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Insulation coordination for equipment within low-voltage systems

Part 2-1: Application guide — Explanation of the application of the IEC 60664 series, dimensioning examples and dielectric testing

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National foreword

This Published Document is the UK implementation of IEC/TR 60664-2-1:2011. It supersedes BS 7822-2.1:1999 which is withdrawn.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.

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

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

INSULATION COORDINATION FOR EQUIPMENT WITHIN LOW-VOLTAGE SYSTEMS –

Part 2-1: Application guide – Explanation of the application of the IEC 60664 series, dimensioning examples and dielectric testing

FOREWORD

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC/TR 60664-2-1, which is a technical report, serves as an application guide for the IEC 60664 series and has been prepared by IEC technical committee 109: Insulation coordination for low-voltage equipment.

This second edition cancels and replaces the first edition, published in 1997, and constitutes a technical revision.

The main changes with respect to the previous edition are listed below:

– the previous edition was only an application guide for IEC 60664-1. This second edition takes into account not only IEC 60664-1 but also the other parts IEC 60664-3, IEC 60664-4, and IEC 60664-5 and their interrelation;
– principles of the IEC 60664 series for insulation dimensioning of LV equipment are explained and examples of practical application are provided together with some background information;
– Annex A provides an overview of clauses of IEC 60664-1 requiring decisions by technical committees, or specification of options, or requiring activities of the manufacturer;
– Annex B provides an overview of such clauses of IEC 60664-4;
– Annex C provides an overview of such clauses of IEC 60664-5;
– Annex D amends the tables of Annex F of IEC 60664-1:2007 with rated impulse voltages for voltages line to neutral derived from nominal d.c. voltages up to and including 1 500 V.

The text of this application guide is based on the following documents:

Enquiry draft	Report on voting
109/82/DTR	109/83/RVC

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

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

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

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

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication 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.

INTRODUCTION

This application guide provides information relating to insulation coordination, as described in the IEC 60664 series, for the benefit of IEC technical committees and manufacturers. It covers general information for the dimensioning of clearances, creepage distances and solid insulation for equipment.

It aims to highlight the use and understanding of the IEC 60664 series when applied by technical committees and manufacturers.

Insulation coordination for equipment implies the assessment of the minimum necessary dimensioning for clearances, creepage distances and solid insulation in order to allow safe use of the equipment during its lifetime, taking into consideration the foreseeable environmental conditions.

The main parameters to be taken into account for the understanding of the IEC 60664 series include:

- the maximum voltage stress to be withstood in order to avoid flashover across clearances;
- the characteristics of the solid insulating material and the environmental conditions regarding tracking. IEC 60664-3 provides methods for improving the micro-environment at the creepage distance;
- the electrical field stress through solid insulation as it relates to the risk of partial discharge and dielectric loss causing a risk of breakdown due to excessive heating. In particular, technical committees and manufacturers should consider a partial discharge test if the maximum peak voltage across the insulation material exceeds 700 V and the peak value of the field strength exceeds 1 kV/mm. Due to the fact that both partial discharge phenomena and dielectric losses increase in importance with voltage frequency, a dedicated standard, IEC 60664-4, applies for frequencies higher than 30 kHz;

NOTE IEC 60664-4 provides information concerning clearances, creepage distances, solid insulation and testing for frequencies above 30 kHz.

- the long-term maximum voltage stress to be withstood in order to avoid tracking over the surface of the insulation material;
- flashover; besides tracking, this is increasingly important with reduction of creepage distance in the presence of high humidity. IEC 60664-5 introduces humidity levels classifying the effects of humidity on creepage distances equal to or less than 2 mm.

Other stresses such as heat, vibration, mechanical shocks, radiation, etc. may influence the performance of solid insulating materials in service. Technical committees and manufacturers should consider the risks related to these stresses when specifying conditions for testing equipment to be used under particular situations.

INSULATION COORDINATION FOR EQUIPMENT WITHIN LOW-VOLTAGE SYSTEMS –

Part 2-1: Application guide – Explanation of the application of the IEC 60664 series, dimensioning examples and dielectric testing

1 Scope

This part of IEC 60664, which is a technical report, serves as an application guide for technical committees and manufacturers specifying dimensioning requirements for products in accordance with the IEC 60664 series.

The significant items for consideration are as follows:

a) nominal system voltage(s) or rated insulation voltage(s);
b) overvoltage category of the products (OV cat.);
c) any type of overvoltages;
d) frequency of the voltage;
e) characteristics of the solid insulating material;
f) pollution degree and humidity levels.

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 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 60112:2003, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*
Amendment 1 (2009)

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

IEC 60364-4-44:2007, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

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

IEC 60664-3:2003, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

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

IEC 60664-5:2007, *Insulation coordination for equipment within low-voltage systems – Part 5: Comprehensive method for determining clearances and creepage distances equal to or less than 2 mm*

IEC 61140:2001, *Protection against electric shock – Common aspects for installation and equipment*

3 Terms and definitions

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

NOTE All definitions can be found in the various parts of the IEC 60664 series, as indicated below.

3.1
approximately homogeneous field
for frequencies exceeding 30 kHz the field is considered to be approximately homogeneous when the radius of curvature of the conductive parts is equal or greater than 20 % of the clearance

[IEC 60664-4:2005, 3.1]

3.2
base material
insulating material upon which a conductive pattern may be formed

NOTE The base material may be rigid or flexible, or both. It may be a dielectric or an insulated metal sheet.

(IEC 60194, definition 40.1334)

[IEC 60664-3:2003, 3.1]

3.3
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)

[IEC 60664-1:2007, 3.17.2]

3.4
clearance
shortest distance in air between two conductive parts

[IEC 60664-1:2007, 3.2]

3.5
coating
insulating material such as varnish or dry film laid on the surface of the assembly

NOTE Coating and base material of a printed board form an insulating system that may have properties similar to solid insulation.

[IEC 60664-3:2003, 3.5]

3.6
conductor
single conductive path in a conductive pattern

(IEC 60194, definition 22.0251)

[IEC 60664-3:2003, 3.3]

3.7
creepage distance
shortest distance along the surface of a solid insulating material between two conductive parts
(IEV 151-15-50)

[IEC 60664-1:2007, 3.3]

3.8
double insulation
insulation comprising both basic insulation and supplementary insulation
(IEV 826-12-16)

[IEC 60664-1:2007, 3.9]

3.9
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

[IEC 60664-1:2007, 3.20]

3.10
electrical field strength
E
voltage gradient per unit length usually expressed in kV/mm

[IEC 60664-4:2005, 3.7]

3.11
environment
surrounding which may affect performance of a device or system

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

(IEV 151-16-03, modified)

[IEC 60664-1:2007, 3.12]

3.12
flashover
electrical breakdown along a surface of solid insulation located in a gaseous or liquid medium

[IEC 60664-1:2007, 3.20.2]

3.13
functional insulation
insulation between conductive parts which is necessary only for the proper functioning of the equipment

[IEC 60664-1:2007, 3.17.1]

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.

[IEC 60664-1:2007, 3.14]

3.15
impulse withstand voltage
highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified conditions

[IEC 60664-1:2007, 3.8.1]

3.16
inhomogeneous field
electric field which does not have an essentially constant voltage gradient between electrodes (non-uniform field)

NOTE 1 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.

NOTE 2 For frequencies exceeding 30 kHz the field is considered to be inhomogeneous when the radius of curvature of the conductive parts is less than 20 % of the clearance.

[IEC 60664-1:2007, 3.15, modified, and IEC 60664-4:2005, 3.2]

3.17
insulation
that part of an electrotechnical product which separates the conducting parts at different electrical potentials

(IEV 212-01-05)

[IEC 60664-1:2007, 3.17]

3.18
insulation coordination
mutual correlation of insulation characteristics of electrical equipment taking into account the expected micro-environment and other influencing stresses

[IEC 60664-1:2007, 3.1, modified]

3.19
macro-environment
environment of the room or other location in which the equipment is installed or used

[IEC 60664-1:2007, 3.12.1]

3.20
micro-environment
immediate environment of the insulation which particularly influences the dimensioning of the creepage distances

[IEC 60664-1:2007, 3.12.2]

3.21
overvoltage
any voltage having a peak value exceeding the corresponding peak value of maximum steady-state voltage at normal operating conditions

[IEC 60664-1:2007, 3.7]

3.22
overvoltage category
numeral defining a transient overvoltage condition

[IEC 60664-1:2007, 3.10, modified]

3.23
partial discharge
PD
electric discharge that partially bridges the insulation

[IEC 60664-1:2007, 3.18]

3.24
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.

[IEC 60664-1:2007, 3.18.4]

3.25
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

[IEC 60664-1:2007, 3.11]

3.26
pollution degree
numeral characterizing the expected pollution of the micro-environment

[IEC 60664-1:2007, 3.13]

3.27
printed board
general term for completely processed printed circuit and printed wiring configurations

NOTE This includes single-sided, double-sided and multilayer boards with rigid, flexible, and rigid-flex base materials.

(IEC 60194, definition 60.1485)

[IEC 60664-3:2003, 3.2]

3.28
protection
any kind of measure which reduces the influence of the environment

[IEC 60664-3:2003, 3.4]

3.29
r.m.s. withstand voltage
highest r.m.s. value of a voltage which does not cause breakdown of insulation under specified conditions

[IEC 60664-1:2007, 3.8.2]

3.30
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

[IEC 60664-1:2007, 3.9.2]

3.31
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.

[IEC 60664-1:2007, 3.9.1]

3.32
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

[IEC 60664-1:2007, 3.9.3]

3.33
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

[IEC 60664-1:2007, 3.9.4]

3.34
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.

[IEC 60664-1:2007, 3.9]

3.35
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.

[IEC 60664-1:2007, 3.6]

3.36
recurring peak withstand voltage
highest peak value of a recurring voltage which does not cause breakdown of insulation under specified conditions

[IEC 60664-1:2007, 3.8.3]

3.37
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)

[IEC 60664-1:2007, 3.17.5]

3.38
routine test
test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

[IEC 60664-1:2007, 3.19.2]

3.39
sampling test
test on a number of devices taken at random from a batch

[IEC 60664-1:2007, 3.19.3]

3.40
solid insulation
solid insulating material interposed between two conductive parts

NOTE In the case of a printed board with a coating, solid insulation consists of the board itself as well as the coating. In other cases, solid insulation consists of the encapsulating material.

[IEC 60664-3:2003, 3.6]

3.41
spacing
any combination of clearances, creepage distances and insulation distances through insulation

[IEC 60664-3:2003, 3.7]

3.42
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.

[IEC 60664-1:2007, 3.18.2]

3.43
supplementary insulation
independent insulation applied in addition to basic insulation for fault protection

(IEV 826-12-15)

[IEC 60664-1:2007, 3.17.3]

3.44
temporary overvoltage
overvoltage at power frequency of relatively long duration

[IEC 60664-1:2007, 3.7.1]

3.45
temporary withstand overvoltage
highest r.m.s. value of a temporary overvoltage which does not cause breakdown of insulation under specified conditions

[IEC 60664-1:2007, 3.8.4]

3.46
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

(ISO/IEC Guide 2:1996, 13.1)

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.

(IEV 151-16-13)

[IEC 60664-1:2007, 3.19]

3.47
transient overvoltage
short duration overvoltage of a few milliseconds or less, oscillatory or non-oscillatory, usually highly damped

(IEV 604-03-13)

[IEC 60664-1:2007, 3.7.2]

3.48
type test
test of one or more devices made to a certain design to show that the design meets certain specifications

[IEC 60664-1:2007, 3.19.1]

3.49
peak value
U_{peak}
peak value of any type of periodic peak voltage across the insulation

[IEC 60664-4:2005, 3.3]

3.50
water adsorption
capability of insulating material to adsorb water on its surface

[IEC 60664-5:2007, 3.1]

3.51
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)

[IEC 60664-1:2007, 3.8]

3.52
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.

[IEC 60664-1:2007, 3.5]

4 Principles and practical application of the IEC 60664 series for insulation dimensioning of LV equipment

4.1 Basic principles

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 regarding voltage and micro-environmental conditions.

With regard to voltage, due consideration shall be made to

– the voltages which can appear within the low-voltage supply system, including working voltage (RMS and peak), temporary overvoltage (peak) and impulse voltages (peak),
– the voltages generated by the equipment (which could adversely affect other equipment in the low-voltage supply system),
– the frequency of the steady-state voltage. For frequencies up to and including 30 kHz, IEC 60664-1 is sufficient, above 30 kHz, IEC 60664-4 also needs to be taken into account,
– 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.

Insulation coordination applies to equipment which is connected to the public low-voltage systems. However, it is recommended to use the same principles for all other low-voltage systems which have no connection to the public low-voltage system. In those cases, however, other overvoltage categories and temporary overvoltages may be applicable for such equipment.

NOTE Technical committees using the IEC 60664 series should determine the appropriate maximum impulse voltage likely to occur in their application. This includes the nature of the source, distribution of the source, physical location (indoor/outdoor) and length of cabling, etc. Special attention is given to the fact that the impulse withstand voltage occurring on the non-mains system does not necessarily depend on the voltage. For certain applications, a minimum impulse withstand voltage independent of the voltage should be considered by technical committees.

Insulation coordination is also applicable to specially protected areas, e.g. as described in IEC 60079. In such cases, however, additional requirements are applicable, in particular with respect to the specification of the overvoltage category and the environmental conditions.

4.2 Coordination of overvoltage categories inside equipment

For equipment which is directly energized by the mains, the following coordination with respect to transient overvoltages originating from the mains is used:

– for circuits directly energized by the mains, the overvoltage category of the equipment is used for dimensioning;
– circuits that are energized from the secondary of an isolation transformer, where the secondary winding is earthed, or from a transformer employing an earth screen between primary and secondary, are not considered directly energized by the mains and an impulse withstand voltage is applicable one step lower in the preferred series of rated impulse voltage of 4.2.3 of IEC 60664-1:2007.

NOTE 1 A step can be considered within the numerals of the overvoltage categories or within the lines of Table F.1 in IEC 60664-1:2007.

NOTE 2 The transfer ratio of the transformer is not taken into account for the choice of the overvoltage category.

If surge protective devices (SPDs) are used to apply a lower overvoltage category for a circuit not directly energized by the mains, but inside the equipment, it is necessary to verify the correct performance of such circuits by an appropriate test using a hybrid generator with a virtual impedance of 2 Ω.

NOTE 3 The correct function of the surge protective device (SPD) depends upon the series impedance within the relevant circuit. Therefore, a test of the SPD in the relevant circuit is required.

4.3 Practical use of the IEC 60664 series for the dimensioning of clearances

4.3.1 General

All values in IEC 60664-1 or IEC 60664-5 are minimum values. These need to be maintained for the whole life of the equipment, taking into account manufacturing tolerances. Additionally, particular situations such as assembly on site of large equipment, e.g. wiring or protective conductive enclosure added on site, need to be considered regarding necessary tolerances.

NOTE 1 When dimensioning clearances to accessible surfaces of insulating material, such surfaces are assumed to be covered by metal foil. Further details can be specified by technical committees.

For clearances which are designed between case A and case B values according to IEC 60664-1, a voltage test is required in any case in order to check that no flashover occurs over the clearance. If this test is carried out with impulse voltage within complete equipment, a very low impedance of the generator can be required. For this purpose, a hybrid generator with a virtual impedance of 2 Ω may be appropriate. However, in any case a measurement of the correct test voltage directly at the clearance is required.

NOTE 2 It is recommended to apply case A during design. If not possible, impulse testing is necessary.

NOTE 3 In practice, some design may exist that lie in between the situation described in case A and case B. In this case, TCs should pay attention to 6.1.2.2.1.2 of IEC 60664-1:2007.

NOTE 4 Case A is the most unfavourable case where the electrical field is absolutely inhomogeneous between a sharp needle and a plane surface. Case B is the most favourable case where the electrical field is completely homogeneous between two plane surfaces. This case can never be reached in a real design.

4.3.2 Practical use of Tables F.2 and F.7 of IEC 60664-1:2007 for the dimensioning of clearances

4.3.2.1 General

Clearances are dimensioned to withstand the required impulse withstand voltage either:

- by requiring dimensions of not less than case A values; or
- by requiring verification by an impulse test (see 6.1.2.2.1.2 of IEC 60664-1:2007).

Clearances of basic and supplementary insulation are each dimensioned as specified in Table F.2 of IEC 60664-1:2007 corresponding to:

- the rated impulse voltage, according to 4.3.3.3 of IEC 60664-1:2007 or 4.3.3.4.1 of IEC 60664-1:2007; or
- the impulse withstand voltage requirements according to 4.3.3.4.2 of IEC 60664-1:2007.

Clearances of reinforced insulation are dimensioned as specified in Table F.2 of IEC 60664-1:2007 corresponding to the rated impulse voltage but one step higher in the preferred series of values in 4.2.3 of IEC 60664-1:2007 than that specified for basic insulation.

If the impulse withstand voltage required for basic insulation according to 4.3.3.4.2 of IEC 60664-1:2007 is other than a value taken from the preferred series, reinforced insulation is dimensioned to withstand 160 % of the impulse withstand voltage required for basic insulation.

NOTE 1 The rated impulse voltage specified in Table F.1 of IEC 60664-1:2007 depends on the appropriate overvoltage category. Overvoltage category I is not applicable to any circuit directly energized by the mains.

NOTE 2 In the case of d.c. voltage, the rated impulse voltage can also be chosen from Table F.1 in IEC 60664-1:2007. The overvoltage category can be chosen with the same rules used by TCs for a.c. systems.

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 of IEC 60664-1:2007. Clearances are dimensioned according to Table F.7a of IEC 60664-1:2007 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 is compared with Table F.2, of IEC 60664-1:2007 taking into account the pollution degree. The larger clearance is selected.

NOTE 3 However, it is recommended to introduce a safety margin for the dimensioning according to Table F.7 of IEC 60664-1:2007 since this table provides a minimum dimensioning with respect to steady-state voltages.

It is recommended that technical committees consider the consequences of a flashover in a d.c. low-voltage system in order to decide whether it is necessary to introduce appropriate safety measures.

NOTE 4 An equipment directly energized by the mains can be either a fixed equipment directly connected to the mains or a normally plugged equipment energized from the mains through a plug and socket-outlet.

NOTE 5 It can be observed from the following example, applicable to most equipment used within an electrical installation directly connected to 230/400 V three-phase system, that the rated impulse voltage as specified in Table F.1 of IEC 60664-1:2007 is the highest overvoltage to be withstood by the equipment and leads to the appropriate dimensioning for clearances of basic insulation.

– EXAMPLE: A single-phase equipment, with a rated voltage equal to 250 V, directly connected to mains, 230 V between line and neutral, overvoltage category III, shall withstand a rated impulse voltage of 4 kV according to Table F.1 of IEC 60664-1:2007. The clearance shall therefore be 3 mm according to Table F.2 Case A, of IEC 60664-1:2007.

– The peak voltage for the steady-state voltage and the recurring peak voltages in this particular example have the same value, this is the peak voltage of the mains: 353 V and leads to a clearance 0,013 mm long according to Table F.7 Case A, of IEC 60664-1:2007.

– The temporary overvoltage is given in 5.3.3.2.3 of IEC 60664-1:2007 for short-term temporary overvoltages as follows: U_n+1 200 V. The peak voltage is therefore 2,050 kV and leads to a clearance 1,27 mm long according to Table F.7 Case A, of IEC 60664-1:2007.

– The length of the clearance for the basic insulation is therefore dimensioned according to the rated impulse voltage.

The pollution degree does not have a strong influence on the dimensioning of clearances. It can be observed from Table F.2 of IEC 60664-1:2007 that, above a certain minimum value, the same distances are given for clearances whatever the chosen pollution degree. However, the pollution degree cannot be ignored for small clearances where pollution such as solid particles, dust and condensation could bridge the air gap.

NOTE 6 More details regarding dimensioning of clearances for distances lower than 2 mm are given in IEC 60664-5 which takes into account humidity. See Clause 7 of this application guide for examples.

With respect to steady-state voltages, recurring peak voltages and temporary overvoltages clearances of reinforced insulation is dimensioned as specified in Table F.7a of IEC 60664-1:2007 to withstand 160 % of the withstand voltage required for basic insulation.

NOTE 7 It should be noted that while clearance for reinforced insulation is dimensioned with respect to 160 % of the temporary overvoltage for basic and supplementary insulation, the test voltage for verification of the clearance of the reinforced insulation is twice the voltage of the test voltage for verification of basic and supplementary insulation.

4.3.2.2 Design for high altitude above 2 000 m

The dimensioning of clearances aims to choose an air distance able to withstand the maximum peak voltage across the air gap between two parts at different voltages. According to Paschen's law, the behaviour of air to withstand a maximum voltage value is in relationship with air pressure. Tables F.2 and F.7 of IEC 60664-1:2007 have been drafted up to 2 000 m. Correction factors for altitudes above 2 000 m are given in Table A.2 of IEC 60664-1:2007.

When these correction factors for altitudes above 2 000 m are applied for determining the clearances, also the test voltage for the impulse voltage test is corrected accordingly. Therefore, the test voltage for the impulse voltage test is determined with the interpolation of Table A.2 of IEC 60664-1:2007 and applying the formulas of 6.1.2.2.1.3 of IEC 60664-1:2007.

4.3.3 Practical use of Tables 2 and 3 of IEC 60664-5:2007 for the dimensioning of clearances

For clearances requiring distances equal to or less than 2 mm for basic insulation, the dimensioning provided in IEC 60664-5 is more precise than that provided in IEC 60664-1. However, if the precision provided in IEC 60664-5 is not required, IEC 60664-1 may be applied instead.

A flashover across a clearance is induced by the peak value of the maximum voltage occurring across it. The purpose is therefore to choose the peak value of the maximum voltage that could occur across the clearance under rated condition in accordance with the manufacturer's declaration. The required impulse voltage for circuits directly energized by low-voltage mains can be directly read in Table F.1 of IEC 60664-1:2007.

The choice of the pollution degree shall be made in accordance with the normal use of equipment within the macro-environment.

Humidity is an influencing parameter for pollution degrees. IEC 60664-5, for distances equal to or less than 2 mm, focuses on humidity which leads to conductivity and possibly flashover. This aspect is taken into account in 4.4.3 of this application guide during the dimensioning of creepage distances with respect to flashover according to Table 5 of IEC 60664-5:2007.

NOTE 1 A relationship between humidity levels and relative humidity of the micro-environment is given in Table 1 in IEC 60664-5:2007.

The dimensioning of clearance with respect to transient overvoltages is specified in Table 2 of IEC 60664-5:2007. The minimum clearances in Table F.2 of IEC 60664-1:2007 for pollution degrees 2, 3 (and 4) have been deleted. Instead of the minimum clearances the more precise dimensioning described in 4.4.3 of this application guide with respect to the possible flashover of the parallel creepage distance according to Table 5 of IEC 60664-5:2007 is used.

For the dimensioning of clearances with respect to steady-state voltages the manufacturer assesses the maximum peak value of the steady-state voltage, temporary overvoltage or recurring peak voltage, and chooses the appropriate value from Table 3 in IEC 60664-5:2007.

NOTE 2 Considerations made on Case A and Case B for Table F.2 in 5.1.3 in IEC 60664-1:2007 and for Table 2 in IEC 60664-5:2007 also apply for this table.

NOTE 3 However, it is recommended to introduce a safety margin for the dimensioning according to Table 3 of IEC 60664-5:2007 since this table provides a minimum dimensioning with respect to steady-state voltages.

This value is compared to the value according to the procedure applicable in Table 2 of IEC 60664-5:2007.

4.4 Practical use of the IEC 60664 series for the dimensioning of creepage distances

4.4.1 General

The dimensioning values in IEC 60664-1 do not take into account the aspect of the minimum insulation resistance. Therefore, in particular within electronic equipment for functional reasons, it may be required to use a larger dimensioning or to improve the micro-environment at the creepage distance. Information for dimensioning with regard to minimum insulation resistance is given in Table A.1 and Table A.2 of IEC 60664-5:2007.

For creepage distances on printed wiring material only used under pollution degree 1 and 2, a reduced dimensioning is applicable according to IEC 60664-1. Attention is drawn on the possible reduction or other path of creepage distances due to the components.

The dimensioning of creepage distances according to IEC 60664-5 with respect to tracking and to flashover along the surface of the material for distances equal or lower than 2 mm can lead to a reduction of the distances.

4.4.2 Practical use of Table F.4 of IEC 60664-1:2007 and Table 4 of IEC 60664-5:2007 for the dimensioning of creepage distances

It is assumed that dry pollution at the surface of a material is generally not conductive. However, presence of water at the surface of the material modifies the conductivity of the pollution. A higher conductivity allows circulation of current at the surface of the materials, either between live parts or between live parts and earth. These currents are called tracking currents. During drying out, the tracking current will break causing surface scintillation whose high temperature (around 1 200 °C) is the origin of degradation of the surface of the insulating material. This phenomenon entails tracking.

NOTE It is obvious that pollution degree 4 cannot be used for the dimensioning of creepage distances since the surface is continuously conductive.

There are some materials, such as ceramic and glass, which do not track because the scintillation cannot break the chemical bonds at the surface of the material. Experience has shown that materials having a higher relative performance with regard to tracking also have approximately the same relative ranking according to the comparative tracking index (CTI). The CTI can be measured with the method given in IEC 60112.

For practical reasons, IEC 60664-1 introduces four different material groups:

– material group I: $600 \leq CTI$;
– material group II: $400 \leq CTI < 600$;
– material group IIIa: $175 \leq CTI < 400$;
– material group IIIb: $100 \leq CTI < 175$.

From the above explanation, Table F.4 of IEC 60664-1:2007 can be used as follows:

– first step: to choose the most appropriate pollution degree according to the normal use of the equipment;
– second step: to choose one insulating material and to allocate it to a material group based on its CTI;
– third step: to assess the highest value of the long-term r.m.s voltage across the creepage distance. This highest value can be either the working voltage or the highest rated voltage if the equipment has several rated voltages. In the case of d.c. rated voltage, the equivalent rated r.m.s voltage is chosen in Table F.4 of IEC 60664-1:2007;
– fourth step: to read the value given at the cross of the chosen column with the chosen line.

At this stage, there are two cases to be considered. Either the creepage distance is greater than the associated clearance or is smaller than the associated clearance.

– If the creepage distance is greater than the associated clearance, no further test is needed;
– If the creepage distance is smaller than the required clearance and if the field is in between an homogeneous and an inhomogeneous case (between Case A and Case B of Table F.2 of IEC 60664-1:2007 and Table F.7 of IEC 60664-1:2007), the associated clearance is tested according to 6.1.2 of IEC 60664-1:2007 in order to check that no flashover occurs over the associated clearance (see 5.2.2.6 in IEC 60664-1:2007). This can be explained as follows: When the electric field is homogeneous (Case B), Tables F.2

and F.7 of IEC 60664-1:2007 give the shortest clearance able to withstand the specified voltage. Therefore, it is not possible to reduce the creepage to a lower value than the clearance value read in Tables F.2 and F.7 of IEC 60664-1:2007. However, in practice, the electric field is generally inhomogeneous but not as inhomogeneous as the one described for Case A in Tables F.2 and F.7 of IEC 60664-1:2007. It is therefore possible that the actual electrical field conditions over the clearance associated with the creepage distance allow the equipment under test to withstand the maximum voltage stress. This shall be checked with an impulse voltage test.

4.4.3 Practical use of Table 5 in IEC 60664-5:2007 for dimensioning of creepage distances

In the presence of humidity, a surface-related phenomenon, called water adsorption, may trap water at the surface of the insulating materials leading to a higher risk of flashover. Insulating materials can be ranked with regard to water adsorption ability. A test provided in Annex B of IEC 60664-5:2007 allows classification of insulating materials with regard to water adsorption. There are four water adsorption groups (WAG) of materials.

The presence of water at the surface of materials depends on the WAG and of the humidity level (HL). The risk of flashover along the creepage distance at the surface of the insulating material increases with the HL and with the ability of the insulating material to trap water.

For HL1, the dimensioning of the clearances requirements according to Tables 2 and 3 of IEC 60664-5:2007 is applicable because the influence of water does not increase significantly the risk of flashover.

For HL2 and HL3, Table 5 of IEC 60664-5:2007 shows the dimensioning of the creepage distances with regard to the WAG in order to avoid flashover. Since the flashover along the surface occurs in air, Table 5 of IEC 60664-5:2007 is valid for altitudes up to 2 000 m above sea level. Above 2 000 m, the altitude correction factor given in IEC 60664-1 is used.

The creepage distance is the higher value in Tables 4 and 5 in IEC 60664-5:2007. In any case it is obvious, that for homogeneous field conditions, the creepage distance cannot be less than the associated clearance. For inhomogeneous field conditions, a creepage distance less than the associated clearance required in Table 2 of IEC 60664-5:2007 may only be used under HL1 and HL2.

Such dimensioning shall be verified with an impulse voltage test.

NOTE In the case of d.c. voltage, the peak value chosen in Table 5 of IEC 60664-5:2007 is the maximum d.c. voltage across the creepage distance.

4.4.4 Practical use of IEC 60664-1:2007 for checking the dimensioning of creepage distances with regard to time under voltage stress

The creepage distances shown in Table F.4 of IEC 60664-1:2007 have been determined for insulation intended to be under continuous voltage stress for a long time.

NOTE 1 Technical committees responsible for equipment in which insulation is under voltage stress for only a short time may consider allowing shorter creepage distances than those specified in Table F.4 of IEC 60664-1:2007.

Creepage distances of basic and supplementary insulation are selected from Table F.4 of IEC 60664-1:2007 for:

– the rationalized voltages given in columns 2 and 3 of Table F.3a of IEC 60664-1:2007 and columns 2, 3 and 4 of Table F.3b of IEC 60664-1:2007, corresponding to the nominal voltage of the supply low-voltage mains;
– the rated insulation voltage according to 4.3.2.2.1 of IEC 60664-1:2007;
– the voltage specified in 4.3.2.2.2 of IEC 60664-1:2007.

NOTE 2 For supplementary insulation, the pollution degree, insulating material, mechanical stresses and environmental conditions of use may be different from those for basic insulation.

Creepage distances for reinforced insulation is twice the creepage distance for basic insulation from Table F.4 of IEC 60664-1:2007.

4.4.5 Practical use of IEC 60664-3:2003 for the reduction of micro-environmental conditions for the dimensioning of creepage distances

Dimensioning of spacings between conductors depends on environmental conditions. Regarding tracking, the choice of the pollution degree is linked to macro-environmental conditions.

The macro-environment influences the micro-environment at the surface of the insulating material. Without any protective measure, the micro-environmental conditions are the same as those of the macro-environment.

It is possible to improve the micro-environmental conditions at the insulation surface by the use of coating, potting or moulding as described in IEC 60664-3. This protection provides a more favourable micro-environmental condition, allowing a reduction of clearance and creepage distances.

NOTE 1 IEC 60664-3 deals mainly with evaluation and testing of the use of coating on PWBs. The standard also covers evaluation and testing when protection is realized by means of potting or moulding. In the latter case, technical committees should carefully consider the relevance of the verification and test procedures described in IEC 60664-3. Modifications to the verification and test procedures might be relevant to reflect the specific application.

IEC 60664-3 describes the requirements and test procedures for two methods of permanent protection applicable to all kinds of protected printed boards, including the surface of inner layers of multi-layer boards, substrates and similarly protected assemblies.

The two types of protection are as follows:

Type 1 protection improves the micro-environment of the parts under protection. The dimensioning of clearances and creepage distances under protection follows the distance requirements of IEC 60664-1 or IEC 60664-5 for pollution degree 1. Between two conductive parts, it is a requirement that one or both conductive parts, together with all the spacings between them, are covered by this protection.

Type 2 protection is considered to be similar to solid insulation. Under this protection, the requirements for solid insulation specified in IEC 60664-1 are applicable and the spacings are not less than those specified in Table 1 of IEC 60664-3:2003. The requirements for clearances and creepage distances in IEC 60664-1 or IEC 60664-5 do not apply. Between two conductive parts, it is a requirement that both conductive parts, together with all the spacings between them, are covered by this protection so that no air gap exists between the protective material, the conductive parts and the printed board.

NOTE 2 Above 30 kHz, the additional requirements of IEC 60664-4 for solid insulation are applicable for Type 2 protection.

4.5 Practical use of the IEC 60664 series for the dimensioning of solid insulation

4.5.1 General

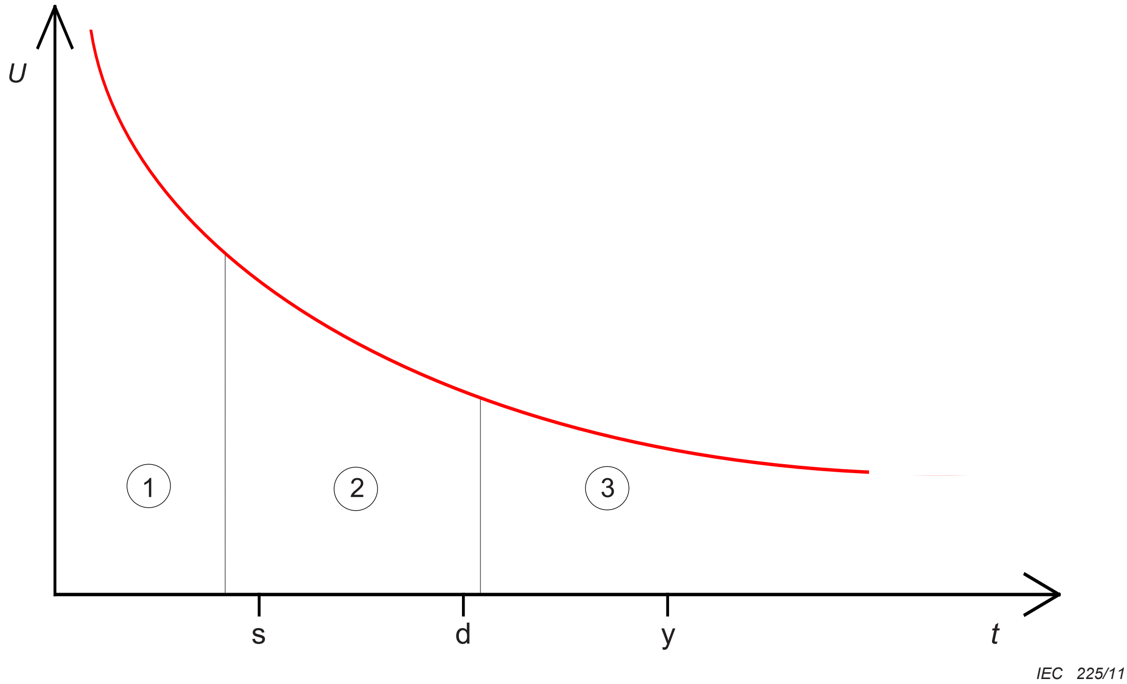
Sometimes, solid insulation is designed according to the breakdown data supplied by the manufacturers of insulating material. When using such data, it has to be taken into account that these have been obtained under particular and rather favourable conditions:

– usually homogeneous field distribution has been provided;
– usually ambient room temperature has been applied during testing;

– usually short-time testing has been performed;

– in many cases d.c. voltage has been used for testing.

The general influence of the time of testing on the breakdown voltage is shown in Figure 1. The time scale applies to the power-frequency voltage.



Key

s seconds; d days; y years; *t* time; *U* voltage

range 1 electrical breakdown

range 2 breakdown caused by excessive heating

range 3 breakdown caused by ageing (i. e. by partial discharges)

Figure 1 – Breakdown voltage of solid insulation depending upon the time of voltage stress

Compared to the conditions within real equipment, such data can deviate by orders of magnitude from the long-term withstand capability of such insulation. Therefore, this data cannot be used directly for dimensioning of solid insulation.

With regard to insulation coordination as described in IEC 60664-1, in general a design of solid insulation according to the thickness and the relevant breakdown field strength is only possible if:

– the field distribution is homogeneous and if no voids or air gaps are present within the insulation system (see IEC 60664-4 for high-frequency voltage stress); or

– the field strength is low enough so that no partial discharges occur.

4.5.2 Coordination of clearances and solid insulation

In many cases, clearances and solid insulation are stressed by the same voltage. In such a case, the dimensioning should take into account that, in contrast to solid insulation, clearances are self restoring. Therefore, the withstand capability of the clearances should be lower than that of the solid insulation so that breakdown of the clearance occurs before the solid insulation can be damaged.

4.5.3 Practical information for checking the correct dimensioning of solid insulation

4.5.3.1 Dimensioning according to the breakdown field strength

In principle, dimensioning of solid insulation may be based on the breakdown field strength data. This, however, requires knowledge of such data for the practical conditions of use, i.e. long-term voltage stress and the additional influence of aggravating effects like increased ambient temperature, humidity and mechanical stress. Even if such data is available, simple dimensioning rules can only be established if the field distribution inside the solid insulation is nearly homogeneous; otherwise, the field strength inside the solid insulation cannot be calculated.

EXAMPLE:

E_{peak} breakdown field strength of the solid insulation (peak value): 45 kV/mm; (specified by the manufacturer of the insulating material);

d thickness of the solid insulation: 0,1 mm;

U_{peak} maximum voltage stress (peak value): 4,5 kV.

However, if air gaps are included within the solid insulation, this procedure can be greatly misleading in practice, see 4.5.3.4.2.

This is caused by the inhomogeneous voltage distribution within such an insulation system and the lower withstand capability of air, compared to that of the solid insulation (see 4.5.3.4.2, in particular case b)).

4.5.3.2 Dimensioning according to testing

If the breakdown field strength of the solid insulation is not known for the conditions of the intended use and/or if the field distribution inside the solid insulation is not known, the correct performance of the solid insulation can only be shown by appropriate testing according to 6.1.3 of IEC 60664-1:2007. This also requires correct conditioning according to 6.1.3.2 of IEC 60664-1:2007.

The following tests may be applicable:

a) The impulse voltage withstand test (see 6.1.3.3 of IEC 60664-1:2007) to verify the capability of the solid insulation to withstand the rated impulse voltage (see 5.3.3.2.2 of IEC 60664-1:2007).
b) The a.c. voltage test (see 6.1.3.4 of IEC 60664-1:2007) to verify the capability of the solid insulation to withstand the highest voltage value from among the following:
   – short-term temporary overvoltage (see 5.3.3.2.3 of IEC 60664-1:2007);
   – highest steady-state voltage;
   – the recurring peak voltage (see 5.3.3.2.4 of IEC 60664-1:2007).

   If the peak value of the a.c. test voltage is equal to or higher than the rated impulse voltage, the a.c. voltage test also covers the impulse voltage test.

   Solid insulation has a different withstand characteristic compared to clearances if the duration of stress is increased. In general, the withstand capability will be decreased significantly. Therefore, the a.c. voltage test, which is specified for the verification of the withstand capability of solid insulation, is not allowed to be replaced by an impulse voltage test.
c) The partial discharge test (see 6.1.3.5 of IEC 60664-1:2007) to verify that no partial discharges are maintained in the solid insulation:
   – at the highest steady-state voltage;
   – at the long-term temporary overvoltage (see 5.3.3.2.3 of IEC 60664-1:2007);
   – at the recurring peak voltage (see 5.3.3.2.4 of IEC 60664-1:2007).

d) The high-frequency voltage test (see 6.1.3.7 in IEC 60664-1:2007) to verify the absence of failure due to dielectric heating according to 5.3.3.2.5 of IEC 60664-1:2007.

For equipment connected to different low-voltage mains, the following test voltages are applicable if the partial discharge test and the high-frequency voltage test are not considered for simplification.

Table 1 – Examples for rated voltage 100 V and 230 V and overvoltage category II

<table>
<tr><th rowspan="4">Insulation
(5.1.6 of IEC 60664-1:2007)</th><th colspan="3" rowspan="2">Impulse voltage
(V)
(6.1.3.3 of IEC 60664-1:2007)</th><th colspan="3">To cover impulse voltage test</th><th colspan="3">For the highest of the voltages mentioned in 6.1.3.1 b)[b] of IEC 60664-1:2007</th></tr>
<tr><th colspan="3">AC voltage
(V r.m.s)[c]</th><th colspan="3">AC voltage (V r.m.s)
6.1.3.4 of IEC 60664-1:2007</th></tr>
<tr><th colspan="2">Rated voltage</th><th rowspan="2">Time</th><th colspan="2">Rated voltage</th><th rowspan="2">Time</th><th colspan="2">Rated voltage</th><th rowspan="2">Time</th></tr>
<tr><th>100 V[e]</th><th>230 V</th><th>100 V[e]</th><th>230 V</th><th>100 V</th><th>230 V</th></tr>
<tr><td>Basic and supplementary</td><td>800
(1 500)</td><td>2 500</td><td rowspan="2">a</td><td>566
(1 061)</td><td>1 768</td><td rowspan="2">60 s[d]</td><td>1 300</td><td>1 430</td><td rowspan="2">60 s[d]</td></tr>
<tr><td>Reinforced</td><td>1 500
(2 500)</td><td>4 000</td><td>1 061
(1 768)</td><td>2 828</td><td>2 600</td><td>2 860</td></tr>
</table>

[a] Five impulses of each polarity with an interval of at least 1 s between impulses.

[b] The voltages are the short-term temporary overvoltage, the highest steady-state voltage and the recurring peak voltage. The values in the two columns are given for the short-term temporary overvoltage, which usually is the most stringent requirement.

[c] The peak values of these voltages are equal to the rated impulse voltage.

[d] The test duration can be reduced to 5 s if the short-term temporary overvoltage does lead to the most stringent requirements.

[e] The values in parenthesis are used for Japan. See footnote 5) of Table F.1 in IEC 60664-1:2007.

4.5.3.3 Series connection of clearances and solid insulation

4.5.3.3.1 General

Three cases can be distinguished.

In the first case, the series connection of clearances and solid insulation is a consequence of the product design. In this case, usually rather large clearances are addressed.

In the second case, the series connection of clearances and solid insulation is a result of the particular design of the insulation system, e.g. the use of several layers of thin sheet insulating material.

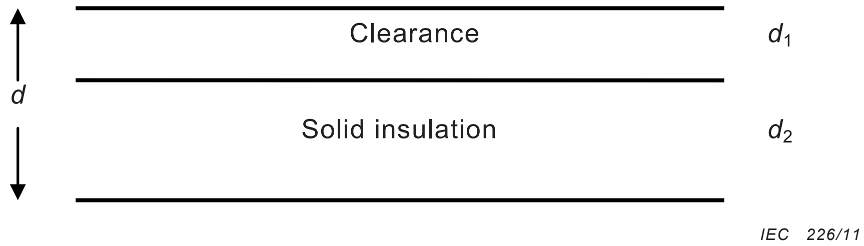
In the third case, the series connection of clearances and solid insulation is a result of the imperfect manufacturing of the solid insulation, including the interface to the conductive parts.

In the latter two cases, rather small air gaps or small air bubbles are connected in series with the solid insulation. All three cases require a calculation of the voltage distribution across the series connected insulators, according to the relevant impedances.

For d.c. voltage, these impedances are determined by the insulation resistances. As in air, the insulation resistance is nearly infinite, the impedance of the air gap is much higher than that of the solid insulator. So, nearly the whole d.c. voltage is applied across the clearance.

For a.c. voltage, the impedances of the series connected insulators are determined by their capacitances. Usually, for rather low frequencies as considered in IEC 60664-1, the dielectric losses do not need to be considered for the calculation of the voltage distribution. Therefore, the permittivity of the solid insulator becomes a decisive influence on the voltage distribution.

For an easy calculation of the capacitive voltage distribution, those capacitances are considered as plate-to-plate capacitors with an homogeneous field distribution. This situation is described in Figure 2:



Key

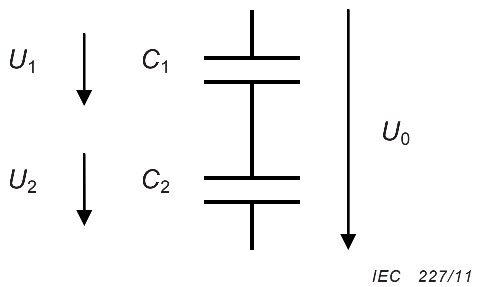
d total distance

d_1 clearance

d_2 thickness of the solid insulation

Figure 2 – Series connection of clearance and solid insulation

C_1 and C_2 form a capacitive voltage divider according to Figure 3 and the applied a.c. voltage U_0 is divided according to Equations (2) and (3) in the voltages U_1 and U_2.



Key

U_0 applied a.c. voltage

C_1 capacitance of the clearance

U_1 voltage across the clearance

C_2 capacitance of the solid insulation

U_2 voltage across the solid insulation

Figure 3 – Capacitive voltage divider

$$U_0 = U_1 + U_2 \quad (1)$$

$$U_1 = U_0 \frac{C_2}{C_1 + C_2} \quad (2)$$

$$U_2 = U_0 \frac{C_1}{C_1 + C_2} \quad (3)$$

The capacitances C_1 and C_2 are given by Equations (4) and (5):

$$C_1 = \varepsilon_0 \frac{A}{d_1} \quad (4)$$

$$C_2 = \varepsilon_0 \varepsilon_r \frac{A}{d_2} \quad (5)$$

where

A is the area of the plate-to-plate capacitors C_1 and C_2;

ε_0 is the permittivity of the air;

ε_r is the permittivity of the solid insulation.

For the voltage division, the capacitance ratio as given in Equation (6) is relevant.

$$C_1 = C_2 \frac{d_2}{d_1} \frac{1}{\varepsilon_r} \quad (6)$$

The breakdown field strength of the clearance (E_1) can be computed using the a.c. breakdown voltage and the corresponding clearance of Table A.1 of IEC 60664-1:2007. For simplification, the examples given in this application guide are based on homogeneous field conditions. The breakdown field strength of the solid insulation (E_2) should be specified by the manufacturer of the material.

A precise calculation of the voltage distribution is much more complicated to make and the above formulae can only be considered as an approximation, taking into account homogeneous field distribution. For small distances up to around 0,1 mm, this approximation is rather precise. For rather large distances, it is not appropriate.

4.5.3.3.2 Series connection of clearances and solid insulation by design

The following examples deal with the series connection of clearances and solid insulation as designed within equipment.

4.5.3.3.3 Series connection of clearances and solid insulation by design for d.c. voltage

For d.c. voltage as mentioned before, nearly the whole voltage is applied across the clearance. So, the clearance alone is designed to withstand this voltage. In case of flashover of the clearance, the whole voltage is applied to the solid insulation.

Rule: In order to prevent any deterioration of the solid insulation in this situation, also the solid insulation is also designed to withstand the entire voltage.

4.5.3.3.4 Series connection of clearances and solid insulation by design for a.c. voltage

For a.c. voltage, the voltage distribution is calculated according to the relevant capacitances. In the following example, the dimensions are assumed according to the most likely situation with a rather large clearance and a thin layer of solid insulation in series.

EXAMPLE:

d_1 = 3 mm, d_2 = 0,1 mm

ε_r = 4,5

Application of Equation (6) results in: $C_1 = 0{,}0074\ C_2$

Application of Equation (2) results in: $U_1 = 0{,}993\ U_0$

Application of Equation (3) results in: $U_2 = 0{,}007\ U_0$

The result is that nearly the whole voltage is applied across the clearance. So, the clearance alone needs a dimensioning to withstand this voltage. In case of flashover of the clearance, the whole voltage is applied to the solid insulation.

Rule: In order to prevent any deterioration of the solid insulation in this situation, the solid insulation is also designed to withstand the entire voltage.

4.5.3.4 Series connection of clearances and solid insulation caused by air gaps or air bubbles

The following examples deal with the series connection of clearances and solid insulation as a result of the particular design of the insulation system, e.g. the use of several layers of thin sheet insulating material, and/or as a result of the imperfect manufacturing of the solid insulation, including the interface to the conductive parts. In these cases, rather small air gaps or small air bubbles are connected in series with the solid insulation.

4.5.3.4.1 Series connection of clearances and solid insulation caused by air gaps or air bubbles for d.c. voltage

For d.c. voltage, the relevant impedances are determined by the insulation resistances. As in air the insulation resistance is nearly infinite, the impedance of the air gap is much higher than that of the solid insulator. So nearly the whole d.c. voltage is applied across the clearance. This can result in partial discharges within the clearance, which can deteriorate the neighbouring solid insulation. However, the repetition frequency of these partial discharges is very low, caused by the high recharging time for the voltage across the clearance. So, the potential of deterioration is rather low and the time to failure will be rather long.

Due to the low repetition rate, partial discharge testing is very difficult for d.c. voltage stress.

4.5.3.4.2 Series connection of clearances and solid insulation caused by air gaps or air bubbles for a.c. voltage

For a.c. voltage, the voltage distribution is calculated according to the relevant capacitances. For the following example, the dimensions are assumed according to the most likely situation with a rather small clearance and a comparatively thick layer of solid insulation in series.

The following example gives a more realistic description of the situation than that addressed in the example of 4.5.3.1.

EXAMPLE:

d = 0,1 mm

ε_r = 4,5

E_{2peak} = 45 kV/mm

Case a)

d_1 = 0,01 mm, d_2 = 0,09 mm

E_{1peak} = 33 kV/mm

NOTE 1 Computed, taking the relevant peak value of the a.c. breakdown voltage for the homogeneous field distribution of Table A.1 in IEC 60664-1:2007 for d_1 = 0,01 mm.

Application of Equation (6) results in: $C_1 = 2\ C_2$

Application of Equation (2) results in: $U_1 = 0{,}333\ U_0$

Application of Equation (3) results in: $U_2 = 0{,}666\ U_0$

The breakdown field strength E_1 of the clearance is:

$$E_{1peak} = \frac{U_1}{d_1} = 0{,}333\,\frac{U_{0peak}}{d_1} = 33\,\frac{\text{kV}}{\text{mm}}$$

Thus, the breakdown of the clearance occurs at:

$$U_{0peak} = \frac{E_{1peak}\ d_1}{0{,}333} = 33\,\frac{0{,}01}{0{,}333}\ \text{kV} = 0{,}99\ \text{kV}$$

This is likely to be the partial discharge inception voltage. For a.c. voltage stress, the repetition frequency of the partial discharges is at least as high as the frequency of the voltage. The potential of deterioration is therefore much higher than for d.c. voltage and failure can occur during much shorter periods of time. To avoid breakdown, in no case a peak value of the steady-state voltage greater than 0,99 kV shall occur across this insulation system.

According to the example of 4.5.3.1, a significantly higher performance of the solid insulation with a peak value of the breakdown voltage of 4,5 kV would have been expected.

The conclusion is that every design of an insulation system, including air gaps caused by using several layers of thin sheet insulation material and/or resulting from the imperfect manufacturing of the solid insulation, should be verified that there is no risk of partial discharge.

Case b)

d_1 = 0,05 mm, d_2 = 0,05 mm

E_{1peak} = 11,2 kV/mm

NOTE 2 Computed, taking the relevant peak value of the a.c. breakdown voltage for the homogeneous field distribution of Table A.1 in IEC 60664-1:2007 for d1 = 0,05 mm.

Application of Equation (6) results in: $C_1 = 0{,}222\ C_2$

Application of Equation (2) results in: $U_1 = 0{,}818\ U_0$

Application of Equation (3) results in: $U_2 = 0{,}182\ U_0$

The breakdown field strength E_1 of the clearance is:

$$E_{1peak} = \frac{U_1}{d_1} = 0{,}818\,\frac{U_{0peak}}{d_1} = 11{,}2\,\frac{\text{kV}}{\text{mm}}$$

Thus, the breakdown of the clearance occurs at:

$$U_{0\text{peak}} = \frac{E_{1\text{peak}}\ d_1}{0{,}818} = 11{,}2\ \frac{0{,}05}{0{,}818}\ \text{kV} = 0{,}685\ \text{kV}$$

This is likely to be the partial discharge inception voltage. So, in no case shall a peak value of the steady-state voltage greater than 0,685 kV occur across this insulation system.

NOTE 3 This value of 685 V should be compared with the value of 700 V given in 6.1.3.1 in IEC 60664-1:2007 as a requirement for the partial discharge test.

According to the example in 4.5.3.1, a much higher performance of the solid insulation with a peak value of the breakdown voltage of 4,5 kV would have been expected. This shows that, in particular rather large air gaps lead to a very poor performance of such insulation.

The conclusion is that every design of an insulation system, including air gaps caused by using several layers of thin sheet insulation material and/or resulting from the imperfect manufacturing of the solid insulation, should be verified so that there is no risk of partial discharge.

4.6 Practical use of the IEC 60664 series for designing functional insulation

4.6.1 General

The minimum clearances, minimum creepage distances and minimum requirements for solid insulation, which are specified in the IEC 60664 series, are also applicable for functional insulation. For functional reasons, additional requirements may be applicable for instance with respect to the minimum insulation resistance (see Annex A of IEC 60664-5:2007).

The withstand voltage requirements for functional insulation, however, can be different from those required for basic insulation.

4.6.2 Dimensioning and testing of functional isolation compared to basic insulation

The principles for dimensioning of functional insulation are given in 4.1.

For a clearance of functional insulation, the required withstand voltage is the maximum impulse voltage (see Table F.2 of IEC 60664-1:2007) or steady-state voltage (with reference to Table F.7 of IEC 60664-1:2007) or recurring peak voltage (see Table F.7 of IEC 60664-1:2007) expected to occur across it, under rated conditions of the equipment, and in particular the rated voltage and rated impulse voltage.

Creepage distances of functional insulation is dimensioned as specified in Table F.4 of IEC 60664-1:2007 corresponding to the working voltage across the creepage distance considered.

If IEC 60664-5 is used, creepage distances of functional insulation is dimensioned according to Table 4 of IEC 60664-5:2007 and the working voltage with respect to tracking, and Table 5 of IEC 60664-5:2007 with respect to the highest peak voltage in order to avoid flashover, the higher value being used.

When the working voltage is used for dimensioning, it is permitted to interpolate values for intermediate voltages. In such a case, linear interpolation is used and values are rounded to the same number of digits as those taken from the Tables.

In equipment which is under voltage stress for only a short time, creepage distances of functional insulation may have a reduced dimensioning, for instance one voltage step lower than specified in Table F.4 of IEC 60664-1:2007.

Testing of functional insulation follows the same procedures as specified in 6.1 of IEC 60664-1:2007. The test voltages, however, can be different from those required for basic insulation.

4.7 Practical use of the IEC 60664 series for dimensioning with respect to the influence of the frequency of the voltage

4.7.1 General influence of the frequency on withstand characteristics

Within the scope of IEC 60664-1, it is considered that the influence of the frequency of the voltage is covered by the minimum values given for frequencies up to and including 30 kHz. For higher frequencies, a reduction of the withstand capability of any type of insulation needs to be expected and taken into account for dimensioning.

For frequencies greater than 30 kHz and up to 10 MHz, IEC 60664-4 shall be applied together with IEC 60664-1 or IEC 60664-5.

4.7.2 Influence of the frequency on the withstand characteristics of clearances

The withstand voltage capability within the scope of IEC 60664-4 will only be influenced by the frequency for periodic voltages. For transient overvoltages, dimensioning according to IEC 60664-1 or IEC 60664-5 is sufficient.

For frequencies exceeding 30 kHz within the scope of IEC 60664-4, the withstand voltage capability of clearances with homogenous and approximately homogenous field distribution can be reduced by up to 20 %. For frequencies exceeding 30 kHz, an approximately homogeneous field is considered to exist when the radius of curvature of the conductive parts is equal to or greater than 20 % of the clearance.

Dimensioning for approximately homogeneous field distribution is carried out, taking into account 125 % of the required withstand voltage of the clearance according to the case A values in Table F.7 of IEC 60664-1:2007 or Table 3 of IEC 60664-5:2007. No withstand voltage test is required.

Dimensioning smaller than for approximately homogeneous field distribution (case A values in Table F.7 of IEC 60664-1:2007 or Table 3 of IEC 60664-5:2007) requires a withstand voltage test according to 6.1.2 of IEC 60664-1:2007 or IEC 60664-5. However, the minimum clearance cannot be smaller than that which is obtained by taking into account 125 % of the required withstand voltage of the clearance according to the case B values in Table F.7 of IEC 60664-1:2007 or Table 3 of IEC 60664-5:2007.

For frequencies exceeding 30 kHz, an inhomogeneous field is considered to exist when the radius of curvature of the conductive parts is less than 20 % of the clearance. For inhomogeneous field distribution, the reduction of the withstand voltage capability of clearances can be much higher. Dimensioning for inhomogeneous field distribution is carried out for the required withstand voltage of the clearance according to the values in Table 1 of IEC 60664-4:2005. No withstand voltage test is required.

The dimensioning for inhomogeneous field and high voltage stress, >1 kV condition, leads to impractical distances. It is therefore preferable to choose a design improving the field distribution (approximately homogeneous field distribution).

4.7.3 Influence of frequency on the withstand characteristics of creepage distances

For frequencies of voltage greater than 30 kHz, in addition to tracking, thermal effects need to be taken into account with respect to the withstand capability of creepage distances. Dimensioning is performed both for the required r.m.s. withstand voltage of the creepage distance according to the values in Table F.4 of IEC 60664-1:2007 and for the required peak withstand voltage according to the values in Table 2 of IEC 60664-4:2005. This peak withstand voltage is the highest value of any periodic peak of the voltage across the creepage distance. The greater of the distances is applicable.

In Table 2 of IEC 60664-4:2005, interpolation for the frequencies is allowed. The values in Table 2 of IEC 60664-4:2005 are applicable for pollution degree 1. The creepage distances for pollution degree 2 and 3 are found by using a multiplication factor of 1,2 for pollution degree 2 respectively 1,4 for pollution degree 3.

The dimensioning according to Table 2 of IEC 60664-4:2005 is applicable for all insulating materials which can be deteriorated by thermal effects. This includes typical base materials for printed wiring boards made from epoxy resin. For insulating materials which cannot be deteriorated by thermal effects and where no tracking needs to be expected, dimensioning according to the clearance requirements, as described in 4.7.2, is sufficient.

4.7.4 Influence of frequency on the withstand characteristics of solid insulation

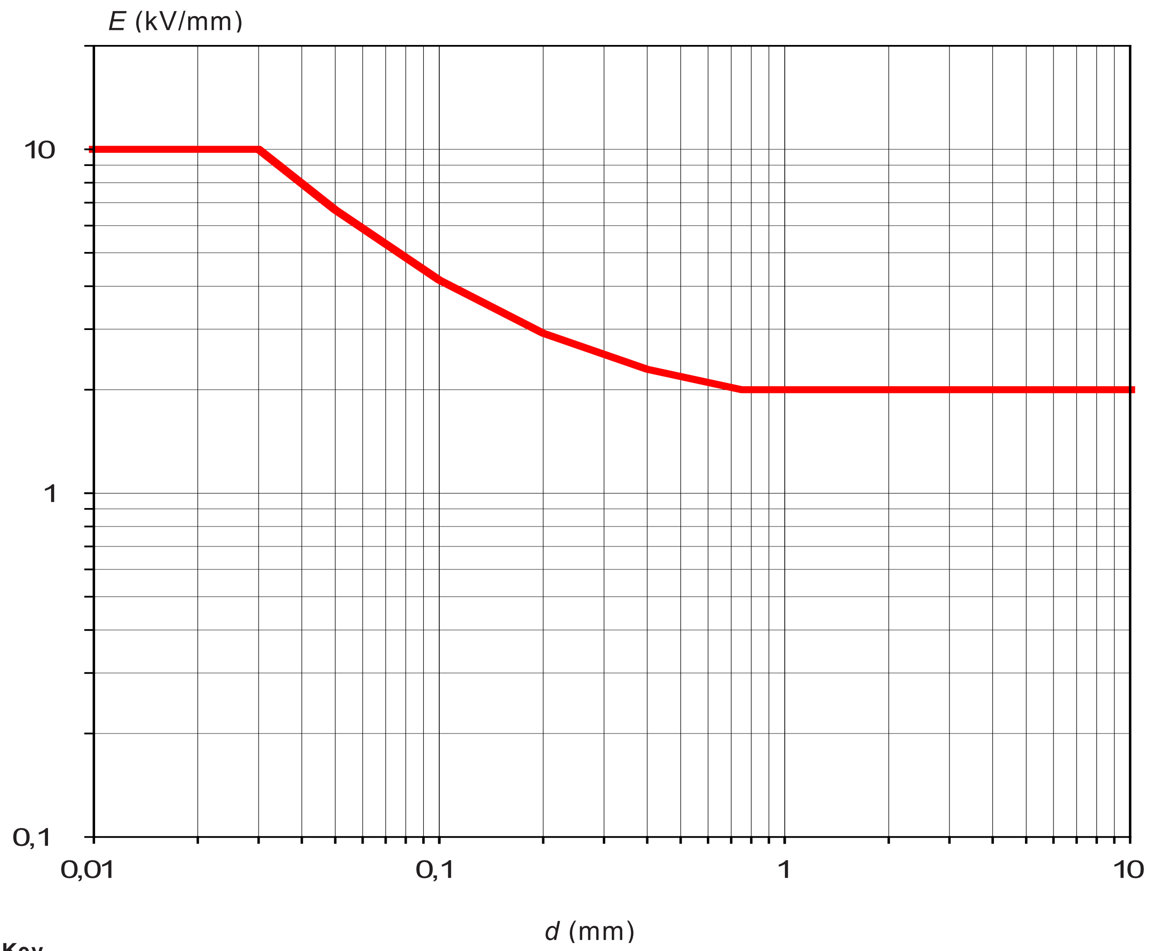
For frequencies greater than 30 kHz, the reduced withstand capability of solid insulation also needs to be taken into account for dimensioning. This reduction is caused by two different effects. The first effect is the increased heating of the solid insulating materials caused by dielectric losses. This is a particular problem for materials with high loss factor as for instance laminated paper. The second effect is the accelerated deterioration caused by the high frequency of partial discharges. Therefore, no partial discharges are permitted in normal service conditions. In addition, a reduction of the partial discharge inception voltage with the increase of the frequency needs to be taken into account.

For these reasons, precise dimensioning of solid insulation requires testing with high-frequency voltage. However, such tests are difficult and require special equipment. Therefore, in IEC 60664-4 also a simplified method of dimensioning of solid insulation based on distance requirements is proposed.

This simplified method of dimensioning can be used instead of high-frequency testing according to Clause 7 of IEC 60664-4:2005. It applies for a maximum frequency of the voltage of 10 MHz, if the field strength is approximately uniform, not exceeding the specified values according to Equation (7) or Figure 4 respectively and if no voids or air gaps are present in between the solid insulation. In this context, the electric field is considered to be approximately uniform if the deviations from the average value of the field strength are less than ±20 %.

For thick layers of solid insulation of $d_1 \geq 0{,}75$ mm, the peak value of the field strength E needs to be equal or less than 2 kV/mm. For thin layers of solid insulation of $d_2 \leq 30$ μm, the peak value of the field strength needs to be equal to or less than 10 kV/mm. For $d_1 > d > d_2$, Equation (7) is used for interpolation for a certain thickness d (see also Figure 4):

$$E = \left(\frac{0{,}25}{d} + 1{,}667 \right) \frac{\text{kV}}{\text{mm}} \qquad (7)$$



Key

E field strength

d thickness

Figure 4 – Permissible field strength for dimensioning of solid insulation according to Equation (7)

The use of the field strength for dimensioning of solid insulation requires an approximately uniform field distribution with no voids or air gaps in between. If the field strength cannot be calculated (because the field is not uniform), or if the peak value is higher than given from Equation (7) or Figure 4, respectively, or if the presence of voids or air gaps cannot be excluded or for frequencies higher than 10 MHz, then a withstand test or a partial discharge test with high-frequency voltage is required. The voltage withstand test applies to short-term stresses; the partial discharge test applies to long term stresses according to 5.3.3.2.3 of IEC 60664-1:2007.

In IEC 60664-3, two types of protection are used in order to achieve a smaller dimensioning. Protection of type 2 is considered to be similar to solid insulation. As IEC 60664-3 is based on IEC 60664-1, the scope with respect to the frequency is limited to 30 kHz. Therefore, if type 2 protection is intended to be used for frequencies greater than 30 kHz, the additional requirements of IEC 60664-4 for solid insulation are applicable.

5 Four examples showing appropriate dimensioning of insulation within equipment

5.1 General

Four examples for dimensioning of clearances are shown in Figures 5a to 5d, each figure illustrating the most important factors influencing the dimensioning of clearances. These are the rated voltages, the steady-state withstand voltages, the impulse withstand voltages, the overvoltage category, the pollution degree and the type of insulation.

Some product standards do not specify the clearance values for circuits supplied by SELV. Figures 5a to 5d show that the clearance is based on the overvoltage category determined from the mains voltage and it is one impulse withstand voltage level lower after the transformer. See 4.2 for further information.

There are four overvoltage categories given in 4.3.3.2 in IEC 60664-1:2007. The overvoltage category is synonymous with the impulse withstand category used in IEC 60364-4-44. The rated impulse voltage of the equipment is selected corresponding to the overvoltage category specified and the rated voltage of the equipment. See Tables F.1 and F.2 of IEC 60664-1:2007.

There are four pollution degrees in the micro-environment given in 4.6.2 of IEC 60664-1:2007.

In the following examples, overvoltage category III (Figures 5b and 5c) and overvoltage category II (Figure 5d) and pollution degree 2 are used to illustrate the dimensioning of clearances according to Tables F.2 and F.7 in IEC 60664-1:2007.

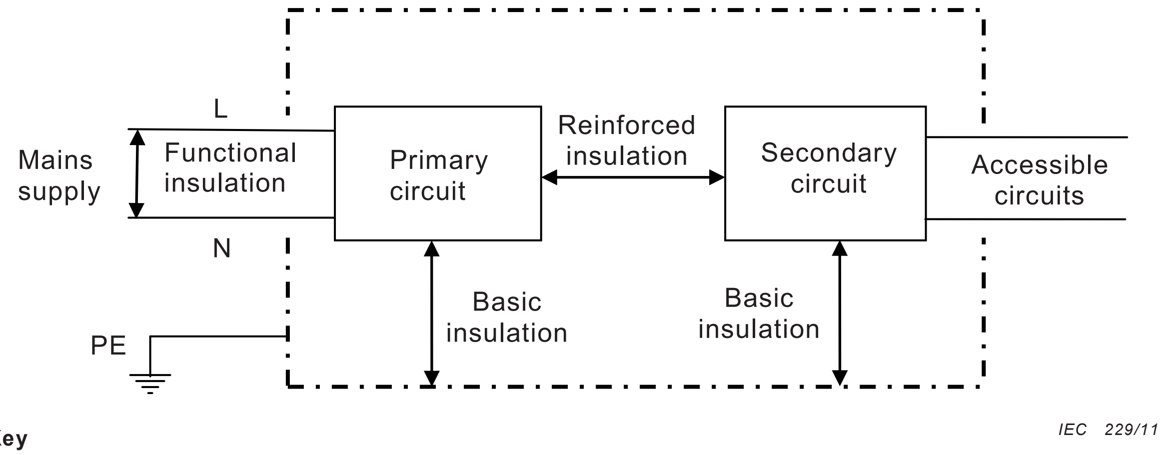
In Figure 5b, the following applies for class I equipment:

– For non-earthed circuits not directly connected to the mains (secondary part of the transformer), the basic insulation is dimensioned for an impulse withstand voltage identical to the circuit directly connected to the mains. (For reduction of the impulse withstand voltage further details regarding the transformer are given in 4.2.)

In Figure 5c and 5d, the following applies for class II equipment:

– For non-earthed circuits not directly connected to the mains (secondary part of the transformer), the basic insulation is dimensioned for an impulse withstand voltage reduced by one step, compared to the circuit directly connected to the mains. (For reduction of the impulse withstand voltage further details regarding the transformer are given in 4.2.)

Information for basic protection and basic insulation is given in IEC 61140.



Key

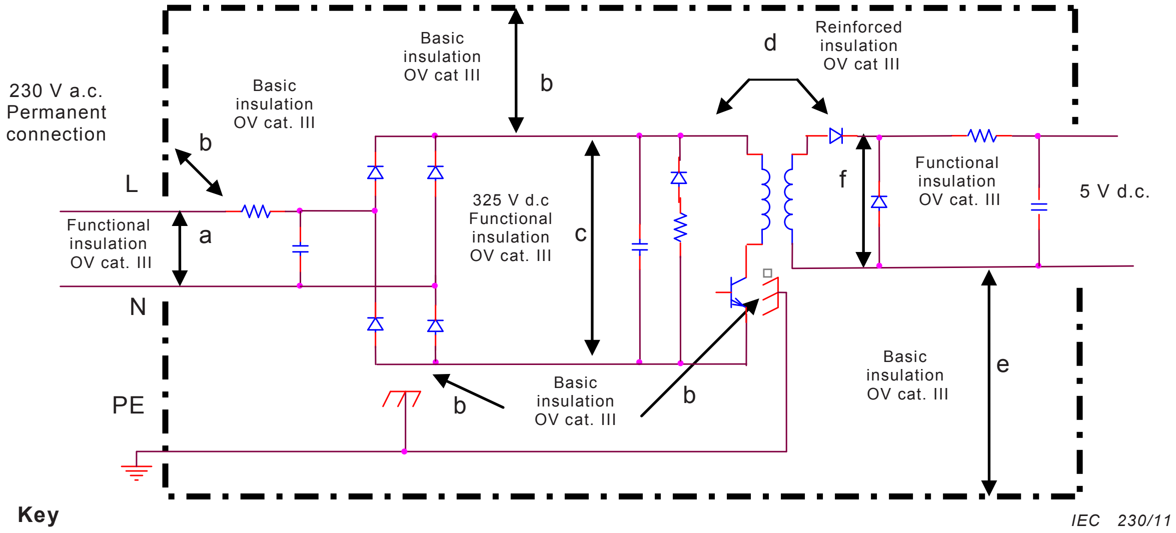
L line conductor

N neutral conductor

PE protective conductor

Figure 5a – Example 1 – Simple illustration of insulation system containing functional, basic and reinforced/double insulation for a class I equipment

5.2 Examples for the dimensioning of clearances for class I equipment according to IEC 60664-1



Key

▬ ▪ ▬ **Protection against direct contact by means of conductive enclosure connected to protective earth (PE)**

Figure 5b – Example 2 – Dimensioning of clearances for class I equipment, based on overvoltage category III

Table 2 – Example 2 – Dimensioning of clearances according to Table F.2 of IEC 60664-1:2007 (pollution degree 2) (see example 2 of Figure 5b)

Example 2	Insulation type[a]	Impulse withstand voltage V	Clearance mm
a	Functional	4 000	3,0
b	Basic	4 000	3,0
c	Functional	4 000	3,0
d	Reinforced	6 000	5,5
e	Basic	4 000	3,0
f	Functional	800[b]	0,2[b]

[a] Applicable to TN system.

[b] According to a voltage line to neutral of 50 V.

For circuits protected against overvoltage by means of a surge protective device, the clearance for functional insulation (a and c) may be designed to a smaller value than that specified for case A in Table F.2 of IEC 60664-1:2007.

In this case, however, an impulse withstand test with the required impulse withstand voltage is necessary. The impulse test generator shall have a low impedance of 2 Ω.

The clearance for reinforced insulation is based on Table F.2, case A of IEC 60664-1:2007 choosing one impulse voltage level higher (preferred values).

Table 3 – Example 2 – Dimensioning of clearances according to Tables F.2 and F.7a of IEC 60664-1:2007, temporary overvoltages according to 5.3.3.2.3 of IEC 60664-1:2007 (U_n+1 200 V) (see example 2 of Figure 5b)

Example 2	Insulation type	Impulse withstand voltage V	Temporary overvoltage (peak)/working voltage (peak)[b] V[d]	Clearance (Table F.2 of IEC 60664-1:2007) (Impulse withstand voltage) mm	Clearance (Table F.7 of IEC 60664-1:2007) (Temporary overvoltage/ working voltage) mm[c]	Clearance[a] mm
a	Functional	4 000	NA / 325	3,0	NA / 0,01	3,0
b	Basic	4 000	2 022 / 325	3,0	1,3 / 0,01	3,0
c	Functional	4 000	NA / 325	3,0	NA / 0,01	3,0
d	Reinforced	6 000	4 044 / 650[f]	5,5	3,9 / 0,078[f]	5,5
e	Basic	4 000	NA / 5	3,0	NA / 0,001	3,0
f	Functional	800[e]	NA / 5	0,2	NA / 0,001	0,2

[a] The dimensioning according to Table F.7 of IEC 60664-1:2007 is compared with Table F.2 of IEC 60664-1:2007, taking into account the pollution degree. The larger clearance is selected.

[b] When the insulation system is evaluated with respect to the working voltage, recurring peak voltages are taken into consideration. In this example, recurring peak voltages are considered to be negligible. Only the peak value of the sinusoidal mains voltage is considered.

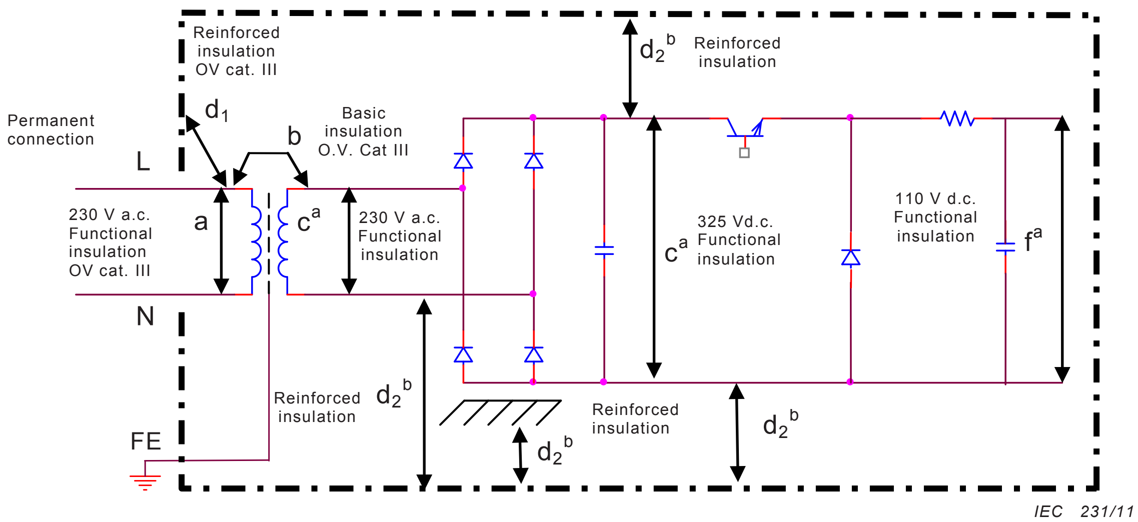
[c] The dimensioning is based on the peak value of the temporary overvoltage.

[d] Peak voltage of temporary overvoltage is used for dimensioning.

[e] According to a voltage line to neutral of 50 V.

[f] It should be noted that while clearance for reinforced insulation is dimensioned with respect to 160 % of the temporary overvoltage for basic and supplementary insulation, the test voltage for verification of the clearance of the reinforced insulation is twice the voltage of the test voltage for verification of basic and supplementary insulation.

5.3 Examples for the dimensioning of clearances for class II equipment according to IEC 60664-1



Key

▬ ▪ Protection against direct contact by means of non conductive enclosure (solid insulation) or clearance providing reinforced insulation.

FE functional earthing conductor

NOTE The transformer follows 4.2.

Figure 5c – Example 3 – Dimensioning of clearances (class II equipment)

Table 4 – Example 3 – Dimensioning of clearances according to Table F.2 of IEC 60664-1:2007 (pollution degree 2) (see example 3 of Figure 5c)

Example 3	Insulation type	Impulse withstand voltage V	Clearance mm
a	Functional	4 000	3,0
b	Basic	4 000	3,0
c[a]	Functional	2 500	1,5
d_1	Reinforced	6 000	5,5
d_2[b]	Reinforced	4 000	3,0
f[a]	Functional	2 500	1,5

[a] The clearance is based on the overvoltage category determined from the mains voltage (230 V a.c. OV cat. III) and it is one impulse withstand voltage level lower after the transformer. The actual d.c. level after rectification does not influence the impulse withstand voltage used for the design of the insulation system.

[b] The clearance for reinforced insulation is based on the overvoltage category determined from the mains voltage (230 V a.c. OV cat. III) and it is one impulse withstand voltage level lower after the transformer. See 4.2 for further information.

Table 5 – Example 3 – Dimensioning of clearances according to Tables F.2 and F.7a of IEC 60664-1:2007, temporary overvoltages according to 5.3.3.2.3 of IEC 60664-1:2007 (U_n+1200 V) (see example 3 of Figure 5c)

Example 3	Insulation type	Impulse withstand voltage V	Temporary overvoltage (peak)/working voltage (peak)[b] V	Clearance (Table F.2 of IEC 60664-1:2007) (Impulse withstand voltage) mm	Clearance (Table F.7a of IEC 60664-1:2007) (Temporary overvoltage/ working voltage) mm[c]	Clearance[a] mm
a	Functional	4 000	NA/ 325	3,0	NA/0,01	3,0
b	Basis	4 000	2 022/325	3,0	1,3/0,01	3,0
c	Functional	2 500	NA/325	1,5	NA/0,01	1,5
d_1	Reinforced	6 000	4 044/650[d]	5,5	3,9/0,078[d]	5,5
d_2	Reinforced	4 000	4 044/650[d]	3,0	3,9/0,078[d]	3,9
f	Functional	2 500	NA/110	1,5	NA/0,004	1,5

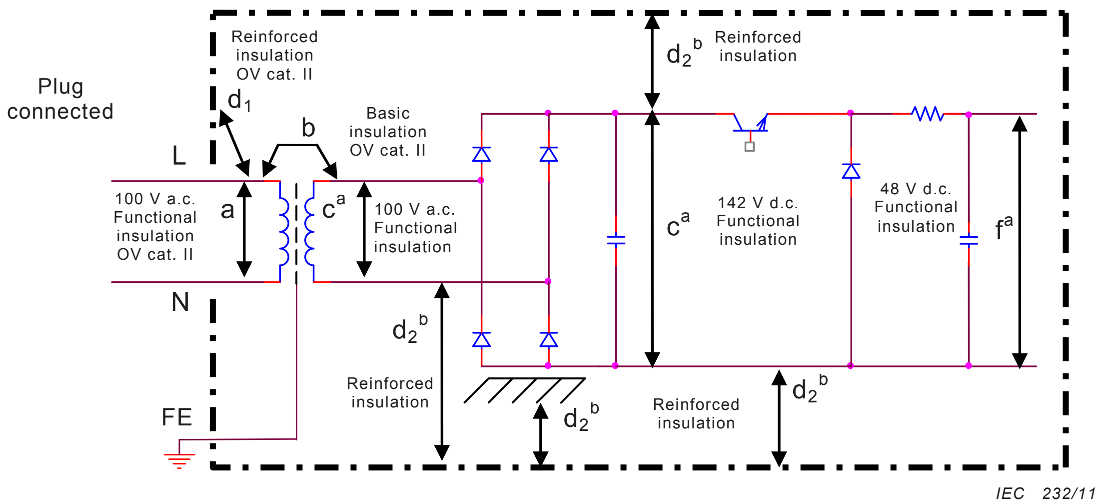
[a] The dimensioning according to Table F.7 of IEC 60664-1:2007 is compared with Table F.2 of IEC 60664-1:2007, taking into account the pollution degree. The larger clearance is selected.

[b] When the insulation system is evaluated with respect to the working voltage, recurring peak voltages are taken into consideration. In this example, recurring peak voltages are considered to be negligible. Only the peak value of the sinusoidal mains voltage is considered.

[c] The dimensioning is based on the peak value of the temporary overvoltage.

[d] It should be noted that while clearance for reinforced insulation is dimensioned with respect to 160 % of the temporary overvoltage for basic and supplementary insulation, the test voltage for verification of the clearance of the reinforced insulation is twice the voltage of the test voltage for verification of basic and supplementary insulation.

5.4 Examples for the dimensioning of clearances for class II equipment according to IEC 60664-5



Key

▬ ▪ ▬ Protection against direct contact by means of non conductive enclosure (solid insulation) or clearance providing reinforced insulation.

NOTE The transformer follows 4.2.

Figure 5d – Example 4 – Dimensioning of clearances (class II equipment)

Table 6 – Example 4 – Dimensioning of clearances according to Table 2 of IEC 60664-5:2007 (see example 4 on Figure 5d)

Example 4	Insulation type	Impulse withstand voltage[c] V	Clearance[c] mm
a	Functional	800 (1 500)	0,1 (0.5)
b	Basic	800 (1 500)	0,1 (0,5)
c[a]	Functional	500 (800)	0,04 (0,1)
d_1	Reinforced	1 500 (2 500)	0,5 (1,5)
d_2[b]	Reinforced	800 (1 500)	0,1 (0,5)
f[a]	Functional	500 (800)	0,04 (0,1)

[a] The clearance is based on the overvoltage category determined from the mains voltage (100 V a.c. OV cat. II) and it is one impulse withstand voltage kV level lower after the transformer. The actual d.c. level after rectification does not influence the impulse withstand voltage used for the design of the insulation system.

[b] The clearance for reinforced insulation is based on the overvoltage category determined from the mains voltage (100 V a.c. OV cat. II) and it is one impulse withstand voltage kV level lower after the transformer. See 4.2 for further information.

[c] The values in parenthesis are used for Japan. See footnote 5) of Table F.1 in IEC 60664-1:2007.

Table 7 – Example 4 – Dimensioning of clearances according to Tables 2 and 3 of IEC 60664-5:2007, temporary overvoltages according to 5.3.3.2.3 of IEC 60664-1:2007 (U_n+1 200 V) (see example 4 on Figure 5d)

Example 4	Insulation type	Impulse withstand voltage[d] V	Temporary overvoltage (peak)/ working voltage (peak)[b] V	Clearance[d] (Table 2 of IEC 60664-5: 2007) (impulse withstand voltage) mm	Clearance (Table 3 of IEC 60664-5:2007) (temporary overvoltage/ working voltage) mm	Clearance[a, d] mm
a	Functional	800 (1 500)	NA/141	0,1 (0,5)	NA/0,005	0,1 (0,5)
b	Basic	800 (1 500)	1 838/141	0,1 (0,5)	1,1[c]/0,005	1,1
c	Functional	500 (800)	NA/141	0,04 (0,1)	NA/0,005	0,04 (0,1)
d_1	Reinforced	1 500 (2 500)	3 676/282[e]	0,5 (1,5)	3,4[c]/0,01[e]	3,4
d_2	Reinforced	800 (1 500)	3 676/282[e]	0,1 (0,5)	3,4[c]/0,01[e]	3,4
f	Functional	500 (800)	NA/48	0,04 (0,1)	NA/0,01	0,04 (0,1)

[a] The dimensioning according to Table 2 of IEC 60664-5:2007 is compared with Table 3 in the same standard. The larger clearance is selected.

[b] When the insulation system is evaluated with respect to the working voltage, recurring peak voltages are taken into consideration. In this example, recurring peak voltages are considered to be negligible. Only the peak value of the sinusoidal mains voltage is considered.

[c] Determined by using interpolation in Table F.7a of IEC 60664-1:2007 (case A).

[d] The values in parenthesis are used for Japan. See footnote 5) of Table F.1 in IEC 60664-1:2007.

[e] It should be noted that while clearance for reinforced insulation is dimensioned with respect to 160 % of the temporary overvoltage for basic and supplementary insulation, the test voltage for verification of the clearance of the reinforced insulation is twice the voltage of the test voltage for verification of basic and supplementary insulation.

6 Practical application of the IEC 60664 series with regards to particular questions

6.1 General

Clause 4 of this application guide provides information about the dimensioning of clearance, creepage and solid insulation for functional, basic, supplementary, double and reinforced insulation based on the working voltage including recurring peak, temporary overvoltage and transient overvoltage across the considered insulation. This clause provides some typical examples on how to test the clearance and solid insulation in some typical applications. These are only examples and are not intended to cover all applications.

This clause does not provide information about testing creepage distances as this in general is not possible. The testing of creepage is more likely to be an evaluation of the effective distance and of the material which provides the insulation across the insulation under consideration.

6.2 Testing complete equipment in case of components bridging the basic insulation

The equipment is first prepared in order to disconnect any component bridging the basic insulation such as surge protective devices in accordance with 6.1.4.1 of IEC 60664-1:2007. The test is then applied in accordance with 6.1.4 of IEC 60664-1:2007 within the condition or limitation given in the product standard.

It is then necessary to ensure that components, bridging the basic insulation and having been disconnected during the impulse voltage test for testing the basic insulation, do not impair the behaviour or the safety of the basic insulation of the equipment during normal use.

The components having been disconnected are therefore connected again, and the equipment is tested in accordance with the following procedure, introducing an a.c. test having the purpose to check that components bridging the basic insulation do not reduce safety, with respect to short-term temporary overvoltages.

The test voltage has a frequency of 50/60 Hz. For basic insulation, the r.m.s. value of the test voltage is equal to the short-term temporary overvoltage, which is 1 200 V + U_n. U_n is the nominal voltage value between line and neutral. For the test duration, see 6.1.3.4.1 of IEC 60664-1:2007.

NOTE 1 As an example, for an equipment having a rated voltage of U_n = 250 V, the value of the a.c. test voltage for basic insulation is 1 200 V + 250 V, thus the r.m.s. test voltage is 1 450 V.

NOTE 2 If it is not possible to perform the a.c. test, a d.c. test can be considered with a voltage value equal to or higher than the a.c. peak voltage.

NOTE 3 The short-circuit output current of the generator is not less than 200 mA. For test voltages exceeding 3 kV, it is sufficient that the rated power of the test equipment is equal to or greater than 600 VA. The tripping current of the generator needs adjustment to a tripping current of 100 mA or for test voltages above 6 kV to the highest possible value..

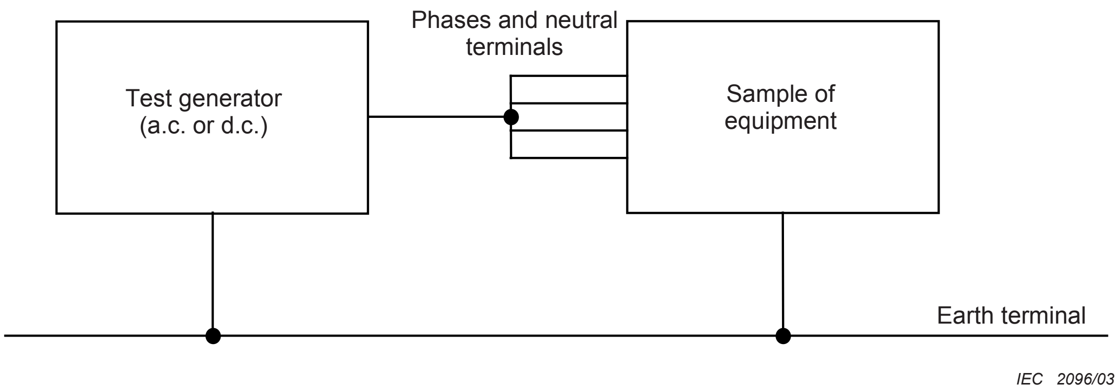


Figure 6 – Arrangement for a.c. (or d.c.) voltage test

The voltage is successively applied for the time given in 6.1.3.4.1 in IEC 60664-1:2007.

Acceptance criteria: the equipment is visually inspected; no component bridging the basic insulation shall show any visible alteration. The equipment is connected to the mains in accordance with the manufacturer’s instructions. The equipment shall work in accordance to its purpose.

NOTE 4 It is permitted to replace a fuse or a similar protective means before connecting the equipment to the mains. If a fuse protecting a surge arrester has blown, it is permitted to replace the surge arrester, too.

6.3 Testing complete equipment in case of components bridging the functional insulation

6.3.1 General

If the equipment incorporates components bridging the functional insulation between live parts connected to mains, the impulse test is applied as described in 6.3.2 and 6.3.3.

6.3.2 Verification of clearances and creepage distances

The correct dimensioning of the insulation distances is first tested without components bridging the insulation. The equipment is prepared in order to disconnect any component bridging the insulation between live parts such as surge protective devices in accordance with

6.1.4.1 of IEC 60664-1:2007. The test is then performed in accordance with 6.1.4 of IEC 60664-1:2007 within the condition or limitation given in the product standard.

NOTE The short-circuit output current of the generator is not less than 200 mA. For test voltages exceeding 3 kV, it is sufficient that the rated power of the test equipment is equal to or greater than 600 VA. The tripping current of the generator needs adjustment to a tripping current of 100 mA or for test voltages above 6 kV to the highest possible value.

6.3.3 Verification of components bridging the insulation

To check the safe behaviour of components having been disconnected during the test in 6.3.2, the components are connected again. Then, the equipment is tested a second time within the same condition.

NOTE 1 If the components bridging the functional insulation are used for EMC purposes only (e.g. an SPD), it is allowed to use a generator having an internal impedance up to 500 Ω maximum.

Acceptance criteria: the equipment is visually inspected; no component bridging the functional insulation should show a visible alteration. Then, the equipment is connected to the mains in accordance with the manufacturer's instructions. The equipment shall work in accordance to its purpose.

NOTE 2 If the components bridging the functional insulation are used for EMC purposes only e.g. an SPD, it is permitted to replace a fuse or a similar protective mean before connecting the equipment to the mains. If a fuse protecting components disconnected during the test in 6.3.2 has blown, it is permitted to replace the components, too.

6.4 Dimensioning of insulation distances for parts of equipment which can have isolation capability

6.4.1 General

General principles for the dimensioning of clearances for low-voltage equipment are given in 4.1.

The dimensioning of clearances across the open contacts or clearances between parts in movement within an equipment, e.g. the poles of a switch, should follow the same requirements than those required for the basic insulation.

NOTE For example, see 7.2.3.1 of IEC 60947-1:2007, 7.1.2 of IEC 60669-1:1998, or 4.5.1 and 4.5.2 of IEC 62019:1999.

6.4.2 Dimensioning for device associated with an equipment declared suitable for isolation

If the device is associated or added as an auxiliary part to an equipment declared suitable for isolation, the minimum requirement for clearances between parts in movement of this auxiliary part follows the minimum requirements for the basic insulation (see 5.1.7 of IEC 60664-1:2007 and 8.3.2 of IEC 61140:2001). The technical committees consider the minimum requirements for circuit dedicated to remote indication.

6.4.3 Dimensioning for device associated with an equipment not declared suitable for isolation

If the device is associated or added as an auxiliary part to an equipment not declared suitable for isolation, or if the device is an independent equipment not declared suitable for isolation, the technical committees can introduce requirements lower than those required for the basic insulation. However, the product should be marked accordingly.

NOTE For example, see IEC 60669-1 or IEC 62019 ask for marking "m" on the device.

6.5 Testing with respect to high-frequency voltage stress

In principle, 4.7.1 to 4.7.4 of this application guide are also applicable to the frequencies of the voltage as specified in IEC 60664-4.

However, it has to be taken into account that the values of the breakdown field strength both for clearances and for solid insulation are decreased by the influence of frequency.

With respect to 4.7.2 of this application guide, it has to be taken into account that the frequency of the test voltage is the same as the frequency of the applied voltage. The minimum test duration is 60 s, as specified for the power-frequency a.c. voltage test. Longer durations can be required, in particular for materials with high dielectric losses, where excessive heating caused by the dielectric losses is decisive for failure.

For testing at high-frequency voltage, the capacitive loading caused by the test specimen is a very important factor. The test equipment used shall allow a capacitive loading of at least 100 pF with negligible voltage drop at the output and negligible influence on the frequency. In case of larger assemblies or complete equipment, it may be necessary to perform the test only on critical components. In such cases, a test on the complete equipment is made using the power-frequency voltage.

6.6 Practical information in case of substitution an impulse withstand test by an AC or DC test

6.6.1 General

The purpose of the impulse withstand voltage test is to verify that clearances will withstand specified transient overvoltages. The impulse withstand test is carried out with a voltage having a 1,2/50 µs waveform with the values specified in Table F.5 of IEC 60664-1:2007.

Due to the scatter of the test results of any impulse voltage test, the test is conducted for a minimum of three impulses of each polarity with an interval of at least 1 s between pulses.

Technical committees may specify an a.c. or d.c. voltage test for particular equipment as an alternative method to the impulse voltage test.

NOTE Technical committees should be aware that while tests with a.c. and d.c. voltages of the same peak value as the impulse test voltage specified in Table F.5 of IEC 60664-1:2007 verify the withstand capability of clearances, they increase the stress for solid insulation because the voltage is applied for a longer duration. They can overload and damage certain solid insulations. Technical committees should therefore consider this when specifying tests with a.c. or d.c. voltages as an alternative to the impulse voltage test given in 6.1.2.2.1 of IEC 60664-1:2007.

6.6.2 Characteristics of the a.c. voltage substituted to an impulse withstand test for dielectric test

The characteristics are as follows:

– the waveshape of the sinusoidal power-frequency test voltage is substantially sinusoidal. This requirement is fulfilled if the ratio between the peak value and the r.m.s. value is $\sqrt{2}$ ± 3 %;

– the peak value is equal to the impulse test voltage of Table F.5 of IEC 60664-1:2007 and applied for three cycles of the a.c. test voltage.

NOTE It is not possible to reduce the peak voltage value of the a.c. voltage test if the test duration is longer than three cycles.

6.6.3 Characteristics of the d.c. voltage substituted to an impulse withstand test for dielectric test

The characteristics are as follows:

– the d.c. test voltage is substantially free of ripple. This requirement is fulfilled if the ratio between the peak values of the voltage and the average value is 1,0 ± 3 %;

– the average value of the d.c. test voltage is equal to the impulse test voltage of Table F.5 of IEC 60664-1:2007 and applied three times for 10 ms in each polarity.

7 Examples of a dimensioning worksheet (based on case A as described in IEC 60664-1:2007)

7.1 Use of IEC 60664-1:2007, for circuits in equipment either directly or not directly connected to the mains supply

This example is based on the assumption that the most stringent dimensioning requirements come from the impulse withstand voltage.

Table 8 – Relationship between influencing parameters and normative references in IEC 60664-1

Influencing parameters	Basis of selection	IEC 60664-1:2007 reference	Value in table
Clearance			
Voltage or rated insulation voltage	Overvoltage category of equipment	Table F.1 (see NOTE)	Table F.2
Creepage distance			
Voltage	Rated voltage or rated insulation voltage	Tables F.3a and F.3b	Table F.4
Pollution	Pollution degree (micro-environment)	4.6.2	Table F.4
Insulating material	Comparative tracking index	4.8.1.3	Table F.4
NOTE If the circuit is not directly connected to the mains, the impulse withstand voltage can be provided by the technical committee or, if not, it should be assessed by the manufacturer. Technical committees should take into account 4.2.			

The following procedure shall be followed:

Step 1: Select overvoltage category.

Step 2: Select impulse voltage (Table F.1).

Step 3: Establish minimum clearance (cl) value (Table F.2) and apply an altitude correction factor (Table A.2) if the equipment with the clearance is used above 2 000 m.

Step 4: Select rated voltage for creepage distance (Tables F.3a and F.3b).

Step 5: Establish pollution degree and comparative tracking index (CTI) from 4.8.1 of IEC 60664-1:2007.

Step 6: Establish minimum creepage distance (cr) value (Table F.4).

Step 7: Where cr <cl:

– if pollution degree is 3, spacing on insulating material meets cl value; see 5.2.2.6 in IEC 60664-1:2007;

– if pollution degree is either 1 or 2, spacing on insulating material may be cr value if the spacing withstands the impulse withstand voltage used to verify the clearance.

7.2 Use of IEC 60664-5:2007, for circuits in equipment either directly or not directly connected to the mains supply

This example is based on the assumption that the most stringent dimensioning requirements come from the impulse withstand voltage.

Table 9 – Relationship between influencing parameters and normative references in IEC 60664-1 or IEC 60664-5

Influencing parameters	Basis of selection	IEC 60664-1:2007 or IEC 60664-5:2007 reference	IEC 60664-5:2007 Value in table
Clearance			
Voltage or rated insulation voltage	Overvoltage category of equipment	Table F.1 of IEC 60664-1 (see NOTE)	Table 2
Creepage distance			
Dimensioning with regard to tracking			
Voltage	Rated voltage or rated insulation voltage	Tables F.3a and F.3b of IEC 60664-1	Table 4
Pollution	Pollution degree (micro-environment)	4.6.2 of IEC 60664-1	Table 4
Insulating material	Comparative tracking index	4.8.2.3 of IEC 60664-5	Table 4
Dimensioning with regard to flashover			
Maximum peak voltage	Assessed by the manufacturer (Transient overvoltage or highest peak voltage which can occur in the circuit)		Table 5
Micro-environment	Humidity level For information see Table 1 in IEC 60664-5	4.6.4 of IEC 60664-5	Table 5
Insulating material	WAG (Water adsorption group)	4.8.6 of IEC 60664-5	Table 5
NOTE If the circuit is not directly connected to the mains, the impulse withstand voltage can be provided by the technical committee or if not, it should be assessed by the manufacturer. Technical committees should take into account 4.2.			

The following procedure shall be followed:

Step 1: Select overvoltage category.

Step 2: Select impulse voltage (Table F.1 in IEC 60664-1:2007).

Step 3: Establish minimum clearance (cl) value (Table 2 in IEC 60664-5:2007) and apply an altitude correction factor (Table A.2 in IEC 60664-1:2007) if the equipment with the clearance is used above 2 000 m.

Dimensioning the creepage distance with regards to tracking:

Step 4: Select rated voltage for creepage distance (Tables F.3a and F.3b in IEC 60664-1:2007).

Step 5: Establish pollution degree and comparative tracking index (CTI) from 4.8.1 of IEC 60664-1:2007.

Step 6: Establish minimum creepage distance (cr) value (Table 4 from IEC 60664-5:2007).

Dimensioning the creepage distance with regards to flashover:

Step 7: Assess the maximum peak voltage which can occur in the circuit.

Step 8: Establish humidity level (HL) and water adsorption group (WAG).

Step 9: Establish minimum creepage distance (cr) value (Table 5 from IEC 60664-5:2007)

Step 10: Select the greater creepage distance (cr) with respect to tracking and flashover

Step 11: Where cr <cl:

– if pollution degree is 3, spacing on insulating material meets cl value; see 5.3.2.6 in IEC 60664-5:2007;

– if pollution degree is either 1 or 2, spacing on insulating material may be cr value if the spacing withstands the impulse withstand voltage used to verify the clearance.

7.3 Use of IEC 60664-4:2005, for circuits in equipment either directly or not directly connected to the mains supply

Table 10 – Relationship between influencing parameters and normative references in IEC 60664-1 or IEC 60664-4

Influencing parameters	Basis of selection	IEC 60664-1:2007 or IEC 60664-4:2005 reference	Value in Table
Clearance			
Voltage or rated insulation voltage	Overvoltage category of equipment	Table F.1 of IEC 60664-1 (see NOTE)	Table F.2 of IEC 60664-1
Peak value of the maximum steady state voltage	Assessed by the manufacturer	Table F.7a of IEC 60664-1 or Table 1 of IEC 60664-4 depending on the field distribution	Depending on the field distribution
Creepage distance			
Dimensioning with regard to tracking			

Influencing parameters	Basis of selection	IEC 60664-1:2007 or IEC 60664-4:2005 reference	Value in Table
Voltage	Rated voltage or rated insulation voltage	Tables F.3a and F.3b of IEC 60664-1	Table F.4 of IEC 60664-1
Pollution	Pollution degree (micro-environment)	4.6.2 of IEC 60664-1	Table F.4 of IEC 60664-1
Insulating material	Comparative tracking index	4.8.1.3 of IEC 60664-1	Table F.4 of IEC 60664-1
Dimensioning with regard to thermal effects			
Peak value of the maximum steady-state voltage	Assessed by the manufacturer		Table 2 of IEC 60664-4
Micro-environment	Pollution degree (micro-environment)	4.6.2 of IEC 60664-1	Table 2 of IEC 60664-4
Insulating material	These dimensioning data are applicable for all materials that can be deteriorated by thermal effects.	Clause 5 of IEC 60664-4	Table 2 of IEC 60664-4
Frequency	Assessed by the manufacturer	Clause 5 of IEC 60664-4	Table 2 of IEC 60664-4
NOTE If the circuit is not directly connected to the mains, the impulse withstand voltage can be provided by the technical committee or if not, it should be assessed by the manufacturer.			

The following procedure shall be followed:

Step 1: Select overvoltage category.

Step 2: Select impulse voltage (Table F.1 in IEC 60664-1:2007).

Step 3: Establish minimum clearance (cl) value (Table F.2 of IEC 60664-1:2007) and apply an altitude correction factor (Table A.2 of IEC 60664-1:2007) if the equipment with the clearance is used above 2 000 m.

Step 4: Assess the peak value of the maximum steady-state voltage.

Step 5: Assess the field distribution.

Step 6: Establish minimum clearance (cl) value (Table F.7a of IEC 60664-1:2007 for 125 % of the peak value of the maximum steady-state voltage or Table 1 of IEC 60664-4:2005 for the peak value of the maximum steady-state voltage.

Step 7: Select the greater clearance (cl) with respect to transient overvoltages or steady-state voltages.

Dimensioning the creepage distance with regards to pollution:

Step 8: Select rated voltage for creepage distance (Tables F.3a and F.3b in IEC 60664-1:2007).

Step 9: Establish pollution degree and comparative tracking index (CTI) from 4.8.1 of IEC 60664-1:2007.

Step 10: Establish minimum creepage distance (cr) value (Table F.4 from IEC 60664-1:2007)

Dimensioning the creepage distance with regards to thermal effects:

Step 11: Assess the maximum peak value of the steady-state voltage which can occur in the circuit.

Step 12: Establish pollution degree from IEC 60664-1.

Step 13: Assess the frequency of the voltage.

Step 14: Establish minimum creepage distance (cr) value (Table 2 of IEC 60664-4:2005).

Step 15: Select the greater creepage distance cr) with respect to tracking and thermal effects.

7.4 Examples comparing the dimensioning of clearances and creepage distances according to IEC 60664-1 and IEC 60664-5 based on case A condition (basic insulation, for equipment up to 2 000 m altitude)

From the following examples, it can be concluded:

– for printed wiring boards, IEC 60664-1 allows shorter distances;

– for printed wiring boards and for equivalent constructions within the scope of IEC 60664-5, IEC 60664-5 may provide a smaller dimensioning depending of the material group characteristics (CTI and WAG).

NOTE 1 In these examples, the pollution degree 2 and HL 2 have been chosen for simplification. However, the HL can be different from the pollution degree.

NOTE 2 The wording “printed board” in IEC 60664-3 includes printed wiring boards.

7.4.1 Circuits not directly connected to mains supply

7.4.1.1 Dimensioning of clearance and creepage following IEC 60664-1

Table 11 – Example for dimensioning a clearance and creepage distance following IEC 60664-1

Clearance			
Impulse voltage	1 500 V	Clearance	0,5 mm
Creepage distance (tracking)			
Pollution degree	2		
Insulating material	CTI GR III		
Rated voltage	200 V	Creepage distance	0,63 mm on printed wiring material; 2,00 mm for other constructions
NOTE At locations where clearance and creepage distances cannot be differentiated (e.g. on printed wiring material), the larger distance is used. Therefore, the minimum clearance and creepage distance is 0,63 mm on printed wiring material or 2,0 mm for other constructions.			

7.4.1.2 Dimensioning of clearance and creepage following IEC 60664-5

Table 12 – Example for dimensioning a clearance and creepage distance following IEC 60664-5

Clearance			
Impulse voltage	1 500 V	Clearance	0,5 mm
Creepage distance (tracking)			
Pollution degree	2		
Insulating material	CTI GR III		
Rated voltage (a.c. r.m.s. or d.c.) see NOTE 2	200 V	Creepage distance	0,63 mm
Creepage distance (flashover)			
Maximum peak voltage	1 500 V		
Humidity level	2		
Water adsorption group	WAG 1	Creepage distance	0,93 mm
	WAG 2		1,02 mm
	WAG 3		1,11 mm
	WAG 4		1,2 mm

NOTE 1 At locations where clearance and creepage distances cannot be differentiated (e.g. on printed wiring material), the larger distance is used, therefore the minimum clearance and creepage distance is 0,93 mm up to 1,20 mm, depending upon the water adsorption characteristics of the insulating material.

NOTE 2 In case of d.c. supply, TCs should carefully consider the dimensioning of the associated clearance during the dimensioning of creepage distances in order to avoid flashover because the consequences of a flashover can be more critical in d.c. circuits than in a.c. circuits.

7.4.2 Circuits not directly connected to mains supply

7.4.2.1 Dimensioning of clearance and creepage following IEC 60664-1

Table 13 – Example for dimensioning a clearance and creepage distance following IEC 60664-1 in circuits not directly connected to mains supply

Clearance			
Impulse voltage	500 V	Clearance	0,20 mm for other construction; 0,04 mm on printed wiring material
Creepage distance (tracking)			
Rated voltage	50 V	Creepage distance	0,04 mm on printed wiring material; 1,20 mm for other constructions
Pollution degree	2		
Insulating material	CTI GR III		

NOTE At locations where clearance and creepage distances cannot be differentiated (e.g. on printed wiring material), the larger distance is used. Therefore the minimum clearance and creepage distance is 0,04 mm on printed wiring material or 1,20 mm for other constructions.

7.4.2.2 Dimensioning of clearance and creepage following IEC 60664-5

Table 14 – Example for dimensioning a clearance and creepage distance following IEC 60664-5 in circuits not directly connected to mains supply

Clearance			
Impulse voltage	500 V	Clearance	0,04 mm
Creepage distance (tracking)			
Rated voltage	50 V	Creepage distance	0,04 mm
Pollution degree	2		
Insulating material	CTI GR III		
Creepage distance (flashover)			
Maximum peak voltage	500 V		
Humidity level	2		
Water adsorption group	WAG 1	Creepage distance	0,17 mm
	WAG 2		0,18 mm
	WAG 3		0,20 mm
	WAG 4		0,22 mm

NOTE 1 At locations where clearance and creepage distances cannot be differentiated (e.g. on printed wiring material), the larger distance is used. Therefore, the minimum clearance and creepage distance is 0,17 mm to 0,22 mm depending upon the water adsorption characteristics of the insulating material.

NOTE 2 In the case of a d.c. supply, technical committees should carefully consider the dimensioning of the associated clearance during the dimensioning of creepage distances in order to avoid flashover because the consequences of a flashover can be more critical in d.c. circuits than in a.c. circuits.

7.5 Examples of dimension comparison for clearances and creepage distances according to IEC 60664-1 and IEC 60664-4 based on case A condition (basic insulation, for equipment up to 2 000 m altitude)

From the following two examples, it can be concluded:

– dimensioning according to IEC 60664-4 will always result in greater distances as compared to dimensioning according to IEC 60664-1, if the clearance requirements with respect to periodic voltages are decisive for dimensioning;

– dimensioning according to IEC 60664-4 will not change the distances as compared to dimensioning according to IEC 60664-1, if the creepage distance requirements with respect to tracking are decisive for dimensioning. This case is applicable for rather small steady-state voltages, in particular for constructions other than printed wiring material.

7.5.1 Circuits not directly connected to mains supply

7.5.1.1 Dimensioning of clearance and creepage following IEC 60664-1

Table 15 – Example for dimensioning a clearance and creepage distance following IEC 60664-1 in circuits not directly connected to mains supply

Clearance			
Recurring peak voltage	1 000 V	Clearance	0,26 mm
Creepage distance (tracking)			
Steady-state voltage (r.m.s)	200 V	Creepage distance	0,63 mm on printed wiring material; 2,0 mm for other constructions
Pollution degree	2		
Insulating material	CTI GR III		

NOTE 1 At locations where clearance and creepage distances cannot be differentiated (e.g. on printed wiring material), the larger distance is used. Therefore, the minimum clearance and creepage distance is 0,63 mm on printed wiring material or 2,0 mm for other constructions.

NOTE 2 In the case of a d.c. supply, technical committees should carefully consider the dimensioning of the associated clearance during the dimensioning of creepage distances in order to avoid flashover because the consequences of a flashover can be more critical in d.c. circuits than in a.c. circuits.

7.5.1.2 Dimensioning of clearance and creepage following IEC 60664-4 (approximately homogeneous field)

Table 16 – Example for dimensioning a clearance and creepage distance following IEC 60664-4 (approximately homogeneous field)

Clearance			
Recurring peak voltage	1 000 V		
Voltage for dimensioning according to Table F.7a of IEC 60664-1:2007	1 250 V	Clearance	0,48 mm
Creepage distance (tracking)			
Steady-state voltage (r.m.s)	200 V	Creepage distance	0,63 mm on printed wiring material; 2,0 mm for other constructions
Pollution degree	2		
Insulating material	CTI GR III		
Creepage distance (thermal effects)			
Maximum steady-state voltage (peak)	1 000 V		
Frequency	30 kHz $< f <$100 kHz	Creepage distance	0,72 mm
	100 kHz $< f <$200 kHz		1,38 mm
	200 kHz $< f <$400 kHz		3,6 mm
	400 kHz $< f <$700 kHz		21,6 mm
Pollution degree	2	Multiplication of the values of Table 2 of IEC 60664-4:2005 with the factor of 1,2	

NOTE At locations where clearance and creepage distances cannot be differentiated (e.g. on printed wiring material), the larger distance is used. Therefore, the minimum clearance and creepage distance is 0,72 mm on printed wiring material for frequencies up to 100 kHz or 2,0 mm for other constructions for frequencies up to 200 kHz.

7.5.2 Circuits not directly connected to mains supply

7.5.2.1 Dimensioning of clearance and creepage following IEC 60664-1

Table 17 – Example for dimensioning a clearance and creepage distance following IEC 60664-1 in circuits not directly connected to mains supply

Clearance			
Recurring peak voltage	500 V	Clearance	0,20 mm for other construction; 0,04 mm on printed wiring material
Creepage distance (tracking)			
Steady-state voltage (r.m.s)	50 V	Creepage distance	0,04 mm on printed wiring material; 1,20 mm for other constructions
Pollution degree	2		
Insulating material	CTI GR III		
NOTE 1 At locations where clearance and creepage distances cannot be differentiated (e.g. on printed wiring material), the larger distance is used. Therefore, the minimum clearance and creepage distance is 0,04 mm on printed wiring material or 1,20 mm for other constructions.			
NOTE 2 In case of d.c. supply, technical committees should carefully consider the dimensioning of the associated clearance during the dimensioning of creepage distances in order to avoid flashover because the consequences of a flashover can be more critical in d.c. circuits than in a.c. circuits.			

7.5.2.2 Dimensioning of clearance and creepage following IEC 60664-4 (approximately homogeneous field)

Table 18 – Example for dimensioning a clearance and creepage distance following IEC 60664-4 (approximately homogeneous field)

Clearance			
Recurring peak voltage	500 V		
Voltage for dimensioning according to Table F.7a of IEC 60664-1:2007	625 V	Clearance	0,2 mm for other construction; 0,069 mm on printed wiring material
Creepage distance (tracking)			
Steady-state voltage (r.m.s)	50 V	Creepage distance	0,04 mm on printed wiring material; 1,20 mm for other construction
Pollution degree	2		
Insulating material	CTI GR III		
Creepage distance (thermal effects)			
Steady-state voltage (peak)	500 V		
Frequency	30 kHz $< f <$ 100 kHz	Creepage distance	0,22 mm
	100 kHz $< f <$ 200 kHz		0,23 mm
	200 kHz $< f <$ 400 kHz		0,3 mm
	400 kHz $< f <$ 700 kHz		0,48 mm
	700 kHz $< f <$ 1 MHz		1,80 mm
	1 MHz $< f <$ 2 MHz		24,0 mm
Pollution degree	2	Multiplication of the values of Table 2 of IEC 60664-4:2005 with the factor of 1,2	
NOTE At locations where clearance and creepage distances cannot be differentiated (e.g. on printed wiring material), the larger distance is used. Therefore, the minimum clearance and creepage distance is 0,22 mm on printed wiring material for frequencies up to 100 kHz or 1,2 mm for other constructions for frequencies up to 700 kHz.			

Annex A
(informative)

Overview of clauses of IEC 60664-1 requiring decisions by technical committees, specification of options or requiring activities by the manufacturer

A.1 Decisions required by technical committees

When referring to IEC 60664-1, technical committees are required to specify the following items.

Table A.1 – Clauses and titles of IEC 60664-1 and items to be considered by technical committees

Clause and title of IEC 60664-1:2007	Items to be considered in IEC 60664-1:2007
4.3.1 General, of 4.3 Voltages and voltage ratings	Specification of: 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
4.3.2.2.1 Equipment energized directly from the low-voltage mains	Selection whether the voltage is based on: – line-to-line voltage, or – line-to-neutral voltage. In the latter case, the technical committees shall specify how to inform the user that the equipment is for use on neutral-earthed systems only
4.3.3.2.2 Equipment energized directly from the supply mains	Specification of the overvoltage category based on the general explanation of overvoltage categories (see also Clause 443 of IEC 60364-4-44:2007)
4.7 Information supplied with the equipment	Specification of the relevant information supplied with the equipment and the way provided
4.8.2 Electric strength characteristics	Consideration of the electric strength characteristics of insulating material, 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	Consideration of the thermal characteristics of insulating material 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 the IEC 60216 series.
4.8.4 Mechanical and chemical characteristics	Consideration of the mechanical and chemical characteristics of insulating material, taking into account the stresses described in 5.3.2.2.3, 5.3.2.3.3 and 5.3.2.4
5.3.2.2.3 Mechanical shock	Consideration of inadequate impact strength, mechanical shock, reduced impact strength of materials when specifying environmental conditions for transportation, storage, installation and use
5.3.2.4 Other stresses	Consideration of other stresses such as: – radiation, both ultraviolet and ionizing; – stress-crazing or stress-cracking caused by exposure to solvents or active chemicals; – effect of migration of plasticizers; – effect of bacteria, moulds or fungi; – mechanical creep
5.3.3.2.1 General, of 5.3.3.2 Withstand of voltage stresses	Specification as to which voltage ratings are to be assigned to their equipment
5.3.3.2.5 High-frequency voltage	Specification as to whether a test according to 6.1.3.7 is

Clause and title of IEC 60664-1:2007	Items to be considered in IEC 60664-1:2007
	necessary
5.3.3.3 Withstand of short-term heating stresses	Specification of severity levels
5.3.3.4 Withstand of mechanical stresses	Specification of severity levels
5.3.3.5 Withstand of long-term heating stresses	Specification as to whether a test is necessary. (see also IEC 60085 and the IEC 60216 series)
5.3.3.7 Withstand of other stresses	Statement of other stresses and specification of test methods
6.1.2.2.1.2 Selection of impulse test voltage	For the test conditions, specification of temperature and humidity values. Consideration as to whether sampling tests or routine tests have to be carried out in addition to type tests
6.1.3.1 Selection of tests	Specification of which type tests are required for the respective stresses occurring in the equipment. Specification of tests performed as sample and routine tests in order to ensure the quality of the insulation during production. Specification of the tests, and conditioning as appropriate, with test parameters adequate to detect faults without causing damage to the insulation
6.1.3.2 Conditioning	Specification of the appropriate conditioning method
6.1.3.4.1 Test method	Consideration as to whether the a.c. test voltage needs to be substituted by a d.c. test voltage of a value equal to the peak value of the a.c. voltage, taking into account that this test will be less stringent than the a.c. voltage test
6.1.3.5.2 Verification	Specification of: – the test circuit (Clause C.1); – the measuring equipment (Clauses C.3 and D.2); – the measuring frequency (C.3.1 and D.3.3); – the test procedure (6.1.3.5.3) according to the kind of test specimen
6.1.4.5 Test criteria	Specification as to whether partial discharges in clearances which do not result in breakdown are disregarded
6.1.5.1 Test purposes other than insulation coordination	Specification of test voltages not higher than those required for insulation coordination.
6.1.5.2 Sampling and routine tests	Specification of sampling tests and routine tests intended to ensure production quality. Specification of test voltages in no case higher than those required for type testing
C.2.1 General, to C.2 Test parameters	Specification of – the frequency f_t of the test voltage (C.2.2); – the specified discharge magnitude (6.1.3.5.4.1); – the climatic conditions for the PD test (C.2.3). NOTE It may be necessary to have different specifications for the type test and the routine test.
C.2.2 Requirements for the test voltage	Consideration of the possible effect of frequency on discharge magnitude

A.2 Optional specifications by technical committees

When referring to IEC 60664-1, technical committees are invited to consider the items in the following list and to decide on the options:

Table A.2 – Clauses and titles of IEC 60664-1 and optional specifications for consideration by technical committees

Clause and title of IEC 60664-1:2007	Items to be considered in IEC 60664-1:2007
1 Scope and object	Specification of special requirements for situations where ionized gases occur
4.3.3.2.3 Systems and equipment not energized directly from the low-voltage mains	Specification of overvoltage categories or rated impulse voltages as appropriate. Recommendation to apply the preferred series of 4.2.3
4.5 Time under voltage stress	Consideration to allow reduced creepage distances for functional insulation, which is under voltage stress for only a short time, for example of one voltage step lower than specified in Table F.4
5.1.1 General, of 5.1 Dimensioning of clearances	To take into account that the dimensioning for steady-state r.m.s. or recurring peak voltage leads to a situation in which there is no margin to breakdown with the continuous application of these voltages
5.1.6 Dimensioning of clearances of basic, supplementary and reinforced insulation	Specification of further details when dimensioning clearances to accessible surfaces of insulating material
5.2.4 Dimensioning of creepage distances of basic, supplementary and reinforced insulation	Specification of further details when dimensioning creepage distances to accessible surfaces of insulating material.
5.3.2.3.3 Mechanical stresses	Consideration of mechanical stresses when specifying conditions for testing long-term stresses
5.3.3.1 General, of 5.3.3 Requirements	Specification of further details when considering electrical stresses to accessible surfaces of solid insulation
6.1.1 General, of 6.1 Tests	Consideration to combine any high-voltage test with a partial discharge measurement according to 6.1.3.5 and Annex C for the test specimen that, after type testing, is intended or required for further use
6.1.2.2.1.1 General, of 6.1.2.2.1 Impulse voltage dielectric test	Specification of alternative dielectric tests according to 6.1.2.2.2
6.1.2.2.1.1 General, of 6.1.2.2.1 Impulse voltage dielectric test	For practical application, rounding of the values of Table F.5 for the impulse test voltages
6.1.2.2.2.1 General, of 6.1.2.2.2 Alternatives to impulse voltage dielectric tests	Specification of an a.c. or d.c. voltage test for particular equipment as an alternative method to the impulse voltage test given in 6.1.2.2.1, taking into account that they can overload and damage certain solid insulations
6.1.3.1 Selection of tests	Specification of test methods regarding vibration and mechanical shock before the dielectric testing.
6.1.3.4.1 Test method	Reduction of the duration of the test to a minimum value of 5 s in those cases where the short-term temporary overvoltage leads to the most stringent requirements with respect to the amplitude of the test voltage
6.1.3.4.1 Test method	Introduction of a safety margin on the test voltage in case of testing with respect to high steady-state stresses, including high recurring peak voltage
C.4.3 Calibration for the PD test	When specifying time intervals for recalibration, consideration that, in case of insufficient sensitivity at the PD meter, potentially harmful discharges cannot be detected
Annex F, Table F.4: Creepage distances to avoid failure due to tracking	Use of dimensions based on own experience for Table F.4 values for voltages higher than 10 000 V

A.3 Clauses requiring activities of the manufacturer

When applying IEC 60664-1 in addition to a product standard or in the absence of a relevant one, the manufacturer is required not only to carry out all relevant dimensioning and tests but also to carry out the items in the following list.

Table A.3 – Clauses and titles of IEC 60664-1 and required manufacturer activities

Clause and title of IEC 60664-1:2007	Activity required
3.9 Rated voltage	Assignment of the value of voltage to a component, device or equipment and to which operation and performance characteristics are referred
3.9.1 Rated insulation voltage	Assignment of the r.m.s. withstand voltage value to the equipment or to a part of it, characterizing the specified (long-term) withstand capability of its insulation
3.9.2 Rated impulse voltage	Assignment of the impulse withstand voltage value 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	Assignment of the recurring peak withstand voltage value 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	Assignment of the temporary withstand overvoltage value to the equipment or to a part of it, characterizing the specified short-term withstand capability of its insulation against a.c. voltages
5.2.2.4 Orientation and location of a creepage distance	If necessary, indication of the intended orientation of the equipment or component in order that creepage distances are not adversely affected by the accumulation of pollution for which they were not designed
6.1.5.2 Sampling and routine tests	Specification of sampling tests and routine tests, intended to ensure production quality, carried out with the waveforms and voltage levels such that faults are detected without causing damage to the equipment (solid insulation or components)

Annex B
(informative)

Overview of clauses of IEC 60664-4 requiring decisions by technical committees

B.1 Decisions required by technical committees

Not applicable.

B.2 Optional specifications by technical committees

When referring to IEC 60664-4, technical committees are invited to consider the items in the following list and to decide on the options:

Table B.1 – Clauses and titles of IEC 60664-4 and optional specifications for consideration by technical committees

Clause and title of IEC 60664-4:2005	Items to be considered
1 Scope and object	Specification of special requirements for situations where ionized gases occur
7.3 Conditioning	Specification of a test

Annex C
(informative)

Overview of clauses of IEC 60664-5 requiring decisions by technical committees, specification of options or requiring activities by the manufacturer

C.1 Decisions required by technical committees

When referring to IEC 60664-5, technical committees are required to specify the following items:

Table C.1 – Clauses and titles of IEC 60664-5 and items to be considered by technical committees

Clause and title of IEC 60664-5:2007	Reference to IEC 60664-1:2007	Items to be considered (in case of reference to IEC 60664-1:2007, consideration of the relevant subclause of IEC 60664-1 is necessary)
4.3.1 General, of 4.3 Voltages and voltage ratings	4.3.1 of IEC 60664-1 is applicable	Specification of 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
4.3.2.2.1 Equipment energized directly from the low-voltage mains		Selection whether the voltage is based on: – line-to-line voltage, or – line-to-neutral voltage. In the latter case the technical committees need to specify how the user is to be informed that the equipment is for use on neutral-earthed systems only
4.3.3.2.2 Equipment energized directly from the supply mains	4.3.3.2.2 of IEC 60664-1 is applicable	Specification of the overvoltage category based on the general explanation of overvoltage categories (see also Clause 443 of IEC 60364-4-44:2007)
4.7 Information supplied with the equipment	4.7 of IEC 60664-1 is applicable	Specification of the relevant information to be supplied with the equipment and the way this is to be provided
4.8.1 General, of 4.8 Insulating material		Classification of insulating material into groups according their CTI values. Consideration of the electric strength characteristics as well as the thermal, mechanical, chemical and water adsorption characteristics of insulating material
4.8.3 Electric strength characteristics	4.8.2 of IEC 60664-1 is applicable	Consideration of the electric strength characteristics of insulating material, taking into account the stresses described in 5.3.1, 5.3.2.2.1 and 5.3.2.3.1
4.8.4 Thermal characteristics	4.8.3 of IEC 60664-1 is applicable	Consideration of the thermal characteristics of insulating material 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 the IEC 60216 series.
4.8.5 Mechanical and chemical characteristics	4.8.4 of IEC 60664-1 is applicable	Consideration of the mechanical and chemical characteristics of insulating material, taking into account the stresses described in 5.3.2.2.3, 5.3.2.3.3 and 5.3.2.4
5.4.2.2.3 Mechanical shock	5.3.2.2.3 of IEC 60664-1 is applicable	Consideration of inadequate impact strength, mechanical shock and reduced impact strength of materials when specifying environmental conditions for transportation, storage, installation and use
5.4.2.4 Other stresses	5.3.2.4 of IEC 60664-1 is applicable	Consideration of other stresses such as: – radiation, both ultraviolet and ionizing; – stress-crazing or stress-cracking caused by exposure to solvents or active chemicals; – the effect of migration of plasticizers; – the effect of bacteria, moulds or fungi; – mechanical creep

Clause and title of IEC 60664-5:2007	Reference to IEC 60664-1:2007	Items to be considered (in case of reference to IEC 60664-1:2007, consideration of the relevant subclause of IEC 60664-1 is necessary)
5.4.3.2.1 General, from 5.3.3.2 Withstand of voltage stresses	5.3.3.2.1 of IEC 60664-1 is applicable	Specification which voltage ratings are to be assigned to their equipment
5.4.3.2.5 High-frequency voltage		Specification whether a test according to 6.1.3.7 is necessary
5.4.3.3 Withstand of short-term heating stresses	5.3.3.3 of IEC 60664-1 is applicable	Specification of severity levels
5.4.3.4 Withstand of mechanical stresses	5.3.3.4 of IEC 60664-1 is applicable	Specification of severity levels
5.4.3.5 Withstand of long-term heating stresses	5.3.3.5 of IEC 60664-1 is applicable	Specification whether a test is necessary. (See also IEC 60085 and the IEC 60216 series)
5.4.3.7 Withstand of other stresses	5.3.3.7 of IEC 60664-1 is applicable	Statement of other stresses and specification of test methods
6.1.2.2.1.2 Selection of impulse test voltage		For the test conditions, specification of temperature and humidity values. Consideration whether sampling tests or routine tests have to be carried out in addition to type tests
6.1.3.1 Selection of tests		Specification as to which type tests are required for the respective stresses occurring in the equipment. Specification of tests performed as sample and routine tests in order to ensure the quality of the insulation during production. Specification of the tests, and conditioning as appropriate, with test parameters adequate to detect faults without causing damage to the insulation
6.1.3.2 Conditioning	6.1.3.2 of IEC 60664-1 is applicable	Specification of the appropriate conditioning method
6.1.3.4.1 Test method		Consideration whether the a.c. test voltage needs to be substituted by a d.c. test voltage of a value equal to the peak value of the a.c. voltage, taking into account that this test will be less stringent than the a.c. voltage test
6.1.3.5.2 Verification		Specification of: – the test circuit (Clause C.1); – the measuring equipment (Clauses C.3 D.2); – the measuring frequency (C.3.1 and D.3.3); – the test procedure (6.1.3.5.3) according to the kind of test specimen
6.1.4.5 Test criteria	6.1.4.5 of IEC 60664-1 is applicable	Specification whether partial discharges in clearances which do not result in breakdown are disregarded.
6.1.5.1 Test purposes other than insulation coordination	6.1.5.1 of IEC 60664-1 is applicable	Specification of test voltages not higher than those required for insulation coordination
6.1.5.2 Sampling and routine tests	6.1.5.2 of IEC 60664-1 is applicable	Specification of sampling tests and routine tests intended to ensure production quality. Specification of test voltages in no case higher than those required for type testing
	C.2.1 General, to C.2 Test parameters	Specification of: – the frequency f_t of the test voltage (C.2.2); – the specified discharge magnitude (6.1.3.5.4.1); – the climatic conditions for the PD test (C.2.3). NOTE It may be necessary to have different specifications for the type test and the routine test.
	C.2.2 Requirements for the test voltage	Consideration of the possible effect of frequency on discharge magnitude

C.2 Optional specifications by technical committees

When referring to IEC 60664-5, technical committees are invited to consider the items in the following list and to decide on the options:

Table C.2 – Clauses and titles of IEC 60664-5 and optional specifications for consideration by technical committees

Clause and title of IEC 60664-5:2007	**Reference to IEC 60664-1:2007**	**Items to be considered** (in case of reference to IEC 60664-1:2007, consideration of the relevant subclause of IEC 60664-1 is necessary)
4.3.3.2.3 Systems and equipment not energized directly from the low-voltage mains	4.3.3.2.3 of IEC 60664-1 is applicable	Specification of overvoltage categories or rated impulse voltages as appropriate. Recommendation to apply the preferred series of 4.2.3
5.2.1 General, of 5.2 Dimensioning of clearances		To take into account that the dimensioning for steady-state r.m.s. or recurring peak voltage leads to a situation in which there is no margin to breakdown with the continuous application of these voltages
5.2.6 Dimensioning of clearances of basic, supplementary and reinforced insulation		Specification of further details when dimensioning clearances to accessible surfaces of insulating material
5.3.2.3.2 imensioning to maintain insulation resistance		To take into account the insulation resistance for dimensioning when a maximum leakage current between live parts or between live parts and an accessible surface of equipment is specified
5.3.4 Dimensioning of creepage distances of basic, supplementary and reinforced insulation		Specification of further details when dimensioning creepage distances to accessible surfaces of insulating material
5.4.2.3.3 Mechanical stresses	5.3.2.3.3 of IEC 60664-1 is applicable	Consideration of mechanical stresses when specifying conditions for testing long-term stresses
5.4.3.1 General, of 5.4.3 Requirements	5.3.3.1 of IEC 60664-1 is applicable	Specification of further details when considering electrical stresses to accessible surfaces of solid insulation
6.1.1 General, of 6.1 Tests		Consideration to combine any high-voltage test with a partial discharge measurement according to 6.1.3.5 and Annex C for test specimen that, after type testing, is intended or required for further use
6.1.2.2.1.1 General, of 6.1.2.2.1 Impulse voltage dielectric test		Specification of alternative dielectric tests according to 6.1.2.2.2
6.1.2.2.1.1 General, of 6.1.2.2.1 Impulse voltage dielectric test		For practical application, rounding of the values of Table F.5 for the impulse test voltages
6.1.2.2.2.1 General, of 6.1.2.2.2 Alternatives to impulse voltage dielectric tests		Specification of an a.c. or d.c. voltage test for particular equipment as an alternative method to the impulse voltage test given in 6.1.2.2.1, taking into account that they can overload and damage certain solid insulations
6.1.3.1 Selection of tests		Specification of test methods regarding vibration and mechanical shock before the dielectric testing
6.1.3.4.1 Test method		Reduction of the duration of the test to a minimum value of 5 s in those cases where the short-term temporary overvoltage leads to the most stringent requirements with respect to the amplitude of the test voltage
6.1.3.4.1 Test method		Introduction of a safety margin on the test voltage in case of testing with respect to high steady-state stresses including high recurring peak voltage
	C.4.3 Calibration for the PD test	When specifying time intervals for recalibration, consideration that, in case of insufficient sensitivity at the

Clause and title of IEC 60664-5:2007	Reference to IEC 60664-1:2007	Items to be considered (in case of reference to IEC 60664-1:2007, consideration of the relevant subclause of IEC 60664-1 is necessary)
		PD meter, potentially harmful discharges cannot be detected
	Annex F, Table F.4, Creepage distances to avoid failure due to tracking	Use of dimensions based on own experience for Table 4 values for voltages higher than 10 000 V

C.3 Clauses requiring activity by the manufacturer

When applying IEC 60664-5 in addition to a product standard or in absence of a relevant one, the manufacturer is required not only to carry out all relevant dimensioning and tests but also to carry out the items in the following list, where he specifically is mentioned:.

Table C.3 – Clauses and titles of IEC 60664-5 and required manufacturer activities

Clause and title of IEC 60664-5:2007	Reference to IEC 60664-1:2007	Activity required (in case of reference to IEC 60664-1:2007, consideration of the relevant subclause of IEC 60664-1 is necessary)
	3.9 Rated voltage	Assignment of the value of voltage to a component, device or equipment and to which operation and performance characteristics are referred
	3.9.1 Rated insulation voltage	Assignment of the r.m.s. withstand voltage value to the equipment or to a part of it, characterizing the specified (long-term) withstand capability of its insulation
	3.9.2 Rated impulse voltage	Assignment of the impulse withstand voltage value 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	Assignment of the recurring peak withstand voltage value 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	Assignment of the temporary withstand overvoltage value to the equipment or to a part of it, characterizing the specified short-term withstand capability of its insulation against a.c. voltages
5.3.2.4 Orientation and location of a creepage distance	5.2.2.4 of IEC 60664-1 is applicable	If necessary, indication of the intended orientation of the equipment or component in order that creepage distances be not adversely affected by the accumulation of pollution for which they were not designed
6.1.5.2 Sampling and routine tests	6.1.5.2 of IEC 60664-1 is applicable	Specification of sampling tests and routine tests intended to ensure production quality. They are carried out with the waveforms and voltage levels such that faults are detected without causing damage to the equipment (solid insulation or components)

Annex D
(informative)

Dimensioning of clearances and creepage distances for d.c. voltages above 1 000 V d.c.

D.1 Introductory remark

IEC 60664-1:2007 deals with the insulation coordination for equipment within low-voltage systems having a rated d.c. voltage up to 1 500 V. The tables in IEC 60664-1:2007 give no specific values for d.c. voltages beyond 1 000 V and up to 1 500 V. This Annex D amends the tables of Annex F of IEC 60664-1:2007.

D.2 Rated impulse voltage for equipment energized directly from the low-voltage mains

Table D.1 can be used in addition to the information provided in Table F.1 of IEC 60664-1:2007.

Table D.1 – Rated impulse voltage for equipment

Nominal voltage of the supply system based on IEC 60038	Voltage line to neutral derived from nominal d.c. voltages up to and including V	Rated impulse voltage			
		Overvoltage category[a]			
Single phase V		I V	II V	III V	IV V
Refer to Table F.1 in IEC 60664-1:2007	Up to 1 000 V, refer to Table F.1 in IEC 60664-1:2007	Refer to Table F.1 in IEC 60664-1:2007			
1 500 d.c.[b]	1 500	6 000	8 000	10 000	15 000

[a] See 4.3.3.2.2 of IEC 60664-1:2007 for an explanation of the overvoltage categories.

[b] Information in line with railway application, consistency to be checked with technical committee 64.

D.3 Dimensioning of clearances of basic, supplementary and reinforced insulation

Clearances of basic and supplementary insulation are each dimensioned as specified in Table F.2 of IEC 60664-1:2007.

With respect to impulse voltages, clearances of reinforced insulation should be dimensioned as described e.g. in 5.1.6 of IEC 60664-1:2007.

D.4 Dimensioning of creepage distances

For dimensioning of creepage distances for d.c. voltages above 1 000 V, see Table F.4 of IEC 60664-1:2007.

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IEC 60050-151, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

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