



BSI Standards Publication

Insulation coordination for equipment within low-voltage supply systems

Part 1: Principles, requirements and tests

National foreword

This British Standard is the UK implementation of EN IEC 60664-1:2020+A1:2025. It is identical to IEC 60664-1:2020, incorporating corrigendum October 2020 and amendment 1:2025. It supersedes BS EN IEC 60664-1:2020, which will be withdrawn on 30 June 2028.

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**.

The UK participation in its preparation was entrusted to Technical Committee GEL/109, Insulation co-ordination for low voltage equipment.

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

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Amendments/corrigenda issued since publication

Date	Text affected
31 December 2020	Implementation of IEC corrigendum October 2020: replacement of Figure G.1 (2 of 2)
30 June 2025	Implementation of IEC amendment 1:2025 with CENELEC endorsement A1:2025

English Version

**Insulation coordination for equipment within low-voltage supply
systems - Part 1: Principles, requirements and tests
(IEC 60664-1:2020)**

Coordination de l'isolement des matériels dans les réseaux
d'énergie électrique à basse tension - Partie 1: Principes,
exigences et essais
(IEC 60664-1:2020)

Isolationskoordination für elektrische Betriebsmittel in
Niederspannungsanlagen - Teil 1: Grundsätze,
Anforderungen und Prüfungen
(IEC 60664-1:2020)

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

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 109/183/FDIS, future edition 3 of IEC 60664-1, prepared by IEC/TC 109 "Insulation co-ordination for low-voltage equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 60664-1:2020.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2021-03-30
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2023-06-30

This document supersedes EN 60664-1:2007 and all of its amendments and corrigenda (if any).

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

Endorsement notice

The text of the International Standard IEC 60664-1:2020 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:

IEC 60038:2009	NOTE	Harmonized as EN 60038:2011 (modified)
IEC 60216 (series)	NOTE	Harmonized as EN 60216 (series)
IEC 60068 (series)	NOTE	Harmonized as EN 60068 (series)
IEC 60068-1:2013	NOTE	Harmonized as EN 60068-1:2014 (not modified)
IEC 60085:2007	NOTE	Harmonized as EN 60085:2008 (not modified)
IEC 60112:2003	NOTE	Harmonized as EN 60112:2003 (not modified)
IEC 60364-4-44:2007	NOTE	Harmonized as HD 60364-4-442:2012 (modified)
IEC 60529	NOTE	Harmonized as EN 60529
IEC 60664-3:2016	NOTE	Harmonized as EN 60664-3:2017 (not modified)
IEC 60664-4:2005	NOTE	Harmonized as EN 60664-4:2006 (not modified)
IEC 61000-4-5:2014	NOTE	Harmonized as EN 61000-4-5:2014 (not modified)

European foreword to Amendment 1

The text of document 109/235/FDIS, future edition 3 of IEC 60664-1/AMD1, prepared by TC 109 "Insulation co-ordination for low-voltage equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 60664-1:2020/A1:2025.

The following dates are fixed:

- latest date by which the document has to be implemented at national (dop) 2026-06-30 level by publication of an identical national standard or by endorsement
- latest date by which the national standards conflicting with the (dow) 2028-06-30 document have to be withdrawn

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Endorsement notice

The text of the International Standard IEC 60664-1:2020/AMD1:2025 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 standard indicated:

IEC 61643 (series)	NOTE Approved as EN IEC 61643 (series)
IEC 60364-1	NOTE Approved as HD 60364-1

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60068-2-2	-	Environmental testing - Part 2-2: Tests - Test B: Dry heat	EN 60068-2-2	-
IEC 60068-2-14	2009	Environmental testing - Part 2-14: Tests - Test N: Change of temperature	EN 60068-2-14	2009
IEC 60068-2-78	-	Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state	EN 60068-2-78	-
IEC 60270	-	High-voltage test techniques - Partial discharge measurements	EN 60270	-
IEC 61140	2016	Protection against electric shock - Common aspects for installation and equipment	EN 61140	2016
IEC 61180	2016	High-voltage test techniques for low-voltage equipment - Definitions, test and procedure requirements, test equipment	EN 61180	2016

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INSULATION COORDINATION FOR EQUIPMENT WITHIN LOW-VOLTAGE SUPPLY SYSTEMS –

Part 1: Principles, requirements and tests

FOREWORD

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International Standard IEC 60664-1 has been prepared by IEC technical committee 109: Insulation co-ordination for low-voltage equipment.

This third edition cancels and replaces the second edition published in 2007. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) update of the Scope, Clauses 2 and 3,
- b) new structure for Clauses 4 and 5,
- c) addition of 1 500 V DC into tables in Annex B and F,
- d) update of distances altitude correction in a new Table F.10,
- e) addition of Annex G with a flowchart for clearances,

f) addition of Annex H with a flowchart for creepage distances.

It has the status of a basic safety publication in accordance with IEC Guide 104.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
109/183/FDIS	109/186/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60664 series, published under the general title *Insulation coordination for equipment within low-voltage supply systems*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

In this document, the following print type is used:

– **Terms defined in Clause 3: in bold type.**

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

The contents of the corrigendum of October 2020 have been included in this copy.

INSULATION COORDINATION FOR EQUIPMENT WITHIN LOW-VOLTAGE SUPPLY SYSTEMS –

Part 1: Principles, requirements and tests

1 Scope

A1 This part of IEC 60664 deals with **insulation coordination** for **electrical equipment** having a **rated voltage** up to AC 1 000 V or DC 1 500 V connected to **low-voltage supply systems**.

NOTE 1 Throughout this document, the term equipment is used with the meaning of **electrical equipment**. **A1**

This document applies to frequencies up to 30 kHz.

A1 NOTE 2 **A1** Requirements for **insulation coordination** for equipment within **low-voltage supply systems** with rated frequencies above 30 kHz are given in IEC 60664-4.

A1 NOTE 3 **A1** Higher voltages can exist in internal circuits of the equipment.

It applies to equipment for use up to 2 000 m above sea level and provides guidance for use at higher altitudes (See 5.2.3.4).

It provides requirements for technical committees to determine **clearances**, **creepage distances** and criteria for **solid insulation**. It includes methods of electrical testing with respect to **insulation coordination**.

The minimum **clearances** specified in this document do not apply where ionized gases are present. Special requirements for such situations can be specified at the discretion of the relevant technical committee.

This document does not deal with distances:

- through liquid insulation;
- through gases other than air;
- through compressed air.

This basic safety publication focusing on safety essential requirements is primarily intended for use by technical committees in the preparation of standards in accordance with the principles laid down in IEC Guide 104 and ISO/IEC Guide 51.

One of the responsibilities of a technical committee is, wherever applicable, to make use of basic safety publications in the preparation of its publications.

However, in case of missing specified values for **clearances**, **creepage distances** and requirements for **solid insulation** in the relevant product standards, or even missing standards, this document applies.

A1 NOTE 4 Further explanations and examples with regard to the use of this document are provided in IEC TR 60664-2-1. **A1**

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60068-2-2, *Environmental testing – Part 2-2: Tests – Tests B: Dry heat*

IEC 60068-2-14:2009, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61180:2016, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

3 Terms, definitions and abbreviated terms

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 Terms and definitions

3.1.1

low-voltage supply system

all installations and plant provided for the purpose of generating, transmitting and distributing electricity

[SOURCE: IEC 60050-601:1985, 601-01-01, modified – The term "electric power system" has been replaced with "low-voltage supply system".]

3.1.2

mains supply

AC or DC power distribution system (external to the equipment) that supplies operating power to the equipment

Note 1 to entry: **Mains supply** includes public or private utilities and, unless otherwise specified in this document, equivalent sources such as motor-driven generators and uninterruptible power supplies.

3.1.3

insulation coordination

mutual correlation of insulation characteristics of electrical equipment taking into account the expected **micro-environment** and other influencing stresses

Note 1 to entry: Expected voltage stresses are characterized in terms of the characteristics defined in 3.1.7 to 3.1.16.

[SOURCE: IEC 60050-442:2014, 442-09-01, modified – "electrical" replaces "electric" and Note 1 to entry has been added.]

3.1.4

clearance

shortest distance in air between two conductive parts

[SOURCE: IEC 60050-581:2008, 581-27-76]

3.1.5

creepage distance

shortest distance along the surface of a solid insulating material between two conductive parts

[SOURCE: IEC 60050-151:2001, 151-15-50]

3.1.6

solid insulation

solid insulating material or a combination of solid insulating materials, placed between two conductive parts or between a conductive part and a body part

[SOURCE: IEC 60050-903:2015, 903-04-14, modified – The example has been deleted.]

3.1.7

working voltage

highest RMS value of the AC or DC voltage across any particular insulation which can occur when the equipment is supplied at **rated voltage**

Note 1 to entry: **Transient overvoltages** are disregarded.

Note 2 to entry: Both open-circuit conditions and normal operating conditions are taken into account.

[SOURCE: IEC 60050-851:2008, 851-12-31]

3.1.8

steady-state working voltage

working voltage after the **transient overvoltage** phenomena have subsided and not taking into account short-term voltage variations

3.1.9

steady-state peak voltage

peak value of the **steady-state working voltage**

3.1.10

recurring peak voltage

U_{rp}

maximum peak value of periodic excursions of the voltage waveform resulting from distortions of an AC voltage or from AC components superimposed on a DC voltage

Note 1 to entry: Random **overvoltages**, for example due to occasional switching, are not considered to be recurring peak voltages.

[SOURCE: IEC 60050-442:2014, 442-09-15]

3.1.11

overvoltage

<electrical system> any voltage having a peak value exceeding the corresponding peak value of maximum **steady-state working voltage** at normal operating conditions

3.1.12

temporary overvoltage

overvoltage at power frequency of relatively long duration

[SOURCE: IEC 60050-614:2016, 614-03-13, modified – “power frequency overvoltage” has been replaced with “**overvoltage** at power frequency” and Note 1 to entry has been deleted.]

3.1.13

transient overvoltage

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

[SOURCE: IEC 60050-614:2016, 614-03-14, modified – “overvoltage with a duration” has been replaced with “short duration overvoltage” and the notes have been deleted.]

3.1.14

withstand voltage

<in an electrical system> voltage to be applied to a specimen under specified test conditions which does not cause breakdown of insulation and/or **flashover** of a satisfactory specimen

3.1.15

impulse withstand voltage

highest peak value of impulse voltage of specified form and polarity which does not cause breakdown of insulation under specified conditions

[SOURCE: IEC 60050-442:2014, 442-09-18, modified – “prescribed” has been replaced with “specified”.]

3.1.16

temporary withstand overvoltage

highest RMS value of a **temporary overvoltage** which does not cause breakdown of insulation under specified conditions

[SOURCE: IEC 60050-442:2014, 442-09-19]

3.1.17

rated voltage

U_n

<of equipment> value of voltage assigned by the manufacturer, to a component, device or equipment and to which operation and performance characteristics are referred

Note 1 to entry: Equipment may have more than one **rated voltage** value or may have a **rated voltage** range.

[SOURCE: IEC 60050-442:2014, 442-09-10, modified – “rated value of the voltage” has been replaced with “value of voltage” and Note 2 to entry has been deleted.]

3.1.18

rated insulation voltage

U_i

value of the RMS **withstand voltage** assigned by the manufacturer to the equipment or to a part of it, characterizing the specified (long-term) withstand capability of its insulation

Note 1 to entry: The **rated insulation voltage** is equal to or greater than the **rated voltage** of equipment which is primarily related to functional performance.

[SOURCE: IEC 60050-312:2014, 312-06-02, modified – symbol has been added, in the definition “rated value” has been replaced by “value” and in the note “not necessarily equal to” has been replaced by “equal to or greater than”.]

3.1.19**rated impulse withstand voltage** U_{imp}

value of the **impulse withstand voltage** assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against **transient overvoltages**

3.1.20**overvoltage category**

numeral defining a **transient overvoltage** condition

Note 1 to entry: **Overvoltage categories** I, II, III and IV are used, see 4.3.2.

[SOURCE: IEC 60050-581:2008, 581-21-02, modified – Note 1 to entry has been added.]

3.1.21**environment**

<of an electrical system> surrounding which can affect performance of a device or system

EXAMPLE Pressure, temperature, humidity, **pollution**, radiation and vibration.

3.1.22**macro-environment**

environment of the room or other location in which the equipment is installed or used

[SOURCE: IEC 60050-442:2014, 442-01-55]

3.1.23**micro-environment**

<of an electrical system> ambient conditions which immediately influences the dimensioning of the **clearance** and **creepage distances**

3.1.24**pollution**

<of an electrical system> any condition of foreign matter, solid, liquid or gaseous (ionized gases), that can affect dielectric strength or surface resistivity

3.1.25**pollution degree**

numeral characterizing the expected **pollution** of the **micro-environment**

[SOURCE: IEC 60050-581:2008, 581-21-07, modified – Note 1 to entry has been deleted.]

3.1.26**homogeneous field**

electric field which has an essentially constant voltage gradient between electrodes

Note 1 to entry: The **homogeneous field** condition is referred to as case B in Table F.2 and Table F.8. See also 4.9.

3.1.27**inhomogeneous field**

non-uniform field

electric field which does not have an essentially constant voltage gradient between electrodes

Note 1 to entry: See also 4.9.

[SOURCE: IEC 60050-442:2014, 442-09-03, modified – "inhomogeneous electric field" has been replaced with "inhomogeneous field", Note 1 to entry has been replaced with a new Note 1 and Note 2 to entry has been deleted.]

3.1.28

electric insulation

part of an electrotechnical product which separates the conducting parts at different electrical potentials during operation or insulates such parts from the surroundings

[SOURCE: IEC 60050-212:2010, 212-11-07, modified – "electric" has been replaced with "electrical".]

3.1.29

functional insulation

insulation between conductive parts which is necessary only for the proper functioning of the equipment

[SOURCE: IEC 60050-195:1998, 195-02-41, modified – "necessary" has been replaced with "which is necessary only".]

3.1.30

basic insulation

insulation of hazardous-live-parts which provides basic protection

Note 1 to entry: This concept does not apply to insulation used exclusively for functional purposes.

[SOURCE: IEC 60050-826:2004, 826-12-14]

3.1.31

supplementary insulation

independent insulation applied in addition to **basic insulation** for fault protection

[SOURCE: IEC 60050-826:2004, 826-12-15]

3.1.32

double insulation

insulation comprising both **basic insulation** and **supplementary insulation**

[SOURCE: IEC 60050-826:2004, 826-12-16]

3.1.33

reinforced insulation

insulation of hazardous-live-parts which provides a degree of protection against electric shock equivalent to **double insulation**

Note 1 to entry: **Reinforced insulation** may comprise several layers which cannot be tested singly as **basic insulation** or **supplementary insulation**.

[SOURCE: IEC 60050-826:2004, 826-12-17]

3.1.34

partial discharge

PD

electric discharge that partially bridges the insulation

Note 1 to entry: A **partial discharge** may occur inside the insulation or adjacent to a conductor.

Note 2 to entry: Scintillations of low energy on the surface of insulating materials are often described as **partial discharges** but should rather be considered as disruptive discharges of low energy, since they are the result of local dielectric breakdowns of high ionization density, or small arcs, according to the conventions of physics.

[SOURCE: IEC 60050-442:2014, 442-09-05, modified – Notes 1 and 2 to entry have been added.]

3.1.35 apparent charge

q_{app}
electric charge which can be measured at the terminals of the specimen under test

Note 1 to entry: The **apparent charge** is smaller than the **partial discharge**.

Note 2 to entry: The measurement of the **apparent charge** requires a short-circuit condition at the terminals of the specimen (see Clause D.2) under test.

[SOURCE: IEC 60050-442:2014, 442-09-06, modified – In the Note 2 to entry, "(see Clause D.2)" has been added.]

3.1.36 specified discharge magnitude

magnitude of the **apparent charge** when this is regarded as the limiting value

Note 1 to entry: The pulse with the maximum amplitude should be evaluated.

[SOURCE: IEC 60050-442:2014, 442-09-07]

3.1.37 pulse repetition rate

average number of pulses per second with an **apparent charge** higher than the detection level

Note 1 to entry: Within the scope of this document, it is not permitted to weigh discharge magnitudes according to the **pulse repetition rate**.

3.1.38 partial discharge inception voltage

lowest peak value of the test voltage at which the **apparent charge** becomes greater than the **specified discharge magnitude** when the test voltage is increased above a low value for which no discharge occurs

Note 1 to entry: For AC tests the RMS value may be used.

[SOURCE: IEC 60050-212:2014, 212-11-41]

3.1.39 partial discharge extinction voltage

<of an electrical system> lowest peak value of the test voltage at which the **apparent charge** becomes less than the **specified discharge magnitude** when the test voltage is reduced below a high level where such discharges have occurred

Note 1 to entry: For AC tests, the RMS value may be used.

3.1.40 partial discharge test voltage

peak value of the voltage in a **partial discharge** test, where the **apparent charge** is less than the **specified discharge magnitude**

Note 1 to entry: For AC tests, the RMS value may be used.

[SOURCE: IEC 60050-212:2014, 212-11-62, modified – Note 1 to entry has been deleted, Note 2 to entry is renumbered as Note 1 to entry.]

3.1.41

type test

<of an electrical system> test made on one or more devices representative to a certain design to check the conformity to the specifications

3.1.42

routine test

conformity test made on each individual item during or after manufacture

[SOURCE: IEC 60050-151:2001, 151-16-17]

3.1.43

sampling test

test on a number of devices taken at random from a batch

[SOURCE: IEC 60050-411:1996, 411-53-05, modified – "machine" has been replaced with "device".]

3.1.44

electric breakdown

failure of insulation under electric stress when the discharge completely bridges the insulation, thus reducing the voltage between the electrodes almost to zero

3.1.45

sparkover

<of an electrical system> **electric breakdown** in a gaseous or liquid medium

3.1.46

flashover

electric breakdown between conductors in a gas or a liquid or in vacuum, at least partly along the surface of **solid insulation**

[SOURCE: IEC 60050-212:2010, 212-11-47]

3.1.47

puncture

electric breakdown through **solid insulation**

[SOURCE: IEC 60050-614:2016, 614-03-17, modified – “disruptive discharge” has been replaced with “electric breakdown” and “dielectric” has been replaced with “insulation”.]

A1 3.1.48

electric power network

particular installations, substations, lines or cables for the transmission and distribution of electricity

Note 1 to entry: The boundaries of the different parts of this network are defined by appropriate criteria, such as geographical situation, ownership, voltage, etc.

[SOURCE: IEC 60050-601:1985, 601-01-02]

3.1.49

electrical installation

assembly of **electrical equipment** which is used for the generation, transmission, conversion, distribution and/or use of electric energy

Note 1 to entry: The **electrical installation** includes energy sources e.g. local power supplies such as batteries, capacitors and all other sources of stored electric energy.

[SOURCE: IEC 60050-651:2014, 651-26-01, modified – "e.g. local power supplies" has been added to the Note to entry.]

3.1.50

electrical equipment

item used for generation, conversion, transmission, distribution or utilization of electric energy

Note 1 to entry: Examples of such items are electric machines, transformers, switchgear and controlgear, measuring instruments, protective devices, wiring systems, and current-using equipment.

[SOURCE: IEC 60050-826:2022, 826-16-01]

3.1.51

electrochemical migration

transport of ions in an electrolyte due to an electric field

[SOURCE: IEC 60050-114:2014, 114-04-06] 

3.2 Abbreviated terms

List of terms with abbreviated terms and symbols together with the corresponding terminological entry:

Abbreviated term/Symbol	Term	Terminological entry
U_n	rated voltage	3.1.17
U_i	rated insulation voltage	3.1.18
U_{imp}	rated impulse withstand voltage	3.1.19
U_{rp}	recurring peak voltage	3.1.10
q_{app}	apparent charge	3.1.35
PD	partial discharge	3.1.34

4 Basic technical characteristics for insulation coordination

4.1 General

Insulation coordination requires the selection of the **electric insulation** technical characteristics of the equipment with regard to its application and in relation to its surroundings and environmental conditions.

Insulation coordination represents one aspect of the safety of persons, livestock and property, so that the probability of risk of incidents due to voltage stresses does not lead to an unacceptable risk of harm.

This document addresses **insulation coordination** for any kind of hazard. Technical committees shall take into account the concepts of **clearance**, **creepage distance** and **solid insulation** as well as the concepts of **functional insulation**, **basic insulation**, **supplementary insulation**, **double insulation** and **reinforced insulation** for the specific hazard considering the nature of the hazard.

The technical committee shall make a risk assessment to identify the hazard in case of fault of **functional insulation**. In case a failure of **functional insulation** could create an unacceptable risk of harm (for example, due to mechanical conditions, ageing behaviour), **functional insulation** shall at a minimum be designed according to the requirements of **basic insulation**, after which another risk assessment is performed to assess the residual risk. See 5.2 to 5.4. In case a fault of **functional insulation** does not create any hazard, the technical committee may choose not to apply the requirements of this basic safety publication.

NOTE See ISO/IEC Guide 51 and IEC Guide 116 for further details about risk assessment and unacceptable risk of harm.

Electric insulation technical characteristics cover:

- voltages across the insulation according to 4.2;
- **overvoltage categories** according to 4.3;
- frequency according to 4.4;
- **pollution degree** according to 4.5;
- insulation materials according to 4.6;
- environmental aspects according to 4.7 (e.g. altitude see 4.7.2, temperature see 4.7.3, vibrations see 4.7.4, humidity see 4.7.5, duration see 4.8);
- field distribution according to 4.9.

Insulation coordination can only be achieved if the design of the equipment is based on the stresses to which it is likely to be subjected during its intended life.

4.2 Voltages

4.2.1 General aspects

When considering insulation performances, the following aspects are relevant:

- the voltages which can appear within the system:
 - **transient overvoltages** according to 4.2.2 and **overvoltage category** according to 4.3;
 - **temporary overvoltages** according to 4.2.3.
- the voltages generated by the equipment (which could adversely affect other equipment in the system):
 - **transient overvoltage** according to 4.2.2;
 - **recurring peak voltage** according to 4.2.4;
 - **steady-state working voltage** according to 4.2.5;
 - **steady-state peak voltage** according to 4.2.6.

4.2.2 Transient overvoltages

4.2.2.1 General

To apply the concept of **insulation coordination**, **transient overvoltage** shall be taken into consideration. The **transient overvoltages** that shall be considered are:

- **transient overvoltages** generated by atmospheric disturbances (for example indirect lightning strikes) and transmitted by the **mains supply** distribution system;
- **transient overvoltages** generated due to switching of loads in the **mains supply**;
- **transient overvoltages** generated by external circuits;
- **transient overvoltages** generated internally in the equipment.

Insulation coordination uses a preferred series of values of impulse voltages. The preferred impulse voltages are:

330 V, 500 V, 800 V, 1 500 V, 2 500 V, 4 000 V, 6 000 V, 8 000 V, 12 000 V.

Insulation coordination with regard to **transient overvoltage** is based on controlled **overvoltage** conditions. There are two kinds of control:

- inherent control: the condition within an electrical system wherein the characteristics of the system can be expected to limit the prospective **transient overvoltages** to a defined level;
- protective control: the condition within an electrical system wherein specific **overvoltage** attenuating means can be expected to limit the prospective **transient overvoltages** to a defined level.

See also Table B.1 and Table B.2.

4.2.2.2 Transient overvoltages entering through the mains supply

To determine the expected transients generated by atmospheric disturbances or due to switching of loads in the **mains supply**, the **rated voltage** (U_n) and the **overvoltage category** are normally used as the basis to determine the required **impulse withstand voltage**.

For equipment subjected to **transient overvoltages** that exceed the **impulse withstand voltage** these **transient overvoltages** shall be taken into account.

4.2.2.3 Transient overvoltages generated by external circuits

The applicable value of the **transient overvoltage** that may occur on any external circuit (for example coaxial cable or twisted pair networks) shall be determined. Where more than one external circuit is present, the highest **transient overvoltage** applies.

If the external circuit **transient overvoltages** are known to be higher than the one from the **overvoltage category** typically defined for such kind of equipment, the highest value of these known **transient overvoltages** shall be used.

4.2.2.4 Transient overvoltages generated internally in the equipment

For the equipment likely to generate an **overvoltage** that is higher than the transients expected to come into the equipment, for example due to switching devices, the required impulse voltage shall take into account the transient generated in the equipment. The value of these **transient overvoltages** generated internally in the equipment shall be used without considering the preferred list in 4.2.2.1.

4.2.2.5 Attenuation of transient overvoltage levels

Equipment or parts of equipment may be used under conditions where the transients are reduced. Various technology of component exists such as surge protective device (SPD), transformer, capacitance, resistance, and can have different behaviour regarding the **transient overvoltage** attenuation. These various technologies shall be verified and the method of propagation measurement shall be defined based on their relevant product standard.

Attention is drawn to the fact that a surge protective device within the installation or within equipment may have to dissipate more energy than a surge protective device at the origin of the installation having a higher protection level (clamping voltage). This applies particularly to the surge protective device with the lowest protection level (clamping voltage).

In case attenuation of the transient is expected, the **transient overvoltage** across the insulation may be measured by applying the required impulse test to the equipment and measuring the actual remaining transient over the insulation, see 6.7. The measured value

may be used as the expected **transient overvoltage**. While performing the test, the equipment is energized at **rated voltage** and transients of both polarities shall be considered.

[A1] Technical committees shall consider the end of life of the means to limit **transient overvoltages**. **[A1]**

4.2.3 Temporary overvoltages

Due to faults on the **mains supply**, **temporary overvoltages** between lines and earth/neutral of several seconds will be generated and shall be considered when applying the concept of **insulation coordination**.

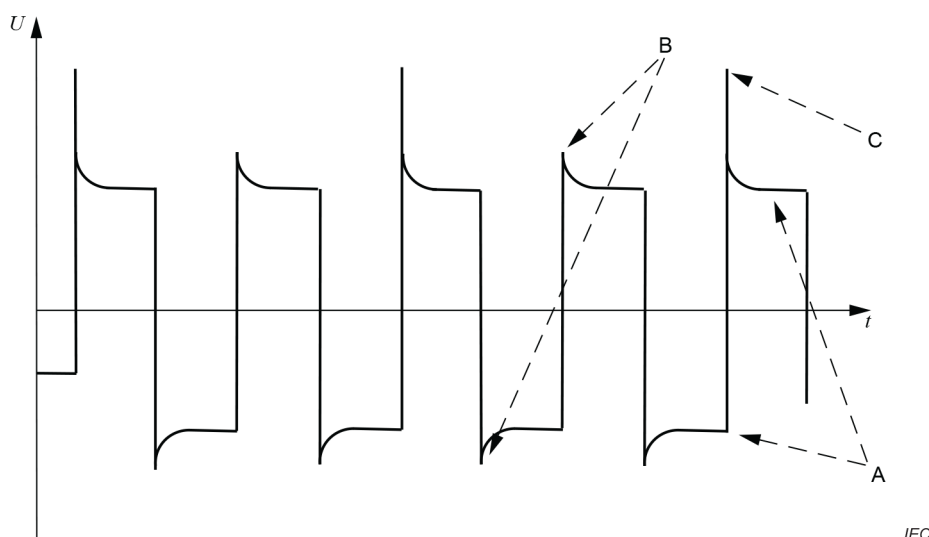
Insulation coordination with regard to **temporary overvoltages** is based on the **temporary overvoltage** specified in **[A1]** IEC 60364-4-44:2024 **[A1]**, Clause 442. The values of **temporary overvoltage** in low-voltage equipment due to an earth fault in the high-voltage system are given in 5.4.3.2.

4.2.4 Recurring peak voltage

Due to the intended operation modes of specific products, internally generated voltages may also include recurring peaks superimposed to the **working voltage**. These recurring peaks voltages shall be considered when applying the concept of **insulation coordination**.

Insulation coordination with regard to **recurring peak voltage** shall consider that **partial discharges** can occur in **solid insulation** (see 4.6.2.3) or along surfaces of insulation (see Table F.9).

Recurring peak voltage has a waveshape which is measured by an oscilloscope of sufficient bandwidth, from which the peak amplitude is determined according to Figure 1.



Key

- A Steady-state voltage value
- B Steady-state peak voltage
- C Recurring peak voltage

Figure 1 – Recurring peak voltage

4.2.5 Steady-state working voltage

The highest **steady-state working voltage** (RMS value of the AC or DC value) across the insulation with the equipment supplied at the **rated voltage** shall be considered. This kind of **steady-state working voltage** can be lower, equal or higher than the **rated voltage** of the equipment. The **steady-state working voltage** of internal circuits is a direct consequence of the design of products and might be significantly higher than the value of **rated voltage**.

4.2.6 Steady-state peak voltage

The peak value of **steady-state working voltage** across the insulation with the equipment supplied at the **rated voltage** shall be considered. The **steady-state peak voltage** of internal circuits is a direct consequence of the design of products.

4.3 Overvoltage categories

4.3.1 General

The concept of **overvoltage categories** is used for equipment energized directly from the **mains supply**.

The **overvoltage categories** have a probabilistic implication rather than the meaning of physical attenuation of the **transient overvoltage** downstream in the installation.

NOTE This concept of **overvoltage categories** is used in Clause 443 of  IEC 60364-4-44:2024  and IEC 60364-4-44:2007/AMD1:2015.

A similar concept can also be used for equipment connected to other systems, for example telecommunication and data systems.

4.3.2 Equipment energized directly from the mains supply

 Equipment is considered to be energized directly from the **mains supply** when the equipment is galvanically connected to an **electric power network** (either public or private).

When defining the **rated impulse withstand voltage** of equipment, technical committees shall take into account the following **overvoltage categories**:

- **Overvoltage category IV** applies at, or in the proximity of, the point where an **electrical installation** is connected to an **electric power network**.

NOTE 1 Equipment of **overvoltage category IV** has a very high impulse withstand capability providing the required high degree of reliability at these locations, for example upstream of the main distribution board.

- **Overvoltage category III** applies in an **electrical installation** downstream of and including the main distribution board.

NOTE 2 Examples of such equipment include distribution boards, local generation, circuit-breakers, wiring systems (see IEC 60050-826:2022, 826-15-01), including cables, busbars, junction boxes, switches, socket-outlets) and equipment for industrial use and some other equipment, e.g. stationary motors.

- **Overvoltage category II** applies for equipment connected to an **electrical installation**.

NOTE 3 Examples of such equipment are appliances, portable tools and similar loads with pluggable or permanent connection to the **electrical installation**.

- **Overvoltage category I** applies to equipment that may only be connected to an **electrical installation** when specific measures are provided.

NOTE 4 Such specific measures are related to **transient overvoltages** as well as to **temporary overvoltages** and are addressed in 4.3.4.

Where a higher degree of reliability and availability is necessary, equipment having higher **rated impulse withstand voltage** should be considered (see 5.2.2.2). 

4.3.3 Systems and equipment not energized directly from the mains supply

It is recommended that technical committees specify **overvoltage categories** or **rated impulse withstand voltage** as appropriate. Application of the preferred series of 4.2.2.1 is recommended.

NOTE Telecommunication or industrial control systems or independent systems on vehicles are examples of such systems.

4.3.4 Equipment requiring specific measures

When equipment is designed for **overvoltage category I** and is intended to be connected to an **electrical installation**, all the following measures and verifications shall be considered by technical committees:

- the **mains supply** to which the equipment is intended to be connected, excludes by design the occurrence of **temporary overvoltages** with peak values above the **rated impulse withstand voltage** of the equipment;

NOTE 1 In TN-system, for example, there are no significant **temporary overvoltages** exceeding the **rated impulse withstand voltage** of equipment designed for **overvoltage category I**.

- **transient overvoltages** are limited to not exceed the **rated impulse withstand voltage** of the equipment by appropriate means, e.g. SPDs.

NOTE 2 SPDs are primarily designed to limit **transient overvoltages**. However they are also tested with certain **temporary overvoltages**; for more explanations see the IEC 61643 series.

- the required **impulse withstand voltage** at the relevant location is tested and confirmed for the equipment in conjunction with the intended protection means, to ensure not only the **withstand voltage**, but also the necessary coordination and withstand as related to impulse energy.

NOTE 3 More information about system level immunity is given in IEC TR 61643-03. 

4.4 Frequency

4.4.1 General

The voltage withstand capability of **clearances**, **creepage distances** and **solid insulation** will be reduced with increased frequency. This effect can be observed from 1 kHz. The design of **clearances**, **creepage distances** and **solid insulation** according to this document cover the effect of high-frequencies up to 30 kHz. For frequencies above 30 kHz, see 5.1.2.

4.4.2 Solid insulation

The frequency of the voltage influences the electric strength of the **solid insulation**. Dielectric heating and the probability of thermal instability increase approximately in proportion to the frequency. Increasing the frequency will reduce the electric strength of most insulating materials.

This condition has been observed in switched-mode power supplies where the insulation is subjected to repetitive voltage peaks at frequencies up to 500 kHz.

4.5 Pollution

4.5.1 General

The **micro-environment** determines the effect of **pollution** on the insulation. The **macro-environment**, however, has to be taken into account when considering the **micro-environment**.

Means may be provided to reduce **pollution** at the insulation under consideration by effective use of enclosures, encapsulation or hermetic sealing. Such means to reduce **pollution** may not be effective when the equipment is subject to condensation or if, in normal operation, it generates pollutants itself. Enclosures for outdoor and indoor installation, intended for use in locations with high humidity and temperatures varying within wide limits, shall be provided with suitable arrangements (natural ventilation, forced ventilation, internal heating, drain holes, etc.) to prevent harmful condensation within the enclosure. Degrees of protection provided by enclosures (IP code), according to the classes specified in IEC 60529, do not necessarily improve the **micro-environment** with regard to **pollution**.

The technical committee shall provide information to verify, according to their standards, the performance of the enclosed system.

Small **clearances** can be bridged completely by solid particles, dust and water and therefore minimum **clearances** are specified where **pollution** may be present in the **micro-environment**.

4.5.2 Degrees of pollution in the micro-environment

For the purpose of evaluating **creepage distances** and **clearances**, the following four degrees of **pollution** in the **micro-environment** are established:

- **Pollution degree 1**
No **pollution** or only dry, non-conductive **pollution** occurs. The **pollution** has no influence.
- **Pollution degree 2**
Only non-conductive **pollution** occurs except that occasionally a temporary conductivity caused by condensation is to be expected. This condensation may occur during periods of on-off load cycles of the equipment.
- **Pollution degree 3**
Conductive **pollution** occurs or dry non-conductive **pollution** occurs which becomes conductive due to condensation which is to be expected.
- **Pollution degree 4**
Continuous conductivity occurs due to conductive dust, rain or other wet conditions.

4.5.3 Conditions of conductive pollution

The dimensions for **creepage distance** cannot be specified where permanently conductive **pollution** is present (**pollution degree 4**). For temporarily conductive **pollution** (**pollution degree 3**), the surface of the insulation may be designed to avoid a continuous path of conductive **pollution**, for example by means of ribs and grooves (see 5.3.3.7).

4.6 Insulating material

4.6.1 Solid insulation

The concept of **insulation coordination** may be realized by an appropriate insulation material. The insulation behaviour of the **solid insulation** is directly affected by its intrinsic material characteristics. Electrical, mechanical and other stresses which might affect the insulation behaviour over the life time of the product shall be considered.

As the electric strength of **solid insulation** is considerably greater than that of air, less attention may be paid to the design of insulation systems. On the other hand, the insulating distances through solid insulating material are, as a rule, much smaller than the **clearances** so that high electric stresses result. Another point to be considered is that the high electric strength of material is seldom made use of in practice. In insulation systems, gaps may occur between electrodes and insulation and between different layers of insulation, or voids may be present in the insulation. **Partial discharges** can occur in these gaps or voids at voltages far

below the level of **puncture** and this may influence decisively the service life of the **solid insulation**. However, **partial discharges** are unlikely to occur below a peak voltage of 500 V.

Of equally fundamental importance is the fact that **solid insulation**, as compared with gases, is not a renewable insulating medium so that, for example, high voltage peaks which may occur infrequently can have a very damaging and irreversible effect on **solid insulation**. This situation can occur while in service and during routine high-voltage testing.

4.6.2 Stresses

4.6.2.1 General

A number of detrimental influences accumulate over the service life of **solid insulation**. These follow complex patterns and result in ageing. Therefore, electrical and other stresses (e.g. thermal, environmental) are superimposed and contribute to ageing.

The long-term performance of **solid insulation** can be simulated by a short-term test in combination with suitable conditioning (see 6.4.3).

There is a general relationship between the thickness of **solid insulation** and the aforesaid failure mechanisms. By a reduction of the thickness of **solid insulation** the field strength is increased and leads to a higher risk of failure. Due to the individual electrical characteristics of the materials it is not possible to calculate the required thickness of **solid insulation**. The performance can only be verified by testing.

4.6.2.2 Mechanical shock

In the case of inadequate impact strength, mechanical shock may cause insulation failure. Failure from mechanical shock could also occur due to the reduced impact strength of materials:

- due to material becoming brittle when the temperature falls below its glass transition temperature;
- after prolonged exposure to a high temperature that has caused loss of plasticizer or degradation of the base polymer.

Technical committees shall consider this when specifying environmental conditions for transportation, storage, installation and use.

4.6.2.3 Partial discharges (PD)

Some types of **solid insulation** can withstand discharges, while others cannot. Voltage, repetition rate of discharges and discharge magnitude are important parameters.

NOTE Ceramic insulators are usually able to withstand **partial discharges**.

The PD behaviour is influenced by the frequency of the applied voltage. It is established from accelerated life tests at increased frequency that the time to failure is approximately inversely proportional to the frequency of the applied voltage. However, practical experience only covers frequencies up to 5 kHz since, at higher frequencies, other failure mechanisms may also be present, for example dielectric heating.

4.6.2.4 Other stresses

Many other stresses can damage insulation and their consequences need to be considered by technical committees.