INTERNATIONAL STANDARD

IEC 60076-3

Second edition
2000-03

Power transformers –

Part 3:
Insulation levels, dielectric tests and external clearances in air

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60076-3 has been prepared by IEC technical committee 14: Power transformers.

This second edition cancels and replaces the first edition published in 1980, amendment 1 (1981) and IEC 60076-3-1 (1987).

The text of this standard is based on the following documents:

FDIS	Report on voting
14/347/FDIS	14/355/RVD

Full information on the voting for the approval of this standard 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 3.

Annexes A, B and C are for information only.

Annex D forms an integral part of this standard.

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

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

The contents of the corrigendum of December 2000 have been included in this copy.

INTRODUCTION

This part of IEC 60076 specifies the insulation requirements and the corresponding insulation tests with reference to specific windings and their terminals. It also recommends clearances in air between live parts of bushings on oil-immersed power transformers and to objects at earth potential (clause 16). Guidance can be obtained from IEC 60071.

The insulation levels and dielectric tests which are specified in clauses 4, 5, 6 and 7 in this standard apply to the internal insulation only. Whilst it is reasonable that the rated withstand voltage values which are specified for the internal insulation of the transformer should also be taken as a reference for its external insulation, this may not be true in all cases. A failure of the non-self-restoring internal insulation is catastrophic and normally leads to the transformer being out of service for a long period, while an external flashover may involve only a short interruption of service without causing lasting damage. Therefore, it may be that, for increased safety, higher test voltages are specified by the purchaser for the internal insulation of the transformer than for the external insulation of other components in the system. When such a distinction is made, the external clearances must be adjusted to fully cover the internal insulation test requirements.

POWER TRANSFORMERS –

Part 3: Insulation levels, dielectric tests and external clearances in air

1 Scope

This International Standard applies to single-phase and three-phase oil-immersed power transformers (including auto-transformers), with the exception of certain small and special transformers, as defined in the scope of IEC 60076-1. It identifies transformer windings to their highest voltage for equipment U_m associated with their corresponding rated insulation levels and details the relevant applicable dielectric tests and minimum external clearances in air between live parts of bushings and to objects at earth potential.

For categories of power transformers and reactors which have their own IEC standards, this standard is applicable only to the extent in which it is specifically called up by cross reference in the other standards.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60076. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 60076 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60050(421), *International Electrotechnical Vocabulary (IEV) – Chapter 421: Power transformers and reactors*

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

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

IEC 60071-1:1993, *Insulation coordination – Part 1: Definitions, principles and rules*

IEC 60071-2:1976, *Insulation coordination – Part 2: Application guide*

IEC 60076-1, *Power transformers – Part 1: General*

IEC 60137:1995, *Bushings for alternating voltages above 1 000 V*

IEC 60270, *Partial discharge measurements*

IEC 60722, *Guide to the lightning impulse and switching impulse testing of power transformers and reactors*

IEC 60790, *Oscilloscopes and peak voltmeters for impulse tests*

IEC 61083-1, *Digital recorders for measurements in high-voltage impulse tests – Part 1: Requirements for digital recorders*

IEC 61083-2, *Digital recorders for measurements in high-voltage impulse tests – Part 2: Evaluation of software used for the determination of the parameters of impulse waveforms*

CISPR 16-1:1993, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus*

3 Definitions

For the purpose of this part of IEC 60076, the following definitions apply. Other terms used have the meanings ascribed to them in IEC 60076-1 or in IEC 60050(421).

3.1
highest voltage for equipment U_m applicable to a transformer winding
the highest r.m.s. phase-to-phase voltage in a three-phase system for which a transformer winding is designed in respect of its insulation

3.2
rated insulation level
a set of standard withstand voltages which characterize the dielectric strength of the insulation

3.3
standard insulation level
a rated insulation level, the standard withstand voltages of which are associated to U_m as recommended in tables 2 and 3 of IEC 60071-1

3.4
uniform insulation of a transformer winding
the insulation of a transformer winding when all its ends connected to terminals have the same rated insulation level

3.5
non-uniform insulation of a transformer winding
the insulation of a transformer winding when it has a neutral terminal end for direct or indirect connection to earth, and is designed with a lower insulation level than assigned for the line terminal

4 General

The insulation requirements for power transformers and the corresponding insulation tests are given with reference to specific windings and their terminals.

For oil-immersed transformers, the requirements apply to the internal insulation only. Any additional requirements or tests regarding external insulation which are deemed necessary shall be subject to agreement between supplier and purchaser, including type tests on a suitable model of the configuration.

If the purchaser intends to make the connections to the transformer in a way which may reduce the clearances provided by the transformer alone, this should be indicated in the enquiry.

When an oil-immersed transformer is specified for operation at an altitude higher than 1 000 m, clearances shall be designed accordingly. It may then be necessary to select bushings designed for higher insulation levels than those specified for the internal insulation of the transformer windings, see clause 16 of this standard and 4.2 of IEC 60137.

Bushings are subject to separate type and routine tests according to IEC 60137, which verify their phase-to-earth insulation, external as well as internal.

It is presupposed that bushings and tap-changers are specified, designed and tested in accordance with relevant IEC standards. The insulation tests on the complete transformer, however, constitute a check on the correct application and installation of these components.

The insulation test shall generally be made at the supplier's works with the transformer approximately at ambient temperature, but at least at 10 °C.

The transformer shall be completely assembled as in service including supervisory equipment. It is not necessary, however, to fit elements which do not influence the dielectric strength of the internal insulation, for example, the external cooling equipment.

If a transformer fails to meet its test requirements and the fault is in a bushing, it is permissible to replace this bushing temporarily with another bushing and continue the test on the transformer to completion without delay. A particular case arises for tests with partial discharge measurements, where certain types of commonly used high-voltage bushings create difficulties because of their relatively high level of partial discharge in the dielectric. When such bushings are specified by the purchaser, it is permitted to exchange them for bushings of a partial discharge free type during the testing of the transformer, see annex A.

Transformers for cable box connection or direct connection to metal-enclosed SF_6 installations should be designed so that temporary connections can be made for insulation tests, using temporary bushings, if necessary. By agreement, oil/SF_6 bushings may for that reason be replaced by appropriate oil/air bushings.

When the supplier intends to use non-linear elements or surge arresters, built into the transformer or externally fitted, for the limitation of transferred overvoltage transients, this shall be brought to the purchaser's attention at the tender and order stage and it is recommended that it be indicated on the transformer rating plate circuit diagram.

5 Highest voltage for equipment and insulation level

To each winding of a transformer, both for the line and neutral side, is assigned a value of highest voltage for equipment U_m, see 3.1.

The rules for coordination of transformer insulation with respect to transient overvoltages are formulated differently depending on the value of U_m.

When rules about related tests for different windings in a transformer are in conflict, the rule for the winding with the highest U_m value shall apply for the whole transformer.

Rules for a number of special classes of transformers are given in clause 6.

Standardized values of U_m are listed in tables 2 to 4. The value to be used for a transformer winding is the one equal to, or nearest above, the rated value of the winding.

NOTE 1 Single-phase transformers intended for connection in star to form a three-phase bank are designated by phase-to-earth rated voltage, for example 400/$\sqrt{3}$ kV. The phase-to-phase value determines the choice of U_m in this case, consequently, U_m = 420 kV.

NOTE 2 It may happen that certain tapping voltages are chosen slightly higher than a standardized value of U_m, but that the system to which the winding will be connected has a system highest voltage which stays within the standard value. The insulation requirements are to be coordinated with actual conditions, and therefore this standard value should be accepted as U_m for the transformer, and not the nearest higher value.

NOTE 3 In certain applications with very special conditions the specification of other combinations of withstand voltages may be justified. In such cases, general guidance should be obtained from IEC 60071-1.

NOTE 4 In certain applications, delta-connected windings are earthed through one of the external terminals. In those applications, a higher withstand voltage with respect to the highest voltage for equipment U_m may be required for this winding and should be agreed between supplier and purchaser.

The highest voltage for equipment U_m and its assigned withstand voltages, that is, their insulation level, determine the dielectric characteristics of a transformer. They are verified by a set of dielectric tests depending on U_m, see clause 7.

The value of U_m and the insulation level which are assigned to each winding of a transformer are part of the information to be supplied with an enquiry and with an order. If there is a winding with non-uniform insulation, the assigned U_m and the insulation level of the neutral terminal shall also be specified by the purchaser, see 7.4.3.

The rated withstand voltages for all windings shall appear on the rating plate. The principles of the standard abbreviated notation are shown in some examples below.

The classifications on the insulation design shall independently of the test procedure be derived from the values in table 2, 3 and 4 or from IEC 60071-1. Since in most cases the long-duration induced AC tests are quality control tests in respect to service conditions and not design proving tests, the insulation level shall be characterized as follows:

U_m is the highest voltage for equipment
SI/LI/AC,

where applicable –/LI/AC.

The abbreviations here and in the examples below have the following meaning:

SI is the switching impulse withstand voltage for the line terminals of the winding with the highest U_m;

LI is the lightning impulse withstand voltage for the line and neutral terminals of each individual winding;

AC is the short duration induced and separate source AC withstand voltage for the line and neutral terminals of each individual winding;

h.v. high voltage;

l.v. low voltage;

m.v. medium voltage.

Example 1:

U_m (h.v.) = 72,5 kV and U_m (l.v.) = 12 kV, both uniformly insulated, Y connected

Insulation levels:	h.v. line terminal and neutral	LI/AC	325/140 kV
	l.v. line terminal and neutral	LI/AC	60/28 kV

Example 2:

U_m (h.v.) line = 245 kV, Y connected;

U_m (h.v.) neutral = 52 kV;

U_m (m.v.) line = 72,5 kV, uniform insulation, Y connected;

U_m (l.v.) line = 24 kV, D connected.

Insulation levels:	h.v. line terminal	SI/LI	650/850 kV
	h.v. neutral	LI/AC	250/95 kV
	m.v. line terminal and neutral	LI/AC	325/140 kV
	l.v. line terminal	LI/AC	125/50 kV

Example 3:

Auto-transformer with U_m = 420 kV and 145 kV with an assigned U_m = 17,5 kV for the neutral for direct earth connection, Y connected. U_m (l.v.) line terminal = 24 kV, D connected.

Insulation levels:	h.v. line terminal	SI/LI	1 050/1 300 kV
	m.v. line terminal	LI/AC	550/230 kV
	h.v./m.v. neutral	LI/AC	–/38 kV
	l.v. line terminal	LI/AC	125/50 kV

or if additionally a short-duration induced test is required:

Insulation levels:	h.v. line terminal	SI/LI/AC	1 050/1 300/570 kV
	m.v. line terminal	LI/AC	550/230 kV
	h.v./m.v. neutral	LI/AC	–/38 kV
	l.v. line terminal	LI/AC	125/50 kV

6 Rules for some particular transformers

In transformers where uniformly insulated windings having different U_m values are connected together within the transformer (usually auto-transformers), the separate source AC withstand test voltages shall be determined by the insulation of the common neutral and its assigned U_m.

In transformers which have one or more non-uniformly insulated windings, the test voltages for the induced withstand voltage test, and for the switching impulse test if used, are determined by the winding with the highest U_m value, and the windings with lower U_m values may not receive their appropriate test voltages. This discrepancy should normally be accepted. If the ratio between the windings is variable by tappings, this should be used to bring the test voltage for the winding with lower U_m voltage as close as possible to the appropriate value.

During switching impulse tests, the voltages developed across different windings are approximately proportional to the ratio of numbers of turns. Rated switching impulse withstand voltages shall only be assigned to the winding with the highest U_m. Test stresses in other windings are also proportional to the ratio of numbers of turns and are adjusted by selecting appropriate tappings to come as close as possible to the assigned value in table 4. The switching impulse test stresses in other windings shall be limited to approximately 80 % of the assigned lightning impulse withstand voltages at these terminals.

Series windings in booster regulating transformers, phase shifting transformers, etc. where the rated voltage of the winding is only a small fraction of the voltage of the system, shall have a value of U_m corresponding to the system voltage. It is often impracticable to test such transformers in formal compliance with this standard, and it should be agreed between the supplier and the purchaser as to which tests have to be omitted or modified.

For single-phase transformers intended to be connected between phases, as in the case of railway traction system supplies, higher test values than indicated in this standard may be necessary.

Special considerations with respect to test connections and number of tests to be performed on multiple re-connectable transformers shall be agreed at the time of placing the order.

7 Insulation requirements and dielectric tests – Basic rules

Transformer windings are identified by their highest voltage for equipment U_m associated to their corresponding insulation levels. This clause details the relevant insulation requirements and applicable dielectric tests. For categories of power transformers and reactors which have their own IEC standards, the requirements are applicable only to the extent in which they are specifically called up by cross reference in the other standards.

7.1 General

The basic rules for insulation requirements and dielectric tests are summarized in table 1.

Levels of standard withstand voltages, identified by the highest voltage for equipment U_m of a winding are given in tables 2, 3 and 4. The choice between the different levels of standard withstand voltages in these tables depends on the severity of overvoltage conditions to be expected in the system and on the importance of the particular installation. Guidance may be obtained from IEC 60071-1.

NOTE 1 Distribution transformers for suburban or rural installation are, in some countries, severely exposed to overvoltages. In such cases, higher test voltages, lightning impulse tests and other tests on individual units may be agreed between supplier and purchaser. They should be clearly stated in the enquiry document.

NOTE 2 Other combinations of U_m may exist in some countries.

Information about the selected transformer insulation requirements and dielectric tests shall be supplied with an enquiry and with an order, see annex C.

The insulation requirements are specified in 7.2. The verification of the withstand voltages by dielectric tests is given in 7.3. The insulation requirements and tests for the neutral terminal of a winding are given in 7.4.