

Insulation coordination for equipment within low-voltage systems —

Part 1: Principles, requirements and tests

The European Standard EN 60664-1:2003 has the status of a
British Standard

ICS 29.080; 29.080.30

National foreword

This British Standard is the official English language version of EN 60664-1:2003. It is identical with IEC 60664-1:1992 and its amendments A1:2000, A2:2002 and corrigendum 1 November 2002. It supersedes BS 7822-1:1995 which will be withdrawn on 2006-04-01.

The UK participation in its preparation was entrusted to Technical Committee GEL/109, Insulation co-ordination for low voltage equipment, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

Cross-references

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

Compliance with a British Standard does not of itself confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 28 May 2003

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 71 and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments
14806	21 October 2003	Examples 1,2,3,7,8 and 11 added

© BSI 21 October 2003

ISBN 0 580 41883 9

Insulation coordination for equipment within low-voltage systems
Part 1: Principles, requirements and tests
(IEC 60664-1:1992 + A1:2000 + A2:2002)

Coordination de l'isolement des matériels
dans les systèmes (réseaux)
à basse tension
Partie 1: Principes, prescriptions et essais
(CEI 60664-1:1992 + A1:2000 + A2:2002)

Isulationskoordination für elektrische
Betriebsmittel in Niederspannungsanlagen
Teil 1: Grundsätze, Anforderungen und
Prüfungen
(IEC 60664-1:1992 + A1:2000 + A2:2002)

This European Standard was approved by CENELEC on 2003-04-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

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

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of the International Standard IEC 60664-1:1992 and its amendments A1:2000 and A2:2002, prepared by IEC TC 109, Insulation co-ordination for low-voltage equipment, was submitted to the Unique Acceptance Procedure and was approved by CENELEC as EN 60664-1 on 2003-04-01 without any modification.

This European Standard supersedes HD 625.1 S1:1996 and its corrigendum November 1996.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2004-04-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2006-04-01

Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, Annex ZA is normative and Annexes A, B, C, D and E are informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60664-1:1992 and its amendments A1:2000 and A2:2002 was approved by CENELEC as a European Standard without any modification.

CONTENTS

INTRODUCTION.....	5
SECTION 1: GENERAL AND DEFINITIONS	
1.1 Scope	6
1.2 Normative references.....	6
1.3 Definitions	8
SECTION 2: BASIS FOR INSULATION COORDINATION	
2.1 Basic principles	13
2.2 Voltages and voltage ratings.....	15
2.3 Frequency	19
2.4 Time under voltage stress.....	19
2.5 Pollution	19
2.6 Information supplied with the equipment	20
2.7 Insulating material	20
SECTION 3: REQUIREMENTS AND DIMENSIONING RULES	
3.1 Dimensioning of clearances	22
3.2 Dimensioning of creepage distances.....	26
3.3 Requirements for design of solid insulation.....	31
SECTION 4: TESTS AND MEASUREMENTS	
4.1 Tests	36
4.2 Measurement of creepage distances and clearances	47
Annex A (informative) Basic data on withstand characteristics of clearances	53
Annex B (informative) Nominal voltages of supply systems for different modes of overvoltage control	58
Annex C (informative) Partial discharge test methods	60
Annex D (informative) Additional information on partial discharge test methods	65
Annex E (informative) Comparison of creepage distances specified in table 4 and clearances in table A.1.....	68
Annex ZA (normative) Normative references to international publications with their corresponding European publications	69
Figure 3 – Recurring peak voltage	18
Figure 2 – Test voltages	46
Figure A.1 – Withstand voltage at 2 000 m above sea level	55
Figure A.2 – Experimental data measured at approximately sea level and their low limits for inhomogeneous field.....	56
Figure A.3 – Experimental data measured at approximately sea level and their low limits for homogeneous field	57
Figure C.1 – Earthed test specimen	60
Figure C.2 – Unearthed test specimen	60

Figure C.3 – Calibration for earthed test specimen	63
Figure C.4 – Calibration for unearthed test specimen.....	64
Figure D.1 – Partial discharge test circuits	65
Figure E.1 – Comparison of creepage distances specified in table 4 and clearances in table A.1	68
Table 1 – Rated impulse voltage for equipment energized directly from the low-voltage mains	17
Table 2 – Clearances to withstand transient overvoltages	23
Table 7 – Clearances to withstand steady-state voltages, temporary overvoltages or recurring peak voltages	24
Table 7a – Dimensioning of clearances to withstand steady-state voltages, temporary overvoltages or recurring peak voltages	24
Table 7b – Additional information concerning the dimensioning of clearances to avoid partial discharge	24
Table 3a – Single-phase three or two-wire a.c. or d.c. systems	28
Table 3b – Three-phase four or three-wire a.c. systems.....	29
Table 4 – Creepage distances to avoid failure due to tracking.....	30
Table 5 – Test voltages for verifying clearances at sea level.....	37
Table 8 – Altitude correction factors.....	39
Table 6 – Severities for conditioning of solid insulation	43
Tableau A.1 – Withstand voltages in kilovolts for an altitude of 2 000 m above sea level	53
Table A.2 – Altitude correction factors	54
Table B.1 – Inherent control or equivalent protective control	58
Table B.2 – Cases where protective control is necessary and control is provided by surge arresters having a ratio of clamping voltage to rated voltage not smaller than that specified by IEC 60099-1	59

INTRODUCTION

This part of IEC 60664 is a revision of the 1st edition of IEC 60664 (including 60664A and amendment 1) which was published in 1980 as a report having the status of a basic safety publication following IEC Guide 104. It is now published as a standard. It is now numbered as part 1 (covering principles, requirements and tests) in the new layout of the IEC 60664 series in which some further parts are foreseen as follows:

- IEC 60664-2 will cover concise requirements for clearances, creepage distances and solid insulation.
- IEC 60664-3 will cover use of coatings to achieve insulation coordination of printed board assemblies.
- IEC 60664-4 will be in the form of an application guide covering:
 - 1) Dimensioning procedure worksheet and dimensioning examples.
 - 2) Interface requirements and transient overvoltage control means.
 - 3) Explanations to the pollution degrees.
 - 4) Dielectric testing.

This part has been revised to

- provide for distinguishing insulation coordination for:
 - low-voltage mains;
 - other installation systems;
 - internal circuits of equipment;
- indicate that controlled overvoltage conditions can either inherently exist in a system or be achieved by means of overvoltage attenuating means;
- emphasize that the overvoltage categories have a probabilistic implication rather than the meaning of physical attenuation of the transient overvoltage downstream in the installation;
- spell out clearly the remaining duties of specialized Technical Committees;
- take into account IEC 60364-4-41, IEC 60364-4-442 and 60364-4-443;
- incorporate requirements for solid insulation.

INSULATION COORDINATION FOR EQUIPMENT WITHIN LOW-VOLTAGE SYSTEMS –

Part 1: Principles, requirements and tests

SECTION 1: GENERAL AND DEFINITIONS

1.1 Scope

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

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

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

This part does not deal with distances

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

NOTE 1 Extension of the scope up to 1 MHz is under consideration.

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

NOTE 3 Requirements for altitudes exceeding 2 000 m can be derived from table A.2 of annex A.

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

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

1.2 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 Guide 104:1984, *Guide to the drafting of safety publications, and the role of committees with safety pilot functions and safety group functions*

IEC 60038:1983, *IEC standard voltages*

IEC 60050(151):1978, *International Electrotechnical Vocabulary (IEV) – Chapter 151: Electrical and magnetic devices*

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

IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

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

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

IEC 60068-2-3:1969, *Environmental testing – Part 2: Tests, Test Ca: Damp heat, steady state*

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

IEC 60085:1984, *Thermal evaluation and classification of electrical insulation*

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

IEC 60112:1979, *Method for determining the comparative and the proof-tracking indices of solid insulating materials under moist conditions*

IEC 60216, *Guide for the determination of thermal endurance properties of electrical insulating materials*

IEC 60243-1:1988, *Methods of test for electric strength of solid insulating materials – Part 1: Tests at power frequencies*

IEC 60335-1:1991, *Safety of household and similar electrical appliances – Part 1: General requirements*

IEC 60364-4-41:1982, *Electrical installations of buildings – Part 4: Protection for safety – Chapter 41: Protection against electric shock*

IEC 60364-4-442:1992, *Electrical installations of buildings – Part 4: Protection for safety – Chapter 44: Protection against overvoltages – Section 442: Protection of low-voltage installations against faults between high-voltage systems and earth*

IEC 60364-4-443:1990, *Electrical installations of buildings – Part 4: Protection for safety – Chapter 44: Protection against overvoltages – Section 443: Protection against overvoltages of atmospheric origin or due to switching*

IEC 60364-5-537:1981, *Electrical installations of buildings – Part 5: Selection and erection of electrical equipment – Chapter 53: Switchgear and controlgear – Section 537: Devices for isolation and switching. Amendment No. 1 (1989)*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60536:1976, *Classification of electrical and electronic equipment with regard to protection against electric shock*

IEC 60664-4:1997, *Insulation coordination for equipment within low-voltage systems – Part 4: Considerations of high-frequency voltage stress*

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

IEC 60669-1:1981, *Switches for household and similar fixed electrical installations – Part 1: General requirements*

IEC 60730-1:1990, *Automatic electrical controls for electrical household appliances – Part 1: General requirements*

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

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

1.3 Definitions

For the purpose of this part of IEC 60664, the following definitions apply:

1.3.1

insulation coordination

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

NOTE Expected voltage stresses are characterized in terms of the characteristics defined in 1.3.5 to 1.3.7.

1.3.2

clearance

shortest distance in air between two conductive parts

1.3.3

creepage distance

shortest distance along the surface of the insulating material between two conductive parts (IEV 151-03-37)

1.3.4

solid insulation

solid insulating material interposed between two conductive parts

1.3.5

working voltage

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

NOTE 1 Transients are disregarded.

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

1.3.6

recurring peak voltage (U_{rp})

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

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

¹⁾ To be published.

1.3.7

overvoltage

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

1.3.7.1

temporary overvoltage

overvoltage at power frequency of relatively long duration

1.3.7.2

transient overvoltage

short duration overvoltage of a few milliseconds or less, oscillatory or non-oscillatory, usually highly damped (IEV 604-03-13)

1.3.7.2.1

switching overvoltage

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

1.3.7.2.2

lightning overvoltage

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

1.3.7.3

functional overvoltage

deliberately imposed overvoltage necessary for the function of a device

1.3.8 Withstand voltages

1.3.8.1

impulse withstand voltage

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

1.3.8.2

r.m.s. withstand voltage

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

1.3.8.3

recurring peak withstand voltage

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

1.3.8.4

temporary withstand overvoltage

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

1.3.9

rated voltage

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

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

1.3.9.1

rated insulation voltage

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

NOTE The rated insulation voltage is not necessarily equal to the rated voltage of equipment which is primarily related to functional performance.

1.3.9.2

rated impulse voltage

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

1.3.9.3

rated recurring peak voltage

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

1.3.9.4

rated temporary overvoltage

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

1.3.10

overvoltage category

numeral defining a transient overvoltage condition

NOTE Overvoltage categories I, II, III and IV are used, see 2.2.2.1.

1.3.11

pollution

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

1.3.12 Environment

1.3.12.1

macro-environment

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

1.3.12.2

micro-environment

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

1.3.13

pollution degree

numeral characterizing the expected pollution of the micro-environment

NOTE Pollution degrees 1, 2, 3 and 4 are used, see 2.5.1.

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.

1.3.15

inhomogeneous field

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

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

1.3.16

controlled overvoltage condition

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

1.3.17 Insulations

1.3.17.1

functional insulation

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

1.3.17.2

basic insulation

insulation applied to live parts to provide basic protection against electric shock

NOTE Basic insulation does not necessarily include insulation used exclusively for functional purposes (2-1 of IEC 60536).

1.3.17.3

supplementary insulation

independent insulation applied in addition to basic insulation, in order to provide protection against electric shock in the event of a failure of basic insulation (2.2 of IEC 60536)

1.3.17.4

double insulation

insulation comprising both basic insulation and supplementary insulation (2.3 of IEC 60536)

1.3.17.5

reinforced insulation

single insulation system applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in the relevant IEC standard (2.4 of IEC 60536)

NOTE A single insulation system does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested singly as basic or supplementary insulation.

1.3.18

partial discharge (PD)

electric discharge that partially bridges the insulation

1.3.18.1

apparent charge q

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

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

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

1.3.18.2**specified discharge magnitude**

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

NOTE The pulse with the maximum amplitude should be evaluated.

1.3.18.3**pulse repetition rate**

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

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

1.3.18.4**partial discharge inception voltage (U_i)**

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

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

1.3.18.5**partial discharge extinction voltage (U_e)**

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

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

1.3.18.6**partial discharge test voltage (U_t)**

peak value of the test voltage for the procedure of 4.1.2.4.2 at which the apparent charge has to be less than the specified discharge magnitude

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

1.3.19 Tests**1.3.19.1****type test**

test of one or more devices made to a certain design to show that the design meets certain specifications (IEV 151-04-15)

1.3.19.2**routine test**

test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria (IEV 151-04-16)

1.3.19.3**sampling test**

test on a number of devices taken at random from a batch (IEV 151-04-17)

1.3.20**electrical breakdown**

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

1.3.20.1

sparkover

electrical breakdown in a gaseous or liquid medium

1.3.20.2

flashover

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

1.3.20.3

puncture

electrical breakdown through solid insulation

SECTION 2: BASIS FOR INSULATION COORDINATION

2.1 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.

2.1.1 Insulation coordination with regard to voltage

Consideration shall be given to:

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

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

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

- rated voltage;
- rated insulation voltage;
- working voltage.

2.1.1.2 Insulation coordination with regard to transient overvoltage

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

- inherent control: The condition within an electrical system wherein the characteristics of the system can be expected to limit the prospective transient overvoltages to a defined level;

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

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

NOTE 2 A probabilistic analysis is recommended to assess whether inherent control exists or whether protective control is needed. This analysis requires knowledge of the electrical system characteristics, the keraunic levels, transient overvoltage levels, etc. This approach has been used in IEC 60364-4-443 for electrical installations of buildings connected to low-voltage mains.

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

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

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

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

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

2.1.1.3 Insulation coordination with regard to recurring peak voltage

Consideration shall be given to the extent partial-discharges can occur in solid insulation (see 3.3.2.2.1) or along surfaces of insulation (under consideration).

2.1.1.4 Insulation coordination with regard to temporary overvoltage

Insulation coordination with regard to temporary overvoltages is based on the temporary overvoltage specified in IEC 60364-4-442 (see 3.3.3.2.2 in this standard).

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

2.1.2 Insulation coordination with regard to environmental conditions

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

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

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

The most important environmental parameters are as follows:

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

2.2 Voltages and voltage ratings

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

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

2.2.1 Determination of voltage for long-term stresses

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

2.2.1.1 Voltage for dimensioning basic insulation

2.2.1.1.1 Equipment energized directly from the low-voltage mains

The nominal voltages of the low-voltage mains have been rationalized according to tables 3a and 3b (see 3.2.1.1) and these voltages are the minimum to be used for the selection of creepage distances. They may also be used for the selection of rated insulation voltages.

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

Technical Committees shall consider whether the voltage is to be selected:

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

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

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

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

NOTE Fault conditions are not taken into account.

2.2.1.2 Voltage for dimensioning functional insulation

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

2.2.2 Determination of rated impulse voltage

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

2.2.2.1 Overvoltage categories

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

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

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

2.2.2.1.1 Equipment energized directly from the supply mains

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

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

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

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

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

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

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

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

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

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

NOTE 1 Examples of such equipment are those containing electronic circuits protected to this level, however see the note in 2.1.1.4.

NOTE 2 Unless the circuits are designed to take the temporary overvoltages into account, equipment of overvoltage category 1 cannot be directly connected to the supply mains.

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

It is recommended that Technical Committees specify overvoltage categories or rated impulse voltages as appropriate. Application of the preferred series of 2.1.1.2 is recommended.

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

2.2.2.2 Selection of rated impulse voltage for equipment

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

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

NOTE 2 For consideration of the switching overvoltage aspect, see 2.2.2.4.

Table 1 – Rated impulse voltage for equipment energized directly from the low-voltage mains

Nominal voltage of the supply system ¹⁾ based on IEC 60038 ³⁾		Voltage line to neutral derived from nominal voltages a.c. or d.c. up to and including V	Rated impulse voltage ²⁾			
			Overvoltage category ⁴⁾			
Three phase	Single phase		I	II	III	IV
230/400 277/480 400/690 1 000	120-240	50	330	500	800	1 500
		100	500	800	1 500	2 500
		150	800	1 500	2 500	4 000
		300	1 500	2 500	4 000	6 000
		600	2 500	4 000	6 000	8 000
		1 000	4 000	6 000	8 000	12 000
1) See annex B for application to existing different low-voltage mains and their nominal voltages. 2) Equipment with these rated impulse voltages can be used in installations in accordance with IEC 60364-4-443. 3) The / mark indicates a four-wire three-phase distribution system. The lower value is the voltage line-to-neutral, while the higher value is the voltage line-to-line. Where only one value is indicated, it refers to three-wire, three-phase systems and specifies the value line-to-line. 4) See 2.2.2.1.1 for an explanation of the overvoltage categories.						

2.2.2.3 Impulse voltage insulation coordination within equipment

2.2.2.3.1 For parts or circuits within equipment which are significantly influenced by external transient overvoltages, the rated impulse voltage of the equipment applies. Transient overvoltages which can be generated by the operation of the equipment shall not influence external circuit conditions beyond that specified in 2.2.2.4.

2.2.2.3.2 For other parts or circuits within equipment which are specifically protected against transient overvoltages so that they are not significantly influenced by external transient overvoltages, the impulse withstand voltage required for basic insulation is not related to the rated impulse voltage of the equipment but to the actual conditions for that part or circuit. Application of the preferred series of impulse voltage values as introduced in 2.1.1.2 is, however, recommended to permit standardization. In other cases, interpolation of table 2 values is allowed.

2.2.2.4 Switching overvoltage generated by the equipment

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

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

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

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

2.2.2.5 Interface requirements

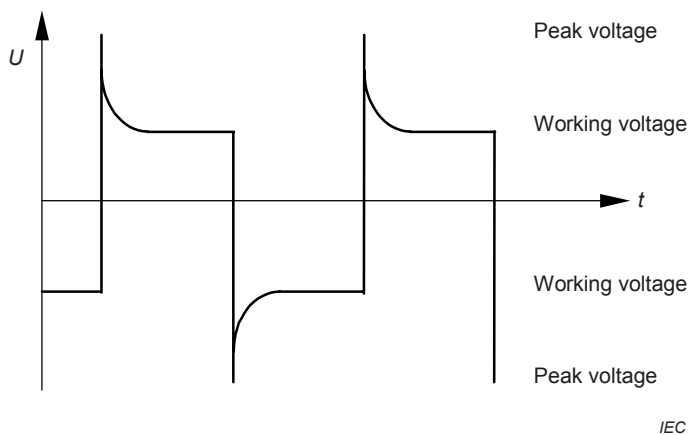
Equipment may be used under the conditions of a higher overvoltage category where appropriate overvoltage reduction is provided. Appropriate overvoltage attenuation can be achieved by:

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

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

2.2.3 Determination of recurring peak voltage

The waveshape of the voltage is measured by an oscilloscope of sufficient bandwidth, from which the peak amplitude is determined according to figure 3.



IEC 1206/02

Figure 3 – Recurring peak voltage

2.2.4 Determination of temporary overvoltage

2.2.4.1 General

Situations related to the most onerous temporary overvoltages due to faults in the supply system are considered in IEC 60364-4-442.

NOTE IEC 60364-4-442 deals with the safety of persons and equipment in a low-voltage system in the event of a fault between the high-voltage system and earth of transformers that supply low-voltage systems.

2.2.4.2 Fault voltage

The magnitude and the duration of the fault voltage or the touch voltage due to an earth fault in the high-voltage system are shown in figure 44A of IEC 60364-4-442.

2.2.4.3 Stress due to temporary overvoltages

The magnitude and duration of a temporary overvoltage in low-voltage equipment due to an earth fault in the high-voltage system are given in 3.3.3.2.2.

2.3 Frequency

Information on the dimensioning for frequencies above 30 kHz is given in IEC 60664-4.

2.4 Time under voltage stress

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

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

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

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

2.5 Pollution

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

Means may be provided to reduce pollution at the insulation under consideration by effective use of enclosures, encapsulation or hermetic sealing. Such means to reduce pollution may not be effective when the equipment is subject to condensation or if, in normal operation, it generates pollutants itself.

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

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

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

2.5.1 Degrees of pollution in the micro-environment

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

- *Pollution degree 1*
No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
- *Pollution degree 2*
Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.
- *Pollution degree 3*
Conductive pollution occurs or dry non-conductive pollution occurs which becomes conductive due to condensation which is to be expected.
- *Pollution degree 4*
Continuous conductivity occurs due to conductive dust, rain or other wet conditions.

2.5.2 Conditions of conductive pollution

The dimensions for creepage distance cannot be specified where permanently conductive pollution is present, e.g. from carbon or metal dust. Instead, the surface of the insulation shall be designed to avoid a continuous path of conductive pollution, e.g. by means of ribs and grooves (see 3.2.1.4).

2.6 Information supplied with the equipment

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

2.7 Insulating material

2.7.1 Comparative tracking index (CTI)

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

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

NOTE Tracking or erosion will occur when

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

Deterioration increases with the time for which the current flows.

2.7.1.2 A method of classification for insulating materials according to 2.7.1.1 does not exist. The behaviour of the insulating material under various contaminants and voltages is extremely complex. Under these conditions, many materials may exhibit two or even all three of the characteristics stated. A direct correlation with the material groups of 2.7.1.3 is not practical. However, it has been found by experience and tests that insulating materials having a higher relative performance also have approximately the same relative ranking according to the comparative tracking index (CTI). Therefore, this standard uses the CTI values to categorize insulating materials.

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

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

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

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

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

2.7.2 Electric strength characteristics

The electric strength characteristics of insulating material shall be considered by the technical committees, taking into account the stresses described in 3.3.1, 3.3.2.1.1 and 3.3.2.2.1.

2.7.3 Thermal characteristics

The thermal characteristics of insulating material shall be considered by the technical committees taking into account the stresses described in 3.3.2.1.2, 3.3.2.2.2 and 3.3.3.5.

NOTE See also IEC 60216.

2.7.4 Mechanical and chemical characteristics

The mechanical and chemical characteristics of insulating material shall be considered by the technical committees, taking into account the stresses described in 3.3.2.1.3, 3.3.2.2.3 and 3.3.2.3.