

Insulation coordination for equipment within low-voltage systems —

Part 1: Principles, requirements and tests

The European Standard EN 60664-1:2007 has the status of a
British Standard

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National foreword

This British Standard is the UK implementation of EN 60664-1:2007. It is identical to IEC 60664-1:2007. It supersedes BS EN 60664-1:2003 which is withdrawn.

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 secretary.

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**Insulation coordination for equipment
within low-voltage systems -
Part 1: Principles, requirements and tests
(IEC 60664-1:2007)**

Coordination de l'isolement
des matériels dans les systèmes
(réseaux) à basse tension -
Partie 1: Principes, exigences
et essais
(CEI 60664-1:2007)

Isolationskoordination
für elektrische Betriebsmittel
in Niederspannungsanlagen -
Teil 1: Grundsätze, Anforderungen
und Prüfungen
(IEC 60664-1:2007)

This European Standard was approved by CENELEC on 2007-07-01. 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.

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CENELEC

European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 109/58/CDV, future edition 2 of IEC 60664-1, prepared by IEC TC 109, Insulation co-ordination for low-voltage equipment, was submitted to the IEC-CENELEC parallel Unique Acceptance Procedure and was approved by CENELEC as EN 60664-1 on 2007-07-01.

This European Standard supersedes EN 60664-1:2003.

In addition to a number of editorial improvements, the following main changes have been made with respect to EN 60664-1:2003:

- amendment of Japanese mains conditions with regard to the rated impulse voltages, the rationalized voltages and the nominal voltages of supply systems for different modes of overvoltage control;
- amendment of dimensioning of clearances smaller than 0,01 mm;
- alignment of the table and the corresponding formula regarding test voltages for verifying clearances at different altitudes;
- amendment of interpolation of the creepage distance values for functional insulation;
- amendment of creepage distance dimensioning taking into account ribs;
- revision of the former Clause 4 "Tests and measurements" (now Clause 6) to achieve a more detailed description of the tests and their purpose, the test equipment and possible alternatives;
- change of Annex C "Partial discharge test methods" from a former technical report, Type 2 (now called TS), to a normative Annex C.

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) | 2008-04-01 |
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Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60664-1:2007 was approved by CENELEC as a European Standard without any modification.

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INSULATION COORDINATION FOR EQUIPMENT WITHIN LOW-VOLTAGE SYSTEMS –

Part 1: Principles, requirements and tests

1 Scope and object

This part of IEC 60664 deals with insulation coordination for equipment within low-voltage systems. It applies to equipment for use up to 2 000 m above sea level having a rated voltage up to a.c. 1 000 V with rated frequencies up to 30 kHz, or a rated voltage up to d.c. 1 500 V.

It specifies the requirements for clearances, creepage distances and solid insulation for equipment based upon their performance criteria. It includes methods of electric testing with respect to insulation coordination.

The minimum clearances specified in this standard do not apply where ionized gases occur. Special requirements for such situations may be specified at the discretion of the relevant technical committee.

This standard does not deal with distances

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

NOTE 1 Insulation coordination for equipment within low-voltage systems with rated frequencies above 30 kHz is given in IEC 60664-4.

NOTE 2 Higher voltages may exist in internal circuits of the equipment.

NOTE 3 Guidance for dimensioning for altitudes exceeding 2 000 m is given in Table A.2.

The object of this basic safety standard is to guide technical committees responsible for different equipment in order to rationalize their requirements so that insulation coordination is achieved.

It provides the information necessary to give guidance to technical committees when specifying clearances in air, creepage distances and solid insulation for equipment.

Care should be taken to see that manufacturers and technical committees are responsible for application of the requirements, as specified in this basic safety publication, or make reference to it, where necessary, in standards for equipment within their scope.

In the case of missing specified values for clearances, creepage distances and requirements for solid insulation in the relevant product standards, or even missing standards, this standard is applicable.

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 60038:1983, *IEC standard voltages*

IEC 60050(151):2001, *International Electrotechnical Vocabulary (IEV) – Chapter 151: Electrical and magnetic devices*

IEC 60050(212):1990, *International Electrotechnical Vocabulary – Chapter 212: Insulating solids, liquids and gases*

IEC 60050(604):1987, *International Electrotechnical Vocabulary (IEV) – Chapter 604: Generation, transmission and distribution of electricity – Operation*
Amendment 1 (1998)

IEC 60050(826):2004, *International Electrotechnical Vocabulary (IEV) – Part 826: Electrical installations*

IEC 60068-1:1988, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-2:1974, *Environmental testing – Part 2: Tests – Tests B: Dry heat*

IEC 60068-2-14:1984, *Environmental testing – Part 2: Tests – Test N: Change of temperature*

IEC 60068-2-78:2001, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60085:2004, *Electrical insulation – Thermal classification*

IEC 60099-1:1991, *Surge arresters – Part 1: Non-linear resistor type gapped surge arresters for a.c. systems*

IEC 60112:2003, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60216, (all parts) *Electrical insulating materials – Properties for thermal endurance*

IEC 60243-1:1998, *Electrical strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60270:2000, *High-voltage test techniques – Partial discharge measurements*

IEC 60364-4-44:2001, *Electrical installations of buildings – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*
Amendment 1 (2003)

IEC 60664-4:2005, *Insulation coordination for equipment within low-voltage systems – Part 4: Consideration of high-frequency voltage stress*

IEC 60664-5, *Insulation coordination for equipment within low-voltage systems – Part 5: A comprehensive method for determining clearances and creepage distances equal to or less than 2 mm*¹

IEC 61140:2001, *Protection against electric shock – Common aspects for installation and equipment*
Amendment 1 (2004)

IEC 61180-1:1992, *High-voltage test techniques for low-voltage equipment – Part 1: Definitions, test and procedure requirements*

¹ A second edition of IEC 60664-5 will be published shortly.

IEC 61180-2:1994, *High-voltage test techniques for low-voltage equipment – Part 2: Test equipment*

IEC Guide 104:1997, *The preparation of safety publications and the use of basic safety publications and group safety publications*

3 Terms and definitions

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

3.1

insulation coordination

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

NOTE Expected voltage stresses are characterized in terms of the characteristics defined in 3.5 to 3.7.

3.2

clearance

shortest distance in air between two conductive parts

3.3

creepage distance

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

(IEV 151-15-50)

3.4

solid insulation

solid insulating material interposed between two conductive parts

3.5

working voltage

highest r.m.s. value of the a.c. or d.c. voltage across any particular insulation which can occur when the equipment is supplied at rated voltage

NOTE 1 Transients are disregarded.

NOTE 2 Both open-circuit conditions and normal operating conditions are taken into account.

3.6

recurring peak voltage

U_{rp}

maximum peak value of periodic excursions of the voltage waveform resulting from distortions of an a.c. voltage or from a.c. components superimposed on a d.c. voltage

NOTE Random overvoltages, for example due to occasional switching, are not considered to be recurring peak voltages.

3.7

overvoltage

any voltage having a peak value exceeding the corresponding peak value of maximum steady-state voltage at normal operating conditions

3.7.1

temporary overvoltage

overvoltage at power frequency of relatively long duration

3.7.2

transient overvoltage

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

(IEV 604-03-13)

3.7.3

switching overvoltage

transient overvoltage at any point of the system due to specific switching operation or fault

3.7.4

lightning overvoltage

transient overvoltage at any point of the system due to a specific lightning discharge

3.7.5

functional overvoltage

deliberately imposed overvoltage necessary for the function of a device

3.8

withstand voltage

voltage to be applied to a specimen under prescribed test conditions which does not cause breakdown and/or flashover of a satisfactory specimen

(IEV 212-01-31)

3.8.1

impulse withstand voltage

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

3.8.2

r.m.s. withstand voltage

highest r.m.s. value of a voltage which does not cause breakdown of insulation under specified conditions

3.8.3

recurring peak withstand voltage

highest peak value of a recurring voltage which does not cause breakdown of insulation under specified conditions

3.8.4

temporary withstand overvoltage

highest r.m.s. value of a temporary overvoltage which does not cause breakdown of insulation under specified conditions

3.9

rated voltage

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

NOTE Equipment may have more than one rated voltage value or may have a rated voltage range.

3.9.1

rated insulation voltage

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

NOTE The rated insulation voltage is not necessarily equal to the rated voltage of equipment which is primarily

related to functional performance.

3.9.2

rated impulse voltage

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

3.9.3

rated recurring peak voltage

recurring peak withstand voltage value assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against recurring peak voltages

3.9.4

rated temporary overvoltage

temporary withstand overvoltage value assigned by the manufacturer to the equipment, or to a part of it, characterizing the specified short-term withstand capability of its insulation against a.c. voltages

3.10

overvoltage category

numeral defining a transient overvoltage condition

NOTE 1 Overvoltage categories I, II, III and IV are used, see 4.3.3.2.

NOTE 2 The term 'overvoltage category' in this standard is synonymous with 'impulse withstand category' used in IEC 60364-4-44, Clause 443.

3.11

pollution

any addition of foreign matter, solid, liquid, or gaseous that can result in a reduction of electric strength or surface resistivity of the insulation

3.12

environment

surrounding which may affect performance of a device or system

NOTE Examples are pressure, temperature, humidity, pollution, radiation and vibration.

(IEV 151-16-03, modified)

3.12.1

macro-environment

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

3.12.2

micro-environment

immediate environment of the insulation which particularly influences the dimensioning of the creepage distances

3.13

pollution degree

numeral characterizing the expected pollution of the micro-environment

NOTE Pollution degrees 1, 2, 3 and 4 are established in 4.6.2.

3.14

homogeneous field

electric field which has an essentially constant voltage gradient between electrodes (uniform field), such as that between two spheres where the radius of each sphere is greater than the distance between them

NOTE The homogeneous field condition is referred to as case B.

3.15

inhomogeneous field

electric field which does not have an essentially constant voltage gradient between electrodes (non-uniform field)

NOTE The inhomogeneous field condition of a point-plane electrode configuration is the worst case with regard to voltage withstand capability and is referred to as case A. It is represented by a point electrode having a 30 µm radius and a plane of 1 m × 1 m.

3.16

controlled overvoltage condition

condition within an electrical system wherein the expected transient overvoltages are limited to a defined level

3.17

insulation

that part of an electrotechnical product which separates the conducting parts at different electrical potentials

(IEV 212-01-05)

3.17.1

functional insulation

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

3.17.2

basic insulation

insulation of hazardous-live-parts which provides basic protection

NOTE The concept does not apply to insulation used exclusively for functional purposes.

(IEV 826-12-14)

3.17.3

supplementary insulation

independent insulation applied in addition to basic insulation for fault protection

(IEV 826-12-15)

3.17.4

double insulation

insulation comprising both basic insulation and supplementary insulation

(IEV 826-12-16)

3.17.5

reinforced insulation

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

NOTE Reinforced insulation may comprise several layers which cannot be tested singly as basic insulation or supplementary insulation.

(IEV 826-12-17)

3.18

partial discharge

PD

electric discharge that partially bridges the insulation

3.18.1**apparent charge** **q**

electric charge which can be measured at the terminals of the specimen under test

NOTE 1 The apparent charge is smaller than the partial discharge.

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

3.18.2**specified discharge magnitude**

magnitude of the apparent charge which is regarded as the limiting value according to the objective of this standard

NOTE The pulse with the maximum amplitude should be evaluated.

3.18.3**pulse repetition rate**

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

NOTE Within the scope of this standard it is not permitted to weigh discharge magnitudes according to the pulse repetition rate.

3.18.4**partial discharge inception voltage** **U_i**

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 For a.c. tests the r.m.s. value may be used.

3.18.5**partial discharge extinction voltage** **U_e**

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 For a.c. tests the r.m.s. value may be used.

3.18.6**partial discharge test voltage** **U_t**

peak value of the test voltage for the procedure of 6.1.3.5.3 where the apparent charge is less than the specified discharge magnitude

NOTE For a.c. tests the r.m.s. value may be used.

3.19**test**

technical operation that consists of the determination of one or more characteristics of a given product, process or service according to a specified procedure

(13.1 of ISO/IEC Guide 2:1996) ^[1]2

NOTE A test is carried out to measure or classify a characteristic or a property of an item by applying to the item a set of environmental and operating conditions and/or requirements.

2 References in square brackets refer to the bibliography.

(IEV 151-16-13)

3.19.1

type test

test of one or more devices made to a certain design to show that the design meets certain specifications

3.19.2

routine test

test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

3.19.3

sampling test

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

3.20

electrical breakdown

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

3.20.1

sparkover

electrical breakdown in a gaseous or liquid medium

3.20.2

flashover

electrical breakdown along a surface of solid insulation located in a gaseous or liquid medium

3.20.3

puncture

electrical breakdown through solid insulation

4 Basis for insulation coordination

4.1 General

Insulation coordination implies the selection of the electric insulation characteristics of the equipment with regard to its application and in relation to its surroundings.

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 anticipated lifetime.

4.2 Insulation coordination with regard to voltage

4.2.1 General

Consideration shall be given to

- the voltages which can appear within the system,
- the voltages generated by the equipment (which could adversely affect other equipment in the system),
- the degree of continuity of service desired,
- the safety of persons and property, so that the probability of undesired incidents due to voltage stresses does not lead to an unacceptable risk of harm.

4.2.2 Insulation coordination with regard to long-term a.c. or d.c. voltages

Insulation coordination with regard to long-term voltages is based on

- rated voltage,
- rated insulation voltage,
- working voltage.

4.2.3 Insulation coordination with regard to transient overvoltage

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.

NOTE 1 Overvoltages in large and complex systems, such as low-voltage mains subjected to multiple and variable influences, can only be assessed on a statistical basis. This is particularly true for overvoltages of atmospheric origin and applies whether the controlled condition is achieved as a consequence of inherent control or by means of protective control.

NOTE 2 A probabilistic analysis is recommended to assess whether inherent control exists or whether protective control is needed. This analysis requires knowledge of the electrical system characteristics, the keraunic levels, transient overvoltage levels, etc. This approach has been used in IEC 60364-4-44 for electrical installations of buildings connected to low-voltage mains.

NOTE 3 The specific overvoltage attenuating means may be a device having means for storage or dissipation of energy and, under defined conditions, capable of harmlessly dissipating the energy of the overvoltages expected at the location.

In order to apply the concept of insulation coordination, distinction is made between transient overvoltages from two different sources:

- transient overvoltages originating in the system to which the equipment is connected through its terminals;
- transient overvoltages originating in the equipment.

Insulation coordination uses a preferred series of values of rated impulse voltage:

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

4.2.4 Insulation coordination with regard to recurring peak voltage

Consideration shall be given to the extent that partial discharges can occur in solid insulation (see 5.3.2.3.1) or along surfaces of insulation (see Table F.7b).

4.2.5 Insulation coordination with regard to temporary overvoltage

Insulation coordination with regard to temporary overvoltages is based on the temporary overvoltage specified in Clause 442 of IEC 60364-4-44 (see 5.3.3.2.3 of this standard).

NOTE Currently available surge protective devices (SPDs) are not able to adequately deal with the energy associated with temporary overvoltages.

4.2.6 Insulation coordination with regard to environmental conditions

The micro-environmental conditions for the insulation shall be taken into account as quantified by pollution degree.

Micro-environmental conditions depend primarily on the macro-environmental conditions in which the equipment is located and in many cases the environments are identical. However, the micro-environment can be better or worse than the macro-environment where, for example, enclosures, heating, ventilation or dust influence the micro-environment.

NOTE Protection by enclosures provided according to the classes specified in IEC 60529 [2] does not necessarily improve the micro-environment with regard to pollution.

The most important environmental parameters are as follows:

- for clearances:
 - air pressure,
 - temperature, if it has a wide variation;
- for creepage distances:
 - pollution,
 - relative humidity,
 - condensation;
- for solid insulation:
 - temperature,
 - relative humidity.

4.3 Voltages and voltage ratings

4.3.1 General

For the purpose of dimensioning equipment in accordance with insulation coordination, technical committees shall specify:

- the basis for voltage ratings;
- an overvoltage category according to the expected use of the equipment, taking into account the characteristics of the system to which it is intended to be connected.

4.3.2 Determination of voltage for long-term stresses

4.3.2.1 General

It is assumed that the rated voltage of equipment is not lower than the nominal voltage of the supply system.

4.3.2.2 Voltage for dimensioning basic insulation

4.3.2.2.1 Equipment energized directly from the low-voltage mains

The nominal voltages of the low-voltage mains have been rationalized according to Tables F.3a and F.3b (see 5.2.2.2) and these voltages are the minimum to be used for the selection of creepage distances. They may also be used for the selection of rated insulation voltages.

For equipment having several rated voltages so that it may be used at different nominal voltages of the low-voltage mains, the voltage selected shall be appropriate for the highest rated voltage of the equipment.

Technical committees shall consider whether the voltage is to be selected

- based on line-to-line voltage, or
- based on line-to-neutral voltage.

In the latter case the technical committee shall specify how the user is to be informed that the equipment is for use on neutral-earthed systems only.

4.3.2.2.2 Systems, equipment and internal circuits not energized directly from the low-voltage mains

The highest r.m.s. voltage which can occur in the system, equipment or internal circuits shall be used for basic insulation. The voltage is determined for supply at rated voltage and under the most onerous combination of other conditions within the rating of the equipment.

NOTE Fault conditions are not taken into account.

4.3.2.3 Voltage for dimensioning functional insulation

The working voltage is used for determining the dimensions required for functional insulation.

4.3.3 Determination of rated impulse voltage

4.3.3.1 General

The transient overvoltages are taken as the basis for determining the rated impulse voltage.

4.3.3.2 Overvoltage categories

4.3.3.2.1 General

The concept of overvoltage categories is used for equipment energized directly from the low-voltage mains.

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

NOTE 1 This concept of overvoltage categories is used in Clause 443 of IEC 60364-4-44.

NOTE 2 The term 'overvoltage category' in this standard is synonymous with 'impulse withstand category' used in Clause 443 of IEC 60364-4-44.

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

4.3.3.2.2 Equipment energized directly from the supply mains

Technical committees shall specify the overvoltage category as based on the following general explanation of overvoltage categories (see also Clause 443 of IEC 60364-4-44):

- Equipment of overvoltage category IV is for use at the origin of the installation.

NOTE 1 Examples of such equipment are electricity meters and primary overcurrent protection equipment.

- Equipment of overvoltage category III is equipment in fixed installations and for cases where the reliability and the availability of the equipment is subject to special requirements.

NOTE 2 Examples of such equipment are switches in the fixed installation and equipment for industrial use with permanent connection to the fixed installation.

- Equipment of overvoltage category II is energy-consuming equipment to be supplied from the fixed installation.

NOTE 3 Examples of such equipment are appliances, portable tools and other household and similar loads.

If such equipment is subjected to special requirements with regard to reliability and availability, overvoltage category III applies.

- Equipment of overvoltage category I is equipment for connection to circuits in which measures are taken to limit transient overvoltages to an appropriately low level.

These measures shall ensure that the temporary overvoltages that could occur are sufficiently limited so that their peak value does not exceed the relevant rated impulse voltage of Table F.1.

NOTE 4 Examples of such equipment are those containing electronic circuits protected to this level, however see the note in 4.2.5.

NOTE 5 Unless the circuits are designed to take the temporary overvoltages into account, equipment of overvoltage category 1 cannot be directly connected to the supply mains.

4.3.3.2.3 Systems and equipment not energized directly from the low-voltage mains

It is recommended that technical committees specify overvoltage categories or rated impulse voltages as appropriate. Application of the preferred series of 4.2.3 is recommended.

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

4.3.3.3 Selection of rated impulse voltage for equipment

The rated impulse voltage of the equipment shall be selected from Table F.1 corresponding to the overvoltage category specified and to the rated voltage of the equipment.

NOTE 1 Equipment with a particular rated impulse voltage and having more than one rated voltage may be suitable for use in different overvoltage categories.

NOTE 2 For consideration of the switching overvoltage aspect, see 4.3.3.5.

4.3.3.4 Impulse voltage insulation coordination within equipment

4.3.3.4.1 Parts or circuits within equipment significantly influenced by external transient overvoltages

The rated impulse voltage of the equipment applies. Transient overvoltages which can be generated by the operation of the equipment shall not influence external circuit conditions beyond that specified in 4.3.3.5.

4.3.3.4.2 Parts or circuits within equipment specifically protected against transient overvoltages

For such parts that are not significantly influenced by external transient overvoltages, the impulse withstand voltage required for basic insulation is not related to the rated impulse voltage of the equipment but to the actual conditions for that part or circuit. Application of the preferred series of impulse voltage values as introduced in 4.2.3 is, however, recommended to permit standardization. In other cases, interpolation of Table F.2 values is allowed.

4.3.3.5 Switching overvoltage generated by the equipment

For equipment capable of generating an overvoltage at the equipment terminals, for example switching devices, the rated impulse voltage implies that the equipment shall not generate overvoltage in excess of this value when used in accordance with the relevant standard and instructions of the manufacturer.

NOTE 1 The residual risk that voltages in excess of the rated impulse voltage can be generated depends on the circuit conditions.

If a switching device with a particular rated impulse voltage or overvoltage category does not generate overvoltages higher than those of a lower overvoltage category, it has two rated impulse voltages or two overvoltage categories: the higher one referring to its impulse withstand voltage, the lower one referring to the generated overvoltage.

NOTE 2 A given value of rated impulse voltage implies that overvoltages up to that magnitude may become effective in the system and that, as a consequence, the equipment may be unsuitable for use in lower overvoltage categories or require suppression means suitable for the lower category.

4.3.3.6 Interface requirements

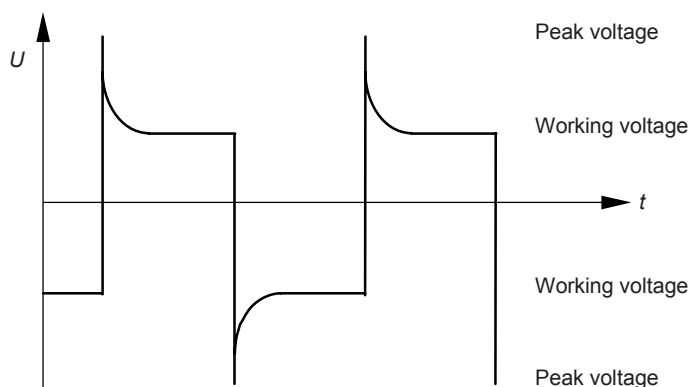
Equipment may be used under the conditions of a higher overvoltage category where appropriate overvoltage reduction is provided. Appropriate overvoltage attenuation can be achieved by

- an overvoltage protective device,
- a transformer with isolated windings,
- a distribution system with a multiplicity of branch circuits (capable of diverting energy of surges),
- a capacitance capable of absorbing energy of surges,
- a resistance or similar damping device capable of dissipating the energy of surges.

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

4.3.4 Determination of recurring peak voltage

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



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Figure 1 – Recurring peak voltage

4.3.5 Determination of temporary overvoltage

4.3.5.1 General

Situations related to the most onerous temporary overvoltages due to faults in the supply system are considered in IEC 60364-4-44.

NOTE IEC 60364-4-44 deals with the safety of persons and equipment in a low-voltage system in the event of a fault between the high-voltage system and earth of transformers that supply low-voltage systems.

4.3.5.2 Fault voltage

The magnitude and the duration of the fault voltage or the touch voltage due to an earth fault in the high-voltage system are shown in Figure 44A of IEC 60364-4-44.

4.3.5.3 Stress due to temporary overvoltages

The magnitude and duration of a temporary overvoltage in low-voltage equipment due to an earth fault in the high-voltage system are given in 5.3.3.2.3.

4.4 Frequency

This standard applies for frequencies up to 30 kHz.

NOTE Dimensioning for frequencies above 30 kHz is specified in IEC 60664-4.

4.5 Time under voltage stress

With regard to creepage distances, the time under voltage stress influences the number of occasions when drying out can result in surface scintillations with energy high enough to entail tracking. The number of such occasions is considered to be sufficiently large to cause tracking

- in equipment intended for continuous use but not generating sufficient heat to keep the surface of the insulation dry,
- in equipment subjected to condensation for extended periods during which it is frequently switched on and off,
- on the input side of a switching device, and between its line and load terminals, that is connected directly to the supply mains.

The creepage distances shown in Table F.4 have been determined for insulation intended to be under voltage stress during a long period of time.

NOTE Technical committees responsible for equipment in which insulation is under voltage stress for only a short time may consider allowing reduced creepage distances for functional insulation, for example of one voltage step lower than specified in Table F.4.

4.6 Pollution

4.6.1 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.

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.

NOTE 1 Pollution will become conductive in the presence of humidity. Pollution caused by contaminated water, soot, metal or carbon dust is inherently conductive.

NOTE 2 Conductive pollution by ionized gases and metallic depositions occurs only in specific instances, for example in arc chambers of switchgear or controlgear, and is not covered by this part of IEC 60664.

4.6.2 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.
- *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.

4.6.3 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, e.g. by means of ribs and grooves (see 5.2.2.5 and 5.2.5).

4.7 Information supplied with the equipment

Technical committees shall specify the relevant information to be supplied with the equipment and the way this is to be provided.

4.8 Insulating material

4.8.1 Comparative tracking index (CTI)

4.8.1.1 Behaviour of insulating material in the presence of scintillations

With regard to tracking, an insulating material can be roughly characterized according to the damage it suffers from the concentrated release of energy during scintillations when a surface leakage current is interrupted due to the drying-out of the contaminated surface. The following behaviour of an insulating material in the presence of scintillations can occur:

- no decomposition of the insulating material;
- the wearing away of insulating material by the action of electrical discharges (electrical erosion);
- the progressive formation of conductive paths which are produced on the surface of insulating material due to the combined effects of electric stress and electrolytically conductive contamination on the surface (tracking).

NOTE Tracking or erosion will occur when

- a liquid film carrying the surface leakage current breaks, and
- the applied voltage is sufficient to break down the small gap formed when the film breaks, and
- the current is above a limiting value which is necessary to provide sufficient energy locally to thermally decompose the insulating material beneath the film.

Deterioration increases with the time for which the current flows.

4.8.1.2 CTI values to categorize insulating materials

A method of classification for insulating materials according to 4.8.1.1 does not exist. The behaviour of the insulating material under various contaminants and voltages is extremely complex. Under these conditions, many materials may exhibit two or even all three of the characteristics stated. A direct correlation with the material groups of 4.8.1.3 is not practical. However, it has been found by experience and tests that insulating materials having a higher relative performance also have approximately the same relative ranking according to the comparative tracking index (CTI). Therefore, this standard uses the CTI values to categorize insulating materials.

4.8.1.3 Material groups

For the purposes of this standard, materials are classified into four groups according to their CTI values. These values are determined in accordance with IEC 60112 using solution A. The groups are as follows:

- material group I: $600 \leq \text{CTI}$;
- material group II: $400 \leq \text{CTI} < 600$;
- material group IIIa: $175 \leq \text{CTI} < 400$;
- material group IIIb: $100 \leq \text{CTI} < 175$.

The proof tracking index (PTI) is used to verify the tracking characteristics of materials. A material may be included in one of these four groups on the basis that the PTI, verified by the method of IEC 60112 using solution A, is not less than the lower value specified for the group.

4.8.1.4 Test for comparative tracking index (CTI)

The test for comparative tracking index (CTI) in accordance with IEC 60112 is designed to compare the performance of various insulating materials under test conditions. It gives a qualitative comparison and in the case of insulating materials having a tendency to form tracks, it also gives a quantitative comparison.

4.8.1.5 Non tracking materials

For glass, ceramics or other inorganic insulating materials which do not track, creepage distances need not be greater than their associated clearance for the purpose of insulation coordination. The dimensions of Table F.2 for inhomogeneous field conditions are appropriate.

4.8.2 Electric strength characteristics

The electric strength characteristics of insulating material shall be considered by the technical committees, taking into account the stresses described in 5.3.1, 5.3.2.2.1 and 5.3.2.3.1.

4.8.3 Thermal characteristics

The thermal characteristics of insulating material shall be considered by the technical committees taking into account the stresses described in 5.3.2.2.2, 5.3.2.3.2 and 5.3.3.5.

NOTE See also IEC 60216.

4.8.4 Mechanical and chemical characteristics

The mechanical and chemical characteristics of insulating material shall be considered by the technical committees, taking into account the stresses described in 5.3.2.2.3, 5.3.2.3.3 and 5.3.2.4.

5 Requirements and dimensioning rules

5.1 Dimensioning of clearances

5.1.1 General

Clearances shall be dimensioned to withstand the required impulse withstand voltage. For equipment directly connected to the low-voltage mains the required impulse withstand voltage is the rated impulse voltage established on the basis of 4.3.3.3. If a steady-state r.m.s. voltage, a temporary overvoltage or a recurring peak voltage requires larger clearances than required for the impulse withstand voltage, the corresponding values of Table F.7a shall be used. The largest clearance shall be selected, resulting from consideration of impulse withstand voltage, steady-state r.m.s. voltage, temporary overvoltage and recurring peak voltage.

NOTE Dimensioning for steady-state r.m.s. or recurring peak voltage leads to a situation in which there is no margin with respect to breakdown with the continuous application of these voltages. Technical committees should take this into account.

5.1.2 Dimensioning criteria

5.1.2.1 General

Clearance dimensions shall be selected, taking into account the following influencing factors:

- impulse withstand voltage according to 5.1.5 for functional insulation and 5.1.6 for basic, supplementary and reinforced insulation;
- steady-state withstand voltages and temporary overvoltages (see 5.1.2.3);
- recurring peak voltages (see 5.1.2.3);
- electric field conditions (see 5.1.3);
- altitude: the clearance dimensions specified in Table F.2 and Table F.7a give withstand capability for equipment for use in altitudes up to 2 000 m. For equipment for use at higher altitudes 5.1.4 applies;
- degrees of pollution in the micro-environment (see 4.6.2).

Larger clearances may be required due to mechanical influences such as vibration or applied forces.

5.1.2.2 Dimensioning to withstand transient overvoltages

Clearances shall be dimensioned to withstand the required impulse withstand voltage, according to Table F.2. For equipment directly connected to the supply mains, the required impulse withstand voltage is the rated impulse voltage established on the basis of 4.3.3.3.

NOTE IEC 60664-5 provides an alternative and more precise dimensioning procedure for clearances equal to or less than 2 mm.

5.1.2.3 Dimensioning to withstand steady-state voltages, temporary overvoltages or recurring peak voltages

Clearances shall be dimensioned according to Table F.7a to withstand the peak value of the steady-state voltage (d.c. or 50/60 Hz), the temporary overvoltage or the recurring peak voltage.

The dimensioning according to Table F.7 shall be compared with Table F.2, taking into account the pollution degree. The larger clearance shall be selected.

NOTE Dimensioning requirements for frequencies higher than 30 kHz are specified in IEC 60664-4.