IS/IEC 60044-1 (2003): Instrument Transformers, Part 1: Current Transformers [ETD 34: Instrument Transformers]

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Indian Standard

INSTRUMENT TRANSFORMERS

PART 1 CURRENT TRANSFORMERS

ICS 17.220.20

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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Instrument Transformers Sectional Committee, ETD 34

NATIONAL FOREWORD

This Indian Standard (Part 1) which is identical with IEC 60044-1 : 2003 'Instrument transformers — Part 1: Current transformers' issued by the International Electrotechnical Commission (IEC) after incorporating Amendment No. 1 in 2000 and Amendment No. 2 in 2002 was adopted by the Bureau of Indian Standards on the recommendation of the Instrument Transformers Sectional Committee and approval of the Electrotechnical Division Council.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, references appear to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60038 : 1983 IEC standard voltages	IS 12360 : 1988 Voltage bands for electrical installations including preferred voltages and frequency	Technically Equivalent
IEC 60050 (321) : 1986 International Electrotechnical Vocabulary — Chapter 321: Instrument transformers	IS 1885 (Part 28) : 1993 Electrotechnical vocabulary: Part 28 Instrument transformers (*first revision*)	Identical
IEC 60060-1 : 1989 High-voltage test techniques — Part 1: General definitions and test requirements	IS 2071 (Part 1) : 1993 High- voltage test techniques: Part 1 General definitions and test requirements (*second revision*)	do
IEC 60071-1 : 1993 Insulation co-ordination — Part 1: Definitions, principles and rules	IS/IEC 60071-1 : 2006 Insulation co-ordination: Part 1 Definitions, principles and rules	Technically Equivalent
IEC 60270 : 1981 Partial discharge measurements	IS/IEC 60270 : 2000 High-voltage test techniques partial discharge measurements	do
IEC 60721 Classification of environmental conditions	IS 13736 (Part 1) : 1993 Classification of environmental conditions: Part 1 Classification of environmental parameters and their severities	Identical to IEC 60721-1 : 1990
	IS 13736 (Part 2/Sec 1, 2, 3, 4 and 7) : 1993 Classification of environmental conditions: Part 2 Environmental conditions appearing in nature	Identical to respective Sections of IEC 60721-2 : 1990

(*Continued on third cover*)

Indian Standard

INSTRUMENT TRANSFORMERS

PART 1 CURRENT TRANSFORMERS

1 General

1.1 Scope

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

Although the requirements relate basically to transformers with separate windings, they are also applicable, where appropriate, to autotransformers.

Clause 11 covers the requirements and tests, in addition to those in clauses 3 to 10, that are necessary for current transformers for use with electrical measuring instruments.

Clause 12 covers the requirements and tests, in addition to those in clauses 3 to 10, that are necessary for current transformers for use with electrical protective relays, and in particular for forms of protection in which the prime requirement is the maintenance of accuracy up to several times the rated current.

For certain protective systems, where the current transformer characteristics are dependant on the overall design of the protective equipment (for example high-speed balanced systems and earth-fault protection in resonant earthed networks), additional requirements are given in clause 13 for class PR transformers and in clause 14 for class PX transformers.

Clause 13 covers the requirements and tests in addition to those in clauses 3 to 10 that are necessary for current transformers for use with electrical protective relays, and in particular for forms of protection in which the prime requirement is the absence of remanent flux.

Clause 14 covers the requirements and tests in addition to those in clauses 3 to 10 that are necessary for current transformers for use with electrical protective relays, and in particular for forms of protection for which knowledge of the transformer's secondary excitation characteristic, secondary winding resistance, secondary burden resistance and turns ratio is sufficient to assess its performance in relation to the protective relay system with which it is to be used.

Current transformers intended for both measurement and protection shall comply with all the clauses of this standard.

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 60044-6:1992, *Instrument transformers – Part 6: Requirements for protective current transformers for transient performance*

IEC 60050(321):1986, *International Electrotechnical Vocabulary – 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 60121:1960, *Recommendation for commercial annealed aluminium electrical conductor wire*

IEC 60270:1981, *Partial discharge measurements*

IEC 60567:1992, *Guide for the sampling of gases and of oil from oil-filled electrical equipment and for the analysis of free and dissolved gases*

IEC 60599:1978, *Interpretation of the analysis of gases in transformers and other oil-filled electrical equipment in service*

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
current transformer
an instrument transformer in which the secondary current, in normal conditions of use, is substantially proportional to the primary current and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections

[IEV 321-02-01]

2.1.3
primary winding
the winding through which flows the current to be transformed

2.1.4
secondary winding
the winding which supplies the current circuits of measuring instruments, meters, relays or similar apparatus

2.1.5
secondary circuit
the external circuit supplied by the secondary winding of a transformer

2.1.6
rated primary current
the value of the primary current on which the performance of the transformer is based

[IEV 321-01-11 modified]

2.1.7
rated secondary current
the value of the secondary current on which the performance of the transformer is based

[IEV 321-01-15 modified]

2.1.8
actual transformation ratio
the ratio of the actual primary current to the actual secondary current

[IEV 321-01-17 modified]

2.1.9
rated transformation ratio
the ratio of the rated primary current to the rated secondary current

[IEV 321-01-19 modified]

2.1.10
current error (ratio error)
the error which a transformer introduces into the measurement of a current and which arises from the fact that the actual transformation ratio is not equal to the rated transformation ratio

IEV 321-01-21 modified]

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

$$\text{Current error } \% = \frac{(K_\text{n}\, I_\text{s} - I_\text{p})\, x\, 100}{I_\text{p}}$$

where

K_n is the rated transformation ratio;

I_p is the actual primary current;

I_s is the actual secondary current when I_p is flowing, under the conditions of measurement.

2.1.11
phase displacement
the difference in phase between the primary and secondary current 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 current vector leads the primary current vector. It is usually expressed in minutes or centiradians.

NOTE This definition is strictly correct for sinusoidal currents only.

2.1.12
accuracy class
a designation assigned to a current transformer the errors of which remain within specified limits under prescribed conditions of use

2.1.13
burden
the impedance of the secondary circuit in ohms and power-factor

The burden is usually expressed as the apparent power in voltamperes absorbed at a specified power-factor and at the rated secondary current.

2.1.14
rated burden
the value of the burden on which the accuracy requirements of this specification are based

2.1.15
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 current and with rated burden connected to it

2.1.16
highest voltage for equipment
the highest r.m.s. phase-to-phase voltage for which a transformer is designed in respect of its insulation

2.1.17
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

2.1.18
rated insulation level
the combination of voltage values which characterizes the insulation of a transformer with regard to its capability to withstand dielectric stresses

2.1.19
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]

2.1.20
solidly earthed neutral system
a system whose neutral point(s) is(are) earthed directly

[IEV 601-02-25]

2.1.21
impedance earthed (neutral) system
a system whose neutral point(s) is(are) earthed through impedances to limit earth fault currents

[IEV 601-02-26]

2.1.22
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 usually self-extinguishing.

2.1.23
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]

2.1.24
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 materially transient oscillations and to give a current sufficient for selective earth fault protection:

a) a system with effectively-earthed neutral at a given location is a system characterized by an earth fault factor at this point which does not exceed 1,4;

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

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

2.1.25
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.

2.1.26
non-exposed installation
an installation in which the apparatus is not subject to overvoltages of atmospheric origin

NOTE Such installations are usually connected to cable networks.

2.1.27
rated frequency
the value of the frequency on which the requirements of this standard are based

2.1.28
rated short-time thermal current (I_{th})
the r.m.s. value of the primary current which a transformer will withstand for one second without suffering harmful effects, the secondary winding being short-circuited

2.1.29
rated dynamic current (I_{dyn})
the peak value of the primary current which a transformer will withstand, without being damaged electrically or mechanically by the resulting electromagnetic forces, the secondary winding being short-circuited

2.1.30
rated continuous thermal current (I_{cth})
the value of the current which can be permitted to flow continuously in the primary winding, the secondary winding being connected to the rated burden, without the temperature rise exceeding the values specified

2.1.31
exciting current
the r.m.s. value of the current taken by the secondary winding of a current transformer, when a sinusoidal voltage of rated frequency is applied to the secondary terminals, the primary and any other windings being open-circuited

2.1.32
rated resistive burden (R_b)
rated value of the secondary connected resistive burden in ohms

2.1.33
secondary winding resistance (R_{ct})
secondary winding d.c. resistance in ohms corrected to 75 °C or such other temperature as may be specified

2.1.34
composite error*
under steady-state conditions, the r.m.s. value of the difference between:

a) the instantaneous values of the primary current, and

b) the instantaneous values of the actual secondary current multiplied by the rated transformation ratio, the positive signs of the primary and secondary currents corresponding to the convention for terminal markings.

The composite error ε_c is generally expressed as a percentage of the r.m.s. values of the primary current according to the formula:

$$\varepsilon_c = \frac{100}{I_p}\sqrt{\frac{1}{T}\int_0^T (K_n i_s - i_p)^2 \mathrm{d}t}$$

where

K_n is the rated transformation ratio;

I_p is the r.m.s. value of the primary current;

i_p is the instantaneous value or the primary current;

i_s is the instantaneous value of the secondary current;

T is the duration of one cycle.

2.1.35
multi-ratio current transformer
current transformer on which more ratios are obtained by connecting the primary winding sections in series or parallel or by means of taps on the secondary winding

2.2 Additional definitions for measuring current transformers

2.2.1
measuring current transformer
a current transformer intended to supply indicating instruments, integrating meters and similar apparatus

2.2.2
rated instrument limit primary current (*IPL*)
the value of the minimum primary current at which the composite error of the measuring current transformer is equal to or greater than 10 %, the secondary burden being equal to the rated burden

NOTE The composite error should be greater than 10 %, in order to protect the apparatus supplied by the instrument transformer against the high currents produced in the event of system fault.

* See annexe A.

2.2.3
instrument security factor (FS)
the ratio of rated instrument limit primary current to the rated primary current

NOTE 1 Attention should be paid to the fact that the actual instrument security factor is affected by the burden.

NOTE 2 In the event of system fault currents flowing through the primary winding of a current transformer, the safety of the apparatus supplied by the transformer is greatest when the value of the rated instrument security factor (FS) is small.

2.2.4
secondary limiting e.m.f
the product of the instrument security factor FS, the rated secondary current and the vectorial sum of the rated burden and the impedance of the secondary winding

NOTE 1 The method by which the secondary limiting e.m.f. is calculated will give a higher value than the real one. It was chosen in order to apply the same test method as in 11.6 and 12.5 for protective current transformers.

Other methods may be used by agreement between manufacturer and purchaser.

NOTE 2 For calculating the secondary limiting e.m.f., the secondary winding resistance should be corrected to a temperature of 75 °C.

2.3 Additional definitions for protective current transformers

2.3.1
protective current transformer
a current transformer intended to supply protective relays

2.3.2
rated accuracy limit primary current
the value of primary current up to which the transformer will comply with the requirements for composite error

2.3.3
accuracy limit factor
the ratio of the rated accuracy limit primary current to the rated primary current

2.3.4
secondary limiting e.m.f.
the product of the accuracy limit factor, the rated secondary current and the vectorial sum of the rated burden and the impedance of the secondary winding

2.3.5
class PR protective current transformer
a current transformer with limited remanence factor for which, in some cases, a value of the secondary loop time constant and/or a limiting value of the winding resistance may also be specified

2.3.6
saturation flux (Ψ_s)
that peak value of the flux which would exist in a core in the transition from the non-saturated to the fully saturated condition and deemed to be that point on the B-H characteristic for the core concerned at which a 10 % increase in B causes H to be increased by 50 %

2.3.7
remanent flux (Ψ_r)
that value of flux which would remain in the core 3 min after the interruption of an exciting current of sufficient magnitude to induce the saturation flux (Ψ_s) defined in 2.3.6

2.3.8
remanence factor (K_r)
the ratio $K_r = 100 \times \Psi_r / \Psi_s$, expressed as a percentage (%)

2.3.9
rated secondary loop time constant (T_s)
value of the time constant of the secondary loop of the current transformer obtained from the sum of the magnetizing and the leakage inductance (L_s) and the secondary loop resistance (R_s)

$$T_s = L_s / R_s$$

2.3.10
excitation characteristic
a graphical or tabular presentation of the relationship between the r.m.s. value of the exciting current and a sinusoidal r.m.s. e.m.f. applied to the secondary terminals of a current transformer, the primary and other windings being open-circuited, over a range of values sufficient to define the characteristics from low levels of excitation up to the rated knee point e.m.f.

2.3.11
class PX protective current transformer
a transformer of low leakage reactance for which knowledge of the transformer secondary excitation characteristic, secondary winding resistance, secondary burden resistance and turns ratio is sufficient to assess its performance in relation to the protective relay system with which it is to be used

2.3.12
rated knee point e.m.f. (E_k)
that minimum sinusoidal e.m.f. (r.m.s.) at rated power frequency when applied to the secondary terminals of the transformer, all other terminals being open-circuited, which when increased by 10 % causes the r.m.s. exciting current to increase by no more than 50 %

NOTE The actual knee point e.m.f. will be ≥ the rated knee point e.m.f.

2.3.13
rated turns ratio
the required ratio of the number of primary turns to the number of secondary turns

EXAMPLE 1 1/600 (one primary turn with six hundred secondary turns).

EXAMPLE 2 2/1 200 (a current transformer of similar ratio to example 1 but employing two primary turns).

2.3.14
turns ratio error
the difference between the rated and actual turns ratios, expressed as a percentage

$$\text{Turns ratio error (\%)} = \frac{\text{(actual turns ratio – rated turns ratio)}}{\text{rated turns ratio}} \times 100$$

2.3.15
dimensioning factor (K_x)
a factor assigned by the purchaser to indicate the multiple of rated secondary current (I_{sn}) occurring under power system fault conditions, inclusive of safety factors, up to which the transformer is required to meet performance requirements

3 Normal and special service conditions

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

3.1 Normal service conditions

3.1.1 Ambient air temperature

The current 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 be also considered.		

3.1.2 Altitude

The altitude does not exceed 1000 m.

3.1.3 Vibrations or earth tremors

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

3.1.4 Other service conditions for indoor current transformers

Other service conditions considered 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, current 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.

3.1.5 Other service conditions for outdoor current transformers

Other service conditions considered are:

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 gas, vapours or salt.
   The pollution levels are given in table 7;
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.

3.2 Special service conditions

When current transformers may be used under conditions different from the normal service conditions given in 3.1, the user's requirements should refer to standardized steps as follows.

3.2.1 Ambient air temperature

For installation in a place where the ambient temperature can be significantly outside the normal service condition range stated in 3.1.1, the preferred ranges of minimum and maximum temperature to be specified should be:

– –50 °C and 40 °C for very cold climates;
– –5 °C and 50 °C for very hot climates.

In certain regions with frequent occurence 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, or derating may be used, in order not to exceed the specified temperature rises.

3.2.2 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.

3.2.3 Earthquakes

Requirements and testing are under consideration.

3.3 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).

4 Ratings

4.1 Standard values of rated primary currents

4.1.1 Single-ratio transformers

The standard values of rated primary currents are:

10 – 12,5 – 15 – 20 – 25 – 30 – 40 – 50 – 60 – 75 A,

and their decimal multiples or fractions.

The preferred values are those underlined.

4.1.2 Multi-ratio transformers

The standard values given in 4.1.1 refer to the lowest values of rated primary current.

4.2 Standard values of rated secondary currents

The standard values of rated secondary currents are 1 A, 2 A and 5 A, but the preferred value is 5 A.

NOTE For transformers intended for delta-connected groups, these ratings divided by $\sqrt{3}$ are also standard values.

4.3 Rated continuous thermal current

The standard value of rated continuous thermal current is the rated primary current.

When a rated continuous thermal current greater than rated primary current is specified, the preferred values should be 120 % to 150 % and 200 % of rated primary current.

4.4 Standard values of rated output

The standard values of rated output up to 30 VA are:

2,5 – 5,0 – 10 – 15 and 30 VA.

Values above 30 VA may be selected to suit the application.

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.

4.5 Short-time current ratings

Current transformers supplied with a fixed primary winding or conductor shall comply with the requirements of 4.5.1 and 4.5.2.

4.5.1 Rated short-time thermal current (I_{th})

A rated short-time thermal current (I_{th}) shall be assigned to the transformer (see 2.1.25).

4.5.2 Rated dynamic current (I_{dyn})

The value of the rated dynamic current (I_{dyn}) shall normally be 2.5 times the rated short-time thermal current (I_{th}) and it shall be indicated on the rating plate when it is different from this value (see 2.1.26).

4.6 Limits of temperature rise

The temperature rise of a current transformer when carrying a primary current equal to the rated continuous thermal current, with a unity power-factor burden corresponding to the rated output, shall not exceed the appropriate value given in table 2. These values are based on the service conditions given in clause 3.

If ambient temperatures in excess of the values given in 3.1 are specified, the permissible temperature rise in table 2 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 2 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 2.

Table 2 – Limits of temperature rise of the 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 With some products (e.g. resin) the manufacturer should specify the relevant insulation class.	

When the transformer is fitted with a conservator tank, 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 2.

5 Design requirements

5.1 Insulation requirements

These requirements apply to all types of current transformer insulation. For gas insulated current transformers, supplementary requirements may be necessary (under consideration).

5.1.1 Rated insulation levels for primary windings

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

For a current transformer without primary winding and without primary insulation of its own, the value U_m = 0,72 kV is assumed.

5.1.1.1 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 3.

5.1.1.2 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 3.

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

5.1.1.3 For windings having U_m greater than or equal to 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 4.

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

Table 3 – 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 levels.

Table 4 – Rated insulation levels for transformer 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	950
	850	1050
362	850	1050
	950	1175
420	1050	1300
	1050	1425
525	1050	1425
	1175	1550
765	1425	1950
	1550	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.

5.1.2 Other requirements for primary winding insulation

5.1.2.1 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 5.

5.1.2.2 Partial discharges

Partial discharge requirements are applicable to current transformers having U_m not less than 7,2 kV.

The partial discharge level shall not exceed the limits specified in table 6, at the partial discharge test voltage specified in the same table, after a prestressing performed according to the procedures of 8.2.2.

Table 5 – Power frequency withstand voltages for transformer primary windings having highest 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

Table 6 – Partial discharge test voltages and permissible levels

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

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

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

5.1.2.3 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.

5.1.2.4 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 to the rated frequency and to 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.

5.1.2.5 Multiple chopped impulses

If additionally agreed, the primary winding of oil-immersed CTs having $U_m \geq 300$ kV shall be capable of withstanding multiple chopped impulses for checking the behaviour to high-frequency stresses expected in operation.

As there is not enough experience to propose a definitive test programme and acceptance criteria, in this standard only some information is given in annex B on a possible test procedure. The proof that the design is adequate is left to the manufacturer.

NOTE The design should be particularly examined with respect to internal shields and connections carrying transient currents.

5.1.3 Between-section insulation requirements

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

5.1.4 Insulation requirements for secondary windings

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

5.1.5 Inter-turn insulation requirements

The rated withstand voltage for inter-turn insulation shall be 4,5 kV peak.

For some types of transformers, lower values can be accepted in accordance with the test procedure given in 8.4.

NOTE Due to the test procedure, the waveshape may be highly distorted.

5.1.6 Requirements for the external insulation

5.1.6.1 Pollution

For outdoor current transformers with ceramic insulators susceptible to contamination, the creepage distances for given pollution levels are given in table 7.

Table 7 – Creepage distances

Pollution level	Minimum nominal specific creepage distance mm/kV [1) 2)]	Creepage distance / 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.

5.1.7 Requirements for radio interference voltage (RIV)

This requirement applies to current 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 7.5.

5.1.8 Transmitted overvoltages

These requirements apply to

- current transformers having primary winding with $U_m \geq 72,5$ kV;
- current transformers without primary winding and associated to equipment with $U_m \geq 72,5$ kV (i.e., GIS, transformer turrets, cable slip-over).

The overvoltages transmitted from the primary to the secondary terminals shall not exceed the values given in table 16, under the test and measuring conditions described in 9.4.

NOTE 1 The wave-shape characteristics are representative of voltage oscillations due to switching operations.

NOTE 2 Other transmitted overvoltage limits may be agreed between manufacturer and purchaser.

Type A impulse requirement applies to current 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 16 and measured in accordance with the methods specified in 9.4, should ensure sufficient protection of electronic equipment connected to the secondary winding.

Table 16 – 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)	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)	1,6 kV	1,6 kV

5.2 Mechanical requirements

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

In table 8 guidance is given on the static loads that current transformers shall be capable 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 8 – Static withstand test loads

Highest voltage for equipment U_m kV	Static withstand loads F_R N	
	Load class I	Load class II
72,5 to 100	1250	2500
123 to 170	2000	3000
245 to 362	2500	4000
≥ 420	4000	6000

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

NOTE 2 Current transformers should withstand rarely occurring extreme dynamic loads (e.g. short circuits) not exceeding 1,4 times the static withstand 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 test shall be agreed between manufacturer and purchaser.

6 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.

6.1 Type tests

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

a) short-time current tests (see 7.1);
b) temperature rise test (see 7.2);
c) lightning impulse test (see 7.3.2);
d) switching impulse test (see 7.3.3);
e) wet test for outdoor type transformers (see 7.4);
f) determination of errors (see 11.4 and/or 12.4, 11.6, 12.5 and 14.3).
g) radio interference voltage measurement (RIV) (see 7.5).

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

After transformers have been subjected to the dielectric type tests of 6.1, they shall be subjected to all the routine tests of 6.2.

6.2 Routine tests

The following tests apply to each individual transformers:

a) verification of terminal markings (see 8.1);
b) power-frequency withstand test on primary winding (see 8.2.1);
c) partial discharge measurement (see 8.2.2);
d) power-frequency withstand test on secondary windings (see 8.3 or 14.4.4);
e) power-frequency withstand tests, between sections (see 8.3 or 14.4.4);
f) inter-turn overvoltage test (see 8.4 or 14.4.5);
g) determination of errors (see 11.5 and/or 12.4, 11.6, 12.6 and 14.4).

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 should be performed at 80 % of the specified test voltage.

6.3 Special tests

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

a) chopped lightning impulse test (see 9.1);

b) measurement of capacitance and dielectric dissipation factor (see 9.2);

c) multiple chopped impulse test on primary winding (see annex B);

d) mechanical tests (see 9.3).

e) measurement of transmitted overvoltages (see 9.4)

7 Type tests

7.1 Short-time current tests

For the thermal short-time current I_{th} test, the transformer shall initially be at a temperature between 10 °C and 40 °C.

This test shall be made with the secondary winding(s) short-circuited, and at a current I for a time t, so that (I^2t) is not less than (I^2_{th}) and provided t has a value between 0,5 s and 5 s.

The dynamic test shall be made with the secondary winding(s) short-circuited, and with a primary current the peak value of which is not less than the rated dynamic current (I_{dyn}) for at least one peak.

The dynamic test may be combined with the thermal test above, provided the first major peak current of that test is not less than the rated dynamic current (I_{dyn}).

The transformer shall be deemed to have passed these tests if, after cooling to ambient temperature (between 10 °C and 40 °C), it satisfies the following requirements:

a) it is not visibly damaged;

b) its errors after demagnetization do not differ from those recorded before the tests by more than half the limits of error appropriate to its accuracy class;

c) it withstands the dielectric tests specified in 8.2, 8.3 and 8.4, but with the test voltages or currents reduced to 90 % of those given;

d) on examination, the insulation next to the surface of the conductor does not show significant deterioration (e.g. carbonization).

The examination d) is not required if the current density in the primary winding, corresponding to the rated short-time thermal current (I_{th}), does not exceed:

– 180 A/ mm^2 where the winding is of copper of conductivity not less than 97 % of the value given in IEC 60028.

– 120 A/ mm^2 where the winding is of aluminium of conductivity not less than 97 % of the value given in IEC 60121.

NOTE Experience has shown that in service the requirements for thermal rating are generally fulfilled in the case of class A insulation, provided that the current density in the primary winding, corresponding to the rated short-time thermal current, does not exceed the above-mentioned values.

Consequently, compliance with this requirement may take the place of the insulation examination, if agreed between manufacturer and purchaser.

7.2 Temperature-rise test

A test shall be made to prove compliance with the requirements of 4.6. For the purpose of this test, current transformers shall be deemed to have attained a steady 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.

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

The temperature rise of windings shall, when practicable, be measured by the increase in resistance method, but for windings of very low resistance, thermocouples may be employed.

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

7.3 Impulse tests on primary winding

7.3.1 General

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

The test voltage shall be applied between the terminals of the primary winding (connected together) and earth. The frame, case (if any), and core (if intended to be earthed) and all terminals of the secondary winding(s) shall be connected to earth.

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.

Improvements in failure detection may be obtained by recording of the current(s) to earth as a complement to the voltage record.

7.3.2 Lightning impulse test

The test voltage shall have the appropriate value, given in tables 3 or 4, depending on the highest voltage for equipment and the specified insulation level.

7.3.2.1 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).

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.

7.3.2.2 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).

7.3.3 Switching impulse test

The test voltage shall have the appropriate value, given in table 4, 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 7.4).

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.

7.4 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 3, 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 4, depending on the highest voltage for equipment and the rated insulation level.

7.5 Radio interference voltage measurement

The current 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 between 10 °C and 30 °C;
- pressure between 0,870 × 10^5 Pa and 1,070 × 10^5 Pa;
- relative humidity between 45 % and 75 %.

NOTE 1 By agreement between purchaser and manufacturer, the tests 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 all terminals of the secondary winding(s) shall be connected to earth.

The measuring circuit (see figure 6) 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 6 shall be 300 Ω ± 40 Ω with a phase angle not exceeding 20°.

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 current 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 at this value for 30 s before measuring the radio interference voltage.

The current 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 5.1.7.

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 8.2.2 for avoiding external discharges (i.e. shielding) should 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 current 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.

8 Routine tests

8.1 Verification of terminal markings

It shall be verified that the terminal markings are correct (see 10.1).

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

8.2.1 Power-frequency test

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

The test voltage shall have the appropriate value given in table 3 or 5, depending on the highest voltage for equipment. The duration shall be 60 s.

The test voltage shall be applied between the short-circuited primary winding and earth. The short-circuited secondary winding(s), the frame, case (if any) and core (if there is a special earth terminal) shall be connected to earth.

8.2.2 Partial discharge measurement

8.2.2.1 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 4.

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 a upper cut-off frequency not exceeding 1,2 MHz.

Narrow-band instruments shall have their resonance frequency in the range 0,15 to 2 MHz. Preferred values should be in the range from 0,5 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 may be disregarded.

NOTE 2 For the suppression of external noise, the balanced test circuit (see figure 4) is appropriate.

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

8.2.2.2 Partial discharge test procedure

After a prestressing performed according to procedures A or B, the partial discharge test voltages specified in table 6 are reached, and the corresponding partial discharge levels are measured in a time within 30 s.

The measured partial discharge shall not exceed the limits specified in table 6.

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

Procedure B: the partial discharge test is performed after the power-frequency withstand test. The applied voltage is raised to 80 % of the power-frequency 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 the procedure is left to the manufacturer. The test method used shall be indicated in the test report.

8.3 Power-frequency withstand tests between sections of primary and secondary windings and on secondary windings

The test voltage, with the appropriate value given in 5.1.3 and 5.1.4 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 there is a special earth terminal), and the terminals of all the other windings or sections shall be connected together and to earth.

8.4 Inter-turn overvoltage test

The inter-turn overvoltage test shall be performed in accordance with one of the following procedures.

If not otherwise agreed, the choice of the procedure is left to the manufacturer.

Procedure A: with the secondary windings open-circuited (or connected to a high impedance device which reads peak voltage), a substantially sinusoidal current at a frequency between 40 Hz and 60 Hz (in accordance with IEC 60060-1) and of r.m.s. value equal to the rated primary current (or rated extended primary current (see 11.3) when applicable) shall be applied for 60 s to the primary winding.

The applied current shall be limited if the test voltage of 4,5 kV peak is obtained before reaching the rated current (or extended rated current).

Procedure B: with the primary winding open-circuited, the prescribed test voltage (at some suitable frequency) shall be applied for 60 s to the terminals of each secondary winding, providing that the r.m.s. value of the secondary current does not exceed the rated secondary current (or rated extended current).

The value of the test frequency shall be not greater than 400 Hz.

At this frequency, if the voltage value achieved at the rated secondary current (or rated extended current) is lower than 4,5 kV peak, the obtained voltage is to be regarded as the test voltage.

When the 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.

NOTE The inter-turn overvoltage test is not a test carried out to verify the suitability of a current transformer to operate with the secondary winding open-circuited. Current transformers should not be operated with the secondary winding open-circuited because of the potentially dangerous overvoltages and overheating which can occur.

9 Special tests

9.1 Chopped impulse test on primary winding

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

The voltage shall be a standard lightning impulse, chopped between 2 µs and 5 µs. The chopping circuit shall be so arranged that the amplitude of overswing of opposite polarity of the actual test 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 3 or 4, depending on the highest voltage for equipment and the specified insulation level.

The chopped impulse test voltage shall be in accordance with 5.1.2.3.

The sequence of impulse applications shall be as following:

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

9.2 Measurement of capacitance and dielectric dissipation factor

The measurement of capacitance and dielectric dissipation factor shall be made after the power-frequency withstand test on the primary windings.

The test voltage shall be applied between the short-circuited primary winding terminals and earth. Generally the short-circuited secondary winding(s), any screen, and the insulated metal casing shall be connected to the measuring bridge. If the current transformer has a special device (terminal) suitable for this measurement, the other low-voltage terminals shall be short-circuited and connected together with the metal casing to the earth or the screen of the measuring bridge.

NOTE In some cases, it is necessary to connect the earth to other points of the bridge.

The test shall be performed with the current transformer at ambient temperature, the value of which shall be recorded.

9.3 Mechanical tests

The tests are carried out to demonstrate that a current transformer is capable of complying with the requirements specified in 5.2.

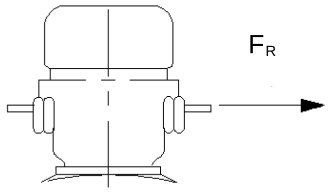
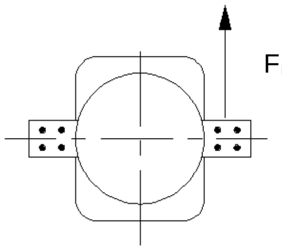
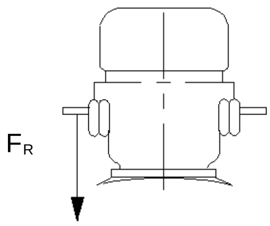
The current transformer shall be completely assembled, installed in a vertical position with the frame rigidly fixed.

Liquid-immersed current 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 9.

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

Table 9 – Modalities of application of test loads to be applied to the primary terminals

Horizontal to each terminal	
	
Vertical to each terminal	
NOTE The test load shall be applied to the centre of the terminal.	

9.4 Transmitted overvoltages measurement

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

For single-phase current transformers for GIS metal-enclosed substations, the impulse shall be applied through a 50 Ω coaxial cable adapter according to figure 7. 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 8.

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 between manufacturer and purchaser.

If the current transformer comprises more than one secondary winding, the measurement shall be successively performed on each 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 overvoltage (see figure 9).

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

The current transformer is considered to have passed the test if the value of the transmitted overvoltage does not exceed the limits given in table 16.

10 Markings

10.1 Terminal markings – General rules

The terminal markings shall identify

a) the primary and secondary windings;
b) the winding sections, if any;
c) the relative polarities of windings and winding sections;
d) the intermediate tappings, if any.

10.1.1 Method of marking

The terminals shall be marked clearly and indelibly, either on their surface or in their immediate vicinity.

The marking shall consist of letters followed, or preceded where necessary, by numbers. The letters shall be in block capitals.

10.1.2 Markings to be used

The markings of current transformer terminals shall be as indicated in the following table 10.

Table 10 – Markings of terminals

<table>
<tr>
<td>Primary terminals

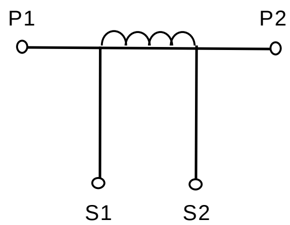
Secondary terminals</td>
<td>

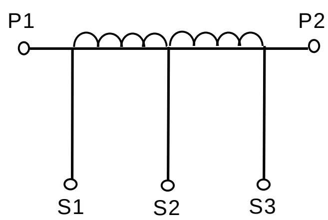
Figure 1 – Single ratio transformer.</td>
<td>

Figure 2 – Transformer with an intermediate tapping on secondary winding.</td>
</tr>
<tr>
<td>Primary terminals

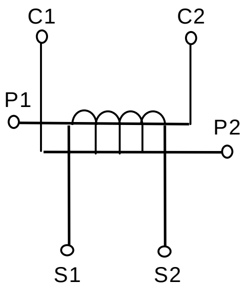
Secondary terminals</td>
<td>

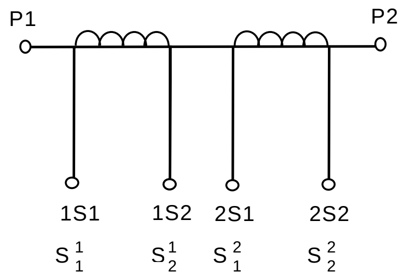
Figure 3 – Transformer with primary winding in 2 sections intended for connections either in series or in parallel.</td>
<td>

Figure 4 – Transformer with 2 secondary windings; each with its own magnetic core. (Two alternative markings for the secondary terminals.)</td>
</tr>
</table>

10.1.3 Indication of relative polarities

All the terminals marked P1, S1 and C1 shall have the same polarity at the same instant.

10.2 Rating plate markings

All current 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 current, i.e.:

$$K_n = I_{pn} / I_{sn} \text{ A (e.g. } K_n = 100/5 \text{ A)}$$

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

e) the rated output and the corresponding accuracy class, together with additional information specified in the later parts of these recommendations (see 11.7 and/or 12.7, 13.5 and 14.5);

NOTE Where appropriate, the category of secondary winding should be marked (e.g. 1S, 15 VA, class 0.5; 2S, 30 VA, class 1).

f) the highest voltage for equipment (e.g. 1,2 kV or 145 kV);

g) the rated insulation level (e.g. 6/–kV* or 275/650 kV).

NOTE The two items f) and g) may be combined into one marking (e.g. 1,2/6/–kV*or 145/275/650 kV).

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

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

h) the rated short-time thermal current (I_{th}) and the rated dynamic current if it differs from 2,5 times the rated short-time thermal current (e.g. 13 kA or 13/40 kA);

i) the 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.

k) on transformers with two secondary windings, the use of each winding and its corresponding terminals.

l) the rated continuous thermal current (for example I_{cth} = 150 %).

11 Additional requirements for measuring current transformers

11.1 Accuracy class designation for measuring current transformers

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

11.1.1 Standard accuracy classes

The standard accuracy classes for measuring current transformers are:

0,1 – 0,2 – 0,5 – 1 – 3 – 5.

11.2 Limits of current error and phase displacement for measuring current transformers

For classes 0.1 – 0.2 – 0.5 and 1, the current error and phase displacement at rated frequency shall not exceed the values given in table 11 when the secondary burden is any value from 25 % to 100 % of the rated burden.

For classes 0,2 S and 0,5 S the current error and phase displacement at the rated frequency shall not exceed the values given in table 12 when the secondary burden is any value from 25 % and 100 % of the rated burden.

* A dash indicates absence of an impulse voltage level.

For current transformers of accuracy class 0,1 - 0,2 - 0,2 S and having a rated burden not exceeding 15 VA, an extended range of burden can be specified. The current error and phase displacement shall not exceed the values given in table 11 to 12, when the secondary burden is any value from 1 VA to 100 % of the rated burden.

For class 3 and class 5, the current error at rated frequency shall not exceed the values given in table 13 when the secondary burden is any value from 50 % to 100 % of the rated burden.

The secondary burden used for test purposes shall have a power-factor of 0,8 lagging except that when the burden is less than 5 VA, a power-factor of 1,0 shall be used. In no case shall the test burden be less than 1 VA.

NOTE 1 For current transformers with a rated secondary current of 1 A, a range limit lower than 1 VA may be agreed.

NOTE 2 This requirement may be requested for certified accuracy of energy measurements.

NOTE 3 At the moment, there is not sufficient experience about the possibility to perform the accuracy measurements at lower current values (test equipment and uncertainty of the obtained results).

NOTE 4 In general the prescribed limits of current error and phase displacement are valid for any given position of an external conductor spaced at a distance in air not less than that required for insulation in air at the highest voltage for equipment (U_m).

Special conditions of application, including lower ranges of operation voltages associated with high current values, should be a matter of separate agreement between manufacturer and purchaser.

For multi-ratio transformers with tappings on the secondary winding, the accuracy requirements refer to the highest transformation ratio, unless otherwise specified.

NOTE When the requirements refer to highest transformation ratio, the manufacturer shall give indications about the accuracy class and the rated burden for the other tappings.

Table 11 – Limits of current error and phase displacement for measuring current transformers (classes from 0.1 to 1)

Accuracy class	**± Percentage current (ratio) error at percentage of rated current shown below**				**± Phase displacement at percentage of rated current shown below**							
					Minutes				Centiradians			
	5	20	100	120	5	20	100	120	5	20	100	120
0.1	0,4	0,2	0,1	0,1	15	8	5	5	0,45	0,24	0,15	0,15
0.2	0,75	0,35	0,2	0,2	30	15	10	10	0,9	0,45	0,3	0,3
0.5	1,5	0,75	0,5	0,5	90	45	30	30	2,7	1,35	0,9	0,9
1.0	3,0	1,5	1,0	1,0	180	90	60	60	5,4	2,7	1,8	1,8

Table 12 – Limits of current error and phase displacement for measuring current transformers for special application

Accuracy class	± Percentage current (ratio) error at percentage of rated current shown below					± Phase displacement at percentage of rated current shown below									
						Minutes					Centiradians				
	1	5	20	100	120	1	5	20	100	120	1	5	20	100	120
0.2 S	0,75	0,35	0,2	0,2	0,2	30	15	10	10	10	0,9	0,45	0,3	0,3	0,3
0.5 S	1,5	0,75	0,5	0,5	0,5	90	45	30	30	30	2,7	1,35	0,9	0,9	0,9

Table 13 – Limits of current error for measuring current transformers (classes 3 and 5)

Class	± Percentage current (ratio) error at percentage of rated current shown below	
	50	120
3	3	3
5	5	5

Limits of phase displacement are not specified for class 3 and class 5.

11.3 Extended current ratings

Current transformers of accuracy classes 0.1 to 1 may be marked as having an extended current rating provided they comply with the following two requirements:

a) the rated continuous thermal current shall be the rated extended primary current expressed as a percentage of the rated primary current;

b) the limits of current error and phase displacement prescribed for 120 % of rated primary current in table 11 shall be retained up to the rated extended primary current.

11.4 Type tests for accuracy of measuring current transformers

Type tests to prove compliance with 11.2 shall, in the case of transformers of classes 0.1 to 1, be made at each value of current given in table 11 at 25 % and at 100 % of rated burden (subject to 1 VA minimum).

Transformers having extended current ratings greater than 120 % shall be tested at the rated extended primary current instead of at 120 % of rated current.

Transformers of class 3 and class 5 shall be tested for compliance with the two values of current given in table 13 at 50 % and at 100 % of rated burden (subject to 1 VA minimum).

11.5 Routine tests for accuracy of measuring current transformers

The routine test for accuracy is in principle the same as the type test in 11.4, but routine tests at a reduced number of currents 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 11.2.

11.6 Instrument security factor

A type test may be performed using the following indirect test:

– with the primary winding open-circuited, the secondary winding is energized at rated frequency by a substantially sinusoidal voltage having an r.m.s. value equal to the secondary limiting e.m.f.

The resulting excitation current (I_{exc}), expressed as a percentage of the rated secondary current (I_{sn}) multiplied by the instrument security factor *FS* shall be equal to or exceed the rated value of the composite error of 10 %:

$$\frac{I_{exc}}{I_{sn}\,FS} \times 100 \geq 10$$

If this result of measurement should be called into question, a controlling measurement shall be performed with the direct test (see annex A), the result of which is then mandatory.

NOTE The great advantage of the indirect test is that high currents are not necessary (for instance 30 000 A at a primary rated current 3000 A and an instrument security factor 10) and also no burdens which must be constructed for 50 A. The effect of the return primary conductors is not physically effective at the indirect test. Under service conditions the effect can only enlarge the composite error, which is desirable for the safety of the apparatus supplied by the measuring transformer.

11.7 Marking of the rating plate of a measuring current transformer

The rating plate shall carry the appropriate information in accordance with 10.2.

The accuracy class and instrument security factor shall be indicated following the indication of corresponding rated output (e.g. 15 VA class 0.5 *FS* 10).

Current transformers having an extended current rating (see 11.3) shall have this rating indicated immediately following the class designation (e.g. 15 VA class 0.5 ext. 150 %).

For current transformers having a rated burden not exceeding 15 VA and an extended burden down to 1 VA, this rating shall be indicated immediately before the burden indication (for example, 1 VA to 10 VA class 0,2).

NOTE The rating plate may contain information concerning several combinations of ratios, output and accuracy class that the transformer can satisfy (for example, 15 VA class 0,5 – 30 VA class 1) and in this case non-standard values of output may be used (for example, 15 VA class 1 – 7 VA class 0,5 in accordance with note to 4.4).

12 Additional requirements for protective current transformers

12.1 Standard accuracy limit factors

The standard accuracy limit factors are:

5 – 10 – 15 – 20 – 30

12.2 Accuracy classes for protective current transformer

12.2.1 Accuracy class designation

For protective current transformers, the accuracy class is designed by the highest permissible percentage composite error at the rated accuracy limit primary current prescribed for the accuracy class concerned, followed by the letter “P” (meaning protection).

12.2.2 Standard accuracy classes

The standard accuracy classes for protective current transformers are:

5P and 10P.

12.3 Limits of errors for protective current transformers

At rated frequency and with rated burden connected, the current error, phase displacement and composite error shall not exceed the values given in table 14.

For testing purposes when determining current error and phase displacement, the burden shall have a power-factor of 0,8 inductive except that, where the burden is less than 5 VA, a power-factor of 1,0 is permissible.

For the determination of composite error, the burden shall have a power-factor of between 0,8 inductive and unity at the discretion of the manufacturer.

Table 14 – Limits of error for protective current transformers

Accuracy class	Current error at rated primary current %	Phase displacement at rated primary current		Composite error at rated accuracy limit primary current %
		minutes	centiradians	
5P	±1	±60	±1,8	5
10P	±3	–	–	10

12.4 Type and routine tests for current error and phase displacement of protective current transformers

Tests shall be made at rated primary current to prove compliance with 12.3 in respect of current error and phase displacement.

12.5 Type tests for composite error

a) Compliance with the limits of composite error given in table 14 shall be demonstrated by a direct test in which a substantially sinusoidal current equal to the rated accuracy limit primary current is passed through the primary winding with the secondary winding connected to a burden of magnitude equal to the rated burden but having, at the discretion of the manufacturer, a power-factor between 0,8 inductive and unity (see annex A).

   The test may be carried out on a transformer similar to the one being supplied, except that reduced insulation may be used, provided that the same geometrical arrangement is retained.

   NOTE Where very high primary currents and single bar-primary winding current transformers are concerned, the distance between the return primary conductor and the current transformer should be taken into account from the point of view of reproducing service conditions.

b) For current transformers having substantially continuous ring cores, uniformly distributed secondary winding(s) or uniformly distributed portions of tapped winding(s) and having either a centrally located primary conductor(s) or a uniformly distributed primary winding, the direct test may be replaced by the following indirect test, provided that the effect of the return primary conductor(s) is negligible.

With the primary winding open-circuited, the secondary winding is energized at rated frequency by a substantially sinusoidal voltage having an r.m.s. value equal to the secondary limiting e.m.f.

The resulting exciting current, expressed as a percentage of the rated secondary current multiplied by the accuracy limit factor, shall not exceed the limit of composite error given in table 14.

NOTE 1 In calculating the secondary limiting e.m.f., the secondary winding impedance should be assumed to be equal to the secondary winding resistance measured at room temperature and corrected to 75 °C.

NOTE 2 In determining the composite error by the indirect method, a possible difference between turns ratio and rated transformation ratio need not be taken into account.

12.6 Routine tests for composite error

For all transformers qualifying under item b) of 12.5, the routine test is the same as the type test.

For other transformers, the indirect test of measuring the exciting current may be used, but a correction factor shall be applied to the results, the factor being obtained from a comparison between the results of direct and indirect tests applied to a transformer of the same type as the one under consideration (see note 2), the accuracy limit factor and the conditions of loading being the same.

In such cases, certificates of test should be held available by the manufacturer.

NOTE 1 The correction factor is equal to the ratio of the composite error obtained by the direct method and the exciting current expressed as a percentage of the rated secondary current multiplied by the accuracy limit factor, as determined by the indirect method specified in item a) of 12.5.

NOTE 2 The expression “transformer of the same type” implies that the ampere turns are the same irrespective of ratio, and that the geometrical arrangements, magnetic materials and the secondary windings are identical.

12.7 Marking of the rating plate of a protective current transformer

The rating plate shall carry the appropriate information in accordance with 10.2. The rated accuracy limit factor shall be indicated following the corresponding output and accuracy class (e.g. 30 VA class 5P 10).

NOTE A current transformer satisfying the requirements of several combinations of output and accuracy class and accuracy limit factor may be marked according to all of them.

Example:

(15 VA class 0.5)	or	(15 VA class 0.5)
(30 VA class 1)		(15 VA class 1, ext. 150 %)
(30 VA class 5P 10)		(15 VA class 5P 20)

13 Additional requirements for class PR protective current transformers

13.1 Standard accuracy limit factors

See 12.1.

13.2 Accuracy classes for class PR protective current transformers

13.2.1 Accuracy class designation

The accuracy class is designated by the highest permissible percentage composite error at the rated accuracy limit primary current prescribed for the accuracy class concerned, followed by the letters "PR" (indicating protection low remanence).

13.2.2 Standard accuracy classes

The standard accuracy classes for low remanence protective current transformers are:

5 PR and 10 PR.

13.3 Limits of error for class PR protective current transformers

13.3.1 Current error, phase displacement and composite error

Refer to 12.3. Limits of error are given in table 15.

Table 15 – Limits of error for class PR protective current transformers

Accuracy class	**Current error at rated primary current** %	**Phase displacement at rated primary current**		**Composite error at rated accuracy limit primary current** %
		Minutes	Centiradians	
5 PR	±1	±60	±1,8	5
10 PR	±3	–	–	10

13.3.2 Remanence factor (K_r)

The remanence factor (K_r) shall not exceed 10 %.

NOTE Insertion of one or more air gaps in the core may be a method for limiting the remanence factor.

13.3.3 Secondary loop time constant (T_s)

If required, the value shall be specified by the purchaser.

13.3.4 Secondary winding resistance (R_{ct})

If required, the maximum value shall be agreed between manufacturer and purchaser.

13.4 Type and routine tests for current error and phase displacement of class PR protective current transformers

Class PR current transformers shall, in addition to the requirements of clause 12, be subjected to the routine tests prescribed below.

13.4.1 Determination of remanence factor (K_r)

The remanence factor (K_r) shall be determined to prove compliance with the limit of 10 %. Refer to IEC 60044-6, annex B for the determination method.

13.4.2 Determination of secondary loop time constant (T_s)

The secondary loop time constant (T_s) shall be determined. It shall not differ from the specified value by more than ±30 %. If required, refer to IEC 60044-6, annex B.

13.4.3 Determination of secondary winding resistance (R_{ct})

The secondary winding resistance shall be measured and an appropriate correction applied if the measurement is made at a temperature which differs from 75 °C or such other temperature as may have been specified. The value so adjusted is the rated value for R_{ct}.

NOTE For determination of secondary loop resistance ($R_s = R_{ct} + R_b$), R_b is the rated resistive burden which, in the case of class PR current transformers, is taken as being equal to the resistive part of the burden used in accordance with 12.3 for the determination of current error and phase displacement.

13.5 Marking of rating plate of class PR current transformers

13.5.1 Principal marking

See 10.2 and 12.7. Replace accuracy classes "5P" and "10P" with "5 PR" and "10 PR" respectively.

13.5.2 Special marking (when required):

a) secondary loop time constant (T_s);

b) secondary winding resistance (R_{ct}) at a temperature of 75 °C.

14 Additional requirements for class PX protective current transformers

14.1 Specification of performance for class PX protective current transformers

The performance of class PX current transformers shall be specified in terms of the following:

a) rated primary current (I_{pn});

b) rated secondary current (I_{sn});

c) rated turns ratio. The turns ratio error shall not exceed ±0,25 %;

d) rated knee point e.m.f. (E_k);

e) maximum exciting current (I_e) at the rated knee point e.m.f. and/or at a stated percentage thereof;

f) maximum resistance of the secondary winding at a temperature of 75 °C (R_{ct});

g) rated resistive burden (R_b);

h) dimensioning factor (K_x).

NOTE The rated knee point e.m.f. is generally determined as follows:

$$E_k = K_x \cdot \left(R_{ct} + R_b\right) \times I_{sn}$$

14.2 Insulation requirements for class PX protective current transformers

14.2.1 Insulation requirements for secondary winding

The secondary winding insulation of class PX current transformers having a rated knee point voltage $E_k \geq 2$ kV shall be capable of withstanding a rated power frequency withstand voltage of 5 kV r.m.s. for 60 s. For $E_k < 2$ kV, the withstand voltage shall be 3 kV r.m.s. for 60 s.

14.2.2 Inter-turn insulation requirements

For class PX transformers having a rated knee point e.m.f. of 450 V or less, the rated withstand voltage for inter-turn insulation shall be in accordance with 8.4. For those with a rated knee point e.m.f. of greater than 450 V, the rated withstand voltage for the inter-turn insulation shall be a peak voltage of 10 times the r.m.s. value of the specified knee point e.m.f., or 10 kV peak, whichever is the lower.

NOTE For some EHV transmission systems, a higher limiting value of peak voltage may be agreed between the manufacturer and the purchaser.

14.3 Type tests for class PX protective current transformers

Class PX current transformers shall, in addition to the requirements of clause 7, be tested as prescribed below.

14.3.1 Proof of low reactance type

In order to establish proof of low leakage reactance design, it shall be shown by a drawing that the current transformer has a substantially continuous ring core, with air gaps uniformly distributed, if any, uniformly distributed secondary winding, a primary conductor symmetrical with respect to rotation and the influences of conductors of the adjacent phase outside of the current transformer housing and of the neighbouring phases are negligible. If compliance with the requirements of low leakage reactance design cannot be established to the mutual satisfaction of the manufacturer and purchaser by reference to drawings, then the composite error shall be determined for the complete secondary winding using either of the direct methods of test given in A.5 or A.6 of annex A at a secondary current of $K_x \cdot I_{sn}$ and with a secondary burden R_b. Proof of low leakage reactance design shall be considered to have been established if the value of composite error from the direct method of test is less than 1,1 times that deduced from the secondary excitation characteristic.

NOTE The value of primary current required to perform direct composite error tests on certain transformer types may be beyond the capability of facilities normally provided by manufacturers. Tests at lower levels of primary current may be agreed between the manufacturer and purchaser.

14.4 Routine tests for class PX protective current transformers

Class PX current transformers shall, in addition to the requirements of clause 8, be tested as prescribed below.

14.4.1 Rated knee point e.m.f. (E_k) and maximum exciting current (I_e)

A sinusoidal e.m.f. of rated frequency equal to the rated knee-point e.m.f. shall be applied to the complete secondary winding, all other windings being open-circuited and the exciting current measured.

The e.m.f. shall then be increased by 10 % and the exciting current shall not increase by more than 50 %. All measurements shall be performed using r.m.s. measuring instruments. Due to the non-sinusoidal nature of the measured quantities, the measurements shall be performed using r.m.s. measuring instruments having a crest factor ≥3.

The excitation characteristic shall be plotted at least up to the rated knee point e.m.f. The exciting current (I'_e) at the rated knee-point e.m.f. and at any stated percentage, shall not exceed the rated value. The number of measurement points shall be agreed between the manufacturer and the purchaser.

14.4.2 Secondary winding resistance (R_{ct})

The resistance of the complete secondary winding shall be measured. The value obtained when corrected to 75 °C shall not exceed the specified value.

14.4.3 Turns ratio error (ε_t)

The turns ratio shall be determined in accordance with IEC 60044-6, annex E. The turns ratio error shall not exceed the value given in 14.1 c).

NOTE A simplified test involving measurement of the ratio error with zero connected burden may be substituted by agreement between the manufacturer and purchaser.

14.4.4 Insulation tests

Tests shall be performed to demonstrate compliance with 14.2.1. For the test method, refer to 8.3.

14.4.5 Inter-turn insulation tests

Tests shall be performed to demonstrate compliance with 14.2.2. For the test method, refer to 8.4.

14.5 Marking of rating plate of class PX current transformers

14.5.1 Principal marking

Refer to 10.2.

14.5.2 Special marking

a) rated turns ratio;

b) rated knee point e.m.f. (E_k);

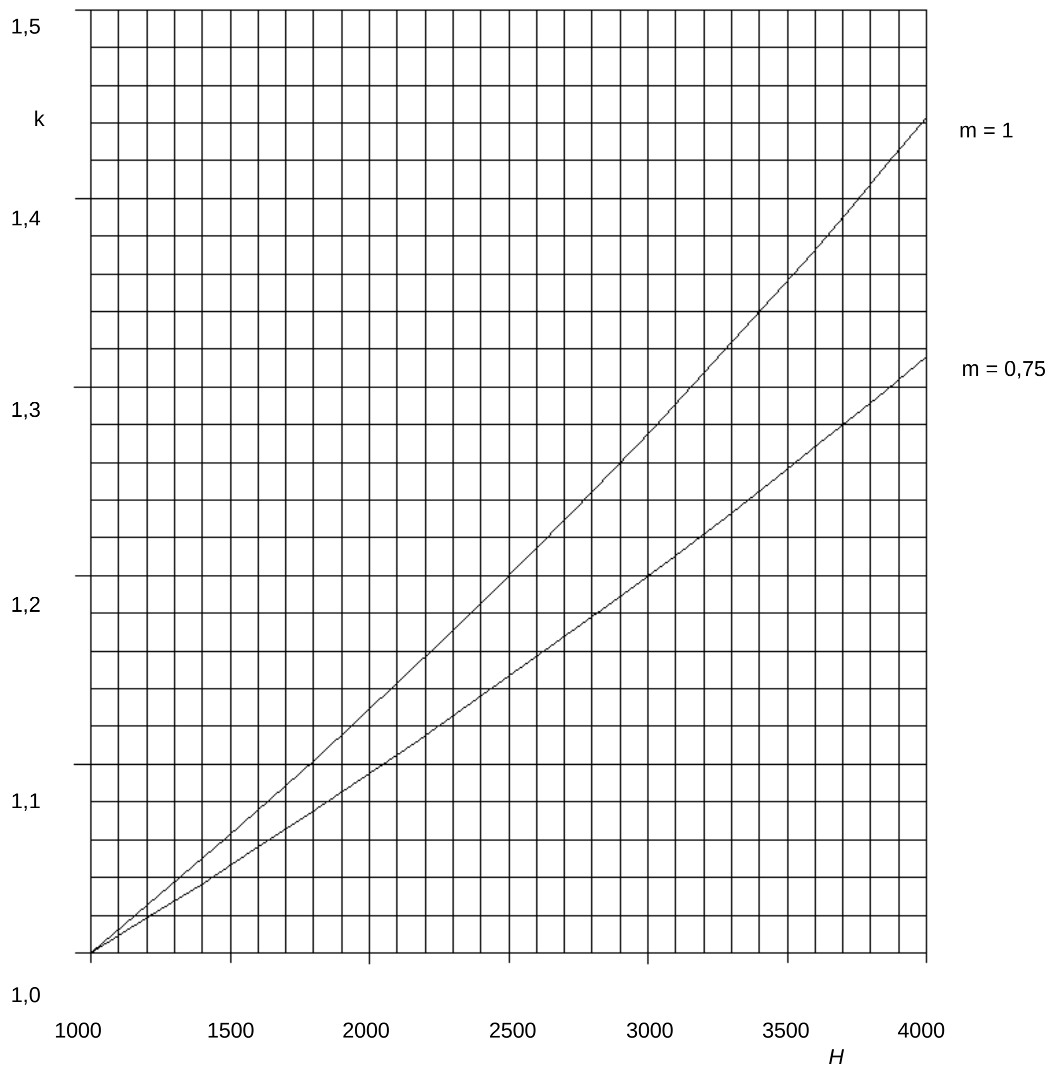
c) maximum exciting current (I_e) at the rated knee point e.m.f. and/or at the stated percentage thereof;

d) maximum resistance of the complete secondary winding at a temperature of 75 °C (R_{ct}).

The following may also be required by the purchaser:

e) dimensioning factor (K_x);

f) rated resistive burden (R_b).



These factors can be calculated with the following equation:

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

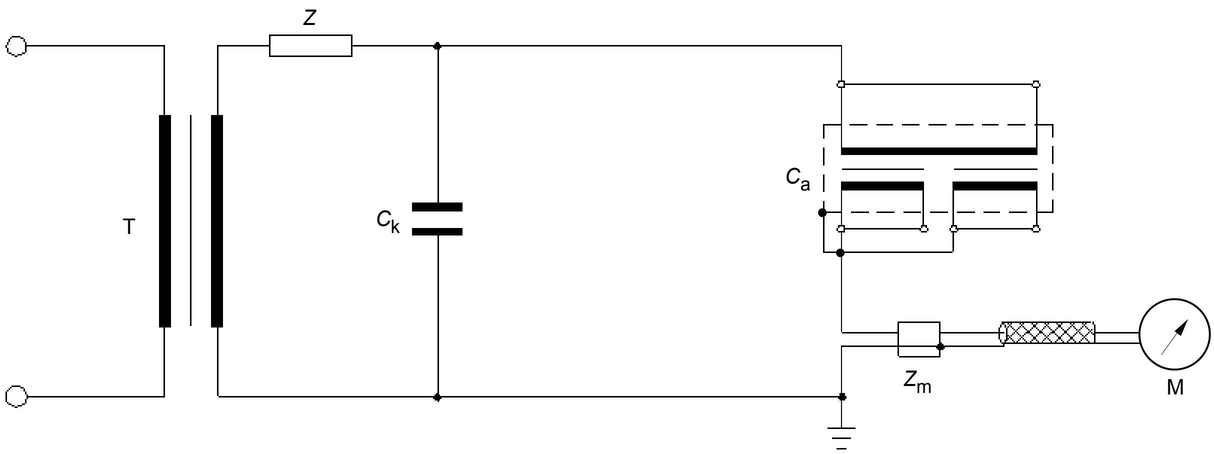
where

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 factors



T test transformer

C_a instrument transformer to be tested

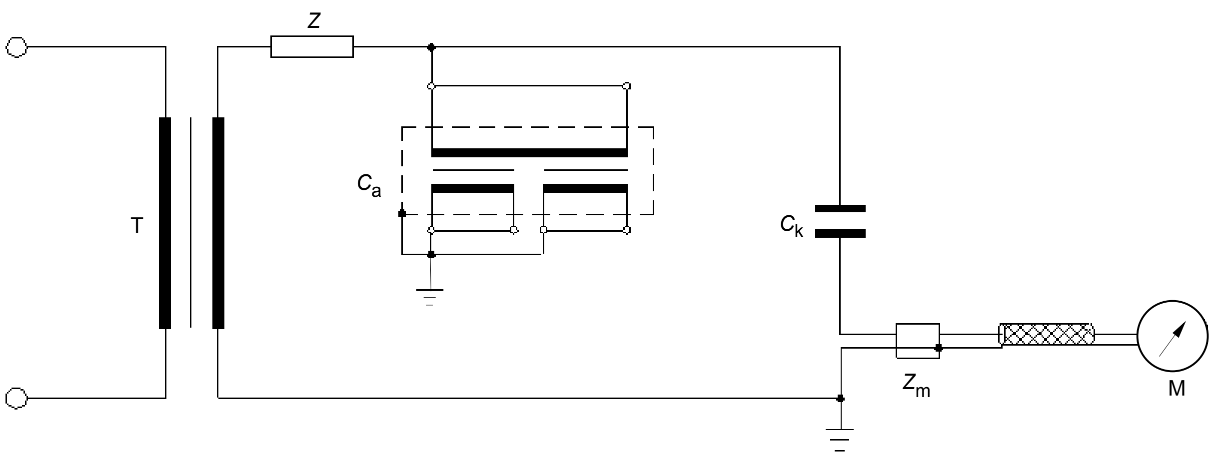
C_k coupling capacitor

M PD measuring instrument

Z_m measuring impedance

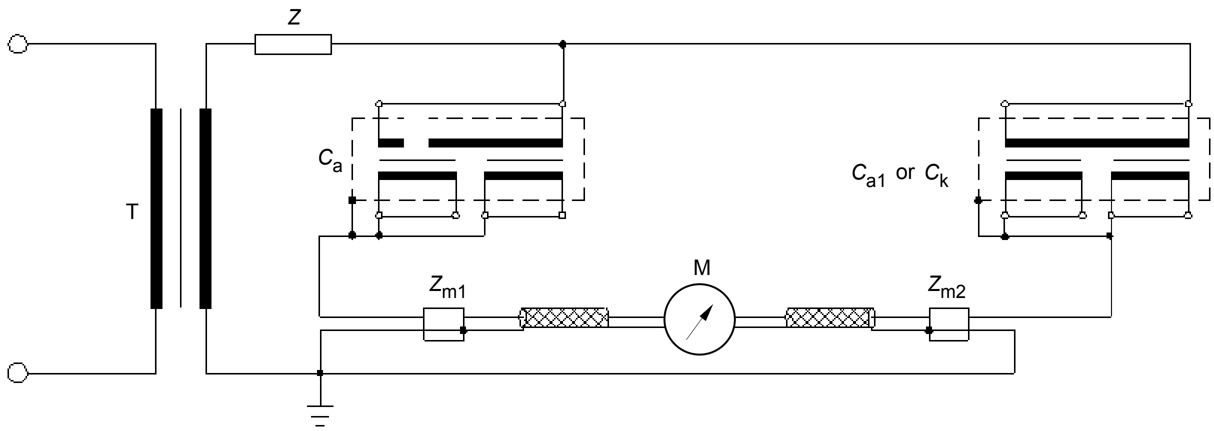
Z filter (not present if C_K is the capacitance of the test transformer)

Figure 2 – Test circuit for partial discharge measurement



Symbols as in figure 2

Figure 3 – Alternative test circuit for partial discharge measurement



T test transformer

C_a instrument transformer to be tested

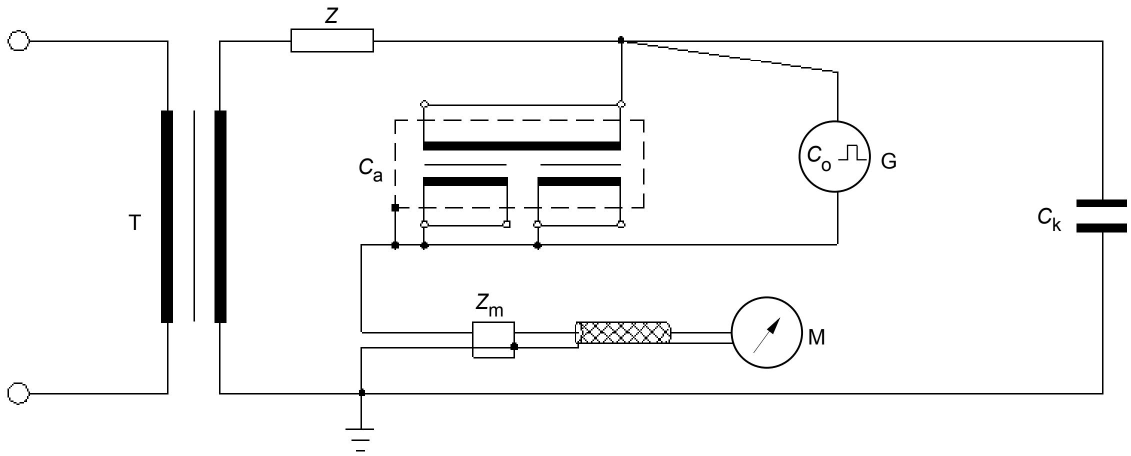
C_{a1} auxiliary PD free object
(or C_k is the coupling capacitor)

M PD measuring instrument

Z_{m1} and Z_{m2} measuring impedances

Z filter

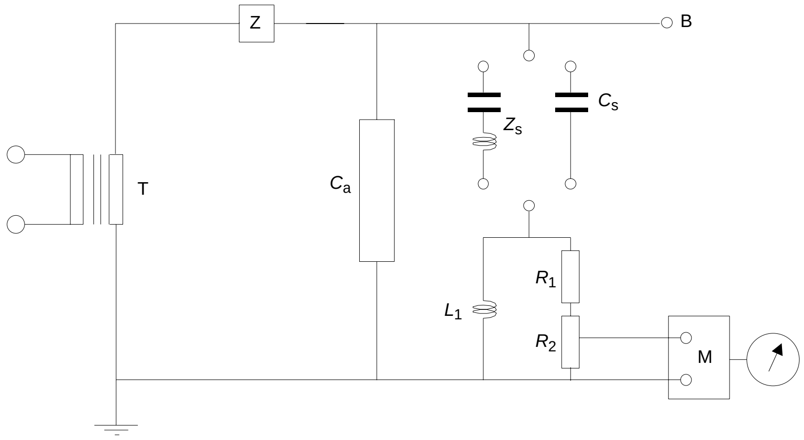
Figure 4 – Example of balanced test circuit for partial discharge measurement



Symbols as in figure 2

G impulse generator with capacitance C_0

Figure 5 – Example of calibration circuit for partial discharge measurement



Key

C_a Test object

Z Filter

B Corona-free termination

M Measuring set

$Z_s+(R_1+R_2) = 300\ \Omega$

T Test transformer

Z_s, C_s, L_1, R_1, R_2 see CISPR 18-2

Figure 6 – Measuring circuit

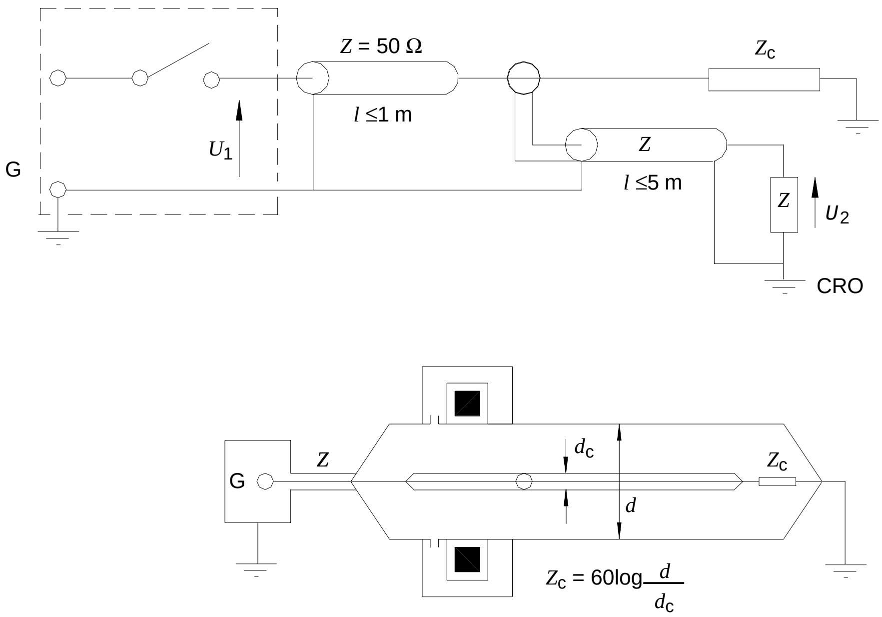


Figure 7 – Transmitted Overvoltages measurement: Test Circuit and GIS Test set-up

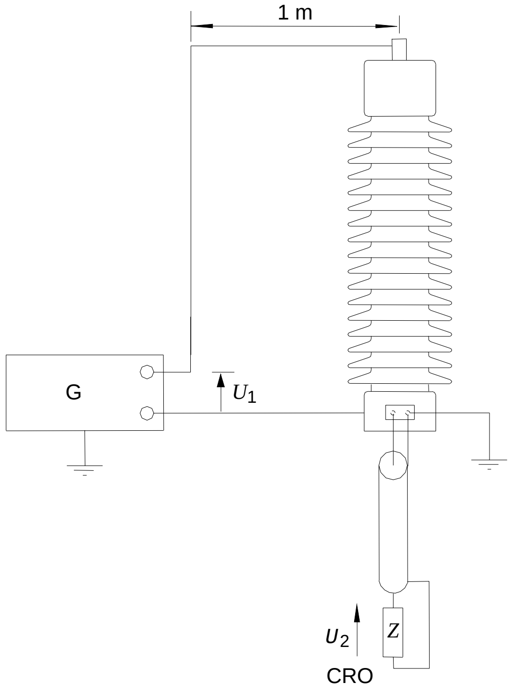
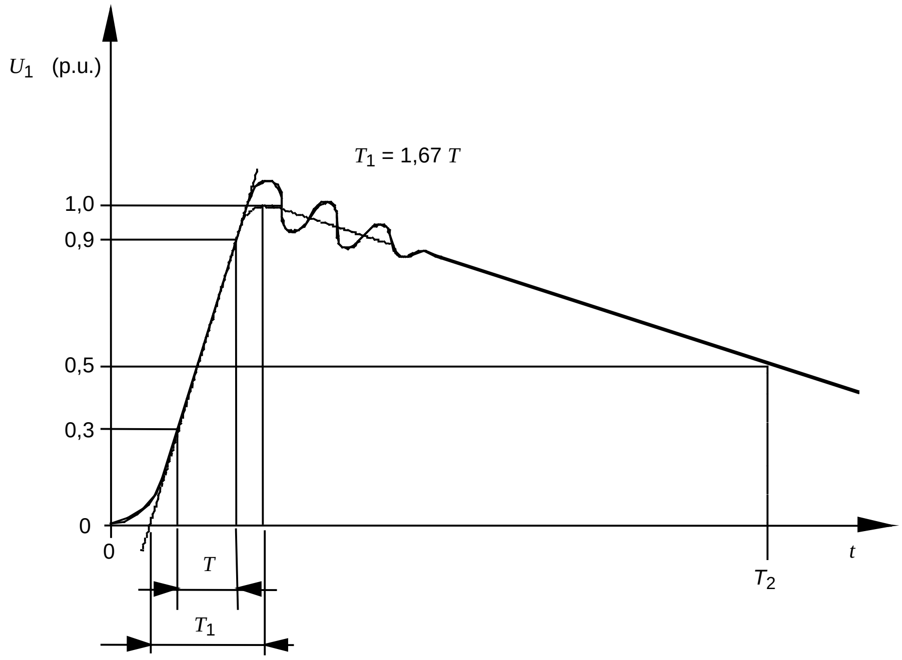
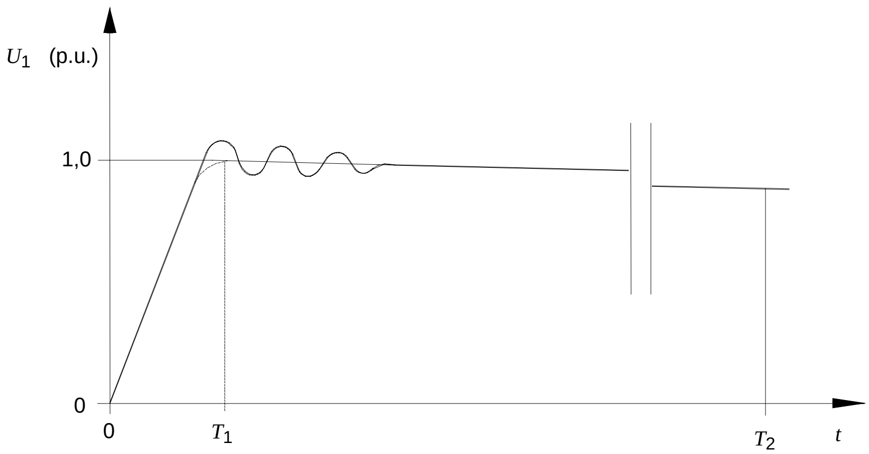


Figure 8 – Transmitted Overvoltages measurement: General Test set-up



Waveshape A



Waveshape B

Figure 9 – Transmitted Overvoltages measurement: Test Waveforms

Annex A
(normative)

Protective current transformers

A.1 Vector diagram

If consideration is given to a current transformer which is assumed to contain only linear electric and magnetic components in itself and in its burden, then, under the further assumption of sinusoidal primary current, all the currents, voltages and fluxes will be sinusoidal, and the performance can be illustrated by a vector diagram such as figure A.1.

In figure A.1, I_s represents the secondary current. It flows through the impedance of the secondary winding and the burden which determines the magnitude and direction of the necessary induced voltage E_s and of the flux Φ which is perpendicular to the voltage vector. This flux is maintained by the exciting current I_e, having a magnetizing component I_m parallel to the flux Φ, and a loss (or active) component I_a parallel to the voltage. The vector sum of the secondary current I_s and the exciting current I_e is the vector I''_p representing the primary current divided by the turns ratio (number of secondary turns to number of primary turns).

Thus, for a current transformer with turns ratio equal to the rated transformation ratio, the difference in the lengths of the vectors I_s and I''_p, related to the length of I''_p, is the current error according to the definition of 2.1.10, and the angular difference δ is the phase displacement according to 2.1.11.

A.2 Turns correction

When the turns ratio is different from (usually less than) the rated transformation ratio, the current transformer is said to have turns correction. Thus, in evaluating the performance, it is necessary to distinguish between I''_p, the primary current divided by the turns ratio, and I'_p, the primary current divided by the rated transformation ratio. Absence of turns correction means $I'_p = I''_p$. If turns correction is present, I'_p is different from I''_p, and since I''_p is used in the vector diagram and I'_p is used for the determination of the current error, it will be seen that turns correction has an influence on the current error (and may be used deliberately for that purpose). However, the vectors I'_p and I''_p have the same direction, so turns correction has no influence on phase displacement.

It will also be apparent that the influence of turns correction on composite error is less than its influence on current error.

A.3 The error triangle

In figure A.2, the upper part of figure A.1 is re-drawn to a larger scale and under the further assumption that the phase displacement is so small that for practical purposes the two vectors I_s and I''_p can be considered to be parallel. Assuming again that there is no turns correction, it will be seen by projecting I_e to I_p that with a good approximation the in-phase component (ΔI) of I_e can be used instead of the arithmetic difference between I''_p and I_s to obtain the current error and, similarly, the quadrature component (ΔI_q) of I_e can be used to express the phase displacement.

It will further be seen that under the given assumptions the exciting current I_e divided by I''_p is equal to the composite error according to 2.1.31.

Thus, for a current transformer without turns correction and under conditions where a vector representation is justifiable, the current error, phase displacement and composite error form a right-angled triangle.

In this triangle, the hypotenuse representing the composite error is dependent on the magnitude of the total burden impedance consisting of burden and secondary winding, while the division between current error and phase displacement depends on the power factors of the total burden impedance and of the exciting current. Zero phase displacement will result when these two power factors are equal, i.e. when I_s and I_e are in phase.

A.4 Composite error

The most important application, however, of the concept of composite error is under conditions where a vector representation cannot be justified because non-linear conditions introduce higher harmonics in the exciting current and in the secondary current (see figure A.3).

It is for this reason that the composite error is defined as in 2.1.31, and not in the far simpler way as the vector sum of current error and phase displacement as shown in figure A.2.

Thus, in the general case, the composite error also represents the deviations from the ideal current transformer that are caused by the presence in the secondary winding of higher harmonics which do not exist in the primary. (The primary current is always considered sinusoidal for the purposes of this standard.)

A.5 Direct test for composite error

Figure A.4 shows a current transformer having a turns ratio of 1/1. It is connected to a source of primary (sinusoidal) current, a secondary burden Z_B with linear characteristics and to an ammeter in such a manner that both the primary and secondary currents pass through the ammeter but in opposite directions. In this manner, the resultant current through the ammeter will be equal to the exciting current under the prevailing conditions of sinusoidal primary current, and the r.m.s. value of that current related to the r.m.s. value of the primary current is the composite error according to 2.1.31, the relation being expressed as a percentage.

Figure A.4 therefore represents the basic circuit for the direct measurement of composite error.

Figure A.5 represents the basic circuit for the direct measurement of composite error for current transformers having rated transformation ratios differing from unity. It shows two current transformers of the same rated transformation ratio. The current transformer marked N is assumed to have negligible composite error under the prevailing conditions (minimum burden), while the current transformer under test and marked X is connected to its rated burden.

They are both fed from the same source of primary sinusoidal current, and an ammeter is connected to measure the difference between the two secondary currents. Under these conditions, the r.m.s. value of the current in the ammeter A_2 related to the r.m.s. value of the current in ammeter A_1 is the composite error of transformer X, the relation being expressed as a percentage.

With this method, it is necessary that the composite error of transformer N is truly negligible under the conditions of use. It is not sufficient that transformer N has a known composite error since, because of the highly complicated nature of composite error (distorted waveform), any composite error of the reference transformer N cannot be used to correct the test results.

A.6 Alternative method for the direct measurement of composite error

Alternative means may be used for the measurement of composite error and one method is shown in figure A.6.

Whilst the method shown in figure A.5 requires a “special” reference transformer N of the same rated transformation ratio as the transformer X and having negligible composite error at the accuracy limit primary current, the method shown in figure A.6, enables standard reference current transformers N and N′ to be used at or about their rated primary currents. It is still essential, however, for these reference transformers to have negligible composite errors but the requirement is easier to satisfy.

In figure A.6 X is the transformer under test, N is a standard reference transformer with a rated primary current of the same order of magnitude as the rated accuracy limit primary current of transformer X (the current at which the test is to be made), and N′ is a standard reference transformer having a rated primary current of the order of magnitude of the secondary current corresponding to the rated accuracy limit primary current of transformer X. It should be noted that the transformer N′ constitutes a part of the burden Z_B of transformer X and must therefore be taken into account in determining the value of the burden Z'_B. A_1 and A_2 are two ammeters and care must be taken that A_2 measures the difference between the secondary currents of transformers N and N′.

If the rated transformation ratio of transformer N is K_n, of transformer X is K_{nx} and of transformer N′ is K'_n, the ratio K_n must equal the product of K'_n and K_{nx}:

$$\text{i.e. } K_n = K'_n \times K_{nx}$$

Under these conditions, the r.m.s. value of the current in ammeter A_2, related to the current in ammeter A_2, is the composite error of transformer X, the relation being expressed as a percentage.

NOTE When using the methods shown in figures A.5 and A.6, care should be taken to use a low impedance instrument for A_2 since the voltage across this ammeter (divided by the ratio of transformer N′ in the case of figure A.6) constitutes part of the burden voltage of transformer X and tends to reduce the burden on this transformer. Similarly, this ammeter voltage increases the burden on transformer N.

A.7 Use of composite error

The numeric value of the composite error will never be less than the vector sum of the current error and the phase displacement (the latter being expressed in centiradians).

Consequently, the composite error always indicates the highest possible value of current error or phase displacement.

The current error is of particular interest in the operation of overcurrent relays, and the phase displacement in the operation of phase sensitive relays (e.g. directional relays).

In the case of differential relays, it is the combination of the composite errors of the current transformers involved which must be considered.

An additional advantage of a limitation of composite error is the resulting limitation of the harmonic content of the secondary current which is necessary for the correct operation of certain types of relays.

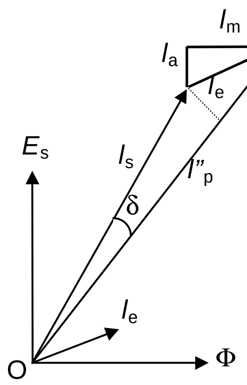


Figure A.1

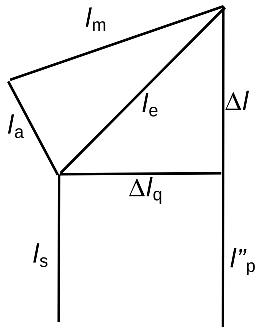


Figure A.2

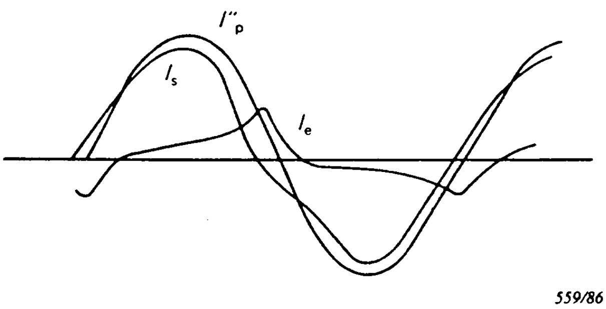


Figure A.3

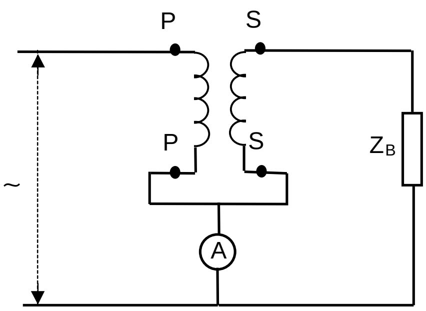


Figure A.4

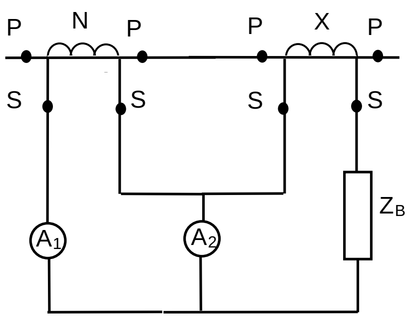


Figure A.5

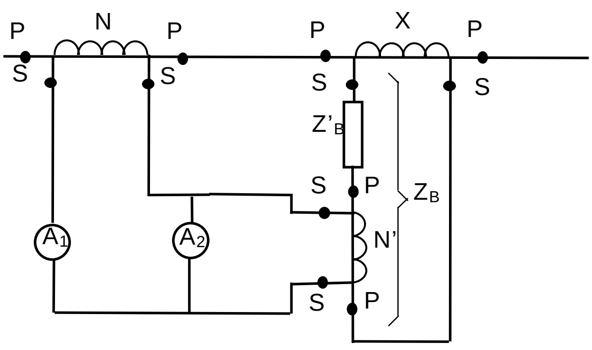


Figure A.6

Annex B
(informative)

Multiple chopped impulse test

The test shall be performed with impulses of negative polarity chopped near the crest.

The virtual duration of voltage collapse, measured according to IEC 60060-1, shall be about 0,5 µs. The circuit shall be so arranged that the overswing to opposite polarity of the recorded impulse shall be of the order of 50 % of the peak value.

The voltage peak value should be about 60 % of the rated lightning impulse withstand voltage.

At least 100 impulses are necessary to put failures in evidence. They shall be applied at the rate of about one impulse per minute.

Before the test and three days after the test the analysis of the gas dissolved in the oil of the transformer shall be carried out.

The criteria for evaluating the result should be based on the amount and composition of the gases produced (ratio of the quantities of significant gases) but no figures can presently be given. Relatively large amounts of H_2 and $C_2 H_2$ are indications of fault.

Oil sampling procedure may be the one given in IEC 60567.

Analysis procedure and basis for fault diagnosis may be based on IEC 60599.

(*Continued from second cover*)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
	IS 13736 (Part 3/Sec 0,1,2,3,4,5,6 and 7) : 1993 Classification of environmental conditions: Part 3 Classification of groups of environmental parameters and their severities	Identical to respective Sections of IEC 60721-3 : 1990
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	IS 12233 (Part 2) : 1993 Electromagnetic interference characterstics of overhead power lines and high voltage equipment: Part 2 Methods of measurement and procedure for determining limits	Identical

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60028 : 1925	International Standard of resistance for copper
IEC 60044-6 : 1992	Instrument transformers — Part 6: Requirements for protective current transformers for transient performance
IEC 60085 : 1984	Thermal evaluation and classification of electrical insulation
IEC 60121 : 1960	Recommendation for commercial annealed aluminium electrical conductor wire
IEC 60567 : 1992	Guide for the sampling of gases and of oil from oil-filled electrical equipment and for the analysis of free and dissolved gases
IEC 60599 : 1978	Interpretation of the analysis of gases in transformers and other oil-filled electrical equipment in service
IEC 60815 : 1986	Guide for the selection of insulators in respect of polluted conditions

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Amendments Issued Since Publication

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