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Edition 1.2
2003-02

Edition 1:1997 consolidated with amendments 1:2000 and 2:2002

Instrument transformers –

Part 2: Inductive voltage transformers

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INSTRUMENT TRANSFORMERS –

Part 2: Inductive voltage transformers

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.
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International Standard IEC 60044-2 has been prepared by IEC technical committee 38: Instrument transformers.

This consolidated version of IEC 60044-2 is based on the first edition (1997) [documents 38/162/FDIS and 38/175/RVD], its amendment 1 (2000) [documents 38/244/FDIS and 38/254/RVD] and its amendment 2 (2002) [documents 38/286/FDIS and 38/290/RVD.

It bears the edition number 1.2.

A vertical line in the margin shows where the base publication has been modified by amendments 1 and 2.

The committee has decided that the contents of the base publication and its amendments will remain unchanged until 2005. At this date, the publication will be

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- withdrawn;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

INSTRUMENT TRANSFORMERS –

Part 2: Inductive voltage transformers

1 General

1.1 Scope

This part of IEC 60044 applies to new inductive voltage transformers for use with electrical measuring instruments and electrical protective devices at frequencies from 15 Hz to 100 Hz.

Although this standard relates basically to transformers with separate windings, it is also applicable, where appropriate, to auto-transformers. This standard does not apply to transformers for use in laboratories.

NOTE Requirements specific to three-phase voltage transformers are not included in this standard but, so far as they are relevant, the requirements in clauses 3 to 11 apply to these transformers and a few references to them are included in those clauses (e.g. see 2.1.4, 5.1.1, 5.2, and 11.2).

Clause 13 covers the requirements and tests, in addition to those in clauses 3 to 12, that are necessary for single-phase inductive protective voltage transformers. The requirements of clause 13 apply particularly to transformers which are required to have sufficient accuracy to operate protective systems at voltages that occur under fault conditions.

1.2 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 60028:1925, *International standard of resistance for copper*

IEC 60038:1983, *IEC standard voltages*

IEC 60050(321):1986, *International Electrotechnical Vocabulary (IEV) – Chapter 321: Instrument transformers*

IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

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

IEC 60085:1984, *Thermal evaluation and classification of electrical insulation*

IEC 60270:1981, *Partial discharge measurements*

IEC 60721: *Classification of environmental conditions*

IEC 60815:1986, *Guide for the selection of insulators in respect of polluted conditions*

CISPR 18-2:1986, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits*

2 Definitions

For the purpose of this part of IEC 60044, the following definitions apply.

2.1 General definitions

2.1.1
instrument transformer
a transformer intended to supply measuring instruments, meters, relays and other similar apparatus

[IEV 321-01-01 modified]

2.1.2
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

[IEV 321-03-01]

2.1.3
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

2.1.4
earthed voltage transformer
a single-phase voltage transformer which is intended to have one end of its primary winding directly earthed or a three-phase voltage transformer which is intended to have the star-point of its primary winding directly earthed

2.1.5
primary winding
the winding to which the voltage to be transformed is applied

2.1.6
secondary winding
the winding which supplies the voltage circuits of measuring instruments, meters, relays or similar apparatus

2.1.7
secondary circuit
the external circuit supplied by the secondary winding of a transformer

2.1.8
rated primary voltage
the value of the primary voltage which appears in the designation of the transformer and on which its performance is based

[IEV 321-01-12 modified]

2.1.9
rated secondary voltage
the value of the secondary voltage which appears in the designation of the transformer and on which its performance is based

[IEV 321-01-16 modified]

2.1.10
actual transformation ratio
the ratio of the actual primary voltage to the actual secondary voltage

[IEV 321-01-18 modified]

2.1.11
rated transformation ratio
the ratio of the rated primary voltage to the rated secondary voltage

[IEV 321-01-20 modified]

2.1.12
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

[IEV 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.

2.1.13
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

[IEV 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.

2.1.14
accuracy class
a designation assigned to a voltage transformer, the errors of which remain within specified limits under prescribed conditions of use

2.1.15
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.

2.1.16
rated burden
the value of the burden on which the accuracy requirements of this specification are based

2.1.17
output

2.1.17.1
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

[IEV 321-01-27 modified]

2.1.17.2
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 5.4

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

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

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

2.1.18
highest voltage for equipment
the highest r.m.s. phase-to-phase voltage for which a transformer is designed in respect of its insulation

2.1.19
highest voltage of a system
highest value of operating voltage which occurs under normal operating conditions at any time and at any point in the system.

2.1.20
rated insulation level
the combination of voltage values which characterizes the isolation of a transformer with regard to its capability to withstand dielectric stresses

2.1.21
isolated neutral system
a system where the neutral point is not intentionally connected to earth, except for high impedance connections for protection or measurement purposes

[IEV 601-02-24]

2.1.22
solidly earthed neutral system
a system whose neutral point(s) is(are) earthed directly

[IEV 601-02-25]

2.1.23
impedance earthed (neutral) system
a system whose neutral point(s) is(are) earthed through impedances to limit earth fault currents

[IEV 601-02-26]

2.1.24
resonant earthed (neutral) system
a system in which one or more neutral points are connected to earth through reactances which approximately compensate the capacitive component of a single-phase-to-earth fault current

[IEV 601-02-27]

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.

2.1.25
earth fault factor
at a given location of a three-phase system, and for a given system configuration, the ratio of the highest r.m.s. phase-to-earth power frequency voltage on a healthy phase during a fault to earth affecting one or more phases at any point on the system to the r.m.s. phase-to-earth power frequency voltage which would be obtained at the given location in the absence of any such fault

[IEV 604-03-06]

2.1.26
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 earth fault factor at this point which does not exceed 1,4.

   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 three and the ratio of zero-sequence resistance to positive-sequence reactance is less than one.

b) A three-phase system with non-effectively earthed neutral at a given location is a system characterized by earth fault factor at this point that may exceed 1,4.

2.1.27
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.

2.1.28
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.

2.1.29
rated frequency
the value of the frequency on which the requirements of this standard are based

2.1.30
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

2.1.31
measuring voltage transformer
a voltage transformer intended to supply indicating instruments, intergrating meters and similar apparatus

2.2 Additional definitions for single-phase inductive protective voltage transformers

2.2.1
protective voltage transformer
a voltage transformer intended to provide a supply to electrical protective relays

2.2.2
residual voltage winding
the winding of a single-phase voltage transformer intended, in a set of three single-phase transformers, for connection in broken delta for the purpose of:

a) producing a residual voltage under earth-fault conditions;

b) damping of relaxion oscillations (ferro-resonances).

3 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 all clauses of this standard.

4 Normal and special service conditions

Detailed information concerning classification of environmental conditions is given in IEC 60721 series.

4.1 Normal service conditions

4.1.1 Ambient air temperature

The voltage transformers are classified in three categories as given in Table 1.

Table 1 – Temperature categories

Category	Minimum temperature °C	Maximum temperature °C
–5/40	–5	40
–25/40	–25	40
–40/40	–40	40
NOTE In the choice of the temperature category, storage and transportation conditions should also be considered.		

4.1.2 Altitude

The altitude does not exceed 1000 m.

4.1.3 Vibrations or earth tremors

Vibrations due to causes external to the voltage transformer or earth tremors are negligible.

4.1.4 Other service conditions for indoor voltage transformers

Other considered service conditions are the following:

a) the influence of solar radiation may be neglected;

b) the ambient air is not significantly polluted by dust, smoke, corrosive gases, vapours or salt;

c) the conditions of humidity are as follows:

   1) the average value of the relative humidity, measured during a period of 24 h, does not exceed 95 %;

   2) the average value of the water vapour pressure for a period of 24 h, does not exceed 2,2 kPa;

   3) the average value of the relative humidity, for a period of one month, does not exceed 90 %;

   4) the average value of the water vapour pressure, for a period of one month, does not exceed 1,8 kPa.

For these conditions, condensation may occasionally occur.

NOTE 1 Condensation can be expected where sudden temperature changes occur in periods of high humidity.

NOTE 2 To withstand the effects of high humidity and condensation, such as breakdown of insulation or corrosion of metallic parts, voltage transformers designed for such conditions should be used.

NOTE 3 Condensation may be prevented by special design of the housing, by suitable ventilation and heating or by the use of dehumidifying equipment.

4.1.5 Other service conditions for outdoor voltage transformers

Other considered service conditions are the following:

a) average value of the ambient air temperature, measured over a period of 24 h, does not exceed 35 °C;

b) solar radiation up to a level of 1000 W/m^2 (on a clear day at noon) should be considered;

c) the ambient air may be polluted by dust, smoke, corrosive gases, vapours or salt. The pollution does not exceed the pollution levels given in Table 8;

d) the wind pressure does not exceed 700 Pa (corresponding to 34 m/s wind speed);

e) account should be taken of the presence of condensation or precipitation.

4.2 Special service conditions

When voltage transformers may be used under conditions different from the normal service conditions given in 4.1, the user's requirements should refer to standardized steps as follows.

4.2.1 Altitude

For installation at an altitude higher than 1000 m, the arcing distance under the standardized reference atmospheric conditions shall be determined by multiplying the withstand voltages required at the service location by a factor k in accordance with Figure 1.

NOTE As for the internal insulation, the dielectric strength is not affected by altitude. The method for checking the external insulation shall be agreed between manufacturer and purchaser.

4.2.2 Ambient temperature

For installation in a place where the ambient temperature can be significantly outside the normal service condition range stated in 4.1.1, the preferred ranges of minimum and maximum temperature to be specified should be:

a) –50 °C and 40 °C for very cold climates;

b) –5 °C and 50 °C for very hot climates.

In certain regions with frequent occurrence of warm humid winds, sudden changes of temperature may occur resulting in condensation even indoors.

NOTE Under certain conditions of solar radiation, appropriate measures e.g. roofing, forced ventilation, etc. may be necessary, in order not to exceed the specified temperature rises.

4.2.3 Earthquakes

Requirements and testing are under consideration.

4.3 System earthing

The considered system earthings are:

a) isolated neutral system (see 2.1.20);

b) resonant earthed system (see 2.1.23);

c) earthed neutral system (see 2.1.25):

   1) solidly earthed neutral system (see 2.1.21);

   2) impedance earthed neutral system (see 2.1.22).

5 Ratings

5.1 Standard values of rated voltages

5.1.1 Rated primary voltages

The standard values of rated primary voltage of three-phase transformers and 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 rated system voltage designated as being usual values in IEC 60038. 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 rated 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 60038.

5.1.2 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 and for three-phase transformers.

a) Based on the current practice of a group of European countries:
   - 100 V and 110 V;
   - 200 V for extended secondary circuits.
b) Based on the current practice in the United States and Canada:
   - 120 V for distribution systems;
   - 115 V for transmission systems;
   - 230 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.

NOTE 1 The rated secondary voltage for windings intended to produce a residual secondary voltage is given in 13.3.

NOTE 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 subclause, the majority of the standard values of rated system voltage of IEC 60038 will be covered.

5.2 Standard values of rated output

The standard values of rated output at a power factor of 0,8 lagging, expressed in voltamperes, are:

<u>10</u>, 15, <u>25</u>, 30, <u>50</u>, 75, <u>100</u>, 150, <u>200</u>, 300, 400, <u>500</u> VA.

The values underlined are preferred values. The rated output of a three-phase transformer shall be the rated output per phase.

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.

5.3 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 2 below, together with the permissible duration of maximum operating voltage (i.e. rated time).

Table 2 – 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 (2.1.25 a))
1,5	30 s	
1,2	Continuous	Between phase and earth in a non-effectively earthed neutral system (2.1.25 b)) with automatic earth-fault tripping
1,9	30 s	
1,2	Continuous	Between phase and earth in an isolated neutral system (2.1.20) without automatic earth-fault tripping or in a resonant earthed system (2.1.23) without automatic earth-fault tripping
1,9	8 h	

NOTE 1 The highest continuous operating voltage of an inductive voltage transformer is equal to the highest voltage for equipment (divided by √3 for transformers connected between a phase of a three-phase system and earth) or the rated primary voltage multiplied by the factor 1,2, whichever is the lowest.

NOTE 2 Reduced rated times are permissible by agreement between manufacturer and user.

5.4 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 3.

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.

   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.

   The test shall be continued until the temperature of the transformer has reached a steady state.

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 3.

   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 3.

The values in Table 3 are based on the service conditions given in clause 4.

If ambient temperatures in excess of the values given in 4.1 are specified, the permissible temperature rise in Table 3 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 1000 m and tested at an altitude below 1000 m, the limits of temperature rise given in Table 3 shall be reduced by the following amounts for each 100 m that the altitude at the operating site exceeds 1000 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 3.

Table 3 – Limits of temperature rise of windings

Class of insulation (in accordance with IEC 60085)	**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 3.

6 Design requirements

6.1 Insulation requirements

These requirements apply to all types of inductive voltage transformers. For gas-insulated voltage transformers supplementary requirements may be necessary (under consideration).

6.1.1 Rated insulation levels for primary windings

The rated insulation level of a primary winding of an inductive voltage transformer shall be based on its highest voltage for equipment U_m.

6.1.1.1 For windings having U_m = 0,72 kV or 1,2 kV, the rated insulation level is determined by the rated power-frequency withstand voltage, according to Table 4.

6.1.1.2 For windings having U_m = 3,6 kV and greater but less than 300 kV, the rated insulation level is determined by the rated lightning impulse and power-frequency withstand voltages and shall be chosen in accordance with Table 4.

For the choice between the alternative levels for the same values of U_m, see IEC 60071-1.

6.1.1.3 For windings having $U_m \geq$ 300 kV, the rated insulation level is determined by the rated switching and lightning impulse withstand voltages and shall be chosen in accordance with Table 5.

For the choice between the alternative levels for the same values of U_m, see IEC 60071-1.

Table 4 – Rated insulation levels for transformer primary windings having highest voltage for equipment U_m < 300 kV

Highest voltage for equipment U_m (r.m.s.) kV	Rated power-frequency withstand voltage (r.m.s.) kV	Rated lightning impulse withstand voltage (peak) kV
0,72	3	–
1,2	6	–
3,6	10	20 40
7,2	20	40 60
12	28	60 75
17,5	38	75 95
24	50	95 125
36	70	145 170
52	95	250
72,5	140	325
100	185	450
123	185	450
	230	550
145	230	550
	275	650
170	275	650
	325	750
245	395	950
	460	1050
NOTE For exposed installations it is recommended to choose the highest insulation level.		

Table 5 – Rated insulation levels for primary windings having highest voltage for equipment $U_m \geq 300$ kV

Highest voltage for equipment U_m (r.m.s.) kV	**Rated switching impulse withstand voltage (peak)** kV	**Rated lightning impulse withstand voltage (peak)** kV
300	750 850	950 1050
362	850 950	1050 1175
420	1050 1050	1300 1425
525	1050 1175	1425 1550
765	1425 1550	1950 2100

NOTE 1 For exposed installation it is recommended to choose the highest insulation levels.

NOTE 2 As the test voltage levels for U_m = 765 kV have not as yet been finally settled, some interchange between switching and lightning impulse test levels may become necessary.

Table 6 – Power-frequency withstand voltages for transformer primary windings having voltage for equipment $U_m \geq 300$ kV

Rated lightning impulse withstand voltage (peak) kV	**Rated power-frequency withstand voltage (r.m.s.)** kV
950	395
1050	460
1175	510
1300	570
1425	630
1550	680
1950	880
2100	975

6.1.2 Other requirements for primary winding insulation

6.1.2.1 Power-frequency withstand voltage

Windings having highest voltage for equipment $U_m \geq 300$ kV shall withstand the power-frequency withstand voltage corresponding to the selected lightning impulse withstand voltage according to Table 6.

6.1.2.2 Power-frequency withstand voltage for the earthed terminal

The terminal of the primary winding intended to be earthed shall, when insulated from the case or frame, be capable of withstanding the rated power-frequency short-duration withstand voltage of 3 kV (r.m.s.).

6.1.2.3 Partial discharges

Partial discharges requirements are applicable to inductive voltage transformers having U_m greater than or equal to 7,2 kV.

The partial discharge level shall not exceed the limits specified in Table 7, at the partial discharge test voltage specified in the same table, after a prestressing performed according to the procedures of 9.2.4.

Table 7 – Partial discharge test voltages and permissible levels

Type of earthing of the system	**Connections of the primary winding**	**PD test voltage (r.m.s.)** kV	**Permissible PD level** pC **Type of insulation**	
			immersed in liquid	**solid**
Earthed neutral system (earthfault factor ≤1,5)	Phase-to-earth	U_m	10	50
		$1,2\, U_m/\sqrt{3}$	5	20
	Phase-to-phase	1,2 U_m	5	20
Isolated or non-effectively earthed neutral system (earth-fault factor >1,5)	Phase-to-earth	1,2 U_m	10	50
		$1,2\, U_m/\sqrt{3}$	5	20
	Phase-to-phase	1,2 U_m	5	20

NOTE 1 If the neutral system is not defined, the values given for isolated or non-earthed systems are valid.

NOTE 2 The permissible PD level is also valid for frequencies different from rated.

NOTE 3 When the rated voltage of a voltage transformer is considerably lower than its highest system voltage U_m, lower pre-stress voltages and measuring voltages may be agreed between manufacturer and purchaser.

6.1.2.4 Chopped lightning impulse

If additionally specified, the primary winding shall also be capable of withstanding a chopped lightning impulse voltage having a peak value of 115 % of the full lightning impulse voltage.

NOTE Lower values of test voltage may be agreed between manufacturer and purchaser.

6.1.2.5 Capacitance and dielectric dissipation factor

These requirements apply only to transformers with liquid immersed primary winding insulation having $U_m \geq 72,5$ kV.

The values of capacitance and dielectric dissipation factor (tan δ) shall be referred at the rated frequency and at a voltage level in the range from 10 kV to $U_m/\sqrt{3}$.

NOTE 1 The purpose is to check the uniformity of the production. Limits for the permissible variations may be the subject of an agreement between manufacturer and purchaser.

NOTE 2 The dielectric dissipation factor is dependent on the insulation design and on both voltage and temperature. Its value at $U_m/\sqrt{3}$ and ambient temperature normally does not exceed 0,005.

NOTE 3 For some types of voltage transformer designs the interpretation of the results may be difficult to assess.

6.1.3 Between-section insulation requirements

For secondary windings divided into two or more sections, the rated power-frequency withstand voltage of the insulation between sections shall be 3 kV (r.m.s.).

6.1.4 Insulation requirements for secondary windings

The rated power-frequency withstand voltage for secondary winding insulation shall be 3 kV (r.m.s.).

6.1.5 Requirements for the external insulation

6.1.5.1 Pollution

For outdoor inductive voltage transformers, with ceramic insulator, susceptible to contamination, the creepage distances for given pollution levels are given in Table 8.

6.1.6 Requirements for radio interference voltage (RIV)

This requirement applies to inductive voltage transformers having $U_m \geq 123$ kV to be installed in air-insulated substations.

The radio interference voltage shall not exceed 2 500 µV at 1,1 $U_m/\sqrt{3}$ under the test and measuring conditions described in 8.5.

Table 8 – Creepage distances

Pollution level	Minimum nominal specific creepage mm/kV [1) 2)]	$\frac{\text{Creepage distance}}{\text{Arcing distance}}$
I Light II Medium	16 20	≤3,5
III Heavy IV Very heavy	25 31	≤4,0

1) Ratio of the creepage distance between phase and earth over the r.m.s. phase-to-phase value of the highest voltage for the equipment (see IEC 60071-1).

2) For other information and manufacturing tolerances on the creepage distance see IEC 60815.

NOTE 1 It is recognized that the performance of surface insulation is greatly affected by insulator shape.

NOTE 2 In very lightly polluted areas, specific nominal creepage distances lower than 16 mm/kV can be used depending on service experience. 12 mm/kV seems to be a lower limit.

NOTE 3 In cases of exceptional pollution severity, a specific nominal creepage distance of 31 mm/kV may not be adequate. Depending on service experience and/or on laboratory test results, a higher value of specific creepage distance can be used, but in some cases the practicability of washing may have to be considered.

6.1.7 Transmitted overvoltages

These requirements apply to inductive voltage transformers having $U_m \geq 72,5$ kV.

The overvoltages transmitted from the primary to the secondary terminals shall not exceed the values given in Table 14, under the test and measuring conditions described in 10.4.

Type A impulse requirement applies to voltage transformers for air-insulated substations, while impulse B requirement applies to current transformers installed in gas insulated metal-enclosed substations (GIS).

The transmitted overvoltage peak limits given in Table 14 and measured in accordance with the methods specified in 10.4, should ensure sufficient protection of electronic equipment connected to the secondary winding.

Table 14 – Transmitted overvoltage limits

Type of impulse	A	B
Peak value of the applied voltage (U_p)	$1,6\times\frac{\sqrt{2}}{\sqrt{3}}\times U_m$	$1,6\times\frac{\sqrt{2}}{\sqrt{3}}\times U_m$
Wave-shape characteristics :		
– conventional front time (T_1) [a]	0,50 µs ± 20 %	–
– time to half-value (T_2)	≥50 µs	–
– front time (T_1)	–	10 ns ± 20 %
– tail length (T_2)	–	>100 ns
Transmitted overvoltage peak value limits (U_s) [b]	1,6 kV	1,6 kV

[a] The wave-shape characteristics are representative of voltage oscillations due to switching operations.

[b] Other transmitted overvoltage limits may be agreed between manufacturer and purchaser.

6.2 Short-circuit withstand capability

The voltage transformer shall be designed and constructed to withstand without damage, when energized at rated voltage, the mechanical and thermal effects of an external short-circuit for the duration of 1 s.

6.3 Mechanical requirements

These requirements apply only to inductive voltage transformers having a highest voltage for equipment of 72,5 kV and above.

In Table 9 guidance is given on the static loads that inductive voltage transformers shall be capable of withstanding. The figures include loads due to wind and ice.

The specified test loads are intended to be applied in any direction to the primary terminals.

Table 9 – Static withstand test loads

Highest voltage for equipment U_m kV	**Static withstand test load F_R** *N*		
	Voltage transformers with:		
	voltage terminals	**through current terminals**	
		Load class I	**Load class II**
72,5 to 100	500	1250	2500
123 to 170	1000	2000	3000
245 to 362	1250	2500	4000
≥420	1500	4000	5000

NOTE 1 The sum of the loads acting in routinely operating conditions should not exceed 50 % of the specified withstand test load.

NOTE 2 In some applications voltage transformers with through current terminals should withstand rarely occurring extreme dynamic loads (e.g. short circuits) not exceeding 1,4 times the static test load.

NOTE 3 For some applications it may be necessary to establish the resistance to rotation of the primary terminals. The moment to be applied during the test shall be agreed between manufacturer and purchaser.

7 Classification of tests

The tests specified in this standard are classified as type tests, routine tests and special tests.

Type test

A test made on a transformer of each type to demonstrate that all transformers made to the same specification comply with the requirements not covered by routine tests.

NOTE A type test may also be considered valid if it is made on a transformer which has minor deviations. Such deviations should be subject to agreement between manufacturer and purchaser.

Routine test

A test to which each individual transformer is subjected.

Special test

A test other than a type test or a routine test, agreed on by manufacturer and purchaser.

7.1 Type tests

The following tests are type tests; for details reference should be made to the relevant subclauses:

a) Temperature-rise test (see 8.1);
b) Short-circuit withstand capability test (see 8.2);
c) Lightning impulse test (see 8.3.2);
d) Switching impulse test (see 8.3.3);
e) Wet test for outdoor type transformers (see 8.4);
f) Determination of errors (see 12.3 and 13.6.2).
g) Measurement of the radio interference voltage (RIV) (see 8.5)

All the dielectric type tests shall be carried out on the same transformer, unless otherwise specified.

After transformers have been subjected to the dielectric type tests of 7.1, they shall be subjected to all routine tests of 7.2.

7.2 Routine tests

The following tests apply to each individual transformer:

a) Verification of terminal markings (see 9.1);
b) Power-frequency withstand tests on primary windings (see 9.2);
c) Partial discharge measurement (see 9.2.4);
d) Power-frequency withstand tests on secondary windings (see 9.3);
e) Power-frequency withstand tests between sections (see 9.3);
f) Determination of errors (see 12.4 and 13.7).

The order of the tests is not standardized but determination of errors shall be performed after the other tests.

Repeated power-frequency tests on primary windings shall be performed at 80 % of the specified test voltage.

7.3 Special tests

The following tests are performed upon agreement between manufacturer and purchaser:

a) Chopped impulse test on primary winding (see 10.1);
b) Measurement of capacitance and dielectric dissipation factor (see 10.2);
c) Mechanical tests (see 10.3);
d) Transmitted overvoltage measurement (see 10.4).

8 Type tests

8.1 Temperature-rise test

A test shall be made to prove compliance with 5.4. For the purpose of this test, voltage transformers shall be considered to have attained a steady-state temperature when the rate of temperature rise does not exceed 1 K per hour. The test site ambient temperature shall be between 10 °C and 30 °C.

When there is more than one secondary winding, the test shall be made with the appropriate rated burden connected to each secondary winding, unless otherwise agreed between manufacturer and purchaser. The residual voltage winding shall be loaded in accordance with 13.6.1 or 5.4.

For this test, the transformer shall be mounted in a manner representative of the mounting in service.

The temperature rise of the windings shall be measured by the increase in resistance method.

The temperature rise of parts other than windings may be measured by thermometers or thermocouples.

8.2 Short-circuit withstand capability test

This test shall be made to prove compliance with 6.2.

For this test, the transformer shall initially be at a temperature between 10 °C and 30 °C.

The voltage transformer shall be energized from the primary side and the short circuit applied between the secondary terminals.

One short circuit shall be applied for the duration of 1 s.

NOTE This requirement applies also where fuses are an integral part of the transformer.

During the short circuit, the r.m.s. value of the applied voltage at the transformer terminals shall be not less than the rated voltage.

In the case of transformers provided with more than one secondary winding, or section, or with tappings, the test connection shall be agreed between manufacturer and purchaser.

NOTE For inductive type transformers, the test may be carried out by energizing the secondary winding and applying the short circuit between the primary terminals.

The transformer shall be deemed to have passed this test if, after cooling to ambient temperature, it satisfies the following requirements:

a) it is not visibly damaged;
b) its errors do not differ from those recorded before the tests by more than half the limits of error in its accuracy class;
c) it withstands the dielectric tests specified in 9.2 and 9.3, but with the test voltage reduced to 90 % of those given;
d) on examination, the insulation next to the surface of both the primary and the secondary windings does not show significant deterioration (e.g. carbonization).

The examination d) is not required if the current density in the winding does not exceed 160 A/mm^2 where the winding is of copper of conductivity not less than 97 % of the value given in IEC 60028. The current density is to be based on the measured symmetrical r.m.s. short-circuit current in the secondary winding (divided by the rated transformation ratio in the case of the primary).

8.3 Impulse test on primary winding

8.3.1 General

The impulse test shall be performed in accordance with IEC 60060-1.

The test voltage shall be applied between each line terminal of the primary winding and earth. The earthed terminal of the primary winding or the non-tested line terminal in the case of an unearthed voltage transformer, at least one terminal of each secondary winding, the frame, case (if any) and core (if intended to be earthed) shall be earthed during the test.

The impulse tests generally consist of voltage application at reference and rated voltage levels. The reference impulse voltage shall be between 50 % and 75 % of the rated impulse withstand voltage. The peak value and the waveshape of the impulse shall be recorded.

Evidence of insulation failure due to the test may be given by variation in the waveshape at both reference and rated withstand voltage.

For failure detection the record of current(s) to earth or of voltages appearing across the secondary winding(s), shall be performed in addition to the voltage record.

NOTE The earth connections may be made through suitable current recording devices.

8.3.2 Lightning impulse test

The test voltage shall have the appropriate value, given in Tables 4 or 5 depending on the highest voltage for equipment and the specified insulation level.

8.3.2.1 Windings having U_m < 300 kV

The test shall be performed with both positive and negative polarities. Fifteen consecutive impulses of each polarity, not corrected for atmospheric conditions, shall be applied.

The transformer passes the test if for each polarity:

– no disruptive discharge occurs in the non-self-restoring internal insulation;
– no flashovers occur along the non-self-restoring external insulation;
– no more than two flashovers occur across the self-restoring external insulation;
– no other evidence of insulation failure is detected (e.g. variations in the waveshape of the recorded quantities).

For unearthed voltage transformers, approximately half the number of impulses shall be applied to each line terminal in turn with the other line terminal connected to earth.

NOTE The application of 15 positive and 15 negative impulses is specified for testing the external insulation. If other tests are agreed between manufacturer and purchaser to check the external insulation, the number of lightning impulses may be reduced to three of each polarity, not corrected for atmospheric conditions.

8.3.2.2 Windings having $U_m \geq 300$ kV

The test shall be performed with both positive and negative polarities. Three consecutive impulses of each polarity, not corrected for atmospheric conditions, shall be applied.

The transformer passes the test if:

– no disruptive discharge occurs;

– no other evidence of insulation failure is detected (e.g. variations in the waveshape of the recorded quantities).

8.3.3 Switching impulse test

The test voltage shall have the appropriate value, given in Table 5, depending on the highest voltage for equipment and the specified insulation level.

The test shall be performed with positive polarity. Fifteen consecutive impulses, corrected for atmospheric conditions, shall be applied.

For outdoor-type transformers the test shall be performed under wet conditions (see 8.4).

NOTE To counteract the effect of core saturation, it is permitted, between consecutive impulses, to modify the magnetic conditions of the core by a suitable procedure.

The transformer passes the test if:

– no disruptive discharge occurs in the non-self-restoring internal insulation;

– no flashovers occur along the non-self-restoring external insulation;

– no more than two flashovers occur across the self-restoring external insulation;

– no other evidence of insulation failure is detected (e.g. variations in the waveshape of the recorded quantities).

NOTE Impulses with flashover to the walls or ceilings of the laboratory shall be disregarded.

8.4 Wet test for outdoor type transformers

The wetting procedure shall be in accordance with IEC 60060-1.

For windings having $U_m < 300$ kV, the test shall be performed with power-frequency voltage of the appropriate value given in Table 4 depending on the highest voltage for equipment applying corrections for atmospheric conditions.

For windings having $U_m \geq 300$ kV, the test shall be performed with switching impulse voltage of positive polarity, of the appropriate value given in Table 5, depending on the highest voltage for equipment and the rated insulation level.

8.5 Radio interference voltage measurement

The voltage transformer, complete with accessories, shall be dry and clean and at approximately the same temperature as the laboratory room in which the test is made.

In accordance with this standard, the test should be performed under the following atmospheric conditions:

– temperature: from 10 °C to 30 °C;

– pressure: from 0,870 × 10^5 Pa to 1,070 × 10^5 Pa;

– relative humidity: from 45 % to 75 %.

NOTE 1 By agreement between purchaser and manufacturer, the test may be carried out under other atmospheric conditions.

NOTE 2 No correction factors for atmospheric conditions in accordance with IEC 60060-1 are applicable to radio interference tests.

The test connections and their ends shall not be a source of radio interference voltage.

Shielding of primary terminals simulating the operation condition should be provided to prevent spurious discharges. The use of sections of tube with spherical terminations is recommended.

The test voltage shall be applied between one of the terminals of the primary winding of the test object (C_a) and earth. The frame, case (if any), core (if intended to be earthed) and one terminal of each secondary winding shall be connected to earth.

The measuring circuit (see Figure 17) shall comply with CISPR 18-2. The measuring circuit shall preferably be tuned to a frequency in the range of 0,5 MHz to 2 MHz, the measuring frequency being recorded. The results shall be expressed in microvolts.

The impedance between the test conductor and earth (Z_S + (R_1 + R_2) in Figure 17) shall be 300 Ω ± 40 Ω with a phase angle not exceeding 20° at the measuring frequency.

A capacitor, C_S, may also be used in place of the filter Z_S and a capacitance of 1 000 pF is generally adequate.

NOTE 3 A specially designed capacitor may be necessary in order to avoid too low a resonant frequency.

The filter Z shall have a high impedance at the measuring frequency in order to decouple the power frequency source from the measuring circuit. A suitable value for this impedance has been found to be 10 000 Ω to 20 000 Ω at the measuring frequency.

The radio interference background level (radio interference caused by external field and by the high-voltage transformer) shall be at least 6 dB (preferably 10 dB) below the specified radio interference level.

NOTE 4 Care should be taken to avoid disturbances caused by nearby objects to the voltage transformer and to the test and measuring circuits.

Calibration methods for the measuring instruments and for the measuring circuit are given in CISPR 18-2.

A pre-stress voltage of 1,5 $U_m/\sqrt{3}$ shall be applied and maintained for 30 s.

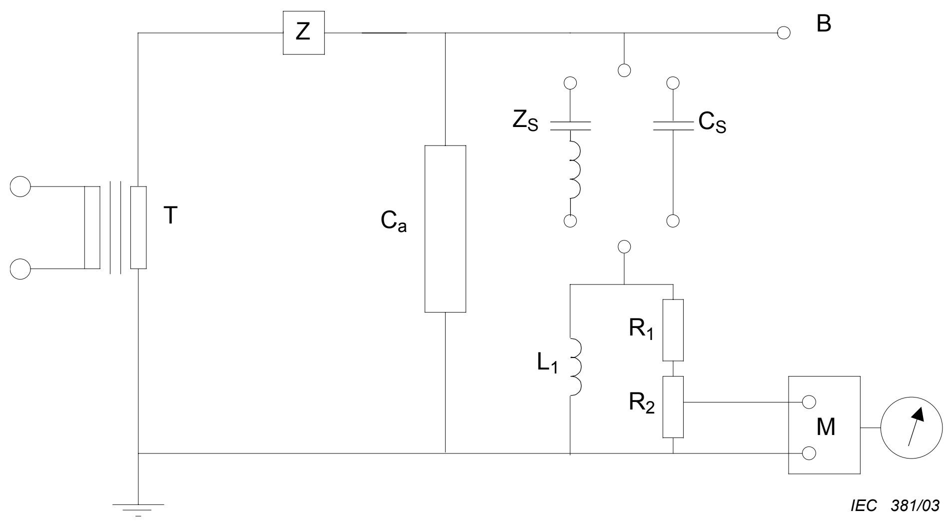
The voltage shall then be decreased to 1,1 $U_m/\sqrt{3}$ in about 10 s and maintained to this value for 30 s before measuring the radio interference voltage.

The voltage transformer shall be considered to have passed the test if the radio interference level at 1,1 $U_m/\sqrt{3}$ does not exceed the limit prescribed in 6.1.6.

NOTE 5 By agreement between manufacturer and purchaser, the RIV test as described above may be replaced by a partial discharge measurement applying the pre-stress and test voltages specified above.

Any precaution taken during partial discharge measurement performed in accordance with 9.2 for avoiding external discharges (i.e., shielding) shall be removed. In this case, the balanced test circuit is not appropriate.

Although there is no direct conversion between RIV microvolts and partial discharge picocoulombs, the voltage transformer is considered to have passed the test if at 1,1 $U_m/\sqrt{3}$ the partial discharge level does not exceed 300 pC.



T is the test transformer

C_a is the test object

Z is the filter

B is the corona-free termination

M is the measuring set

$Z_S + R_1 + R_2 = 300\ \Omega$

Z_S, C_S, L_1, R_1, R_2 see CISPR 18-2

Figure 17 – Measuring circuit

9 Routine tests

9.1 Verification of terminal markings

It shall be verified that the terminal markings are correct (see 11.2).

9.2 Power-frequency withstand tests on primary windings and partial discharge measurement

9.2.1 General

The power-frequency withstand test shall be performed in accordance with IEC 60060-1.

For separate source withstand test the duration shall be 60 s.

For the induced voltage withstand test, the frequency of the test voltage may be increased above the rated value to prevent saturation of the core. The duration of the test shall be 60 s. If, however, the test frequency exceeds twice the rated frequency, the duration of the test may be reduced from 60 s as below:

$$\text{duration of test (in s)} = \frac{\text{(twice the rated frequency)}}{\text{test frequency}} \times 60$$

with a minimum of 15 s.

9.2.2 Windings having U_m < 300 kV

The test voltages for windings having $U_m < 300$ kV shall have the appropriate values given in Table 4 depending on the highest voltage for equipment.

When there is a considerable difference between the specified highest voltage for equipment (U_m) and the specified rated primary voltage, the induced voltage shall be limited to five times the rated primary voltage.

9.2.2.1 Unearthed voltage transformers

Unearthed voltage transformers shall be submitted to the following tests:

a) Separate source withstand voltage test

   The test voltage shall be applied between earth and all primary winding terminals connected together. The frame, case (if any), core (if there is a special earth terminal) and all secondary winding terminals shall be connected together and to earth.

b) Induced voltage withstand test

   At the manufacturer's discretion, the test shall be made by exciting the secondary winding with a voltage of sufficient magnitude to induce the specified test voltage in the primary winding, or by exciting the primary winding directly at the specified test voltage.

   The test voltage shall be measured at the high-voltage side in each case. The frame, case (if any), core (if intended to be earthed) and one terminal of each secondary winding and the other terminal of the primary winding shall be connected together and to earth.

   The test should be performed by test voltage applications to each line terminal for half the required time, with a minimum of 15 s for each terminal.

9.2.2.2 Earthed voltage transformers

Earthed voltage transformers shall be submitted to the following tests:

a) Separate source withstand voltage test (when applicable)

The test voltage shall have the appropriate value given in 6.1.2.2 between the primary voltage terminal intended to be earthed.

The frame, case (if any), core (if intended to be earthed) and all secondary voltage terminals shall be connected together and to earth.

b) Induced voltage withstand test

The test shall be performed as specified in 9.2.2.1. The primary voltage terminal intended to be earthed in service shall be earthed during the test.

9.2.3 Windings having $U_m \geq 300$ kV

The transformer shall be submitted to the following tests:

a) Separate source withstand voltage test (when applicable)

The test voltage shall have the appropriate value given in 6.1.2.2 and the test shall be performed as specified in 9.2.2.2.

b) Induced voltage withstand test

The test voltage shall have the appropriate value given in Table 6, depending on the rated lightning impulse withstand voltage. The test shall be performed as specified in 9.2.2.2.

9.2.4 Partial discharge measurement

9.2.4.1 Test circuit and instrumentation

The test circuit and the instrumentation used shall be in accordance with IEC 60270. Some examples of test circuits are shown in Figures 2 to 5.

The instrument used shall measure the apparent charge *q* expressed in picocoulomb (pC). Its calibration shall be performed in the test circuit (see an example in Figure 5).

A wide-band instrument shall have a bandwidth of at least 100 kHz, with an upper cut-off frequency not exceeding 1,2 MHz.

Narrow-band instruments shall have their resonance frequency in the range 0,15 MHz to 2 MHz. Preferred values should be in the range from 0,5 MHz to 2 MHz but, if feasible, the measurement should be performed at the frequency which gives the highest sensitivity.

The sensitivity shall allow to detect a partial discharge level of 5 pC.

NOTE 1 The noise shall be sufficiently lower than the sensitivity. Pulses that are known to be caused by external disturbances can be disregarded.

NOTE 2 For the suppression of external noise, the balanced test circuit is appropriate (Figure 4). The use of a coupling capacitor to balance the circuit may be inadequate for the elimination of external interference.

NOTE 3 When electronic signal processing and recovery are used to reduce the background noise, this shall be demonstrated by varying its parameters such that it allows the detection of repeatedly occurring pulses.

9.2.4.2 Test procedure for earthed voltage transformers

After a prestressing performed according to procedure A or B, the partial discharge test voltages specified in Table 7 are reached and the corresponding partial discharge level is measured in a time within 30 s.

The measured partial discharge levels shall not exceed the limits specified in Table 7.

Procedure A: the partial discharge test voltages are reached while decreasing the voltage after the induced voltage withstand test.

Procedure B: the partial discharge test is performed after the induced voltage withstand test. The applied voltage is raised to 80 % of the induced withstand voltage, maintained for not less than 60 s, then reduced without interruption to the specified partial discharge test voltages.

If not otherwise specified, the choice of procedure is left to the manufacturer. The test method used shall be indicated in the test report.

9.2.4.3 Test procedure for unearthed voltage transformers

The test circuit for unearthed voltage transformers shall be the same as for earthed voltage transformers but two tests shall be performed by applying the voltages alternately to each of the high voltage terminals with the other high voltage terminal connected to a low-voltage terminal, frame and case (if any) (see Figures 2 to 4).

9.3 Power-frequency withstand tests between sections and on secondary windings

The test voltage, with the appropriate value given in 6.1.3 and 6.1.4 respectively, shall be applied for 60 s in turn between the short-circuited terminals of each winding section or each secondary winding and earth.

The frame, case (if any), core (if intended to be earthed) and the terminals of all the other windings or sections shall be connected together and to earth.

10 Special tests

10.1 Chopped impulse test on primary winding

The test shall be carried out with negative polarity only and combined with the negative polarity lightning impulse test in the manner described below.

The voltage shall be a standard lightning impulse as defined in IEC 60060-1, chopped between 2 µs and 5 µs. The chopping circuit shall be so arranged that the amount of overswing of opposite polarity of the recorded impulse shall be limited to approximately 30 % of the peak value.

The test voltage of the full impulses shall have the appropriate value, given in Tables 4 or 5 depending on the highest voltage for equipment and the specified insulation level.

The chopped impulse test voltage shall be in accordance with 6.1.2.4.

The sequence of impulse applications shall be as follows:

a) for windings having U_m < 300 kV:
   - one full impulse;
   - two chopped impulses;
   - fourteen full impulses.

   For unearthed voltage transformers, two chopped impulses and approximately half the number of full impulses shall be applied to each terminal,

b) for windings having $U_m \geq$ 300 kV:
   - one full impulse;
   - two chopped impulses;
   - two full impulses.

Differences in wave shape of full-wave applications before and after the chopped impulses are an indication of an internal fault.

Flashovers during chopped impulses along self-restoring external insulation shall be disregarded in the evaluation of the behaviour of the insulation.

10.2 Measurement of capacitance and dielectric dissipation factor

The test shall be carried out in accordance with 6.1.2.5, after the power-frequency withstand test on the primary windings.

The test circuit shall be agreed between manufacturer and purchaser, the bridge method being preferred.

The test shall be performed with the voltage transformer at ambient temperature whose value shall be recorded.

10.3 Mechanical tests

The tests are carried out to demonstrate that an inductive voltage transformer is capable of complying with the requirements specified in 6.3.

The voltage transformer shall be completely assembled, installed in vertical position with the frame rigidly fixed.

Liquid-immersed voltage transformers shall be filled with the specified insulation medium and submitted to the operating pressure.

The test loads shall be applied for 60 s for each of the conditions indicated in Table 10.

The voltage transformer shall be considered to have passed the test if there is no evidence of damage (deformation, rupture or leakage).

10.4 Transmitted overvoltage measurement

A low-voltage impulse (U_1) shall be applied between one of the primary terminals and earth.

For voltage transformers for GIS metal-enclosed substations, the impulse shall be applied through a 50 Ω coaxial cable adapter according to Figure 18. The enclosure of the GIS section shall be connected to earth as planned in service.

For other applications, the test circuit shall be as described in Figure 19.

The terminal(s) of the secondary winding(s) intended to be earthed shall be connected to the frame and to earth.

The transmitted voltage (U_2) shall be measured at the open secondary terminals through a 50 Ω coaxial cable terminated with the 50 Ω input impedance of an oscilloscope having a bandwidth of 100 MHz or higher which reads the peak value.

NOTE Other test methods to avoid the intrusion of the instrumentation may be agreed upon between the manufacturer and the purchaser.

If the voltage transformer comprises more than one secondary winding, the measurement shall be successively performed on each one of the windings.

In the case of secondary windings with intermediate tappings, the measurement shall be performed only on the tapping corresponding to the full winding.

The overvoltages transmitted to the secondary winding (U_s) for the specified overvoltages (U_p) applied to the primary winding shall be calculated as follows:

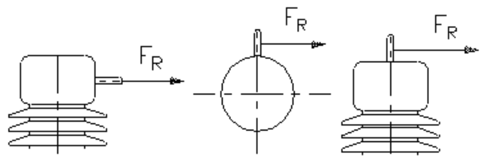
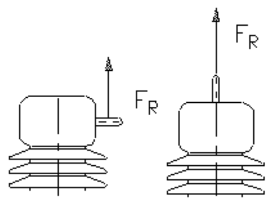
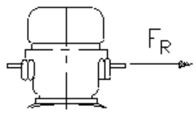
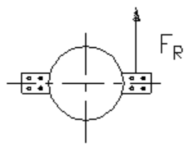
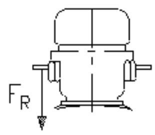
$$U_s = \frac{U_2}{U_1} \times U_p$$

In the case of oscillations on the crest, a mean curve should be drawn, and the maximum amplitude of this curve is considered as the peak value U_1 for the calculation of the transmitted voltage (see Figure 20).

NOTE Amplitude and frequency of the oscillation on the voltage wave may affect the transmitted voltage.

The voltage transformer is considered to have passed the test if the value of the transmitted overvoltage does not exceed the limits given in Table 14.

Table 10 – Modalities of application of the test loads to be applied to the line primary terminals

Type of voltage transformer	**Modality of application**	
With voltage terminal	Horizontal	
	Vertical	
With through current terminals	Horizontal to each terminal	
		
	Vertical to each terminal	
NOTE The test load shall be applied to the centre of the terminal		

11 Markings

11.1 Rating plate markings

All voltage transformers shall carry at least the following markings:

a) the manufacturer's name or other mark by which he may be readily identified;

b) a serial number or a type designation, preferably both;

c) the rated primary and secondary voltage (e.g. 66/0,11 kV);

d) rated frequency (e.g. 50 Hz);

e) rated output and the corresponding accuracy class (e.g. 50 VA Class 1.0);

NOTE When two separate secondary windings are provided, the marking should indicate the output range of each secondary winding in VA, the corresponding accuracy class and the rated voltage of each winding.

f) highest system voltage (e.g. 72,5 kV);

g) rated insulation level (e.g. 140/325 kV).

NOTE The two items f) and g) may be combined into one marking (e.g. 72,5/140/325 kV).

All information shall be marked in an indelible manner on the voltage transformer itself or on a rating plate securely attached to the transformer.

In addition, the following information should be marked whenever space is available:

h) rated voltage factor and corresponding rated time;

i) class of insulation if different from Class A;

NOTE If several classes of insulating material are used, the one which limits the temperature rise of the windings should be indicated.

j) on transformers with more than one secondary winding, the use of each winding and its corresponding terminals.

11.2 Terminal markings

11.2.1 General rules

These markings are applicable to single-phase voltage transformers and also to sets of single-phase voltage transformers assembled as one unit and connected as a three-phase voltage transformer or to a three-phase voltage transformer having a common core for the three phases.

11.2.2 Terminal identifiers

Markings shall be in accordance with Figures 6 to 15 as appropriate.

Capital letters A, B, C and N denote the primary-winding terminals and the lower-case letters a, b, c and n denote the corresponding secondary-winding terminals.

The letters A, B and C denote fully insulated terminals and the letter N denotes a terminal intended to be earthed and the insulation of which is less than that of the other terminal(s).

Letters da and dn denote the terminals of windings intended to supply a residual voltage.

11.2.3 Relative polarities

Terminals having corresponding capital and lower-case markings shall have the same polarity at the same instant.

12 Accuracy requirements for single-phase inductive measuring voltage transformers

12.1 Accuracy class designation for measuring voltage transformers

For measuring voltage transformers, the accuracy class is designated by the highest permissible percentage voltage error at rated voltage and with rated burden, prescribed for the accuracy class concerned.

12.1.1 Standard accuracy classes for measuring voltage transformers

The standard accuracy classes for single-phase inductive measuring voltage transformers are:

0,1 – 0,2 – 0,5 – 1,0 – 3,0

12.2 Limits of voltage error and phase displacement for measuring voltage transformers

The voltage error and phase displacement at rated frequency shall not exceed the values given in Table 11 at any voltage between 80 % and 120 % of rated voltage and with burdens of between 25 % and 100 % of rated burden at a power factor of 0,8 lagging.

For voltage transformers of accuracy class 0,1 and 0,2 and having a rated burden lower than 10 VA an extended range of burden can be specified. The voltage error and phase displacement shall not exceed the values given in Table 11, when the secondary burden is any value from 0 VA to 100 % of the rated burden, at a power factor equal to 1.

NOTE This requirement may be requested for certified accuracy of energy measurements.

The errors shall be determined at the terminals of the transformer and shall include the effects of any fuses or resistors as an integral part of the transformer.

Table 11 – Limits of voltage error and phase displacement measuring voltage transformers

Class	Percentage voltage (ratio) error ±	Phase displacement ±	
		Minutes	Centiradians
0,1	0,1	5	0,15
0,2	0,2	10	0,3
0,5	0,5	20	0,6
1,0	1,0	40	1,2
3,0	3,0	Not specified	Not specified

NOTE When ordering transformers having two separate secondary windings, because of their interdependence, the user should specify two output ranges, one for each winding, the upper limit of each output range corresponding to a standard rated output value. Each winding should fulfil its respective accuracy requirements within its output range, whilst at the same time the other winding has an output of any value from zero up to 100 % of the upper limit of the output range specified for the other winding. In proving compliance with this requirement, it is sufficient to test at extreme values only. If no specification of output ranges is supplied, these ranges are deemed to be from 25 % to 100 % of the rated output for each winding.

If one of the windings is loaded only occasionally for short periods or only used as a residual voltage winding, its effect upon other windings may be neglected.

12.3 Type tests for accuracy of measuring voltage transformers

To prove compliance with 12.2, type tests shall be made at 80 %, 100 % and 120 % of rated voltage, at rated frequency and at 25 % and 100 % of rated burden.

12.4 Routine tests for accuracy of measuring voltage transformers

The routine tests for accuracy are in principle the same as the type tests in 12.3, but routine tests at a reduced number of voltages and/or burdens are permissible, provided it has been shown by type tests on a similar transformer that such a reduced number of tests is sufficient to prove compliance with 12.2.

12.5 Marking of the rating plate of a measuring voltage transformer

The rating plate shall carry the appropriate information in accordance with 11.1.

The accuracy class shall be indicated following the indications of the corresponding rated output (e.g. 100 VA, class 0,5).

For voltage transformers having a rated burden not exceeding 10 VA and with an extended burden down to 0 VA, this rating shall be indicated immediately before the burden indication (for example, 0 VA-10 VA class 0,2).

NOTE The rating-plate may contain information concerning several combinations of output and accuracy class that the transformer can satisfy.

13 Additional requirements for single-phase inductive protective voltage transformers

13.1 Accuracy class designation for protective voltage transformers

All voltage transformers intended for protective purposes, with the exception of residual voltage windings, shall be assigned a measuring accuracy class in accordance with 12.1 and 12.2. In addition, they shall be assigned one of the accuracy classes specified in 13.1.1.

The accuracy class for a protective voltage transformer is designated by the highest permissible percentage voltage error prescribed for the accuracy class concerned, from 5 % of rated voltage to a voltage corresponding to the rated voltage factor (see 5.3). This expression is followed by the letter P.

13.1.1 Standard accuracy classes for protective voltage transformers

The standard accuracy classes for protective voltage transformers are 3P and 6P, and the same limits of voltage error and phase displacement will normally apply at both 5 % of rated voltage and at the voltage corresponding to the rated voltage factor. At 2 % of rated voltage, the error limits will be twice as high as those at 5 % of rated voltage.

Where transformers have different error limits at 5 % of rated voltage and at the upper voltage limit (i.e. the voltage corresponding to rated voltage factor 1,2, 1,5 or 1,9), agreement should be made between manufacturer and user.

13.2 Limits of voltage error and phase displacement for protective voltage transformers

The voltage error and phase displacement at rated frequency shall not exceed the values in Table 12 at 5 % rated voltage and at rated voltage multiplied by the rated voltage factor (1,2, 1,5 or 1,9) with burdens of between 25 % and 100 % of rated burden at a power factor of 0,8 lagging.

At 2 % of rated voltage, the limits of error and phase displacement with burdens of between 25 % and 100 % of rated burden at a power factor of 0,8 lagging will be twice as high as those given in Table 12.

Table 12 – Limits of voltage error and phase displacement for protective voltage transformers

Class	Percentage voltage (ratio) error + or –	Phase displacement + or –	
		Minutes	Centiradians
3P	3,0	120	3,5
6P	6,0	240	7,0

NOTE When ordering transformers having two separate secondary windings, because of their interdependence, the user should specify two output ranges, one for each winding, the upper limit of each output range corresponding to a standard rated output value. Each winding should fulfil its respective accuracy requirements within its output range, whilst at the same time the other winding has an output of any value from zero up to 100 % of the upper limit of its output range. In proving compliance with this requirement, it is sufficient to test at extreme values only. If no specification of output ranges is supplied, these ranges are deemed to be from 25 % to 100 % of the rated output for each winding

13.3 Rated voltages for secondary windings intended to produce a residual voltage

Rated secondary voltages of windings intended to be connected in broken delta with similar windings to produce a residual voltage are given in Table 13.

Table 13 – Rated voltages for secondary intended to produce a residual voltage

Preferred values V		Alternative (non-preferred) values V
100	110	200
$\frac{100}{\sqrt{3}}$	$\frac{110}{\sqrt{3}}$	$\frac{200}{\sqrt{3}}$
$\frac{100}{3}$	$\frac{110}{3}$	$\frac{200}{3}$
NOTE Where system conditions are such that the preferred values of rated secondary voltages would produce a residual voltage that is too low, the non-preferred values may be used, but attention is drawn to the need to take precautions for purposes of safety.		

13.4 Output for secondary windings intended to produce a residual voltage

13.4.1 Rated output

The rated output of windings intended to be connected in broken delta with similar windings to produce a residual voltage shall be specified in voltamperes and the value shall be chosen from the values specified in 5.2.

13.4.2 Rated thermal limiting output

The rated thermal limiting output of the residual voltage winding shall be specified in voltamperes; the value shall be 15, <u>25</u>, <u>50</u>, 75, <u>100</u> VA and their decimal multiples, related to the rated secondary voltage with unity power factor. The values underlined should be preferred.

NOTE Since the residual voltage windings are connected in a broken delta, these windings are only loaded under fault conditions.

Deviating from the definition in 2.1.17.2, the rated thermal output of the residual voltage winding should be referred to a duration of 8 h.

13.5 Accuracy class for secondary windings intended to produce a residual voltage

The accuracy class for a residual voltage winding shall be 6P as defined in 13.1.1 and 13.2.

NOTE 1 If a residual voltage winding is used for special purposes, another standard accuracy class in accordance with 12.1.1, 12.2, 13.1.1 and 13.2 can be agreed between manufacturer and purchaser.

NOTE 2 If the residual voltage winding is used only for damping purposes, an accuracy class designation is not mandatory.

13.6 Type tests for protective voltage transformers

13.6.1 Temperature-rise test for residual voltage windings

If one of the secondary windings is used as a residual voltage winding, a test shall be made in accordance with 8.1, starting with the test in accordance with 5.4 item a) at 1,2 times the rated primary voltage and directly followed by the test in accordance with 5.4 item c).

During the preconditioning test with 1,2 times the rated primary voltage, the residual voltage winding is unloaded. During the test, at 1,9 times the rated primary voltage for 8 h, the residual voltage winding shall be loaded with the burden corresponding to the rated thermal limiting output (see 13.4.2) while the other windings are loaded with the rated burden.

If, for other secondary windings, a thermal limiting output is specified, an additional test shall be made in accordance with item a) of 5.4 at rated primary voltage without loading the residual voltage winding.

NOTE The voltage measurement has to be performed on the primary winding, as the actual secondary voltage may be appreciably smaller than the rated secondary voltage multiplied by the voltage factor.

13.6.2 Tests for accuracy

To prove compliance with 13.2, type tests shall be made at 2 %, 5 % and at 100 % of rated voltage and at rated voltage multiplied by the rated voltage factor, at 25 % and at 100 % of rated burden at a power-factor of 0,8 lagging.

When the transformer has several secondary windings, they are to be loaded as stated in the note to 13.2.

A residual voltage winding is unloaded during the tests with voltages up to 100 % of rated voltage and loaded with rated burden during the test with a voltage equal to rated voltage multiplied by the rated voltage factor.

13.7 Routine tests for protective voltage transformers

13.7.1 Tests for accuracy

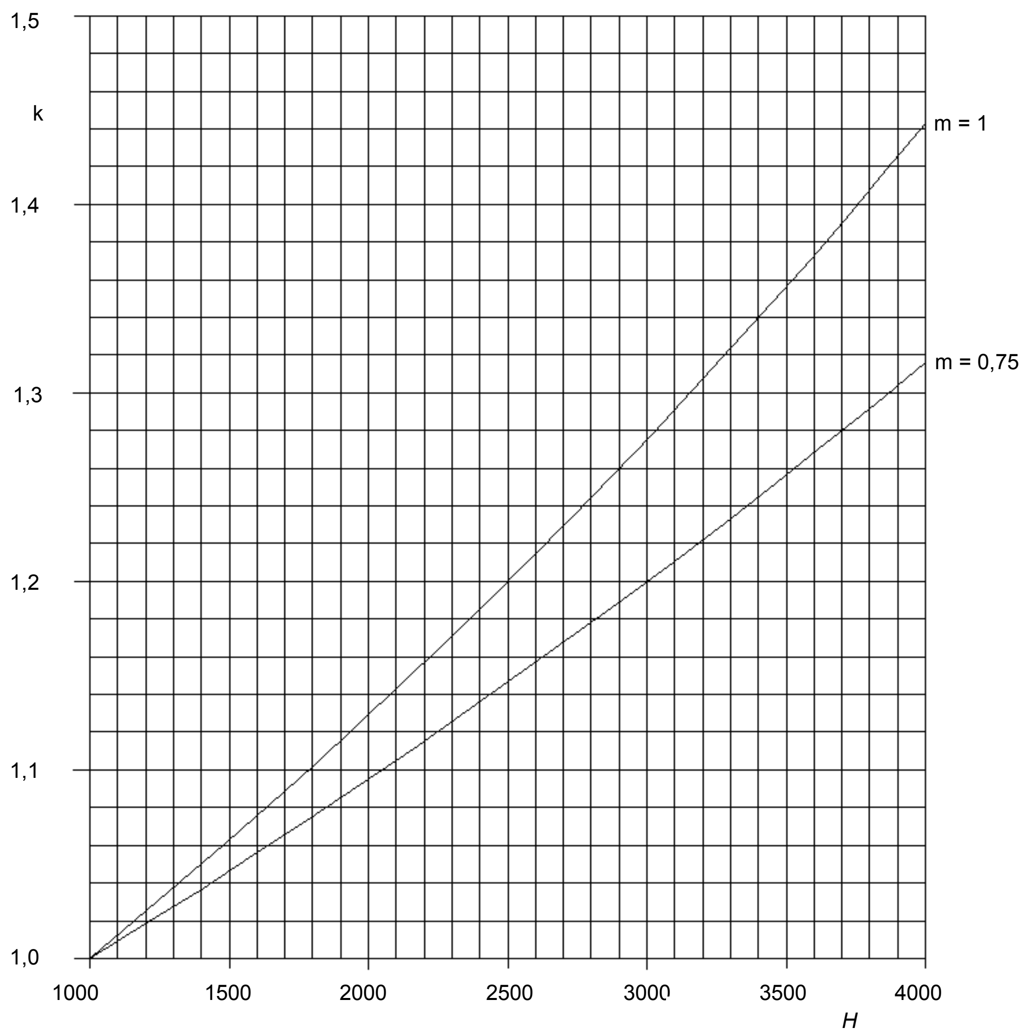
The routine tests for accuracy are in principle the same as the type tests in 13.6.2, but routine tests at a reduced number of voltages and/or burdens are permissible, provided it has been shown by type tests on a similar transformer that such a reduced number of tests is sufficient to prove compliance with 13.2.

13.8 Marking of the rating plate of a protective voltage transformer

The rating plate shall carry the appropriate information in accordance with 11.1.

The accuracy class shall be indicated after the corresponding rated output.

An example of a typical rating plate is given in Figure 16.



These factors can be calculated with the following equation:

$k = e^{m\,(H - 1000)/8150}$

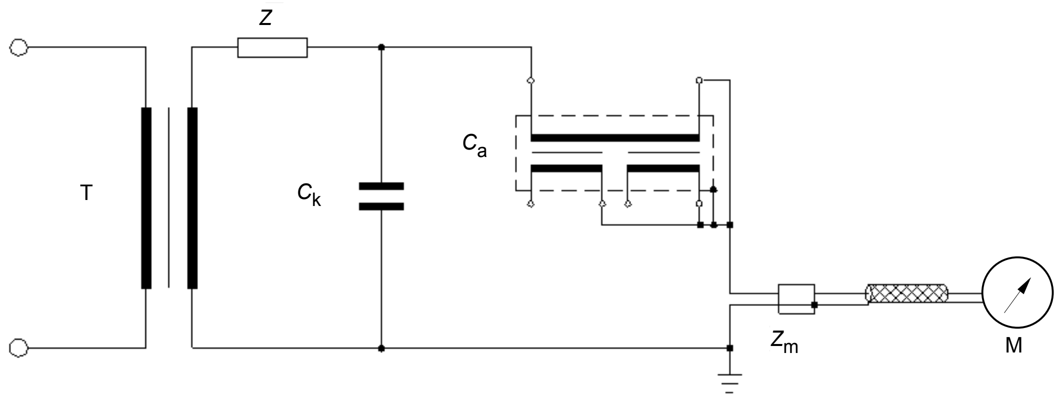
where

H is the altitude in metres;

m = 1 for power-frequency and lightning impulse voltage;

m = 0,75 for switching impulse voltage.

Figure 1 – Altitude correction factor



T is the test transformer

C_a is the instrument transformer to be tested

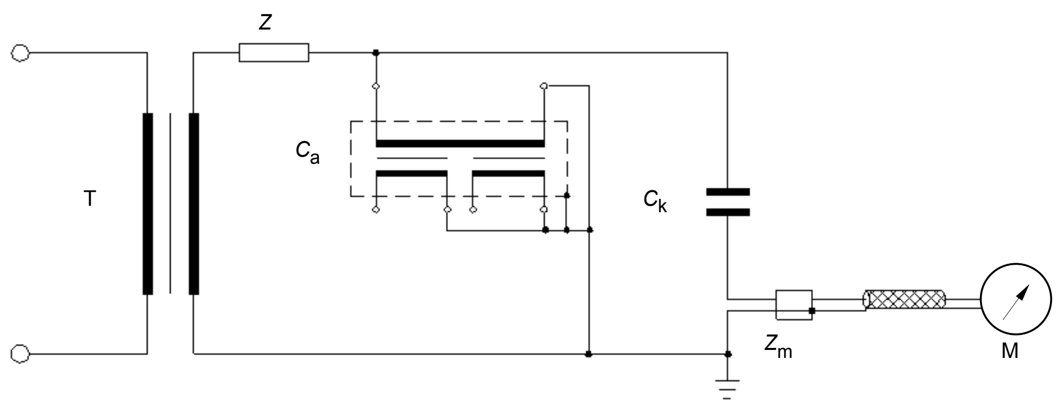
C_k is the coupling capacitor

M is the PD measuring instrument

Z_m is the measuring impedance

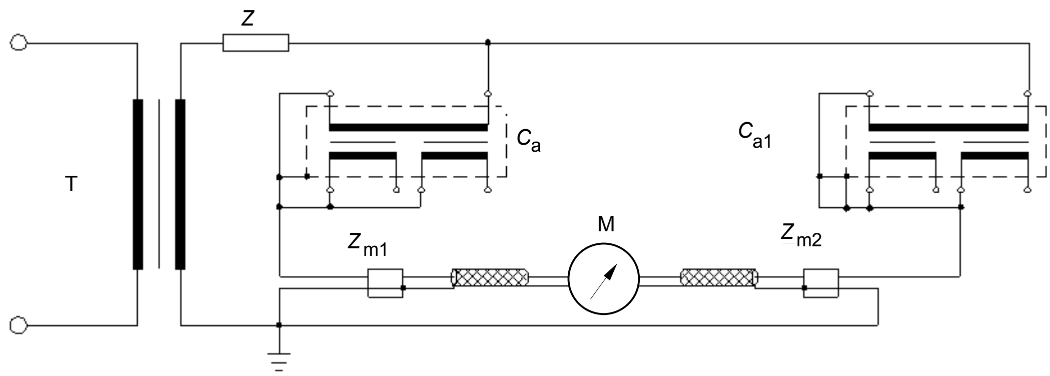
Z is the filter (not present if C_k is the capacitance of the test transformer)

Figure 2 – Test circuit for partial discharge measurement



Symbols as in Figure 2

Figure 3 – Alternative circuit for partial discharge measurement



T is the test transformer for partial discharge measurement

C_a is the instrument transformer to be tested

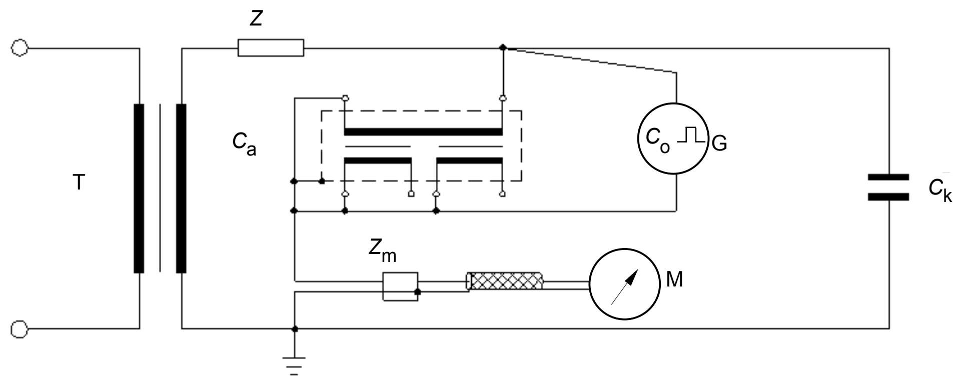
C_{a1} is the auxiliary PD free object (or C_k is the coupling capacitor)

M is the PD measuring instrument

Z_{m1} and Z_{m2} are the measuring impedances

Z is the filter

Figure 4 – Example of balanced test circuit for partial discharge measurement



Symbols as in Figure 2

G is the impulse generator with capacitance C_0

Figure 5 – Example of calibration circuit for partial discharge measurement

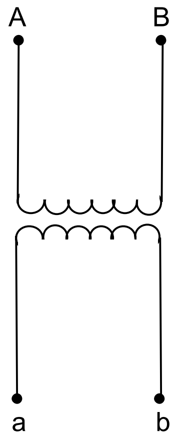


Figure 6 – Single-phase transformer with fully insulated terminals and a single secondary

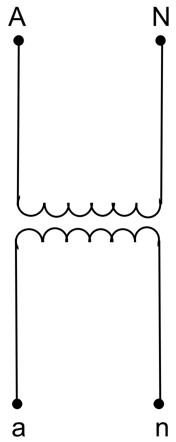


Figure 7 – Single-phase transformer with a neutral primary terminal with reduced insulation and a single secondary

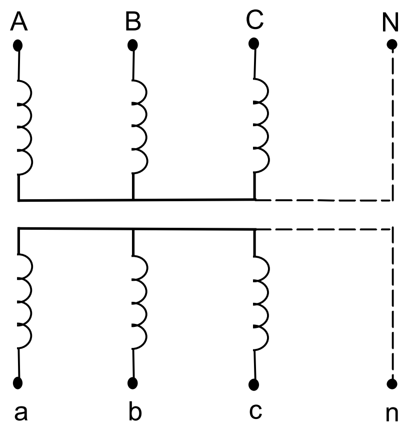


Figure 8 – Three-phase assembly with a single secondary

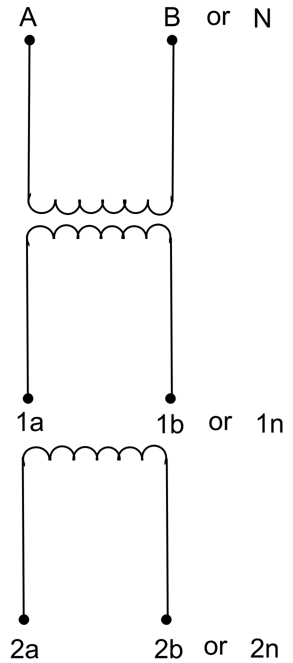


Figure 9 – Single-phase transformer with two secondaries

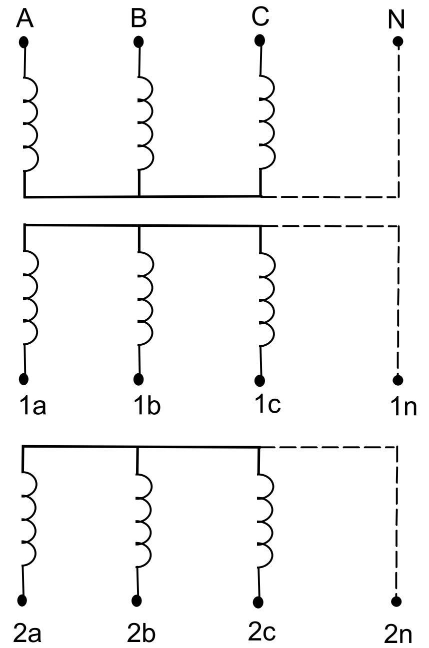


Figure 10 – Three-phase assembly with two secondaries

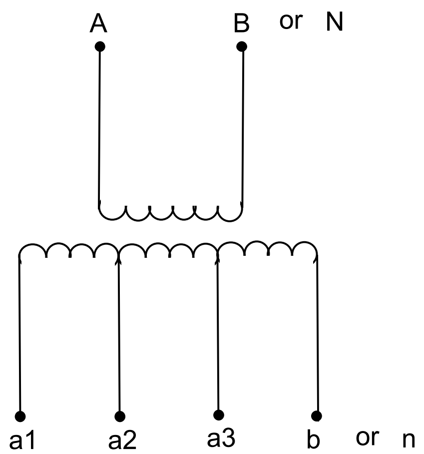


Figure 11 – Single-phase transformer with one multi-tap secondary

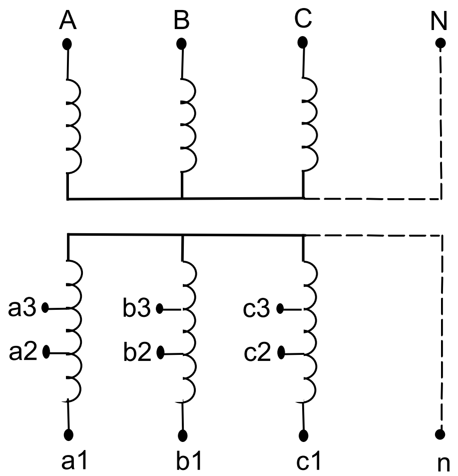


Figure 12 – Three-phase assembly with one multi-tap secondary

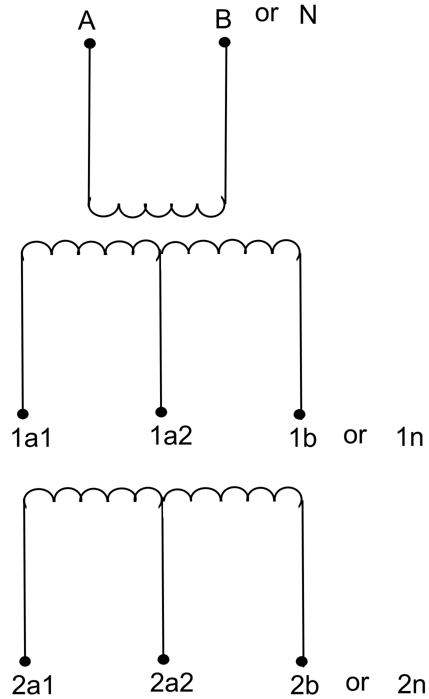


Figure 13 – Single-phase transformer with two multi-tap secondaries

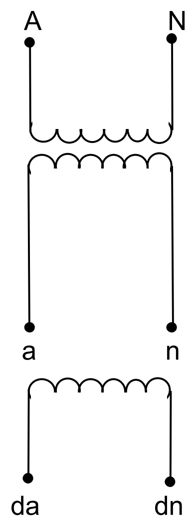


Figure 14 – Single-phase transformer with one residual voltage winding

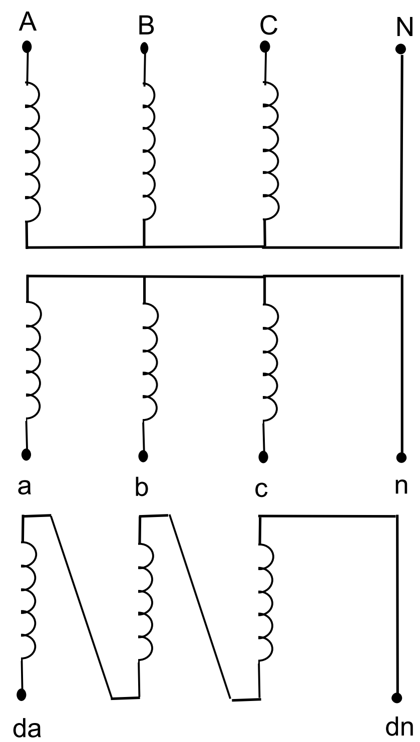


Figure 15 – Three-phase transformer with one residual voltage winding

Voltage transformer		A – N 220000: $\sqrt{3}$ V			
Manufacturer		1a – 1n		(2a – 2n)	da – dn
Serial No.:		110: $\sqrt{3}$			110:3
Type	50 Hz	VA:25	50		25
245/460/1050 kV	1,9 U_n 30 s	Cl:0,5	3P		6P

Figure 16 – Example of a typical rating plate

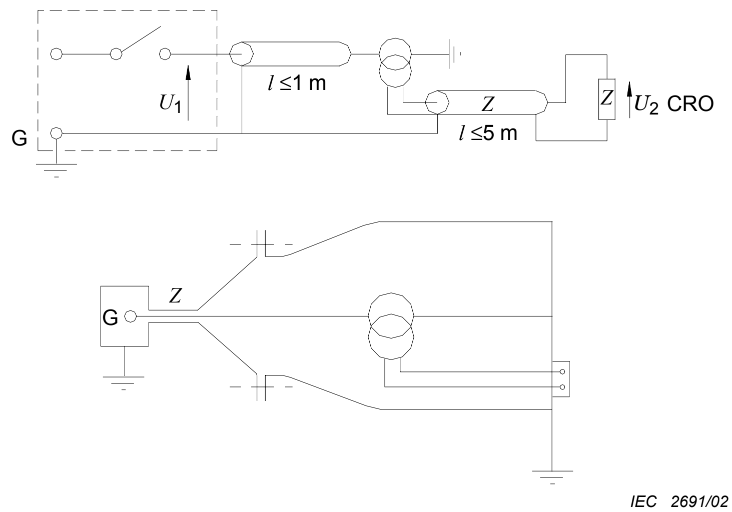


Figure 18 – Transmitted Overvoltages measurement: Test Circuit and GIS Test set-up

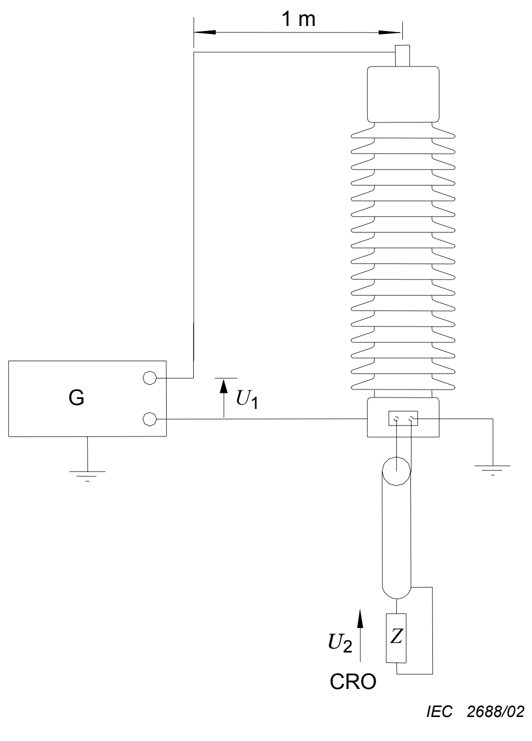
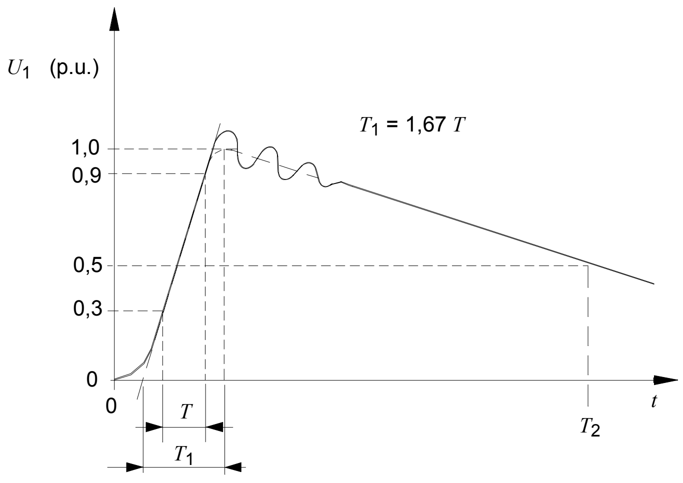


Figure 19 – Transmitted Overvoltages measurement: General Test set-up



Wave shape A

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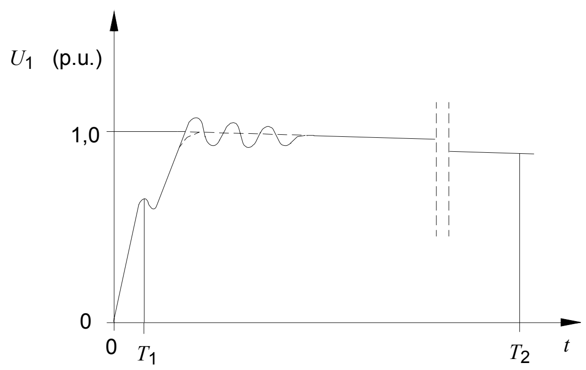

Wave shape B

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Figure 20 – Transmitted Overvoltages measurement: Test Waveforms

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