

Specification for

Voltage transformers

(Implementation of CENELEC HD 554 S1)

UDC 621.314.21

Committees responsible for this British Standard

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- Association of Consulting Engineers
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- Electricity Association
- Transmission and Distribution Association (BEAMA Limited)

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National foreword

This British Standard has been prepared under the direction of the Power Electrical Engineering Standards Policy Committee. It implements Harmonization Document HD 554 S1 : 1992, published by the European Committee for Electrotechnical Standardization (CENELEC), which was derived from IEC 186 : 1987 plus Amendment No. 1 (1988), published by the International Electrotechnical Commission (IEC).

The CENELEC common modifications have been implemented at the appropriate places in the text and are indicated by a side line in the margin. Parts of the original IEC text that have been modified by CENELEC have been quoted in national annex NA.

This British Standard supersedes BS 3941 : 1975, which is declared obsolescent.

Products may continue to be manufactured to BS 3941 : 1975 until 1 June 1998.

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

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Descriptors: Instrument transformer, voltage transformer, specification, test, marking

English version

Voltage transformers

(IEC 186 : 1987 + A1 : 1988, modified)

Transformateurs de tension
(CEI 186 : 1987 + A1 : 1988, modifiée)

Spannungswandler
(IEC 186 : 1987 + A1 : 1988, modifiziert)

This Harmonization Document was approved by CENELEC on 1992-03-24. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for implementation of this Harmonization Document on a national level.

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

This Harmonization Document exists in three official versions (English, French, German).

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, 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 CENELEC 53rd Technical Board decided the issue of a primary questionnaire on IEC Publication 186 : 1987 and its amendment 1 : 1988. Based on the comments received from National Committees, 56 BT set up a task force (BTTF 56-3) to prepare common modifications. These modifications were discussed on 1988-11-24 and the voting procedure was started on 1990-02-08.

The vote had a positive result for EEC Committees but, taking into account some negative votes received, 65 BT committed BTTF 56-3 to prepare a final text with some improvements, basically of an editorial nature, before ratification. BTTF 56-3 finalized the text on 1990-10-23 for submission to 66 BT, which accepted it for submission to a second vote.

The text of this draft was approved by CENELEC as HD 554 S1 on 24 March 1992.

The following dates were fixed:

- latest date of announcement of the HD at national level (doa) 1992-12-01
- latest date of publication of a harmonized national standard (dop) 1993-06-01
- latest date of withdrawal of conflicting national standards (dow) 1993-06-01

For products which have complied with the relevant national standard before 1993-06-01, as shown by the manufacturer or by a certification body, this previous standard may continue to apply for production until 1998-06-01.

Annexes designated 'normative' are part of the body of the standard. In this standard, annex ZA is normative and annex ZB is informative.

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VOLTAGE TRANSFORMERS

CHAPTER I: GENERAL REQUIREMENTS APPLICABLE TO ALL VOLTAGE TRANSFORMERS

SECTION ONE — GENERAL

1. Scope

This standard applies to new voltage transformers for use with electrical measuring instruments and electrical protective devices at frequencies from 15 Hz to 100 Hz.

The general requirements of this chapter apply to all voltage transformers, but, for certain types, for example capacitor voltage transformers, the requirements are subject to the modifications stated in the appropriate chapter.

Although the requirements relate basically to transformers with separate windings, they are also applicable, where appropriate, to auto-transformers. The standard does not apply to transformers for use in laboratories.

Note. — Requirements specific to three-phase voltage transformers are not included in this standard.

2. General requirements

All the transformers shall be suitable for measuring purposes, but, in addition, certain types may be suitable for protection purposes. Transformers for the dual purpose of measurement and protection shall comply with Chapters I, II, III and IV of this standard.

3. Service conditions

Unless otherwise specified, this standard is valid for the following service conditions.

Note. — The manufacturers should be informed if the conditions, including the conditions under which transformers are to be transported, differ from those specified.

3.1 Ambient air temperature

— maximum	40 °C
— daily mean, not exceeding	30 °C
— minimum, for indoor type transformers	–5 °C
— minimum, for class –25 outdoor type transformers	–25 °C
— minimum, for class –40 outdoor type transformers	–40 °C

In extreme cases, for outdoor transformers, lower minimum ambient temperatures (i.e. –50 °C) may be required.

3.2 Altitude

Up to 1 000 m (3 300 ft) above sea level.

3.3 Atmospheric conditions

Atmospheres which are not heavily polluted.

3.4 *System earthing*

- 1) Isolated neutral system (see Sub-clause 4.20).
- 2) Resonant earthed system (see Sub-clause 4.21).
- 3) Earthed neutral system (see Sub-clause 4.23):
 - a) effectively earthed neutral system;
 - b) non-effectively earthed neutral system.

4. Definitions

For the purpose of this standard, the following definitions shall apply. Some of the definitions agree with or are similar to those of IEC Publication 50(321): International Electrotechnical Vocabulary (IEV), Chapter 321: Instrument Transformers. These are indicated by the relevant IEV reference number in brackets.

4.1 *Instrument transformer*

A transformer intended to supply measuring instruments, meters, relays and other similar apparatus (321-01-01 modified).

4.2 *Voltage transformer*

An instrument transformer in which the secondary voltage, in normal conditions of use, is substantially proportional to the primary voltage and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections (321-03-01).

4.3 *Unearthed voltage transformer*

A voltage transformer which has all parts of its primary winding, including terminals, insulated from earth to a level corresponding to its rated insulation level.

4.4 *Earthed voltage transformer*

A single-phase voltage transformer which is intended to have one end of its primary winding directly earthed.

4.5 *Primary winding*

The winding to which the voltage to be transformed is applied.

4.6 *Secondary winding*

The winding which supplies the voltage circuits of measuring instruments, meters, relays or similar apparatus.

4.7 *Secondary circuit*

The external circuit supplied by the secondary winding of a transformer.

4.8 *Rated primary voltage*

The value of the primary voltage which appears in the designation of the transformer and on which its performance is based (321-01-12 modified).

4.9 *Rated secondary voltage*

The value of the secondary voltage which appears in the designation of the transformer and on which its performance is based (321-01-16 modified).

4.10 *Actual transformation ratio*

The ratio of the actual primary voltage to the actual secondary voltage (321-01-18 modified).

4.11 *Rated transformation ratio*

The ratio of the rated primary voltage to the rated secondary voltage (321-01-20 modified).

4.12 *Voltage error (ratio error)*

The error which a transformer introduces into the measurement of a voltage and which arises when the actual transformation ratio is not equal to the rated transformation ratio (321-01-22 modified).

The voltage error, expressed in per cent, is given by the formula:

$$\text{voltage error \%} = \frac{k_n U_s - U_p}{U_p} \times 100$$

where:

k_n is the rated transformation ratio

U_p is the actual primary voltage

U_s is the actual secondary voltage when U_p is applied under the conditions of measurement

4.13 *Phase displacement*

The difference in phase between the primary voltage and the secondary voltage vectors, the direction of the vectors being so chosen that the angle is zero for a perfect transformer (321-01-23 modified).

The phase displacement is said to be positive when the secondary voltage vector leads the primary voltage vector. It is usually expressed in minutes or centiradians.

Note. — This definition is strictly correct for sinusoidal voltages only.

4.14 *Accuracy class*

A designation assigned to a voltage transformer, the errors of which remain within specified limits under prescribed conditions of use.

4.15 *Burden*

The admittance of the secondary circuit expressed in siemens and power factor (lagging or leading).

Note. — The burden is usually expressed as the apparent power in voltamperes, absorbed at a specified power factor and at the rated secondary voltage.

4.16 *Rated burden*

The value of the burden on which the accuracy requirements of this specification are based.

4.17 *Output*

4.17.1 *Rated output*

The value of the apparent power (in voltamperes at a specified power factor) which the transformer is intended to supply to the secondary circuit at the rated secondary voltage and with rated burden connected to it (321-01-27 modified).

4.17.2 *Thermal limiting output*

The value of the apparent power referred to rated voltage which can be taken from a secondary winding, at rated primary voltage applied, without exceeding the limits of temperature rise of Clause 8.

Notes 1. — In this condition the limits of error may be exceeded.

2. — In the case of more than one secondary winding, the thermal limiting output is to be given separately.

3. — The simultaneous use of more than one secondary winding is not admitted unless there is an agreement between manufacturer and purchaser.

4.18 *Highest voltage (U_m) for equipment*

The highest r.m.s. phase-to-phase voltage for which a transformer is designed in respect of its insulation.

4.19 *Rated insulation level*

The combination of voltage values which characterizes the insulation of a transformer with regard to its capability to withstand dielectric stresses.

4.20 *Isolated neutral system*

A system which has no intentional connection to earth except through indicating, measuring or protective devices of very high impedance.

4.21 *A resonant earthed system (a system earthed through an arc-suppression coil)*

A system earthed through a reactor, the reactance being of such value that, during a single phase-to-earth fault, the power-frequency inductive current passed by this reactor substantially neutralizes the power-frequency capacitance component of the earth-fault current.

Note. — With resonant earthing of a system, the residual current in the fault is limited to such an extent that an arcing fault in air is self-extinguishing.

4.22 *Factor of earthing*

The factor of earthing at a selected location of a three-phase system (generally, the point of installation of equipment), for a given system layout, is the ratio, expressed as a percentage, of the highest r.m.s. line-to-earth power-frequency voltage on a fault-free phase at the selected location during a fault to earth (affecting one or more phases at any point) to the line-to-line r.m.s. power-frequency voltage which would be obtained at the selected location with the fault removed.

4.23 *An earthed neutral system*

A system in which the neutral is connected to earth either solidly or through a resistance or reactance of low enough value to reduce transient oscillations and to give a current sufficient for selective earth fault protection.

a) A three-phase system with effectively earthed neutral at a given location is a system characterized by a factor of earthing at this point which does not exceed 80%.

Note. — This condition is obtained approximately when, for all system configurations, the ratio of zero-sequence reactance to the positive-sequence reactance is less than 3 and the ratio of zero-sequence resistance to positive-sequence reactance is less than 1.

b) A three-phase system with non-effectively earthed neutral at a given location is a system characterized by a factor of earthing at this point that may exceed 80%.

4.24 *Exposed installation*

An installation in which the apparatus is subject to overvoltages of atmospheric origin.

Note. — Such installations are usually connected to overhead transmission lines either directly or through a short length of cable.

4.25 *Non-exposed installation*

An installation in which the apparatus is not subject to overvoltages of atmospheric origin.

Note. — Such installations are usually connected to underground cable networks.

4.26 *Rated frequency*

The value of the frequency on which the requirements of this standard are based.

4.27 *Rated voltage factor*

The multiplying factor to be applied to the rated primary voltage to determine the maximum voltage at which a transformer must comply with the relevant thermal requirements for a specified time and with the relevant accuracy requirements.

SECTION TWO — RATING AND PERFORMANCE REQUIREMENTS APPLICABLE TO ALL VOLTAGE TRANSFORMERS

5. **Standard values of rated voltages**

5.1 *Rated primary voltages*

The standard values of rated primary voltage of single-phase transformers for use in a single-phase system or between lines in a three-phase system shall be one of the values of nominal system voltage designated as being usual values in IEC Publication 38: IEC Standard Voltages. The standard values of rated primary voltage of a single-phase transformer connected between one line of a three-phase system and earth or between a system neutral point and earth shall be $1/\sqrt{3}$ times one of the values of nominal system voltage.

Note. — The performance of a voltage transformer as a measuring or protection transformer is based on the rated primary voltage, whereas the rated insulation level is based on one of the highest voltages for equipment of IEC Publication 38.

5.2 *Rated secondary voltages*

The rated secondary voltage shall be chosen according to the practice at the location where the transformer is to be used. The values given below are considered standard values for single-phase transformers in single-phase systems or connected line-to-line in three phase systems:

100 V and 110 V;

200 V for extended secondary circuits.

For single-phase transformers intended to be used phase-to-earth in three-phase systems where the rated primary voltage is a number divided by $\sqrt{3}$, the rated secondary voltage shall be one of the fore-mentioned values divided by $\sqrt{3}$, thus retaining the value of the rated transformation ratio.

Notes 1. — The rated secondary voltage for windings intended to produce a residual secondary voltage is under consideration.

2. — Whenever possible, the rated transformation ratio should be of a simple value. If one of the following values: 10 - 12 - 15 - 20 - 25 - 30 - 40 - 50 - 60 - 80 and their decimal multiples is used for the rated transformation ratio together with one of the rated secondary voltages of this sub-clause, the majority of the standard values of nominal system voltage of IEC Publication 38 will be covered.

6. Standard values of rated output

The standard values of rated output at a power factor of 0.8 lagging, expressed in volt-amperes, are:

10, 15, 25, 30, 50, 75, 100, 150, 200, 300, 400, 500 VA.

The values underlined are preferred values.

Note. — For a given transformer, provided one of the values of rated output is standard and associated with a standard accuracy class, the declaration of other rated outputs, which may be non-standard values but associated with other standard accuracy classes, is not precluded.

7. Standard values of rated voltage factor

The voltage factor is determined by the maximum operating voltage which, in turn, is dependent on the system and the voltage transformer primary winding earthing conditions.

The standard voltage factors appropriate to the different earthing conditions are given in Table I below, together with the permissible duration of maximum operating voltage (i.e. rated time).

TABLE I
Standard values of rated voltage factors

Rated voltage factor	Rated time	Method of connecting the primary winding and system earthing conditions
1.2	Continuous	Between phases in any network Between transformer star-point and earth in any network
1.2	Continuous	Between phase and earth in an effectively earthed neutral system (Sub-clause 4.23 a))
1.5	30 s	
1.2	Continuous	Between phase and earth in a non-effectively earthed neutral system (Sub-clause 4.23 b)) with automatic earth fault tripping
1.9	30 s	
1.2	Continuous	Between phase and earth in an isolated neutral system without automatic earth fault tripping (Sub-clause 4.20) or in a resonant earthed system (Sub-clause 4.21) without automatic earth fault tripping
1.9	8 h	

Note. — Reduced rated times are permissible by agreement between manufacturer and user.

8. Limits of temperature rise

Unless otherwise specified below, the temperature rise of a voltage transformer at the specified voltage, at rated frequency and at rated burden, or at the highest rated burden if there are several rated burdens, at any power factor between 0.8 lagging and unity, shall not exceed the appropriate value given in Table II.

The voltage to be applied to the transformer shall be in accordance with Item *a)*, *b)* or *c)* below, as appropriate:

- a) All voltage transformers irrespective of voltage factor and time rating shall be tested at 1.2 times the rated primary voltage. The test shall be continued until the temperature of the transformer has reached a steady state.*

If a thermal limiting output is specified, the transformer shall be tested at rated primary voltage, at a burden corresponding to the thermal limiting output at a unity power factor without loading the residual voltage winding.

If a thermal limiting output is specified for one or more secondary windings, the transformer shall be tested separately with each of these windings connected, one at a time, to a burden corresponding to the relevant thermal limiting output at a unity power factor.

- b) Transformers having a voltage factor of 1.5 for 30 s or 1.9 for 30 s shall be tested at their respective voltage factor for 30 s starting after the application of 1.2 times rated voltage for a time sufficient to reach stable thermal conditions; the temperature rise shall not exceed by more than 10 K the value specified in Table II.*

Alternatively, such transformers may be tested at their respective voltage factor for 30 s starting from the cold condition; the winding temperature rise shall not exceed 10 K.

Note. — This test may be omitted if it can be shown by other means that the transformer is satisfactory under these conditions.

- c) Transformers having a voltage factor of 1.9 for 8 h shall be tested at 1.9 times the rated voltage for 8 h starting after the application of 1.2 times rated voltage for a time sufficient to reach stable thermal conditions; the temperature rise shall not exceed by more than 10 K the values specified in Table II.*

The values in Table II are based on the service conditions given in Clause 3.

If ambient temperatures in excess of the values given in Sub-clause 3.1 are specified, the permissible temperature rise in Table II shall be reduced by an amount equal to the excess ambient temperature.

If a transformer is specified for service at an altitude in excess of 1 000 m and tested at an altitude below 1 000 m, the limits of temperature rise given in Table II shall be reduced by the following amounts for each 100 m that the altitude at the operating site exceeds 1 000 m:

- a) oil-immersed transformers 0.4%;*
b) dry-type transformers 0.5%.

The temperature rise of the windings is limited by the lowest class of insulation either of the winding itself or of the surrounding medium in which it is embedded. The maximum temperature rises of the insulation classes are as given in Table II.

TABLE II
Limits of temperature rise of windings

Class of insulation (in accordance with IEC Publication 85*)	Maximum temperature rise (K)
All classes, immersed in oil	60
All classes, immersed in oil and hermetically sealed	65
All classes, immersed in bituminous compound	50
Classes not immersed in oil or bituminous compound:	
Y	45
A	60
E	75
B	85
F	110
H	135

Note. — For some materials (e.g. resin) the manufacturer should specify the relevant insulation class.

When the transformer is fitted with a conservator tank or has an inert gas above the oil, or is hermetically sealed, the temperature rise of the oil at the top of the tank or housing shall not exceed 55 K.

When the transformer is not so fitted or arranged, the temperature rise of the oil at the top of the tank or housing shall not exceed 50 K.

The temperature rise measured on the external surface of the core and other metallic parts where in contact with, or adjacent to, insulation shall not exceed the appropriate value in Table II.

9. Insulation requirements

9.1 Rated insulation levels, primary windings

The choice of the insulation level for transformers having highest voltage for equipment equal to or above 3.6 kV shall be made in accordance with IEC Publication 71: Insulation Co-ordination. For transformers having highest voltage for equipment below 3.6 kV the insulation level is determined by the rated power-frequency short-duration withstand voltage.

9.1.1 For windings having highest voltage for equipment in the range $3.6 \text{ kV} \leq U_m < 300 \text{ kV}$, the rated insulation level, defined by the rated lightning-impulse and power-frequency short-duration withstand voltages, shall be one of those given in Table IIIA.

9.1.2 For windings having highest voltage for equipment $U_m \geq 300 \text{ kV}$, the rated insulation level, defined by the rated switching and lightning-impulse withstand voltages, shall be one of those given in Table IIIC.

Note. — In this voltage range, it is considered that switching impulse should have priority in the selection of insulation level.

* IEC Publication 85: Thermal Evaluation and Classification of Electrical Insulation.

9.2 Other requirements for primary winding insulation

9.2.1 Power-frequency withstand voltage

Windings having highest voltage for equipment $U_m \geq 300$ kV shall also be capable of withstanding the specified power-frequency test. There are two alternative methods specified in this standard for windings in this category. These methods are based on different requirements regarding the test voltages and the test procedures.

Method I: the winding shall withstand the power-frequency short-duration withstand voltage corresponding to the selected rated lightning-impulse voltage as given in Table IIID.

Method II: the winding shall withstand a power-frequency test of longer duration at a voltage level lower than the short-duration test combined with a partial discharge test requirement. The test voltages, depending on the highest voltage for equipment U_m , are given in Table IIIE.

Method I shall be used unless otherwise specified.

The adoption of Method II requires special agreement between manufacturer and purchaser.

Note. — Method II test may be preceded by a lightning-impulse test in order to complete the dielectric routine tests of the primary winding.

If Method I is adopted, the lightning-impulse test should be considered a type test.

TABLE IIIA

Rated insulation levels for transformer primary windings having highest voltage for equipment below 300 kV

Highest voltage for equipment U_m (r.m.s.)	Rated lightning-impulse withstand voltage (peak)	Rated power-frequency short-duration withstand (r.m.s.)
kV	kV	kV
0.72		3
1.2		6
3.6	20	10
	40	10
7.2	40	20
	60	20
12	60	28
	75	28
17.5	75	38
	95	38
24	95	50
	125	50
36	145	70
	170	70
52	250	95
72.5	325	140
100	380	150
	450	185
123	450	185
145	550	230
170	650	275
	750	325
	850	360
245	950	395
	1 050	460