INTERNATIONAL STANDARD

IEC 60076-5

Second edition
2000-07

Power transformers –

Part 5: Ability to withstand short circuit

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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 60076-5 has been prepared by IEC technical committee 14: Power transformers.

This second edition cancels and replaces the first edition published in 1976 and amendment 2 (1994). This second edition constitutes a technical revision.

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

FDIS	Report on voting
14/346/FDIS	14/353/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.

Annex A is for information only.

Annex B forms an integral part of this standard.

The committee has decided that this publication remains valid until 2004. At this date, in accordance with the committee's decision, the publication will be

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- withdrawn;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

POWER TRANSFORMERS –

Part 5: Ability to withstand short circuit

1 Scope

This part of IEC 60076 identifies the requirements for power transformers to sustain without damage the effects of overcurrents originated by external short circuits. It describes the calculation procedures used to demonstrate the thermal ability of a power transformer to withstand such overcurrents and both the special test and the calculation method used to demonstrate its ability to withstand the relevant dynamic effects. The requirements apply to transformers as defined in the scope of IEC 60076-1.

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 60076-1:1993, *Power transformers – Part 1: General*

IEC 60076-8:1997, *Power transformers – Part 8: Application guide*

IEC 60726:1982, *Dry-type power transformers*

3 Requirements with regard to ability to withstand short circuit

3.1 General

Transformers together with all equipment and accessories shall be designed and constructed to withstand without damage the thermal and dynamic effects of external short circuits under the conditions specified in 3.2.

External short circuits are not restricted to three-phase short circuits; they include line-to-line, double-earth and line-to-earth faults. The currents resulting from these conditions in the windings are designated as 'overcurrents' in this part of IEC 60076.

3.2 Overcurrent conditions

3.2.1 General considerations

3.2.1.1 Application conditions requiring special consideration

The following situations affecting overcurrent magnitude, duration, or frequency of occurrence require special consideration and shall be clearly identified in transformer specifications:

- regulating transformers with very low impedance that depend on the impedance of directly connected apparatus to limit overcurrents;
- unit generator transformers susceptible to high overcurrents produced by connection of the generator to the system out of synchronism;
- transformers directly connected to rotating machines, such as motors or synchronous condensers, that can act as generators to feed current into the transformer under system fault conditions;
- special transformers and transformers installed in systems characterized by high fault rates; see 3.2.6;
- operating voltage higher than rated maintained at the unfaulted terminal(s) during a fault condition.

3.2.1.2 Current limitations concerning booster transformers

When the combined impedance of the booster transformer and the system result in short-circuit current levels for which the transformer cannot feasibly or economically be designed to withstand, the manufacturer and the purchaser shall mutually agree on the maximum allowed overcurrent. In this case, provision should be made by the purchaser to limit the overcurrent to the maximum value determined by the manufacturer and stated on the rating plate.

3.2.2 Transformers with two separate windings

3.2.2.1 For the purpose of this standard, three categories for the rated power of three-phase transformers or three-phase banks are recognized:

- category I: up to 2 500 kVA;
- category II: 2 501 kVA to 100 000 kVA;
- category III: above 100 000 kVA.

3.2.2.2 In the absence of other specifications, the symmetrical short-circuit current (r.m.s. value, see 4.1.2) shall be calculated using the measured short-circuit impedance of the transformer plus the system impedance.

For transformers of category I, the contribution of the system impedance shall be neglected in the calculation of the short-circuit current if this impedance is equal to or less than 5 % of the short-circuit impedance of the transformer.

The peak value of the short-circuit current shall be calculated in accordance with 4.2.3.

3.2.2.3 Commonly recognized minimum values for the short-circuit impedance of transformers at rated current (principal tapping) are given in table 1. If lower values are required, the ability of the transformer to withstand short circuit shall be subject to agreement between the manufacturer and the purchaser.

Table 1 – Recognized minimum values of short-circuit impedance for transformers with two separate windings

Short-circuit impedance at rated current	
Rated power kVA	**Minimum short-circuit impedance** %
Up to 630	4,0
631 to 1 250	5,0
1 251 to 2 500	6,0
2 501 to 6 300	7,0
6 301 to 25 000	8,0
25 001 to 40 000	10,0
40 001 to 63 000	11,0
63 001 to 100 000	12,5
Above 100 000	>12,5

NOTE 1 Values for rated power greater than 100 000 kVA are generally subjected to agreement between manufacturer and purchaser.

NOTE 2 In case of single-phase units connected to form a three-phase bank, the value of rated power applies to three-phase bank rating.

3.2.2.4 The short-circuit apparent power of the system at the transformer location should be specified by the purchaser in his enquiry in order to obtain the value of the symmetrical short-circuit current to be used for the design and tests.

If the short-circuit apparent power of the system is not specified, the values given in table 2 shall be used.

Table 2 – Short-circuit apparent power of the system

Highest voltage for equipment, U_m kV	**Short-circuit apparent power** MVA	
	Current European practice	**Current North American practice**
7,2; 12; 17,5 and 24	500	500
36	1 000	1 500
52 and 72,5	3 000	5 000
100 and 123	6 000	15 000
145 and 170	10 000	15 000
245	20 000	25 000
300	30 000	30 000
362	35 000	35 000
420	40 000	40 000
525	60 000	60 000
765	83 500	83 500

NOTE If not specified, a value between 1 and 3 should be considered for the ratio of zero-sequence to positive-sequence impedance of the system.

3.2.2.5 For transformers with two separate windings, normally only the three-phase short circuit is taken into account, as the consideration of this case is substantially adequate to cover also the other possible types of fault (exception is made in the special case considered in the note to 3.2.5).

NOTE In the case of winding in zigzag connection, the single-line-to-earth fault current may reach values higher than the three-phase short-circuit current. However, these high values are limited, in the two limbs concerned, to a half of the coil and furthermore the currents in the other star-connected winding are lower than for a three-phase short circuit. Electrodynamic hazard to the winding assembly may be higher either at three- or single-phase short circuit depending on the winding design. The manufacturer and the purchaser should agree which kind of short circuit is to be considered.

3.2.3 Transformers with more than two windings and auto-transformers

The overcurrents in the windings, including stabilizing windings and auxiliary windings, shall be determined from the impedances of the transformer and the system(s). Account shall be taken of the different forms of system faults that can arise in service, for example line-to-earth faults and line-to-line faults associated with the relevant system and transformer earthing conditions; see IEC 60076-8. The characteristics of each system (at least the short-circuit apparent power level and the range of the ratio between zero-sequence impedance and positive-sequence impedance) shall be specified by the purchaser in his enquiry.

Delta-connected stabilizing windings of three-phase transformers shall be capable of withstanding the overcurrents resulting from different forms of system faults that can arise in service associated with relevant system earthing conditions.

In the case of single-phase transformers connected to form a three-phase bank, the stabilizing winding shall be capable of withstanding a short-circuit on its terminals, unless the purchaser specifies that special precautions will be taken to avoid the risk of line-to-line short circuits.

NOTE It may not be economical to design auxiliary windings to withstand short circuits on their terminals. In such cases, the overcurrent level must be limited by appropriate means, such as series reactors or, in some instances, fuses. Care must be taken to guard against faults in the zone between the transformer and the protective apparatus.

3.2.4 Booster transformers

The impedance of booster transformers can be very low and, therefore, the overcurrents in the windings are determined mainly by the characteristics of the system at the location of the transformer. These characteristics shall be specified by the purchaser in his enquiry.

If a booster transformer is directly associated to a transformer for the purpose of voltage amplitude and/or phase variation, it shall be capable of withstanding the overcurrents resulting from the combined impedance of the two machines.

3.2.5 Transformers directly associated with other apparatus

Where a transformer is directly associated with other apparatus, the impedance of which would limit the short-circuit current, the sum of impedance of the transformer, the system and the directly associated apparatus may, by agreement between the manufacturer and the purchaser, be taken into account.

This applies, for example, to unit generator transformers if the connection between generator and transformer is constructed in such a way that the possibility of line-to-line or double-earth faults in this region is negligible.

NOTE If the connection between generator and transformer is constructed in this way, the most severe short-circuit conditions may occur, in the case of a star/delta-connected unit generator transformer with earthed neutral, when a line-to-earth fault occurs on the system connected to the star-connected winding, or in the case of out-of-phase synchronization.