
Power transformers

Part 1. General

Transformateurs de puissance
Partie 1. Généralités

Leistungswandler
Teil 1. Allgemeines

Foreword

This revision of BS 171 : 1970, of which this is Part 1, was prepared under the direction of the Power Electrical Engineering Standards Committee and published in 1978. In the revision the standard was divided into five Parts which were identical with the corresponding Parts of Publication 76 'Power transformers', of the International Electrotechnical Commission (IEC). These Parts are as follows:

IEC 76	BS 171 : 1978
76-1 : 1976 : Part 1 : General	Part 1
76-2 : 1976 : Part 2 : Temperature rise	Part 2
76-3 : 1980 : Part 3 : Insulation levels and dielectric tests	—
76-4 : 1976 : Part 4 : Tappings and connections	Part 4
76-5 : 1976 : Part 5 : Ability to withstand short circuit	Part 5

Amendment No. 1 implements the requirements of CENELEC HD 398.1 issued on 11 July 1980. Since the HD introduces deviations from IEC Publication 76-1 : 1976, this Part of BS 171 is no longer identical with the IEC Publication.

Publication of Part 3 of this standard has been delayed. IEC Publication 76-3 has been published, but CENELEC harmonization is under consideration and Part 3 of this standard will be deferred until after this has been agreed. Until Part 3 of this standard is published, the insulation levels and dielectric tests of BS 171 : 1970 continue to apply.

Supplementary material relating to power transformers can be found in BS 5953 'Guide on power transformers' Part 1 'Application of power transformers', which is identical with IEC Publication 606. Pending the publication of additional supplementary material, information from the appendices of BS 171 : 1970 remains valid for power transformers for guidance only, as explained in Amendment No. 3 of that standard.

Caution. Concerning the reference to synthetic insulating liquids in 3.1.4 and 5.2*v*), attention is drawn to the fact that because of environmental considerations the use of synthetic insulating liquids containing polychlorinated biphenyls is deprecated.

NOTE. *Textual error in 8.8.2.* The footnote applying to 8.8.2 reads 'Pending publication of Part 3, see Publication 76 (1967)'. However, there is no reference to the auxiliary circuits insulation test in Publication 76 (1967). Therefore for the purposes of this British Standard the footnote is to be taken to read 'Pending publication of Part 3, the auxiliary circuits insulation test is subject to agreement between the manufacturer and the purchaser'.

In due time the text of the international document itself will be corrected.

Cross-references. The following international standards are referred to in the text for information purposes, and for each there is a corresponding British Standard; these are as listed below:

International standard	Corresponding British Standard
IEC 71	BS 5622 Guide for insulation co-ordination (Identical)
IEC 76-2 (clauses 2.2 and 2.3, tables III and IV)	BS 171 Power transformers Part 2 : 1978 Specification for temperature-rise requirements (clauses 2.2 and 2.3, tables III and IV: Identical)
IEC 76-5	Part 5 : 1978 Specification for ability to withstand short circuit (Identical)
IEC 85	BS 2757 Classification of insulating materials for electrical machinery and apparatus on the basis of thermal stability in service (Related)
IEC 146	BS 4417 Semiconductor rectifier equipments (Related)
IEC 185	BS 3938 Current transformers (Related)
IEC 186	BS 3941 Voltage transformers (Related)
IEC 354	CP 1010 Loading guide for oil-immersed transformers (Technically equivalent)
IEC 606	BS 5935 Guide on power transformers Part 1 : 1980 Application of power transformers (Identical)
ISO R3 (now ISO 3)	BS 2045 Preferred numbers (Technically equivalent)
International Electrotechnical Vocabulary (I.E.V.)	BS 4727 Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms (Related)

NOTE 1. The references to IEC 84, IEC 119 and IEC 542, for which there are no corresponding British Standards, constitute informative matter only, and since no mandatory requirements are involved, the validity of this British Standard is not affected.

NOTE 2 A British Standard corresponding to IEC 551 is in course of preparation. In the meantime the requirements of the IEC Publication are to be regarded as applicable for the purposes of this standard.

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British Standard

Power transformers

Part 1. General

1. Scope

This standard applies to power transformers (including auto-transformers) with the exception of certain small and special transformers as follows:

- Single-phase transformers rated at less than 1 kVA and polyphase transformers rated at less than 5 kVA.
- Instrument transformers (covered by IEC Publications 185¹ and 186²).
- Transformers for static convertors (covered by IEC Publications 84,³ 119⁴ and 146⁵).
- Starting transformers.
- Testing transformers.
- Traction transformers mounted on rolling stock.
- Welding transformers.

Where IEC standards do not exist for the transformers mentioned above or for other special transformers, this standard may be applicable either as a whole or in part.

2. Service conditions

2.1 Normal service conditions

This standard gives detailed requirements for transformers for use under the following conditions:

a) Altitude

A height above sea-level not exceeding 1 000 m (3 300 ft).

Note. — For greater altitudes, see Sub-clause 2.2.

b) Temperature of cooling medium

For water-cooled apparatus, cooling water at a temperature not exceeding 25 °C at the inlet.

For air-cooled apparatus, air at a temperature never exceeding 40 °C, and:

- never below –25 °C in the case of outdoor transformers, or
- never below –5 °C in the case of indoor transformers.

In addition, for air-cooled apparatus, an air temperature never exceeding the following values:

- 30 °C average in any one day;
- 20 °C average in any one year.

Note. — For higher temperatures, see Sub-clause 2.2.

c) Wave shape of supply voltage

A supply voltage of which the wave shape is approximately sinusoidal.

¹ Current Transformers.

² Voltage Transformers.

³ Recommendations for Mercury-arc Convertors.

⁴ Recommendations for Polycrystalline Semiconductor Rectifier Stacks and Equipments.

⁵ Semiconductor Convertors.

d) Symmetry of polyphase supply voltages

For polyphase transformers, supply voltages which are approximately symmetrical.

2.2 *Provision for unusual service conditions*

The purchaser shall specify in his enquiry any conditions not covered by the normal service conditions in Sub-clause 2.1.

Supplementary requirements, within defined limits, for the rating and testing of transformers designed for other than the normal service conditions listed in Sub-clause 2.1, are given:

- for air-cooled transformers of the dry and oil-immersed types for operation outside the normal temperature limits of cooling air, in Sub-clause 2.2 of IEC Publication 76-2;
- for all types of transformers for operation at altitudes in excess of 1 000 m (3 300 ft) above sea-level, in Sub-clause 2.3 of IEC Publication 76-2, and IEC Publication 76-3 *, Part 3: Insulation Levels and Dielectric Tests.

Temperature conditions outside the limits covered by the supplementary requirements and special operating conditions, e.g. restricted cooling air circulation, are subject to agreement between the manufacturer and the purchaser.

3. Definitions

For the purposes of this standard, the following definitions apply. Other terms used have the meanings ascribed to them in the International Electrotechnical Vocabulary (I.E.V.).

3.1 *General*

3.1.1 *Transformer ***

A static piece of apparatus which, by electro-magnetic induction, transforms alternating voltage and current between two or more windings at the same frequency and usually at different values of voltage and current.

3.1.2 *Auto-transformer*

A transformer in which at least two windings have a common part.

3.1.3 *Booster transformer*

A transformer of which one winding is intended to be connected in series with a circuit in order to alter its voltage. The other winding is an energizing winding.

3.1.4 *Oil-immersed type transformer*

A transformer of which the core and windings are immersed in an oil.

Note. — For the purposes of this standard, a synthetic insulating liquid, e.g. askarel, is regarded as an oil.

3.1.5 *Dry-type transformer*

A transformer of which the core and windings are not immersed in an insulating liquid.

* Pending publication of Part 3, see Clause 22 of Publication 76 (1967).

** Transformers other than auto-transformers or booster transformers can be designated separate winding transformers. In the case of a two-winding transformer, the term double-wound transformer may be used.

3.1.6 *Sealed transformer*

A transformer which is non-breathing, that is, so sealed that there can be no significant interchange between its contents and the the external atmosphere.

Note. — Sealed transformers fall into two categories:

- a) Transformers in which the total volume of oil, gas, air, or any combination, remains constant over the temperature range.
- b) Transformers in which the total volume of oil, gas, air, or any combination, varies over the temperature range and this variation is accommodated by a sealed flexible container or a flexible membrane.

3.2 *Terminals and neutral point*

3.2.1 *Terminal*

A conducting element intended for connecting a winding to external conductors.

3.2.2 *Line terminal*

A terminal intended for connection to a line conductor of a system.

3.2.3 *Neutral terminal*

a) *For polyphase transformers and polyphase banks of single-phase transformers*

The terminal(s) connected to the neutral point of a star-connected or zigzag-connected winding.

b) *For single-phase transformers*

The terminal intended for connection to a neutral point of a system.

3.2.4 *Neutral point*

The point of a symmetrical system of voltages which is normally at zero potential.

Note. — For a star-connected or zigzag-connected polyphase system, it is the common point.

3.2.5 *Corresponding terminals*

Terminals of different windings of a transformer, marked with the same letter or corresponding symbol.

3.3 *Windings*

3.3.1 *Winding*

The assembly of turns forming an electrical circuit associated with one of the voltages assigned to the transformer.

Note. — For a polyphase transformer, the “winding” is the combination of the phase windings (see Sub-clause 3.3.2).

3.3.2 *Phase winding*

The assembly of turns forming one phase of a polyphase winding.

Note. — The term “phase winding” should not be used for identifying the assembly of coils on a certain leg.

3.3.3 *High-voltage winding* *

The winding having the highest rated voltage.

3.3.4 *Low-voltage winding* *

The winding having the lowest rated voltage.

Note. — For a booster transformer, the winding having the lower rated voltage may be that having the higher insulation level.

3.3.5 *Intermediate-voltage winding* *

A winding of a multi-winding transformer having rated voltage intermediate between the highest and lowest winding rated voltages.

* The winding which receives the active power from the supply system in service conditions can be designated as the “primary”; that which delivers the active power to the load circuit as the “secondary”.

3.3.6 *Auxiliary winding*

A winding intended only for a small load compared with the rated power of the transformer.

3.3.7 *Stabilizing winding*

A supplementary delta-connected winding, especially provided on star-star-connected or star-zigzag-connected transformers to decrease the zero-sequence impedance of the star-connected winding (see Sub-clause 3.7.6).

Notes 1. — Decrease of this impedance may be necessary, for example, to reduce the magnitude of third-harmonic voltages or to stabilize voltages to the neutral.

2. — A winding is regarded as a stabilizing winding if its terminals are not brought out for connection to an external circuit. However, one or two points of the winding which are intended to form the same corner point of the delta may be brought out, for example for earthing. For a three-phase transformer, if other points of the winding are brought out, the winding should be regarded as a normal winding as defined in Sub-clauses 3.3.3, 3.3.4 or 3.3.5, or an auxiliary winding as defined in Sub-clause 3.3.6, as the case may be.

3.3.8 *Common winding*

The common part of the windings of an auto-transformer.

3.3.9 *Series winding*

The part of the winding of an auto-transformer or the winding of a booster transformer which is intended to be connected in series with a circuit.

3.3.10 *Energizing winding*

The winding of a booster transformer which is intended to supply power to the series winding.

3.4 *Rating*

3.4.1 *Rating*

Those numerical values assigned to the quantities which define the operation of the transformer in the conditions specified in this standard and on which the manufacturer's guarantees and the tests are based.

3.4.2 *Rated quantities*

Quantities (voltage, current, etc.) the numerical values of which define the rating.

Notes 1. — Unless otherwise specified, rated quantities are related to principal tapplings (see Sub-clause 3.5.1.1). For quantities related to other tapplings, see Sub-clause 3.5 and IEC Publication 76-4.

2. — Voltages and currents are always expressed by their r.m.s. values, unless otherwise specified.

3.4.3 *Rated voltage of a winding*

The voltage assigned to be applied, or developed at no-load, between the line terminals of a winding of a polyphase transformer, or between the terminals of a winding of a single-phase transformer.

Notes 1. — The rated voltages of all windings appear simultaneously at no-load when the voltage applied to one of them has its rated value.

2. — For single-phase transformers intended to be associated in a three-phase bank, the rated voltage of a winding intended to be connected in star is indicated by a fraction, in which the numerator is the line-to-line voltage, and the denominator is $\sqrt{3}$, for example:

$$\frac{380}{\sqrt{3}} \text{ V}$$

For the series winding of a three-phase booster transformer which is designed as an open winding (see Sub-clause 3.10.5), the voltage is indicated as if the winding were connected in star.

3.4.4 *Rated voltage ratio*

The ratio of the rated voltage of a winding to the rated voltage of another winding associated with a lower or equal rated voltage.

3.4.5 *Rated frequency*

The frequency at which the transformer is designed to operate.

3.4.6 Rated power

A conventional value of apparent power (in kVA or MVA), establishing a basis for the design, the manufacturer's guarantees and the tests, determining a well-defined value for the rated current that may be carried with rated voltage applied, under the conditions specified in this standard.

Notes 1. — If the power of a transformer varies, with different methods of cooling for example, the rated power is the highest power.

2. — Both windings of a two-winding transformer have the same rated power, which by definition is the rated power of the transformer.
3. — For multi-winding transformers, the rated power for each of the windings should be stated. Half the arithmetic sum of the values of the rated power of the windings gives a rough estimate for determining the dimensions of a multi-winding transformer as compared with a two-winding transformer.

3.4.7 Rated current

The current, flowing through a line terminal of a winding, derived by dividing the rated power of the winding by the rated voltage of the winding and by an appropriate phase factor (see Table I, page 25).

Notes 1. — If the delta or other polygon connection is made externally by linking the terminals of two-phase windings in pairs, this current corresponds to the value obtained for the pair of terminals thus connected.

2. — For single-phase transformers intended to be associated in a three-phase bank, the rated current of a winding intended to be connected in delta is indicated by a fraction, in which the numerator is the corresponding line current and the denominator is $\sqrt{3}$, for example:

$$\frac{500}{\sqrt{3}} \text{ A}$$

3.5 Tappings

3.5.1 Definitions relating to a tapped winding

3.5.1.1 Principal tapping

The tapping to which the rated quantities are related.

3.5.1.2 Tapping factor (corresponding to a given tapping)

The ratio $\frac{U_d}{U_N}$ (tapping factor) or $100 \frac{U_d}{U_N}$ (tapping factor expressed as a percentage),

where:

U_N = rated voltage of the winding

U_d = voltage which would be developed at no-load at the terminals of the winding, connected on the tapping concerned, by applying rated voltage to an untapped winding

Note. — The “tapping factor” expresses the relative value of the “effective number of turns” of the tapped winding at the relevant tapping, the basis 1 being the effective number of turns of this winding at the principal tapping.

3.5.1.3 Plus tapping—Minus tapping

A tapping whose tapping factor is higher than 1 (plus tapping) or lower than 1 (minus tapping).

3.5.1.4 Tapping step

The difference between the “tapping factors expressed as a percentage” of two adjacent tappings.

Note. — This is the number of turns of a step referred to the effective number of turns of the winding at the principal tapping and expressed as a percentage.

3.5.1.5 Tapping range

The variation range of the “tapping factor expressed as a percentage” compared with the value “100” (if this factor ranges from $100 + a$ to $100 - b$, the tapping range is said to be $+a\%$, $-b\%$, or $\pm a\%$ if $a = b$).

3.5.2 Tapping voltage ratio (of a pair of windings)

The ratio which is equal to the rated voltage ratio:

- multiplied by the tapping factor of the tapped winding if this is the high-voltage winding;
- divided by the tapping factor of the tapped winding if this is the low-voltage winding.

Note. — While the rated voltage ratio is, by definition, at least equal to 1, the tapping voltage ratio can be lower than 1 (for certain tappings when the rated voltage ratio is close to 1).