
7.4.1	General	48
7.4.2	Additional requirements for gas-insulated metal-enclosed switchgear	48
7.5	Requirements for buildings	50
7.5.1	Introduction	50
7.5.2	Structural provisions	50
7.5.3	Rooms for switchgear	51
7.5.4	Maintenance and operating areas	51
7.5.5	Doors	52
7.5.6	Draining of insulating liquids	52
7.5.7	Air conditioning and ventilation	52
7.5.8	Buildings which require special consideration	53
7.6	High voltage/low voltage prefabricated substations	53
7.7	Electrical installations on mast, pole and tower	53
8	Safety measures	60
8.1	General	59
8.2	Protection against direct contact	59
8.2.1	Measures for protection against direct contact	59
8.2.2	Protection requirements	60
8.3	Means to protect persons in case of indirect contact	61
8.4	Means to protect persons working on electrical installations	61
8.4.1	Equipment for isolating installations or apparatus	61
8.4.2	Devices to prevent reclosing of isolating devices	62
8.4.3	Devices for determining the de-energized state	62
8.4.4	Devices for earthing and short-circuiting	62
8.4.5	Equipment acting as protective barriers against adjacent live parts	63
8.4.6	Storage of personal protection equipment	64
8.5	Protection from danger resulting from arc fault	64
8.6	Protection against direct lightning strokes	64
8.7	Protection against fire	65
8.7.1	General	65
8.7.2	Transformers, reactors	66
8.7.3	Cables	69
8.7.4	Other equipment with flammable liquid	69
8.8	Protection against leakage of insulating liquid and SF ₆	69
8.8.1	Insulating liquid leakage and subsoil water protection	69
8.8.2	SF ₆ leakage	71
8.8.3	Failure with loss of SF ₆ and its decomposition products	71
8.9	Identification and marking	71
8.9.1	General	71
8.9.2	Information plates and warning plates	71
8.9.3	Electrical hazard warning	72
8.9.4	Installations with incorporated capacitors	72
8.9.5	Emergency signs for emergency exits	72
8.9.6	Cable identification marks	72
9	Protection, control and auxiliary systems	78
9.1	Monitoring and control systems	78
9.2	DC and AC supply circuits	79
9.2.1	General	79

9.2.2	AC supply	79
9.2.3	DC supply	80
9.3	Compressed air systems	80
9.4	SF ₆ gas handling plants	81
9.5	Hydrogen handling plants	81
9.6	Basic rules for electromagnetic compatibility of control systems	82
9.6.1	General	82
9.6.2	Electrical noise sources in high voltage installations	82
9.6.3	Measures to be taken to reduce the effects of high frequency interference	82
9.6.4	Measures to be taken to reduce the effects of low frequency interference	83
9.6.5	Measures related to the selection of equipment	83
9.6.6	Other possible measures to reduce the effects of interference	84
10	Earthing systems	84
10.1	General	84
10.2	Fundamental requirements	84
10.2.1	Safety criteria	84
10.2.2	Functional requirements	85
10.2.3	High and low voltage earthing systems	85
10.3	Design of earthing systems	86
10.3.1	General	86
10.3.2	Power system faults	87
10.3.3	Lightning and transients	87
10.4	Construction of earthing systems	88
10.5	Measurements	88
10.6	Maintainability	88
10.6.1	Inspections	88
10.6.2	Measurements	88
11	Inspection and testing	89
11.1	General	89
11.2	Verification of specified performances	90
11.3	Tests during installation and commissioning	90
11.4	Trial running	90
12	Operation and maintenance manual	91
Annex A (normative) Values of rated insulation levels and minimum clearances based on current practice in some countries		92
Annex B (normative) Method of calculating permissible touch voltages		95
Annex C (informative) Permissible touch voltage according IEEE 80		96
Annex D (informative) Earthing system design flow chart		97
Annex E (informative) Protection measures against direct lightning strokes		98
Bibliography		115

Figure 1 – Protection against direct contact by protective barriers/protective obstacles within closed electrical operating areas 54

Figure 2 – Boundary distances and minimum height at the external fence/wall 55

Figure 3 – Minimum heights and working clearances within closed electrical operating areas 56

Figure 4 – Approaches with buildings (within closed electrical operating areas) 57

Figure 5 – Minimum approach distance for transport.....	58
Figure 6 – Separating walls between transformers	73
Figure 7 – Fire protection between transformer and building	74
Figure 8 – Sump with integrated catchment tank.....	76
Figure 9 – Sump with separate catchment tank.....	76
Figure 10 – Sump with integrated common catchment tank.....	77
Figure 11 – Example for small transformers without gravel layer and catchment tank.....	77
Figure 12 – Permissible touch voltage U_{Tp}	89
Figure C.1 – Permissible touch voltage U_{Tp} according IEEE 80.....	96
Figure E.1 – Single shield wire	99
Figure E.2 – Two shield wires.....	99
Figure E.3 – Single lightning rod.....	100
Figure E.4 – Two lightning rods	100
Table 1 – Minimum clearances in air – Voltage range I ($1 \text{ kV} < U_m \leq 245 \text{ kV}$).....	33
Table 2 – Minimum clearances in air – Voltage range II ($U_m > 245 \text{ kV}$)	33
Table 3 – Guide values for outdoor transformer clearances	67
Table 4 – Minimum requirements for the installation of indoor transformers	68
Table 5 – Minimum requirements for interconnection of low-voltage and high-voltage earthing systems based on EPR limits	86
Table A.1 – Values of rated insulation levels and minimum clearances in air for $1 \text{ kV} < U_m \leq 245 \text{ kV}$ for highest voltage for installation U_m not standardized by the IEC based on current practice in some countries	92
Table A.2 – Values of rated insulation levels and minimum clearances in air for $1 \text{ kV} < U_m \leq 245 \text{ kV}$ for highest voltage for installation U_m not standardized by IEC based on current practice in some countries	93
Table A.3 – Values of rated insulation levels and minimum clearances in air for $U_m > 245 \text{ kV}$ for highest voltages for installation U_m not standardized by IEC based on current practice in some countries	94

INTRODUCTION

There are many national laws, standards and internal rules dealing with the matter coming within the scope of this standard and these practices have been taken as a basis for this work.

This part of IEC 61936 contains the minimum requirements valid for IEC countries and some additional information which ensures an acceptable reliability of an installation and its safe operation.

The publication of this standard is believed to be a decisive step towards the gradual alignment all over the world of the practices concerning the design and erection of high voltage power installations.

Particular requirements for transmission and distribution installations as well as particular requirements for power generation and industrial installations are included in this standard.

The relevant laws or regulations of an authority having jurisdiction takes precedence.

POWER INSTALLATIONS EXCEEDING 1 kV AC –

Part 1: Common rules

1 Scope

This part of IEC 61936 provides common rules for the design and the erection of electrical power installations in systems with nominal voltages above 1 kV a.c. and nominal frequency up to and including 60 Hz, so as to provide safety and proper functioning for the use intended.

For the purpose of interpreting this standard, an electrical power installation is considered to be one of the following:

- a) Substation, including substation for railway power supply
- b) Electrical installations on mast, pole and tower
Switchgear and/or transformers located outside a closed electrical operating area
- c) One (or more) power station(s) located on a single site
The installation includes generators and transformers with all associated switchgear and all electrical auxiliary systems. Connections between generating stations located on different sites are excluded.
- d) The electrical system of a factory, industrial plant or other industrial, agricultural, commercial or public premises

- A1** e) Electrical installations erected on offshore platforms e.g. offshore wind power farms. **A1**

The electrical power installation includes, among others, the following equipment:

- rotating electrical machines;
- switchgear;
- transformers and reactors;
- converters;
- cables;
- wiring systems;
- batteries;
- capacitors;
- earthing systems;
- buildings and fences which are part of a closed electrical operating area;
- associated protection, control and auxiliary systems;
- large air core reactor.

NOTE In general, a standard for an item of equipment takes precedence over this standard.

This standard does not apply to the design and erection of any of the following:

- overhead and underground lines between separate installations;
- electric railways;
- mining equipment and installations;
- fluorescent lamp installations;
- A1** – installations on ships according to IEC 60092 [34] series and offshore units according to IEC 61892 [35] series, which are used in the offshore petroleum industry for drilling, processing and storage purposes. **A1**
- electrostatic equipment (e.g. electrostatic precipitators, spray-painting units);

- test sites;
- medical equipment, e.g. medical X-ray equipment.

A1 This standard does not apply to the design of prefabricated, type-tested switchgear and high voltage/low voltage prefabricated substation, for which separate IEC standards exist. **A1**

This standard does not apply to the requirements for carrying out live working on electrical installations.

If not otherwise required in this standard, for low-voltage electrical installations the standard series IEC 60364 applies.

2 Normative references

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

IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-3, *Rotating electrical machines – Part 3: Specific requirements for synchronous generators driven by steam turbines or combustion gas turbines*

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guide*

IEC 60076-2:1993, *Power transformers – Part 2: Temperature rise*

IEC 60076-11, *Power transformers – Part 11: Dry-type transformers*

IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60255 (all parts), *Measuring relays and protection equipment*

IEC 60331-21, *Tests for electric cables under fire conditions – Circuit integrity – Part 21: Procedures and requirements – Cables of rated voltage up to and including 0,6/1,0 kV*

IEC 60331-1, *Tests for electric cables under fire conditions – Circuit integrity – Part 1: Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm*

IEC 60332 (all parts), *Tests on electric and optical fibre cables under fire conditions*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC/TS 60479-1:2005, *Effects of current on human beings and livestock – Part 1: General aspects*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60617, *Graphical symbols for diagrams*

IEC 60721-2-6, *Classification of environmental conditions – Part 2-6: Environmental conditions appearing in nature – Earthquake vibration and shock*

IEC 60721-2-7, *Classification of environmental conditions – Part 2-7: Environmental conditions appearing in nature. Fauna and flora*

IEC 60754-1, *Test on gases evolved during combustion of materials from cables – Part 1: Determination of the amount of halogen acid gas*

IEC 60754-2, *Test on gases evolved during combustion of electric cables – Part 2: Determination of degree of acidity of gases evolved during the combustion of materials taken from electric cables by measuring pH and conductivity*

IEC/TS 60815-1, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

IEC 60826, *Design criteria of overhead transmission lines*

IEC 60865-1, *Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods*

IEC 60909 (all parts), *Short-circuit currents in three-phase a.c. systems*

IEC 60949, *Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects*

IEC/TR 61000-5-2, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling*

IEC 61034-1, *Measurement of smoke density of cables burning under defined conditions – Part 1: Test apparatus*

IEC 61082-1, *Preparation of documents used in electrotechnology – Part 1: Rules*

IEC 61100, *Classification of insulating liquids according of fire-point and net calorific value*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61219, *Live working – Earthing or earthing and short-circuiting equipment using lances as a short-circuiting device – Lance earthing*

IEC 61230, *Live working – Portable equipment for earthing or earthing and short-circuiting*

IEC 60079-10-2, *Explosives atmospheres – Part 10-2: Classification of areas – Combustible dust atmospheres*

IEC 61243 (all parts), *Live working – Voltage detectors*

 IEC/TS 61463, *Bushings – Seismic qualification*

IEC 62271-1:2007, *High-voltage switchgear and controlgear – Part 1: Common specifications*
Amendment 1:2011 

IEC 62271-200, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-201, *High-voltage switchgear and controlgear – Part 201: AC insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-202, *High-voltage switchgear and controlgear – Part 202: High-voltage/low-voltage prefabricated substation*

IEC 62271-203, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

A1 IEC 62271-206, *High-voltage switchgear and controlgear – Part 206: Voltage presence indicating systems for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-207, *High-voltage switchgear and controlgear – Part 207: Seismic qualification for gas-insulated switchgear assemblies for rated voltages above 52 kV*

IEC/TR 62271-300, *High-voltage switchgear and controlgear – Part 300: Seismic qualification of alternating current circuit-breakers* **A1**

IEC/TR 62271-303, *High-voltage switchgear and controlgear – Part 303: Use and handling of sulphur hexafluoride (SF₆)*

IEC 62305 (all parts), *Protection against lightning*

IEC 62305-4, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

A1 IEC 82079-1, *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements* **A1**

IEC Guide 107, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*

ISO/IEC Guide 51, *Safety aspects – Guidelines for their inclusion in standards*

ISO 1996-1, *Acoustics – Description, measurement and assessment of environmental noise – Part 1: Basic quantities and assessment-procedures*

C Text deleted **C**

Official Journal of the European Communities, No. C 62/23 dated 28.2.1994: *Interpretative document, Essential requirements No. 2, “safety in case of fire”*

3 Terms and definitions

For the purposes of this document, the following definitions apply.

3.1 General definitions

3.1.1

electrical equipment

item used for such purposes as generation, conversion, transmission, distribution or utilization of electric energy, such as electric machines, transformers, switchgear and controlgear, measuring instruments, protective devices, wiring systems, current-using equipment

[IEC 60050-826:2004, 826-16-01]

3.1.2

nominal value

value of a quantity used to designate and identify a component, device, equipment or system

[IEC 60050-151:2001, 151-16-09]

3.1.3

nominal voltage of a system

suitable approximate value of voltage used to designate or identify a system

[IEC 60050-601:1985, 601-01-21]

3.1.4

rated value

value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[IEC 60050-151:2001, 151-16-08]

3.1.5

highest voltage for installation

highest r.m.s value of phase-to-phase voltage for which the installation is designed in respect of its insulation

3.1.6

tested connection zone

zone in the vicinity of equipment terminals which has passed a dielectric type test with the appropriate withstand value(s), the applicable conductors being connected to the terminals in a manner specified by the manufacturer of the equipment

3.1.7

isolating distance

clearance between open contacts meeting the safety requirements specified for disconnectors

[IEC 60050-441:1984, 441-17-35]

3.1.8

isolation

switching off or disconnection of an installation, a part of an installation or an equipment from all non-earthed conductors by creating isolating gaps or distances

3.1.9

live part

conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

[IEC 60050-195:1998, 195-02-19]

NOTE 1 This concept does not necessarily imply a risk of electric shock.

NOTE 2 For definitions of PEM and PEL see IEC 60050-195:1998, 195-02-13 and IEC 60050-195:1998, 195-02-14.

3.1.10

feeder

electric line originating at a main substation and supplying one or more secondary substations, or one or more branch lines, or any combination of these two types of installations

[IEC 60050-601:1985, 601-02-08, modified]

3.1.11

ferro-resonance

resonance of the capacitance of an apparatus with the inductance of the saturable magnetic circuit of an adjacent apparatus

[IEC 60050-604:1987, 604-01-14]

3.1.12

transient overvoltage

short duration overvoltage of a few milliseconds, or less, oscillatory or non-oscillatory, usually highly damped

[IEC 60050-604, Amendment 1:1998, 604-03-13]

3.1.13

high voltage

voltage exceeding 1 000 V a.c.

3.1.14

low voltage

voltage not exceeding 1 000 V a.c.

3.1.15

operation

all activities, including both electrical and non-electrical work activities, necessary to permit the power installation to function

NOTE These activities include switching, controlling, monitoring and maintenance.

3.1.16

normal conditions of operation

all operating conditions frequently encountered

NOTE These include rated operating conditions, maximum and minimum operating conditions, partial load, normal transients (start-up, shut-down, load changes) standby situations.

3.1.17

abnormal conditions of operation

operating conditions of low occurrence (typical only a few times during equipment lifetime)

NOTE These include human errors, loss of power supply, overvoltages, earthquake, etc. After such a condition has occurred, equipment inspection may be required.

3.1.18

electrical work

work on, with or near an power installation such as testing and measurement, repairing, replacing, modifying, extending, erection and inspection

3.2 Definitions concerning installations

3.2.1

closed electrical operating area

room or location for operation of electrical installations and equipment to which access is intended to be restricted to skilled or instructed persons or to lay personnel under the supervision of skilled or instructed persons, e.g. by opening of a door or removal of protective barrier only by the use of a key or tool, and which is clearly marked by appropriate warning signs

3.2.2

operating areas subject to fire hazard

rooms, areas or locations, indoors or outdoors, where there is a danger, due to local or operating conditions, that hazardous quantities of easily flammable materials may come so close to the electrical equipment as to cause a fire hazard resulting from the high temperature of the equipment or due to arcing

3.2.3

sump

receptacle which is intended to receive the insulating liquid of a transformer or other equipment in case of leakage

[IEC 60050-605:1983, 605-02-30, modified]

3.2.4

catchment tank

collecting tank for the leakage liquids, rain water, etc. for one or more transformers or other equipment

3.2.5

busbar

conductor with associated connections, joints and insulated supports forming a common electrical connection between a number of circuits or individual pieces of apparatus

3.3 Definitions concerning types of installations

3.3.1

substation

part of a power system, concentrated in a given place, including mainly the terminations of transmission or distribution lines, switchgear and housing and which may also include transformers. It generally includes facilities necessary for system security and control (e.g. the protective devices).

NOTE According to the nature of the system within which the substation is included, a prefix may qualify it.

EXAMPLE Transmission substation (of a transmission system), distribution substation, 400 kV substation, 20 kV substation.

[IEC 60050-605:1983, 605-01-01]

3.3.2

power station

installation whose purpose is to generate electricity and which includes civil engineering works, energy conversion equipment and all the necessary ancillary equipment.

[IEC 60050-602:1983, 602-01-01]

3.3.3

installations of open design

installations where the equipment does not have protection against direct contact

3.3.4

installations of enclosed design

installations where the equipment has protection against direct contact

NOTE For degrees of enclosure protection see IEC 60529.

3.3.5

switchgear 'bay' or 'cubicle'

each branch of a busbar in an installation

3.4 Definitions concerning safety measures against electric shock

3.4.1

protection against direct contact

measures which prevent persons coming into hazardous proximity to live parts or those parts which could carry a hazardous voltage, with parts of their bodies or objects (reaching the danger zone)

3.4.2

protection in case of indirect contact

protection of persons from hazards which could arise, in event of fault, from contact with exposed conductive parts of electrical equipment or extraneous conductive parts

3.4.3

enclosure

part providing protection of equipment against certain external influences and, in any direction, protection against direct contact

3.4.4

protective barrier

part providing protection against direct contact from any usual direction of access

[IEC 60050-195:1998, 195-06-15]

3.4.5

protective obstacle

part preventing unintentional direct contact, but not preventing direct contact by deliberate action

[IEC 60050-195:1998, 195-06-16]

3.5 Definitions concerning clearances

3.5.1

clearance

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

[IEC 60050-441:1984, 441-17-31]

3.5.2

minimum clearance

smallest permissible clearance in air between live parts or between live parts and earth

3.5.3

protective barrier clearance

smallest permissible clearance between a protective barrier and live parts or those parts which may become subject to a hazardous voltage

3.5.4

protective obstacle clearance

smallest permissible clearance between a protective obstacle and live parts or those parts which may become subject to a hazardous voltage

3.5.5

danger zone

area limited by the minimum clearance (D_L) around live parts without complete protection against direct contact (see Figure 3)

NOTE Infringing the danger zone is considered the same as touching live parts.

ⓘ NOTE Additional definition of danger zone (D_L) is given in EN 50110-1 and EN 50110-2. ⓘ

3.5.6

vicinity zone

zone surrounding a danger zone, the outer boundary of which is limited by the distance D_V (see Figure 3)

NOTE 1 The outer boundary of the vicinity zone depends upon the voltage of the live part.

NOTE 2 Work in the vicinity zone is considered to be all work where a worker is either inside the zone or reaches into the zone with parts of the body or tools, equipment and devices being handled but does not reach into the danger zone.

NOTE 3 Additional definition of vicinity zone (D_v) is given in EN 50110-1 and EN 50110-2.

3.5.7

working clearance

minimum safe distance (D_w) to be observed between normally exposed live parts and any person working in a substation or any conductive tool directly handled (see Figure 3)

[IEC 60050-605:1983, 605-02-25, modified]

NOTE 1 Values for electrically skilled or instructed persons are given in Figure 3. This refers only to non-live working. Specific definitions related to live working practices are found in IEC 60050-651.

NOTE 2 In Europe the term “minimum working distance” is used instead of “working clearance”.

3.5.8

boundary clearance

smallest permissible clearance between an external fence and live parts or those parts which may become subject to a hazardous voltage

3.5.9

minimum height

smallest permissible vertical clearance between accessible surfaces and live parts without protection against direct contact or those parts which may become subject to a hazardous voltage (see Figure 3)

3.6 Definitions concerning control and protection

3.6.1

interlocking device

device which makes the operation of a switching device dependent upon the position or operation of one or more other pieces of equipment

[IEC 60050-441:1984, 441-16-49]

3.6.2

local control

control of operation from a point on or adjacent to the controlled switching device.

[IEC 60050-441:1984, 441-16-06]

3.6.3

remote control

control of operation at a point distant from the controlled switching device

[IEC 60050-441:1984, 441-16-07]

3.6.4

automatic reclosing

automatic reclosing of a circuit-breaker associated with a faulted section of a network after an interval of time which permits that section to recover from a transient fault

[IEC 60050-604:1987, 604-02-32]

3.7 Definitions concerning earthing

3.7.1

(local) earth

(local) ground

part of the Earth which is in electric contact with an earth electrode and the electric potential of which is not necessarily equal to zero

NOTE The conductive mass of the earth, whose electric potential at any point is conventionally taken as equal to zero.

[IEC 60050-195:1998, 195-01-03, modified]

3.7.2

reference earth

reference ground (remote earth/ground)

part of the Earth considered as conductive, the electric potential of which is conventionally taken as zero, being outside the zone of influence of the relevant earthing arrangement

NOTE The concept "Earth" means the planet and all its physical matter.

[IEC 60050-195:1998, 195-01-01, modified]

3.7.3

earth electrode

ground electrode

conductive part, which may be embedded in a specific conductive medium, e.g. in concrete or coke, in electric contact with the Earth

[IEC 60050-195:1998, 195-02-01]

3.7.4

earthing conductor

grounding conductor

conductor which provides a conductive path, or part of the conductive path, between a given point in a system or in an installation or in equipment and an earth electrode

[IEC 60050-195:1998, 195-02-03]

NOTE Where the connection between part of the installation and the earth electrode is made via a disconnecting link, disconnecting switch, surge arrester counter, surge arrester control gap etc., then only that part of the connection permanently attached to the earth electrode is an earthing conductor.

3.7.5

protective bonding conductor

protective conductor for ensuring equipotential bonding

3.7.6

earthing system

grounding system

arrangement of connections and devices necessary to earth equipment or a system separately or jointly

[IEC 60050-604:1987, 604-04-02]

3.7.7

earth rod

ground rod

earth electrode consisting of a metal rod driven into the ground

[IEC 60050-604:1987, 604-04-09]

3.7.8

structural earth electrode

metal part, which is in conductive contact with the earth or with water directly or via concrete, whose original purpose is not earthing, but which fulfils all requirements of an earth electrode without impairment of the original purpose

NOTE Examples of structural earth electrodes are pipelines, sheet piling, concrete reinforcement bars in foundations and the steel structure of buildings, etc.

3.7.9

electric resistivity of soil

ρ_E

resistivity of a typical sample of soil

3.7.10

resistance to earth

R_E

real part of the impedance to earth

3.7.11

impedance to earth

Z_E

impedance at a given frequency between a specified point in a system or in an installation or in equipment and reference earth

NOTE The impedance to earth is determined by the directly connected earth electrodes and also by connected overhead earth wires and wires buried in earth of overhead lines, by connected cables with earth electrode effect and by other earthing systems which are conductively connected to the relevant earthing system by conductive cable sheaths, shields, PEN conductors or in another way.

3.7.12

earth potential rise

EPR

U_E

voltage between an earthing system and reference earth

3.7.13

potential

voltage between an observation point and reference earth

3.7.14

(effective) touch voltage

U_T

voltage between conductive parts when touched simultaneously

NOTE The value of the effective touch voltage may be appreciably influenced by the impedance of the person in electric contact with these conductive parts.

[IEC 60050-195:1998, 195-05-11, modified]

3.7.15

prospective touch voltage

U_{vT}

voltage between simultaneously accessible conductive parts when those conductive parts are not being touched

[IEC 60050-195:1998, 195-05-09, modified]

3.7.16

step voltage

U_s

voltage between two points on the Earth's surface that are 1 m distant from each other, which is considered to be the stride length of a person

[IEC 60050-195:1998, 195-05-12]

3.7.17

transferred potential

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

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

3.7.18

stress voltage

voltage appearing during earth fault conditions between an earthed part or enclosure of equipment or device and any other of its parts and which could affect its normal operation or safety

3.7.19

global earthing system

equivalent earthing system created by the interconnection of local earthing systems that ensures, by the proximity of the earthing systems, that there are no dangerous touch voltages

NOTE 1 Such systems permit the division of the earth fault current in a way that results in a reduction of the earth potential rise at the local earthing system. Such a system could be said to form a quasi equipotential surface.

NOTE 2 The existence of a global earthing system may be determined by sample measurements or calculation for typical systems. Typical examples of global earthing systems are in city centres; urban or industrial areas with distributed low- and high-voltage earthing.

3.7.20

multi-earthed (multi-grounded) HV neutral conductor

neutral conductor of a distribution line connected to the earthing system of the source transformer and regularly earthed

3.7.21

exposed-conductive-part

conductive part of equipment which can be touched and which is not normally live, but which can become live when basic insulation fails

[IEC 60050-826:2004, 826-12-10]

3.7.22

extraneous-conductive-part

conductive part not forming part of the electrical installation and liable to introduce an electric potential, generally the electric potential of a local earth

[IEC 60050-826:2004, 826-12-11, modified]

3.7.23

PEN conductor

conductor combining the functions of both protective earthing conductor and neutral conductor

[IEC 60050-826:2004, 826-13-25]

3.7.24

earth/ground fault

fault caused by a conductor being connected to earth or by the insulation resistance to earth becoming less than a specified value

[IEC 60050-151:1978², 151-03-40]

² IEC 60050-151:1978 has been replaced in 2001, but for this definition (151-03-40) the 1978 publication is applicable.

NOTE Earth faults of two or several phase conductors of the same system at different locations are designated as double or multiple earth faults.

3.7.25 earth fault current

I_F

current which flows from the main circuit to earth or earthed parts at the fault location (earth fault location)

NOTE 1 For single earth faults, this is

- in systems with isolated neutral, the capacitive earth fault current,
- in systems with high resistive earthing, the RC composed earth fault current,
- in systems with resonant earthing, the earth fault residual current,
- in systems with solid or low impedance neutral earthing, the line-to-earth short-circuit current.

NOTE 2 Further earth fault current may result from double earth fault and line to line to earth

3.7.26 circulating transformer neutral current

portion of fault current which flows back to the transformer neutral point via the metallic parts and/or the earthing system without ever discharging into soil

4 Fundamental requirements

4.1 General

4.1.1 General requirements

Installations and equipment shall be capable of withstanding electrical, mechanical, climatic and environmental influences anticipated on site.

The design shall take into account:

- the purpose of the installation,
- the users requirements such as power quality, reliability, availability, and ability of the electrical network to withstand the effects of transient conditions such as starting of large motors, short power outages and re-energization of the installation.
- the safety of the operators and the public,
- the environmental influence,
- the possibility for extension (if required) and maintenance.

The user shall define preferences for specific maintenance features and identify the safety requirements to be met for levels of segregation of the switchgear and controlgear to ensure minimal plant shutdown. Where necessary, the levels of segregation of switchgear shall be such as to minimize the spread of a fault, including a fire, occurring in any defined module into adjacent modules.

There are operating conditions of low occurrence or low cumulative duration which can occur and for which specific design criteria may be agreed between the user and the manufacturer. In such cases, measures required to prevent unsafe conditions and to avoid damage to electrical or plant equipment shall be taken.

The generators shall be capable of meeting the requirements for connection to the power system grid or local grid, e.g. for voltage regulation, frequency response, etc.

4.1.2 Agreements between supplier (manufacturer) and user

The working procedures of the user shall be taken into account in the design of the installation.

For design and erection of power installations, additional agreements between manufacturer/contractor/planner and user/orderer/owner shall be followed, which also may have effects to necessary operational requirements. References can be found in the following subclauses:

Subclause	Item
4.1.1	General requirements (specific design criteria)
4.2.2	Voltage classification
[A1] 4.3.9	Special conditions and requirements for seismic environment [A1]
4.4.2.1	Climatic and environmental conditions (for auxiliary equipment: indoor)
4.4.2.2	Climatic and environmental conditions (for auxiliary equipment: outdoor)
4.4.3.1	Conditions different from the normal environmental conditions
[A1] 4.4.3.5	Special conditions and requirements for vibrations [A1]
6.1.2	Compliance with operational and safety procedures
6.2.1	Method of indication (contact position of interrupting or isolating equipment)
6.2.1	Interlocks and/or locking facilities
6.2.1	Switching devices (reduced rating)
6.2.1	Rating of switchgear (specific requirements)
6.2.8	Level of pollution
6.2.8	Outdoor insulators in polluted or heavy wetting conditions
6.2.9.1	Insulated cables (temperature rise)
7.1	Higher values for distances, clearances and dimensions
7.1	Installations (operating procedures)
7.1.2	Documentation (extent of the documentation)
7.1.3	Transport routes (load capacity, height and width)
7.1.5	Lighting (presence and extent of the lighting)
7.5.4	Maintenance and operating areas (distances of the escape route)
8.4	Means to protect persons working on electrical installations (working procedures)
8.4.3	Devices for determining the de-energized state (extent of provisions)
8.4.4	Devices for earthing and short-circuiting (Extent of provision or supply)
8.4.5.1	Equipment acting as protective barriers against adjacent live parts (extent of Insertable insulated partitions)
8.4.5.2	Equipment acting as protective barriers against adjacent live parts (extent of insertable partition walls)
8.5	Protection from danger resulting from arc fault (degree of importance of measures)
8.6	Protections against direct lightning strokes (method of analysis)
8.7.1	Requirements for fire extinguishing equipment
[A1] 8.7.2.1	Reduction of distances G_1/G_2 [A1]
9.1	Monitoring and control systems (agreement of fault level and protection grading studies)
9.3	Compressed air system (sectionalization for maintenance)
9.4	SF ₆ gas handling plants (design and capacity of the plant)
[A1] 10.2.1	Fundamental requirements for design of the earthing system [A1]
11	Inspection and testing (extent of the inspection and testing / specification / documentation)
11.3	Tests during installation and commissioning (requirements / test equipment / schedule of tests)
11.4	Trial running (performance)

4.2 Electrical requirements

4.2.1 Methods of neutral earthing

The method of neutral earthing strongly influences the fault current level and the fault current duration. Furthermore the neutral earthing method is important with regard to the following:

- selection of insulation level;
- characteristics of overvoltage - limiting devices - such as spark gaps or surge arresters;
- selection of protective relays;
- design of earthing system.

The following are examples of neutral earthing methods:

- isolated neutral;
- resonant earthing;
- high resistive earthing;
- solid (low impedance) earthing.

The choice of the type of neutral earthing is normally based on the following criteria:

- local regulations (if any);
- continuity of supply required for the network;
- limitation of damage to equipment caused by earth faults;
- selective elimination of faulty sections of the network;
- detection of fault location;
- touch and step voltages;
- inductive interference;
- operation and maintenance aspects.

One galvanically connected system has only one method of neutral earthing. Different galvanically independent systems may have different methods of neutral earthing. If different neutral earthing configurations can occur during normal or abnormal operating conditions, equipment and protective system shall be designed to operate under these conditions.

4.2.2 Voltage classification

The users shall define the nominal voltage and the maximum operating voltage of their system. Based on the maximum operating voltage, the highest voltage for installation (U_m) shall be selected either from Table 1, Table 2 or Annex A.

4.2.3 Current in normal operation

Every part of an installation shall be designed and constructed to withstand currents under defined operating conditions.

4.2.4 Short-circuit current

Installations shall be designed, constructed and erected to safely withstand the mechanical and thermal effects resulting from short-circuit currents.

NOTE 1 Where an installation has on-site generation, motors or parallel operation with a network (co-generation), fault levels can increase. **NOTE 2**

For the purpose of this standard all types of short-circuit shall be considered, e.g.:

- three-phase;
- phase-to-phase;

- phase-to-earth;
- double phase-to-earth.

Installations shall be protected with automatic devices to disconnect three-phase and phase-to-phase short-circuits.

Installations shall be protected either with automatic devices to disconnect earth faults or to indicate the earth fault condition. The selection of the device is dependent upon the method of neutral earthing.

The standard value of rated duration of the short-circuit is 1,0 s.

NOTE 2 If a value other than 1 s is appropriate, recommended values would be 0,5 s, 2,0 s and 3,0 s.

NOTE 3 The rated duration should be determined taking into consideration the fault switching time.

Methods for the calculation of short-circuit currents in three-phase a.c. systems are given in the IEC 60909 series.

Methods for the calculation of the effects of short-circuit current are given in IEC 60865-1 and, for power cables, in IEC 60949.

4.2.5 Rated frequency

Installations shall be designed for the rated frequency of the system in which they shall operate.

4.2.6 Corona

The design of installations shall be such that radio interference due to electromagnetic fields, e.g. caused by corona effects, will not exceed a specified level.

NOTE 1 Recommendations for minimizing the radio interference of high-voltage installations are reported in CISPR 18-1, CISPR 18-2 and CISPR 18-3 [1],[2],[3]³.

NOTE 2 Maximum permissible levels of radio interference may be given by national or local authorities.

NOTE 3 Guidance on acceptable levels of radio interference voltage for switchgear and controlgear can be found in IEC 62271-1:2007.

When the acceptable value is exceeded, the corona level may be controlled, for example, by the installation of corona rings or the recessing of fasteners on bus fittings for high-voltage suspension insulator assemblies, bus support assemblies, bus connections and equipment terminals.

4.2.7 Electric and magnetic fields

The design of an installation shall be such as to limit the electric and magnetic fields generated by energized equipment to an acceptable level for exposed people.

NOTE National and/or international regulations may specify acceptable levels. Further information is available from International Commission on Non-Ionizing Radiation Protection (ICNIRP) or IEEE. **NOTE**

4.2.8 Overvoltages

Equipment shall be protected against overvoltages resulting from switching operations or lightning that could exceed the withstand values according to IEC 60071-1 and 60071-2.

³ Figures in square brackets refer to the bibliography.

4.2.9 Harmonics

Consideration should be given to the effect of harmonic currents and harmonic voltages on the installation, e.g. in industrial installations. Harmonic analyses may be required to determine what corrective measures are needed to meet local regulations and/or to ensure correct operation of the whole electrical system.

[C] NOTE For more information consult EN 50160. **[C]**

4.3 Mechanical requirements

4.3.1 Equipment and supporting structures

Equipment and supporting structures, including their foundations, shall withstand the anticipated mechanical stresses.

Two load cases shall be considered, normal and exceptional. In each of these load cases, several combinations shall be investigated, the most unfavourable of which shall be used to determine the mechanical strength of the structures.

In the normal load case, the following loads shall be considered:

- dead load;
- tension load;
- erection load;
- ice load;
- wind load.

[A1] Consideration shall be given to temporary stresses and loads that may be applied during construction or maintenance procedures. Specific equipment can be affected by cyclic loads and stresses due to thermal expansions (refer to specific equipment standards). **[A1]**

In the exceptional load case, dead load and tension load acting simultaneously with the largest of the following occasional loads shall be considered:

- switching forces;
- short-circuit forces;
- loss of conductor tension;

[A1] – seismic loads. **[A1]**

[A1] *Text deleted* **[A1]**

4.3.2 Tension load

The tension load shall be calculated from the maximum conductor tension under the most unfavourable local conditions.

Possible combinations include, for example:

- –20 °C without ice and without wind;
- –5 °C with ice and without wind;
- +5 °C with wind.

4.3.3 Erection load

The erection load is a load of at least 1,0 kN applied at the most critical position of a supporting structure, tensioning portal, etc.

4.3.4 Ice load

In regions where icing can occur, the resulting load on flexible conductors and on rigid busbars and conductors shall be taken into account.

If local experience or statistics are not available, ice coatings of 1 mm, 10 mm or 20 mm based on criteria given in IEC 62271-1:2007 may be assumed. The density of the ice is assumed to be 900 kg/m³ in accordance with IEC 60826.

4.3.5 Wind load

Wind loads, which can be very different depending on the local topographic influences and the height of the structures above the surrounding ground, shall be taken into account. The most unfavourable wind direction shall be considered.

IEC 62271-1:2007 contains requirements for wind loading on switchgear and controlgear.

4.3.6 Switching forces

Switching forces shall be considered when designing supports. The forces shall be determined by the designer of the equipment.

4.3.7 Short-circuit forces

The mechanical effects of a short-circuit can be estimated by the methods detailed in IEC 60865-1.

NOTE The CIGRÉ technical brochure "Mechanical effects of short-circuit currents in open air substations" gives additional advice.

4.3.8 Loss of conductor tension

A structure with tension insulator strings shall be designed to withstand the loss of conductor tension resulting from breakage of the insulator or conductor which gives the most unfavourable load case.

NOTE 1 General practice is to base the calculation on 0 °C, no ice and no wind load.

NOTE 2 For bundle conductors, only one subconductor is assumed to fail.

4.3.9 Seismic loads

Special conditions and requirements shall be agreed between user and supplier. (See also 4.4.3.5 Vibration).

Installations situated in a seismic environment shall be designed to take this into account.

Where load specifications apply to the installation of civil work or equipment to meet seismic conditions, then these specifications shall be observed.

Seismic loads shall be dealt with in accordance with appropriate standards for power installations: e.g. IEC 62271-207 for GIS, IEC/TR 62271-300 for circuit-breakers and IEC/TS 61463 for bushings.

The following measures shall be taken into account:

- a) Any individual equipment shall be designed to withstand the dynamic forces resulting from the vertical and horizontal motions of the soil. These effects may be modified by the response of the foundation and/or the supporting frame and/or the floor in which this equipment is installed. The response spectrum of the earthquake shall be considered for the design of the equipment. 

- A1** b) The layout shall be chosen in order to limit the loads due to interconnections between adjoining devices needing to accommodate large relatively axial, lateral, torsional or other movements to acceptable values. Attention should be paid to other stresses which may develop during an earthquake. **A1**

4.3.10 Dimensioning of supporting structures

The dimensioning of supporting structures shall be in accordance with applicable codes and standards. Security factors are given in national rules.

C NOTE For more information consult EN 50341 and EN 50423. **C**

4.4 Climatic and environmental conditions

4.4.1 General

Installations, including all devices and auxiliary equipment which form an integral part of them, shall be designed for operation under the climatic and environmental conditions listed below.

The presence of condensation, precipitation, particles, dust, corrosive elements and hazardous atmospheres shall be specified in such a manner that appropriate electrical equipment can be selected. Zone classification for hazardous areas shall be performed in accordance with IEC 60079-10-1 and IEC 60079-10-2. Equipment can be selected according to IEC 60721 series.

4.4.2 Normal conditions

4.4.2.1 Indoor

- a) The ambient air temperature does not exceed 40 °C and its average value, measured over a period of 24 h, does not exceed 35 °C.

The minimum ambient air temperatures are:

- –5 °C for class “–5 indoor”,
- –15 °C for class “–15 indoor” and
- –25 °C for class “–25 indoor”.

On auxiliary equipment, such as relays and control switches, intended to be used in ambient air temperature below –5 °C, an agreement between supplier and user is necessary.

- b) The influence of solar radiation may be neglected.
- c) The altitude does not exceed 1 000 m above sea level.
- d) The ambient air is not significantly polluted by dust, smoke, corrosive and/or flammable gases, vapours or salt.
- e) The average value of the relative humidity, measured over a period of 24 h, does not exceed 95 %.

For these conditions condensation may occasionally occur.

NOTE 1 Condensation can be expected where sudden temperature changes occur in periods of high humidity.

NOTE 2 To avoid breakdown of insulation and/or corrosion of metallic parts due to high humidity and condensation, equipment designed for such conditions and tested accordingly should be used.

NOTE 3 Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment.

- f) Vibration due to causes external to the equipment or to earth tremors is negligible.
- g) Electromagnetic disturbances **AC1** should **AC1** be considered as described in IEC Guide 107.

4.4.2.2 Outdoor

- a) The ambient air temperature does not exceed 40 °C and its average value, measured over a period of 24 h, does not exceed 35 °C.

The minimum ambient air temperatures are:

- –10 °C for class “–10 outdoor”,
- –25 °C for class “–25 outdoor”,
- –30 °C for class “–30 outdoor” and
- –40 °C for class “–40 outdoor”.

Rapid temperature changes AC_1 should AC_1 be taken into account.

Auxiliary equipment, such as relays and control switches, intended to be used in ambient air temperatures below –5 °C, shall be the subject of an agreement between supplier and user.

- b) Solar radiation up to a level of 1 000 W/m² (on a clear day at noon) AC_1 should AC_1 be considered.

NOTE 1 Under certain conditions of solar radiation, appropriate measures, for example roofing, forced ventilation, etc., may be necessary, or AC_1 derating may be used AC_1 in order not to exceed the specified temperature rises.

NOTE 2 Details of global solar radiation are given in IEC 60721-2-4.

NOTE 3 UV radiation can damage some synthetic materials. For more information, consult the IEC 60068 series.

- c) The altitude does not exceed 1 000 m above sea level.
- d) The ambient air is not significantly polluted by dust, smoke, corrosive gases, vapours or salt. Pollution does not exceed pollution class c – Medium, according to IEC/TS 60815-1.
- e) The ice coating does not exceed 1 mm for class 1, 10 mm for class 10 and 20 mm for class 20. Additional information is given in 4.3.4.
- f) The wind speed does not exceed 34 m/s (corresponding to 700 Pa on cylindrical surfaces).

NOTE 4 Characteristics of wind are described in IEC 60721-2-2.

- g) Account should be taken of the presence of condensation or precipitation. Precipitation in the form of dew, condensation, fog, rain, snow, ice or hoar frost shall be taken into account.

NOTE 5 Precipitation characteristics for insulation are described in IEC 60060-1 and IEC 60071-1. For other properties, precipitation characteristics are described in IEC 60721-2-2.

- h) Vibration due to causes external to the equipment or to earth tremors is negligible.
- i) Electromagnetic disturbances AC_1 should AC_1 be considered as described in IEC Guide 107.

4.4.3 Special conditions

4.4.3.1 General

When high-voltage equipment is used under conditions different from the normal environmental conditions given in 4.4.2, the user's requirements AC_1 should refer AC_1 , for example, to the standardized steps given in the following subclauses.

4.4.3.2 Altitude

For installations situated at an altitude higher than 1 000 m above sea level, the insulation level of external insulation under the standardized reference atmospheric conditions shall be determined by multiplying the insulation withstand voltages required at the service location by a factor K_a in accordance with IEC 62271-1:2007.

NOTE 1 For internal pressurized insulation, the dielectric characteristics are identical at any altitude and no special precautions need be taken.

NOTE 2 For low-voltage auxiliary and control equipment, no special precautions need be taken if the altitude is lower than 2 000 m above sea level. For higher altitudes, see IEC 60664-1.

NOTE 3 The pressure variation due to altitude is given in IEC 60721-2-3. Regarding this phenomenon, particular attention should be devoted to the following points:

- thermal exchanges by convection, conduction or radiation;
- efficiency of heating or air-conditioning;
- operating level of pressure devices;
- efficiency of diesel generating set or compressed air station;
- increase of corona effect.

NOTE 4 The correction factor K_a of IEC 62271-1:2007 reflects the fact that modification is not required for altitudes below 1 000 m.

4.4.3.3 Pollution

For equipment in polluted ambient air, a pollution class d (heavy), or class e (very heavy), as defined in IEC/TS 60815-1, should be specified.

4.4.3.4 Temperature and humidity

For equipment in a place where the ambient temperature can be significantly outside the normal service condition range stated in 4.4.2, the preferred ranges of minimum and maximum temperature to be specified should be as follows:

- 50 °C and +40 °C for very cold climates;
- 5 °C and +50 °C for very hot climates.

In certain regions with frequent occurrence of warm, humid winds, sudden changes of temperature may occur, resulting in condensation, even indoors.

In tropical indoor conditions, the average value of relative humidity measured during a period of 24 h can be 98 %.

In some underground installations, equipment might be located under water. Such equipment shall be designed accordingly and proper operating procedures defined.

4.4.3.5 Vibration

A1 Special conditions and requirements shall be agreed between user and supplier. (See also 4.3.9 Seismic loads).

Vibration caused by wind, electromagnetic stresses, traffic (e. g. temporary road and railway traffic) and industrial processes shall be considered. The withstand capability of equipment against vibrations shall be given by the manufacturer.

The service stresses of equipment, which may be transmitted through a common monolithic foundation or floor (for example opening/reclosing of circuit-breakers) shall be taken into account. **A1**

4.5 Special requirements

4.5.1 Effects of small animals and micro-organisms

If biological activity (through birds, other small animals or micro-organisms) is a hazard, measures against such damage shall be taken. These may include appropriate choice of materials, measure to prevent access and adequate heating and ventilating (for more details see IEC 60721-2-7).

4.5.2 Noise level

If noise level limits are given (usually by administrative authorities), they shall be achieved by appropriate measures such as

- using sound insulation techniques against sound transmitted through air or solids;
- using low noise equipment.

Criteria for noise evaluation for different places and different periods of day are given in ISO 1996-1.

4.5.3 Transport

The transport to site, e.g. large transformers and storage constraints may have consequences on the design of the high-voltage electrical installation.

5 Insulation

5.1 General

As conventional (air insulated) installations are normally not impulse tested, the installation requires minimum clearances between live parts and earth and between live parts of phases in order to avoid flashover below the impulse withstand level selected for the installation.

Insulation coordination shall be in accordance with IEC 60071-1.

5.2 Selection of insulation level

The insulation level shall be chosen according to the established highest voltage for installation U_m and/or impulse withstand voltage.

5.2.1 Consideration of methods of neutral earthing

The choice should be made primarily to ensure reliability in service, taking into account the method of neutral earthing in the system and the characteristics and the locations of overvoltage limiting devices to be installed.

In installations in which a high level of safety is required, or in which the configuration of the system, the adopted method of neutral earthing or the protection by surge arresters make it inappropriate to lower the level of insulation, one of the higher alternative values of Table 1, Table 2 and Annex A shall be chosen.

In installations in which the configuration of the system, the adopted method of neutral earthing or the protection by surge arresters makes it appropriate to lower the level of insulation, the lower alternative values of Table 1, Table 2 and Annex A are sufficient.

5.2.2 Consideration of rated withstand voltages

In the voltage range I ($1 \text{ kV} < U_m \leq 245 \text{ kV}$), the choice shall be based on the rated lightning impulse withstand voltages and the rated short-duration power-frequency withstand voltages of Table 1; in the voltage range II ($U_m > 245 \text{ kV}$) the choice shall be based on the rated switching impulse withstand voltages and the rated lightning impulse withstand voltages given in Table 2. Values of rated insulation levels not standardized by IEC but based on current practice in some countries are listed in Annex A (Tables A.1, A.2 and A.3).

5.3 Verification of withstand values

If the minimum clearances in air given in Table 1, Table 2 and Annex A are maintained, it is not necessary to apply dielectric tests.

If the minimum clearances in air are not maintained, the ability to withstand the test voltages of the chosen insulation level shall be established by applying the appropriate dielectric tests in accordance with IEC 60060-1 for the withstand voltage values given in Table 1, Table 2 and Annex A.

If the minimum clearances in air are not maintained in parts or areas of an installation, dielectric tests restricted to these parts or areas will be sufficient.

NOTE In accordance with IEC 60071-2:1996, Annex A, minimum clearances may be lower if this has been proven by tests or by operating experience of lower overvoltages.

5.4 Minimum clearances of live parts

5.4.1 General

The minimum clearances in air given in Table 1, Table 2 and Annex A apply for altitudes up to 1 000 m above sea level. For higher altitudes, see 4.4.3.2.

NOTE Some values of minimum clearances are designated as “N”. This is a symbol for those minimum clearances on which safety distances as given in 7 are based.

A1 If parts of an installation can be separated from each other by a disconnecter, these parts shall be tested at the rated impulse withstand voltage for the isolating distance (see Tables 1a and 1b as well as Tables 2a and 2b of IEC 62271-1:2007, Amendment 1:2011). **A1** If between such parts of an installation the minimum clearances of Table 1 for range I, respectively the minimum phase-to-phase clearances of Table 2 for range II are increased by 25 % or more, it is not necessary to apply dielectric tests.

5.4.2 Minimum clearances in voltage range I

In the voltage range I (see Table 1) the minimum clearances in air are based on unfavourable electrode configurations with small radii of curvature (i.e. rod-plate). As the rated lightning impulse withstand voltage (LIWV) in these voltage ranges is the same as for the phase-phase insulation and phase-earth insulation, the clearances apply for both insulation distances.

5.4.3 Minimum clearances in voltage range II

In voltage range II (see Table 2) the clearances in air are determined by the rated switching impulse withstand voltage (SIWV). They substantially depend on the electrode configurations. In cases of difficulty in classifying the electrode configuration, it is recommended to make a choice based on the phase-to-earth clearances of the most unfavourable configuration such as, for example, the arm of an isolator against the tower construction (rod-structure).

Table 1 – Minimum clearances in air – Voltage range I
(1 kV < $U_m \leq 245$ kV)

Voltage range	Highest voltage for installation	Rated short-duration power-frequency withstand voltage	Rated lightning impulse withstand voltage ^a	Minimum phase-to-earth and phase-to-phase clearance	
	U_m r.m.s.	U_d r.m.s.	U_p 1,2/50 μ s (peak value)	N	
	kV	kV	kV	Indoor installations	Outdoor installations
I	3,6	10	20	60	120
			40	60	120
	7,2	20	40	60	120
			60	90	120
	12	28	60	90	150
			75	120	150
			95	160	160
	17,5	38	75	120	160
			95	160	160
	24	50	95	160	
			125	220	
			145	270	
	36	70	145	270	
			170	320	
	52	95	250	480	
	72,5	140	325	630	
	123	185 ^b	450 ^b	900	
			550	1 100	
	145	185 ^b	450 ^b	900	
			550	1 100	
650			1 300		
170	230 ^b	550 ^b	1 100		
		650	1 300		
		750	1 500		
245	275 ^b	650 ^b	1 300		
	325 ^b	750 ^b	1 500		
	360	850	1 700		
	395	950	1 900		
	460	1 050	2 100		
^a The rated lightning impulse is applicable to phase-to-phase and phase-to-earth.					
^b If values are considered insufficient to prove that the required phase-to-phase withstand voltages are met, additional phase-to-phase withstand tests are needed.					