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EN 60076-4

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English version

Power transformers
Part 4: Guide to the lightning impulse and switching impulse testing - Power transformers and reactors
(IEC 60076-4:2002)

Transformateurs de puissance
Partie 4: Guide pour les essais au choc de foudre et au choc de manoeuvre - Transformateurs de puissance et bobines d'inductance
(CEI 60076-4:2002)

Leistungstransformatoren
Teil 4: Leitfaden zur Blitz- und Schaltstoßspannungsprüfung von Leistungstransformatoren und Drosselspulen
(IEC 60076-4:2002)

This European Standard was approved by CENELEC on 2002-09-01. 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.

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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

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Foreword

The text of document 14/413/FDIS, future edition 1 of IEC 60076-4, prepared by IEC TC 14, Power transformers, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60076-4 on 2002-09-01.

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)	2003-06-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2005-09-01

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 and B are informative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60076-4:2002 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60060-1	- [1]	High-voltage test techniques Part 1: General definitions and test requirements	HD 588.1 S1	1991 [2]
IEC 60060-2	- [1]	Part 2: Measuring systems	EN 60060-2	1994 [2]
IEC 60076-3	- [1]	Power transformers Part 3: Insulation levels, dielectric tests and external clearances in air	EN 60076-3	2001 [2]
IEC 60289	- [1]	Reactors	EN 60289	1994 [2]
IEC 61083-1	- [1]	Instruments and software used for measurement in high-voltage impulse tests Part 1: Requirements for instruments	EN 61083-1	2001 [2]
IEC 61083-2	- [1]	Digital recorders for measurements in high-voltage impulse tests Part 2: Evaluation of software used for the determination of the parameters of impulse waveforms	EN 61083-2	1997 [2]

[1] Undated reference.

[2] Valid edition at date of issue.

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Transformateurs de puissance –

Partie 4: Guide pour les essais au choc de foudre et au choc de manoeuvre – Transformateurs de puissance et bobines d'inductance

Power transformers –

Part 4: Guide to the lightning impulse and switching impulse testing – Power transformers and reactors

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Международная Электротехническая Комиссия

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

POWER TRANSFORMERS –

Part 4: Guide to the lightning impulse and switching impulse testing – Power transformers and reactors

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 60076-4 has been prepared by IEC technical committee 14: Power transformers.

This International Standard cancels and replaces IEC 60722 published in 1982 and constitutes a technical revision of that document.

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

FDIS	Report on voting
14/413/FDIS	14/446/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 and B are for information only.

IEC 60076 consists of the following parts, under the general title *Power transformers:*

Part 1: General

Part 2: Temperature rise

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

Part 4: Guide to lightning impulse and switching impulse testing – Power transformers and reactors

Part 5: Ability to withstand short-circuit

Part 8: Application guide

Part 10: Determination of sound levels

The committee has decided that the contents of this publication will remain unchanged until 2007. At this date, the publication will be

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

POWER TRANSFORMERS –

Part 4: Guide to the lightning impulse and switching impulse testing – Power transformers and reactors

1 Scope

This part of IEC 60076 gives guidance and explanatory comments on the existing procedures for lightning and switching impulse testing of power transformers to supplement the requirements of IEC 60076-3. It is also generally applicable to the testing of reactors (see IEC 60289), modifications to power transformer procedures being indicated where required.

Information is given on waveshapes, test circuits including test connections, earthing practices, failure detection methods, test procedures, measuring techniques and interpretation of results.

Where applicable, the test techniques are as recommended in IEC 60060-1 and IEC 60060-2.

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 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 60076-3, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60289, *Reactors*

IEC 61083-1, *Instruments and software used for measurement in high-voltage impulse tests – Part 1: Requirements for instruments*

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*

3 General

This standard is primarily based on the use of conventional impulse generators for both lightning and switching impulse testing of transformers and reactors. The practice of switching impulse generation with discharge of a separate capacitor into an intermediate or low-voltage winding is also applicable. However, the method which employs an additional inductance in series with the capacitor to provide slightly damped oscillations transferred into the high-voltage winding is not applicable.

Alternative means of switching impulse generation or simulation such as d.c. current interruption on an intermediate or low-voltage winding or the application of a part-period of power frequency voltage are not discussed since these methods are not as generally applicable.

Different considerations in the choice of test circuits (terminal connections) for lightning and switching impulse tests apply for transformers and reactors. On transformers, all terminals and windings can be lightning impulse tested to specific and independent levels. In switching impulse testing, however, because of the magnetically transferred voltage, a specified test level may only be obtained on one winding (see IEC 60076-3).

Whilst, on reactors, lightning impulse testing is similar to that on transformers, i.e., all terminals can be tested separately, different considerations apply and different problems arise in switching impulse testing. Hence, in this standard, lightning impulse testing is covered by a common text for both transformers and reactors whilst switching impulse testing is dealt with separately for the two types of equipment.

4 Specified waveshapes

The voltage waveshapes to be used normally during lightning and switching impulse testing of transformers and reactors are given in IEC 60076-3 and the methods for their determination are given in IEC 60060-1.

5 Test circuit

The physical arrangement of test equipment, test object and measuring circuits can be divided into three major circuits:

– the main circuit including the impulse generator, additional waveshaping components and the test object;
– the voltage measuring circuit;
– the chopping circuit where applicable.

This basic arrangement is shown in figure 1.

The following parameters influence the impulse waveshape;

a) the effective capacitance C_t, and inductance of the test object, L_t; C_t is constant for any given design and any given waveshape, L_t is also a constant for any given design. The effective L_t, however, may be influenced by the terminal treatment. It varies between the leakage inductance L_s for short-circuited terminals and L_o for open-circuited terminals. More details in this respect are given in 7.1 and 7.3 and in annex A;

b) the generator capacitance C_g;

c) waveshaping components, both internal and external to the generator, R_{si}, R_{se}, R_p, C_L (plus, where applicable, the impedance of a voltage divider Z_1);

d) the stray inductance and capacitance of the generator and the complete test circuit;

e) chopping equipment, where applicable.

The front time T_1 is determined mainly by combination of the effective surge capacitance of the test object, including C_L, and the generator internal and external series resistances.

The time to half-value T_2 is, for lightning impulses, primarily determined by the generator capacitance, the inductance of the test object and the generator discharge resistance or any other parallel resistance. However, there are cases, for example, windings of extremely low inductance, where the series resistance will have a significant effect also on the wavetail. For switching impulses, other parameters apply; these are dealt with in clause 8.

The test equipment used in lightning and switching impulse applications is basically the same. Differences are in details only, such as values of resistors and capacitors (and the terminal connections of the test object).

To meet the different requirements of the waveshape for lightning and switching impulses, due consideration has to be given to the selection of the impulse generator parameters, such as capacitance and series and discharge (parallel) resistances. For switching impulses, large values of series resistors and/or load capacitors may be necessary, which will result in significant reduction of the efficiency.

While the output voltage of the impulse generator is determined by the test levels of the windings with respect to their highest voltage for equipment U_m for the test object, the required energy storage capability is essentially dependent on the inherent impedances of the test object.

A brief explanation of the principles of waveshape control is given in annex A.

The arrangement of the test plant, test object and the interconnecting cables, earthing strips, and other equipment is limited by the space in the test room and, particularly, the proximity effect of any structures. During impulse testing, zero potential cannot be assumed throughout the earthing systems due to the high values and rates of change of impulse currents and voltages and the finite impedances involved. Therefore, the selection of a proper reference earth is important.

The current return path between the test object and the impulse generator should be of low impedance. It is good practice to firmly connect this current return path to the general earth system of the test room, preferably close to the test object. This point of connection should be used as reference earth and to attain good earthing of the test object it should be connected to the reference earth by one or several conductors of low impedance (see IEC 60060-2).

The voltage measuring circuit, which is a separate loop of the test object carrying only the measuring current and not any major portion of the impulse current flowing through the windings under test, should also be effectively connected to the same reference earth.

In switching impulse testing, since the rates of change of the impulse voltages and currents are much reduced compared with those in a lightning impulse test and no chopping circuit is involved, the problems of potential gradients around the test circuit and with respect to the reference earth are less critical. Nevertheless, it is suggested that, as a precaution, the same earthing practices should be followed as used for lightning impulse testing.

6 Calibration

It is not the intention of this standard to give any recommendation on measuring systems or their calibration but, of course, the apparatus which is used should be approved in accordance with IEC 60060. Before a test, an overall check of the test circuit and the measuring system may be performed at a voltage lower than the reduced voltage level. In this check, voltage may be determined by means of a sphere gap or by comparative measurement with another approved device. When using a sphere gap, it should be recognized that this is only a check and does not replace the periodically performed calibration of the approved measuring system. After any check has been made, it is essential that neither the measuring nor the test circuit is altered except for the removal of any devices for checking.

Information on types of voltage dividers, their applications, accuracy, calibration and checking is given in IEC 60060-2.

7 Lightning impulse tests

7.1 Waveshapes

The values of waveshape specified may not always be obtainable. In the impulse testing of large power transformers and reactors, of low winding inductance and/or high surge capacitance, wider tolerances may have to be accepted.

The surge capacitance of the transformer under test being constant, the series resistance may have to be reduced in an attempt to obtain the correct front time T_1 or rate of rise, but the reduction should not be to the extent that oscillations on the crest of the voltage wave become excessive. If it is considered desirable to have a short front time (preferably within the specified limits) then oscillations and/or overshoots greater than ±5 % of the peak voltage, allowed in IEC 60060-1, may have to be accepted. In such an event, a compromise between the extent of allowable oscillations and the obtainable front time is necessary. In general, oscillations not greater than ±10 % should be aimed at, even with extensions to the front time as necessary and as agreed between manufacturer and purchaser. The value of the test voltage is determined according to the principles of IEC 60060-1.