

Instrument transformers —

Part 8: Electronic current transformers

The European Standard EN 60044-8:2002 has the status of a British Standard

ICS 17.220.20

National foreword

This British Standard is the official English language version of EN 60044-8:2002. It is identical with IEC 60044-8:2002.

The UK participation in its preparation was entrusted to Technical Committee PEL/38, Instrument transformers, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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Foreword

The text of document 38/280/FDIS, future edition 1 of IEC 60044-8, prepared by IEC TC 38, Instrument transformers, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60044-8 on 2002-09-01.

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Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, annexes D and ZA are normative and annexes A, B, C and E are informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60044-8:2002 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60038	NOTE	Harmonized as HD 472 S1:1989 (modified).
IEC 60068-2 Series	NOTE	Harmonized in EN 60068-2/HD 323.2 Series (not modified).
IEC 60071-2	NOTE	Harmonized as EN 60071-2:1997 (not modified).
IEC 60255-24	NOTE	Harmonized as EN 60255-24:2001 (not modified).
IEC 60270	NOTE	Harmonized as EN 60270:2001 (not modified).
IEC 60437	NOTE	Harmonized as EN 60437:1997 (not modified).
IEC 60567	NOTE	Harmonized as EN 60567:1992 (not modified).
IEC 60599	NOTE	EN 60599:1999 is based on IEC 60599:1999 (not modified).
IEC 60721-2-2	NOTE	Harmonized as HD 478.2.2 S1:1990 (not modified).
IEC 60721-2-4	NOTE	Harmonized as HD 478.2.4 S1:1989 (not modified).
IEC 61508-1	NOTE	Harmonized as EN 61508-1:2001 (not modified).
IEC 61508-3	NOTE	Harmonized as EN 61508-3:2001 (not modified).
IEC 61754-1	NOTE	Harmonized as EN 61754-1:1997 (not modified).
IEC 61754-15	NOTE	Harmonized as EN 61754-15:2001 (not modified).

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INSTRUMENT TRANSFORMERS –

Part 8: Electronic current transformers

1 Scope

1.1 General

This part of IEC 60044 applies to newly manufactured electronic current transformers having an analogue voltage output or a digital output, for use with electrical measuring instruments and electrical protective devices at nominal frequencies from 15 Hz to 100 Hz.

NOTE Additional requirements due to the bandwidth are considered. The accuracy requirements on harmonics are given in annex D.

Clause 12 covers the accuracy requirements that are necessary for electronic current transformers for use with electrical measuring instruments.

Clause 13 covers the accuracy requirements that are necessary for electronic current transformers for use with electrical protective relays, and particularly for forms of protection in which the prime requirement is to maintain the accuracy up to several times the rated current. If required, the transient accuracy of an electronic current transformer during fault is also given in this clause.

Electronic current transformers intended for both measurement and protection should comply with all the clauses of this standard and are called multipurpose electronic current transformers.

The transformer technology can be based on optical arrangements equipped with electrical components, on air-core coils (with or without a built-in integrator), or on iron-core coils with integrated shunt used as a current-to-voltage converter, alone or equipped with electronic components.

For analogue output, the electronic current transformer may include the secondary signal cable. Examples of electronic current transformer technologies using air-core coils and iron-core coils with integrated shunt are given in annex C.

For digital output, this standard takes into account a point-to-point connection from the electronic transformer to electrical measuring instruments and electrical devices (see annex B).

Some information has been added in order to ensure the compatibility of this point-to-point link with the overall system of communication in the substation, thus allowing data exchange between all kinds of substation devices. This information builds what is called the mapping of the link layer of the point-to-point serial link. Processbus communication is under consideration.

This mapping allows interoperability between devices from different manufacturers.

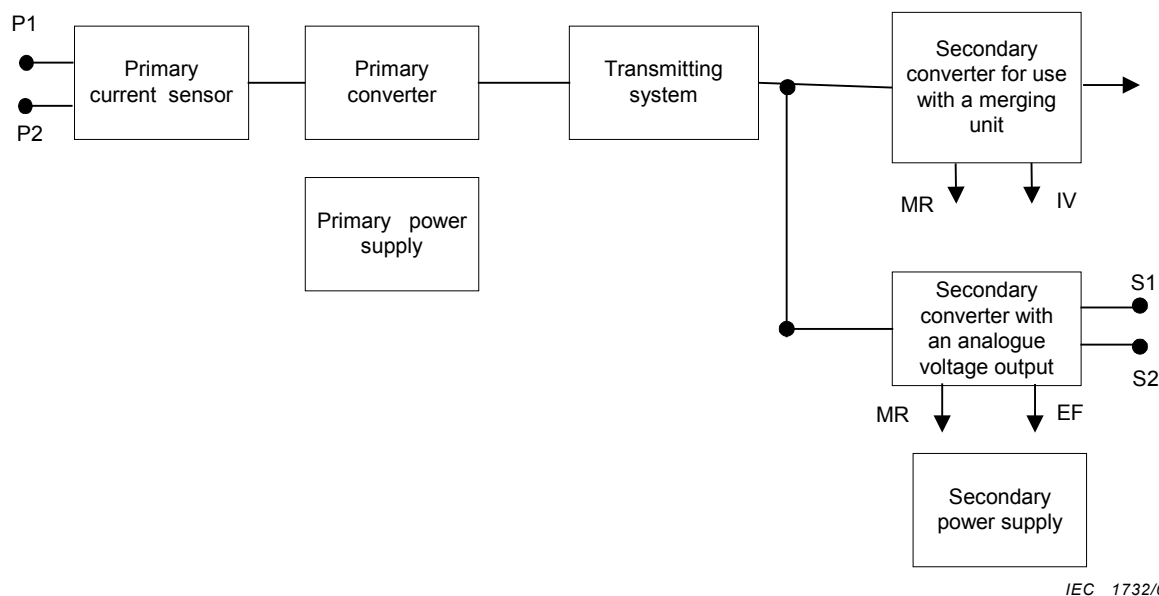
This standard does not specify individual implementations or products, nor does it constrain the implementation of entities and interfaces within a computer system. This standard specifies the externally visible functionality of implementations together with conformance requirements for such functionalities.

NOTE 1 Translation of the analogue requirements on CT and VT into digital parameters, such as the number of bits and the sampling speed, has been carried out as far as was reasonable, since the requirements on the conventional CT and VT are expressed according to the actual technologies used and their shortcomings, rather than on needs from the equipment using the information on current and voltage.

NOTE 2 The approach chosen is to concentrate on what is needed by the secondary equipment and how the performance can be calibrated. The concept is compatible with a processbus.

1.2 General block diagram of electronic current transformers

The applied technology decides which parts are necessary for the realization of an electronic current transformer, i.e. it is not absolutely necessary that all the parts described in figures 1 and 2 be included in the transformer.

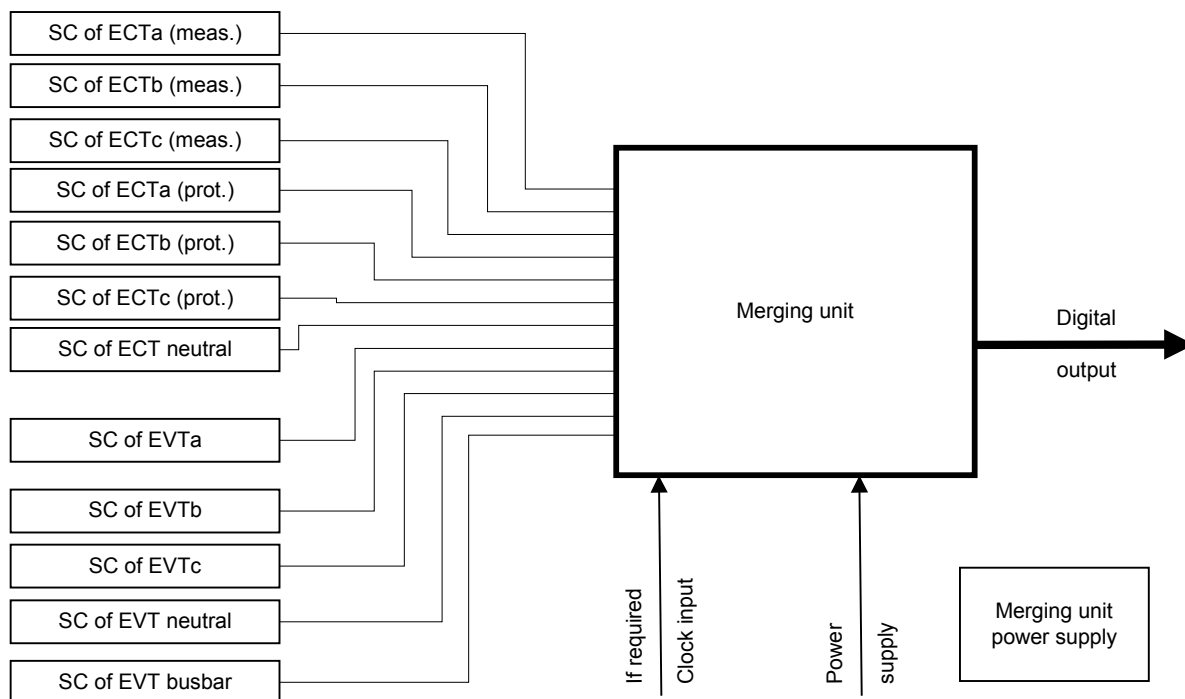


Key

- IV Output invalid
- EF Equipment failure
- MR Maintenance request

Figure 1 – General block diagram of a single-phase electronic current transformer

1.3 General block diagram of electronic transformers with a digital output



IEC 1733/02

NOTE SC of EVTa is the secondary converter of the electronic voltage transformer of phase a (see IEC 60044-7). SC of ECTa is the secondary converter of the electronic current transformer of phase a. Other data channel mappings are possible (see 6.2.3).

Figure 2 – Example of digital interface block diagram

Up to 12 secondary converter data channels are grouped together (merged) using a merging unit (MU). A data channel carries a single stream of sampled measurement values from an electronic current transformer or an electronic voltage transformer (see figure 2). Several data channels may be transmitted via one physical interface from the secondary converter to the merging unit in case of multiphase or combined units. The merging unit supplies the secondary equipment with a time-coherent set of current and voltage samples. A secondary converter can be used also for the acquisition of signals coming from conventional voltage instrument transformers or current instrument transformers and may be integrated into the merging unit.

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 60044-1, *Instrument transformers – Part 1: Current transformers*

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

IEC 60044-7, *Instrument transformers – Part 7: Electronic voltage transformers*

IEC 60050(161):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electro-magnetic compatibility*

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

IEC 60050(601):1985, *International Electrotechnical Vocabulary (IEV) – Chapter 601: Generation, transmission and distribution of electricity – Generation*

IEC 60050(604):1987, *International Electrotechnical Vocabulary (IEV) – Chapter 604: Generation, transmission and distribution of electricity – Operation*

IEC 60056, *High voltage alternating current circuit-breakers*

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

IEC 60068-2-6:1995, *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-17: *Environmental testing – Part 2: Tests – Test Q: Sealing*

IEC 60068-2-75: *Environmental testing – Part 2: Tests – Test Eh: Hammer test*

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, *Recommendation for commercial annealed aluminium electrical conductor wire*

IEC 60255-5:2000, *Electrical relays – Part 5: Insulation coordination for measuring relays and protection equipment – Requirements and tests*

IEC 60255-22-1:1988, *Electrical relays – Part 22: Electrical disturbance tests for measuring relays and protection equipment – Section 2: Electrostatic discharge tests*

IEC 60296:1982, *Specification for unused mineral insulating oils for transformers and switchgear*

IEC 60304:1982, *Standard colours for insulation for low-frequency cables and wires*

IEC 60376:1971, *Specification and acceptance of new sulphur hexafluoride*

IEC 60376B:1974, *Specification and acceptance of new sulphur hexafluoride – Second supplement – Clause 26*

IEC 60417 (all parts), *Graphical symbols for use on equipment*

IEC 60480:1974, *Guide to the checking of sulphur hexafluoride (SF₆) taken from electrical equipment*

IEC 60529, *Degrees of protection provided by enclosures (IP code)*

IEC 60664-1:1992, *Insulation co-ordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60694, *Common specifications for high-voltage switchgear and controlgear standards*

IEC 60707:1999, *Flammability of solid non-metallic materials when exposed to flame sources – List of test methods*

IEC 60721-3-3:1994, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 3: Stationary use at weather-protected locations*

IEC 60721-3-4:1995, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 4: Stationary use at non-weather-protected locations*

IEC 60794 (all parts), *Optical fibre cables*

IEC 60812:1985, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*

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

IEC 60870-5-1:1990, *Telecontrol equipment and systems – Part 5: Transmission protocols – Section One: Transmission frame formats*

IEC 61000-4-1:2000, *Electromagnetic compatibility (EMC) – Part 4-1: Testing and measurement techniques – Overview of IEC 61000-4 series*

IEC 61000-4-2: *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3: *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test – Basic EMC publication*

IEC 61000-4-5: *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-7:1991, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 7: General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*

IEC 61000-4-8: *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-9: *Electromagnetic compatibility (EMC) – Part 4-9: Testing and measurement techniques – Pulse magnetic field immunity test*

IEC 61000-4-10: *Electromagnetic compatibility (EMC) – Part 4-10: Testing and measurement techniques – Damped oscillatory magnetic field immunity test*

IEC 61000-4-11: *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-12: *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Oscillatory waves immunity test*

IEC 61000-4-13: *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests*

IEC 61000-4-29:2000, *Electromagnetic compatibility (EMC) – Part 4-29: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests*

IEC 61025:1990, *Fault tree analysis (FTA)*

IEC 61166:1993, *High-voltage alternating circuit-breakers – Guide for seismic qualification of high-voltage alternating current*

IEC/TS 61462:1998, *Composite insulators – Hollow insulators for use in outdoor and indoor electrical equipment – Definitions, test methods, acceptance criteria and design recommendations*

IEC 61850-3: *Communication networks and systems in substations – Part 3: General requirements*

IEC 61850-9-1: *Communication networks and systems in substations – Part 9-1: Specific communication system mappings (SCSM) – Serial unidirectional multidrop point-to-point link*¹

CISPR 11:1999, *Industrial scientific and medical (ISM) radio-frequency equipment – Electro-magnetic disturbance characteristics – Limits and methods of measurement*

EIA RS-485: *Standard for electrical characteristics of generators and receivers for use in balanced digital multipoint systems*

EN 50160:2000, *Voltage characteristics of electricity supplied by public distribution system*

3 Definitions

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

3.1 General definitions

3.1.1

electronic instrument transformer

arrangement consisting of one or more current or voltage sensor(s) which may be connected to transmitting systems and secondary converters, all intended to transmit a measuring quantity in a proportional quantity to supply measuring instruments, meters and protective or control devices. In case of a digital interface this is done by using a merging unit for a set of electronic instrument transformers

3.1.2

electronic current transformer (ECT)

electronic instrument transformer in which the output of the secondary converter in normal conditions of use is substantially proportional to the primary current and differs in phase from it by a known angle for an appropriate direction of the connections

3.1.3

primary terminals

terminals through which the current to be measured flows

3.1.4

primary current sensor

electric, electrical, optical or other device intended to transmit a signal corresponding to the current flowing through the primary terminals to the secondary converter, either directly or by means of a primary converter

3.1.5

primary converter

arrangement that converts the signal coming from one or more primary current sensors into a signal suitable for the transmitting system

3.1.6

primary power supply

power supply to the primary converter and/or primary current sensor (can be combined with secondary power supply (see 3.1.10))

¹ To be published.

3.1.7

transmitting system

short- or long-distance coupling arrangement between primary and secondary parts intended to transmit the signal. Depending on the technology used, the transmitting system can also be used for power transmission

3.1.8

secondary converter (SC)

arrangement that converts the signal transmitted through the transmitting system into a quantity proportional to the current between the primary terminals, to supply measuring instruments, meters and protective or control devices. For ECTs with analogue output, the secondary converter directly supplies measuring instruments, meters and protective or control devices. For electronic instrument transformers with digital output the secondary converter is generally connected to a merging unit before supplying the secondary equipment

3.1.9

maintenance request (MR)

information indicating that the equipment needs maintenance

3.1.10

secondary power supply

power supply of the secondary converter (can be combined with primary power supply (see 3.1.6) or a power supply of other transformers)

3.1.11

rated auxiliary power supply voltage (U_{ar})

auxiliary power supply voltage value on which the requirements of a specification are based

3.1.12

rated supply current (I_{ar})

value of the current required from the auxiliary power supply, including the MU power supply if required, in the rated conditions

3.1.13

maximum supply current ($I_{a\ max}$)

maximum value of the current required by the auxiliary power supply, including the MU power supply if required, in the worst conditions

3.1.14

secondary circuit

external circuit receiving the information signals supplied by the secondary converter (or the merging unit) of an electronic instrument transformer

3.1.15

secondary terminals

terminals of the secondary converter (or the merging unit) which supply the secondary circuit

3.1.16

connecting point

point provided to connect electrical cables during site installation and test installation. Where shielded cables are used, only the external shield is considered to be a connecting point. The connecting points are specified by the manufacturer

3.1.17

low-voltage components

all electric or electrical components separated from the primary circuit at the full rated withstand voltage level

3.1.18**rated frequency (f_r)**

value of the fundamental frequency on which the requirements of this standard are based

3.1.19**primary current in steady-state condition**

in a steady-state condition, the primary current is defined by the following equation

[IEC 60044-7, modified]:

$$i_p(t) = I_p \times \sqrt{2} \times \sin(2\pi \times f \times t + \varphi_p) + i_{p \text{ res}}(t);$$

where

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

f is the fundamental frequency;

φ_p is the primary phase displacement;

$i_{p \text{ res}}(t)$ is the primary residual current including harmonic and subharmonic components and primary direct current;

t is the instantaneous value of the time;

f, I_p, φ_p being constant for steady-state condition.

3.1.20**rated primary current (I_{pr})**

r.m.s. value of the component of the primary current at rated frequency f_r on which the performance of the electronic current transformer is based

[IEV 321-01-11, modified].

3.1.21**secondary output in steady-state condition**

for an analogue output: in an electrical steady-state condition, the secondary voltage is defined by the following equation:

$$u_s(t) = U_s \sqrt{2} \cdot \sin(2\pi \cdot f \cdot t + \varphi_s) + U_{sdc} + u_{s \text{ res}}(t);$$

where

U_s is the r.m.s. value of secondary converter output, when $U_{sdc} + u_{s \text{ res}}(t) = 0$;

f is the frequency;

φ_s is the secondary phase displacement;

U_{sdc} is the secondary direct voltage;

$u_{s \text{ res}}(t)$ is the secondary residual voltage including harmonic and subharmonic components;

t is the instantaneous value of the time;

f, U_s, φ_s being constant for steady-state condition.

For a digital output:

$$i_s(n) = I_s \sqrt{2} \cdot \sin(2\pi \cdot f \cdot t_n + \varphi_s) + I_{sdc}(n) + i_{s \text{ res}}(t_n);$$

where

i_s is a digital number at the merging unit output representing the actual instantaneous value of the primary current;

I_s is the r.m.s. value of a certain digital merging unit output, when $I_{sdc}(n) + i_{s \text{ res}}(t_n) = 0$;

f is the frequency;

φ_s is the secondary phase displacement;

$I_{sdc}(n)$ is the secondary direct output;

$i_{s\text{ res}}(t_n)$ is the secondary residual output including harmonic and subharmonic components;
 n is the data sample counter;
 t_n is the time where primary current (and voltage) of the n^{th} data set have been sampled;
 f, I_s, φ_s being constant for steady-state condition.

3.1.22

rated secondary output

for analogue output, the r.m.s. value of the component at frequency f_r of the secondary voltage output (U_{sr}) on which the performance of the electronic current transformer is based. For digital output, the hexadecimal number representing the rated primary current on the digital side

3.1.23

actual transformation ratio (K_a and K_d)

For analogue output, the ratio of the actual r.m.s. primary current to the actual r.m.s. secondary output of an electronic current transformer (abbreviation: K_a). For digital output, the ratio of the actual r.m.s. primary current to the actual r.m.s. secondary output, which is a numerical value (abbreviation: K_d)

NOTE 1 For stand-alone air-core coils, these definitions are only valid for steady-state condition for a pure sinusoidal wave at rated frequency. When the frequency f of the primary current differs to f_r , the actual transformation ratio is calculated according to $K_a(f) = f/f_r * K_{ra}$ (or $K_d(f) = f/f_r * K_{rd}$).

NOTE 2 For instantaneous and composite error measurement an integrator has to be used with the air-core coil. In this case K_a (or K_d) is the ratio of the primary current to the secondary output of the integrator.

3.1.24

rated transformation ratio (K_{ra} and K_{rd})

rated value of the transformation ratio

3.1.25

current error (ratio error) (ε %)

error which an electronic current 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].

For analogue output, the current error expressed in per cent is given by the formula:

$$\varepsilon \% = \frac{K_{ra} \cdot U_s - I_p}{I_p} \times 100$$

where

K_{ra} is the rated transformation ratio;

I_p is the r.m.s. value of the actual primary current when $i_{p\text{ res}}(t) = 0$;

U_s is the r.m.s. value of secondary converter output when $U_{sdc} + u_{s\text{ res}}(t) = 0$.

NOTE This definition is only related to components at rated burden and rated frequency of both primary current and secondary voltage. This definition is compatible with IEC 60044-1.

For digital output, the current error expressed in per cent is given by the formula:

$$\varepsilon \% = \frac{K_{rd} \cdot I_s - I_p}{I_p} \times 100$$

where

K_{rd} is the rated transformation ratio;

I_p is the r.m.s. value of the actual primary current when $i_{p\ res}(t) = 0$;

I_s is the r.m.s. value of the digital output when $I_{sdc}(n) + i_{s\ res}(t_n) = 0$.

NOTE The current error is the result of a digital calculation (see annex B).

3.1.26

phase displacement (φ)

for analogue output, the difference in phase between the primary current phasor and the secondary output phasor, the direction of the phasors being so chosen that the angle is equal to its rated value at the rated frequency for a perfect transformer. The phase displacement is said to be positive when the secondary output phasor leads the primary current phasor. It is usually expressed in minutes or centiradians

[IEV 321-01-23, modified]

$$\varphi = \varphi_s - \varphi_p$$

where

φ_p is the primary phase displacement;

φ_s is the secondary phase displacement.

For digital output, the time between the instant a certain current is present at the primary terminals and the instant the transmission of the relevant digital data set at the MV output starts (expressed in angular units relative to the rated frequency)

NOTE 1 This definition is strictly correct for sinusoidal current only.

NOTE 2 For both analogue and digital output, the phase displacement φ of an ideal transformer (see B6.1 and 3.1.29) can be considered to be made up of two components: the rated phase offset φ_{0r} and the rated delay time t_{dr} .

NOTE 3 See annex B for more explanation about phase-displacement calculation.

3.1.27

rated delay time (t_{dr})

rated value of time needed e.g. for digital data processing and transmission

3.1.28

rated phase offset (φ_{0r})

rated phase displacement of the ECT due to the technology employed and which is not affected by the frequency

3.1.29

phase error (φ_e)

The phase error is the phase displacement φ minus the displacement caused by the rated phase offset and the rated delay time. The phase error is related to the rated frequency.

$$\varphi_e = \varphi - (\varphi_{0r} + \varphi_{tdr}) \quad \text{and} \quad \varphi_{tdr} = -2\pi \cdot f \cdot t_{dr}$$

For digital output intended to be synchronized with clock pulses, the phase error is the time between a clock pulse and the sampling of the primary current belonging to the corresponding digitally transmitted value (expressed in angular units relative to the rated frequency).

The phase error is usually expressed in minutes or centiradians

NOTE An explanation of the phase error and an explanatory drawing can be found in annex B.

3.1.30

accuracy class

designation assigned to an electronic current transformer, the current error and phase displacement of which remain within specified limits under prescribed conditions of use

3.1.31

highest voltage for equipment (U_m)

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

[IEV 604-03-01, modified]

3.1.32

rated insulation level

combination of voltage values which characterizes the insulation of an electronic current transformer with regard to its capability to withstand dielectric stresses

3.1.33

isolated neutral system

system where the neutral point is not intentionally connected to earth, with the exception of high-impedance connections for protection or measurement purposes

[IEV 601-02-24]

3.1.34

resonant earthed (neutral) system

system in which one or more neutral points are connected to earth through a reactor which approximately compensates the capacitive component of a single phase-to-earth fault current

[IEV 601-02-27]

3.1.35

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 value of 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]

3.1.36

solidly earthed (neutral) system

system whose neutral point(s) is (are) earthed directly

[IEV 601-02-25]

3.1.37

impedance earthed (neutral) system

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

[IEV 601-02-26]

3.1.38

earthed neutral system

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

- a) A three-phase system with effectively earthed neutral at a given location is a system characterized by an earth-fault factor at this point which does not exceed 1.4.

NOTE This condition is obtained approximately when, for all system configurations, the ratio of zero-sequence reactance to the positive-sequence reactance is less than three and the ratio of zero-sequence resistance to positive-sequence reactance is less than one.

- b) A three-phase system with non-effectively earthed neutral at a given location is a system characterized by an earth-fault factor at this point that may exceed 1.4.

3.1.39**exposed installation**

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 and not protected by surge arresters.

3.1.40**non-exposed installation**

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

3.1.41**rated short-time thermal current (I_{th})**

r.m.s. value of the primary current which an electronic current transformer will withstand for 1 s without suffering harmful effects

3.1.42**rated dynamic current (I_{dyn})**

peak value of the primary current which an electronic current transformer will withstand, without being damaged electrically or mechanically by the resulting electromagnetic forces

3.1.43**rated continuous thermal current (I_{cth})**

value of the current which can be permitted to flow continuously in the primary terminals, the analogue secondary output being connected to the rated burden, without the temperature rise exceeding the values specified

3.1.44**wake-up time**

some electronic current transformers are powered by the line current. The power supply of such transformers needs a delay to establish after the primary current is switched on. This delay is called "wake-up time". During this delay, the output of the electronic current transformer is zero

3.1.45**wake-up current**

minimum r.m.s. value of the primary current necessary to wake up the electronic current transformer (see 3.1.44)

3.1.46**IP code**

coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water and to give additional information in connection with such protection

[3.4 of IEC 60529]

3.1.47**degree of protection**

extent of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects and/or ingress of water and verified by standardized test methods

[3.3 of IEC 60529]

3.1.48**rated filling pressure for gas insulation p_{re} (or density ρ_{re})**

pressure in Pascals (Pa), for gas insulation, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the electronic current transformer is filled before being put into service, or automatically replenished

[3.6.4.1 of IEC 60694, modified]

3.1.49

alarm pressure for gas insulation p_{ae} (or density ρ_{ae})

pressure (Pa), for insulation, referred to the standard atmospheric air conditions of +20 °C 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which a monitoring signal may be provided to indicate that replenishment is necessary in a relatively short time

[3.6.4.3 of IEC 60694, modified]

3.1.50

minimum functional pressure for gas insulation p_{me} (or density ρ_{me})

pressure (Pa), for insulation, referred to the standard atmospheric air conditions of +20 °C 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of electronic current transformer are maintained and at which a replenishment becomes necessary

[3.6.4.5 of IEC 60694, modified]

3.1.51

absolute leakage rate, F

amount of gas escaped by time unit, expressed in Pa.m³/s

3.1.52

relative leakage rate, F_{rel}

absolute leakage rate related to the total amount of gas in the system at rated filling pressure (or density) expressed in percentage per year or per day

3.2 Additional definitions for measuring electronic current transformers

3.2.1

measuring electronic current transformer

electronic current transformer intended to transmit an information signal to indicating instruments, integrating meters and similar apparatus

3.2.2

rated extended primary current

primary current up to which the same accuracy as the accuracy at the rated primary current is guaranteed, and which cannot exceed the rated continuous thermal current I_{cth}

3.2.3

rated extended primary current factor (K_{pcr})

ratio of the rated extended primary current to the rated primary current

3.3 Additional definitions for protective electronic current transformers

3.3.1

protective electronic current transformer

electronic current transformer intended to transmit an information signal to protective or control devices

3.3.2

rated accuracy limit primary current

under steady-state conditions, value of primary current up to which the protective electronic current transformer will comply with the requirements for composite error

3.3.3

accuracy limit factor (K_{alf})

under steady-state conditions, the ratio of the rated accuracy limit primary current to the rated primary current

3.3.4**composite error (ε_c)**

under steady-state conditions, the composite error is 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 output multiplied by the rated transformation ratio, the positive signs of the primary current and secondary output corresponding to the convention for terminal markings.

For analogue output, 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:

$$\varepsilon_c (\%) = \frac{100}{I_p} \sqrt{\frac{1}{T} \int_0^T [K_{ra} u_s(t) - i_p(t - t_{dr})]^2 dt}$$

where

K_{ra} is the rated transformation ratio;

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

i_p is the primary current;

u_s is the secondary voltage;

T is the duration of one cycle;

t is the instantaneous value of the time;

t_{dr} is the rated delay time.

NOTE 1 For stand-alone air-core coils, secondary output is measured at the output of an integrator (see definition of K_{ra} or K_{rd} and annex C).

For digital output, 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:

$$\varepsilon_c (\%) = \frac{100}{I_p} \sqrt{\frac{T_s}{kT} \sum_{n=1}^{kT/T_s} [K_{rd} i_s(n) - i_p(t_n)]^2}$$

where

K_{rd} is the rated transformation ratio;

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

i_p is the primary current;

i_s is the secondary digital output;

T is the duration of one power cycle;

n is the sample counter;

t_n is the time where primary currents and voltages of the n^{th} data set have been sampled;

k is the number of summation periods;

T_s is the distance in time between two samples of the primary current;

NOTE 2 For practical purposes the composite error is the result of a digital calculation, the algorithm of which is given in annex B.

3.3.5

rated primary short-circuit current for transient performance (I_{psc})

under transient conditions, the r.m.s. value of the primary symmetrical short-circuit current on which the rated accuracy performance of the electronic current transformer is based

[3.1 of IEC 60044-6, modified]

3.3.6

rated symmetrical short-circuit-current factor for transient performance (K_{ssc})

under transient conditions, the ratio:

$$K_{ssc} = I_{psc}/I_{pr}$$

[3.15 of IEC 60044-6, modified]

3.3.7

rated primary time constant for transient performance (τ_{pr})

under transient conditions, rated value of the time constant of the d.c. component of the primary current on which the performance of the current transformer is based

[3.6 of IEC 60044-6, modified].

3.3.8

dead time (t_{fr})

time interval between interruption and re-application of the primary short circuit during a breaker auto-reclosing duty cycle (refer also to IEC 60056)

[3.9 of IEC 60044-6]

3.3.9

rated duty cycle (C – O and/or C – O – C – O)

duty cycle in which during each specified energization, the primary current is assumed to be “fully offset” with the rated primary time constant (τ_{pr}) and be of rated amplitude (I_{psc})

[3.10 of IEC 60044-6, modified]

Duty cycles are as follows.

Single energization: C – t' – O

Double energization: C – t' – O – t_{fr} – C – t'' – O

(both energizations in the same polarity of magnetic flux when applicable)

where

t' is the duration of first current flow;

t'' is the duration of the second current flow.

3.3.10

transient response

response of the secondary output to a transient change of the primary current

[2.2.3 of IEC 60044-7, modified]

3.3.11

primary current in transient condition ($i_p(t)$)

in the transient condition, primary current is defined as follows

[A.1 of IEC 60044-6, modified]:

$$i_p(t) = I_{psc} \sqrt{2} \cdot (\sin(2\pi \cdot f \cdot t + \varphi_p) - \sin(\varphi_p) \cdot \exp(-t/\tau_p)) + i_{p \text{ res}}(t);$$

where

- I_{psc} is the r.m.s. value of the symmetrical component of primary current;
 f is the frequency;
 τ_p is the primary time constant;
 φ_p is the primary phase displacement;
 $i_{p\ res}(t)$ is the primary residual current including harmonic and subharmonic components and primary direct current;
 t is the instantaneous value of time.

3.3.12

instantaneous error current ($i_e(t)$, $i_e(n)$)

difference between the instantaneous values of the secondary output multiplied by the rated transformation ratio and the primary current

[3.2 of IEC 60044-6, modified]

For an analogue output, the instantaneous error current is defined for $t \geq t_{dr}$ and is given by the following expression:

$$i_e(t) = K_{ra} \cdot u_s(t) - i_p(t - t_{dr})$$

NOTE 1 For stand-alone air-core coils the voltage $u_s(t)$ is measured at the output of an integrator (see definition of K_{ra} and K_{rd} and annex C).

For digital output, the instantaneous error current is defined for $t_n \geq t_{dr}$ and is given by the following expression:

$$i_e(n) = K_{rd} \cdot i_s(n) - i_p(t_n)$$

NOTE 2 For practical purposes, the instantaneous error is the result of a digital calculation, the algorithm of which is given in annex B.

NOTE 3 For stand-alone air-core coils, secondary output is measured at the output of an integrator. The integrator can be realized digitally in the evaluation unit. Since the integrator may influence the delay time, it is allowed in this test set-up that the rated delay time differs from the regular rated delay time of the transformer under test.

3.3.13

maximum peak instantaneous error ($\hat{\varepsilon}$)

maximum instantaneous error current, for the specified duty cycle, expressed as a percentage of the peak value of the rated primary short-circuit current.

[3.4 of IEC 60044-6, modified]

$$\hat{\varepsilon} = 100 \hat{i}_e / (\sqrt{2} \cdot I_{psc}) \quad \%$$

3.4 Additional definitions for digital output

3.4.1

digital output

the digital output is made up of an optical or an electrical output interface at the merging unit.

It supplies measuring instruments, meters and protective or control devices with digitally coded time-coherent sets of current and/or voltage data

3.4.2

merging unit (MU)

physical unit used to do the time-coherent combination of the current and/or voltage data coming from the secondary converters. The merging unit can be part of one of the transformers in the field or may be a separate unit, for example, in the control room (see figure 2)

3.4.3

merging unit clock input

electrical or optical input of the merging unit that can be used to synchronize several merging units if required

3.4.4

merging unit power supply

power supply of the merging unit (can be combined with the secondary power supply (see 3.1.10))

3.4.5

data rate ($1/T_s$)

number of current and/or voltage data sets transmitted per second

3.4.6

output invalid (IV)

information indicating that the output signal of the electronic current transformer is invalid

3.5 Additional definitions for analogue voltage output

3.5.1

equipment failed (EF)

information indicating that the equipment has failed

3.5.2

burden

impedance of the secondary circuit expressed in ohms, at power factor of 1

3.5.3

rated burden (Rb_r)

value of the burden on which the accuracy requirements of a specification are based

3.5.4

secondary direct voltage offset (U_{sdc0})

direct voltage component of the secondary voltage of an electronic current transformer when $I_p(t) = 0$

NOTE For a primary converter powered by the primary current, this definition is not applicable. In this case, the evaluation method should be agreed between manufacturer and purchaser (see annex E).

3.5.5

stand-alone air-core coil

transformer based on air-core coil technology without a built-in integrator (see annex C)

3.6 Index of main definitions and abbreviations

ECT	electronic current transformer, definition 3.1.2
EVT	electronic voltage transformer, see IEC 60044-7
EF	equipment failed, definition 3.5.1
IV	output invalid, definition 3.4.6
MR	maintenance request, definition 3.1.9
MU	merging unit, definition 3.4.2
Rb_r	rated burden, definition 3.5.3
SC	secondary converter, definition 3.1.8
f_r	rated frequency, definition 3.1.18
K_{ra}, K_{rd}	rated transformation ratio of an electronic current transformer, definition 3.1.24

K_{pcr}	rated extended primary current factor, definition 3.2.3
K_{alf}	accuracy limit factor, definition 3.3.3
K_{ssc}	rated symmetrical short-circuit factor, definition 3.3.6
t	instantaneous value of time, definition 3.1.19
t_{dr}	rated delay time, definition 3.1.27
t_{fr}	dead time, definition 3.3.8
T_{s}	time between two data sets, reciprocal of the data rate, definition 3.4.5
U_{m}	highest voltage for equipment, definition 3.1.31
U_{sr}	for analogue output, rated secondary output, definition 3.1.22
U_{sdco}	secondary direct voltage offset, definition 3.5.4
U_{ar}	rated auxiliary power supply voltage, definition 3.1.11
I_{ar}	rated supply current, definition 3.1.12
I_{amax}	maximum supply current, definition 3.1.13
I_{th}	rated short-time thermal current, definition 3.1.41
I_{cth}	rated continuous thermal current, definition 3.1.43
I_{dyn}	rated dynamic current, definition 3.1.42
I_{psc}	rated primary short-circuit current for transient, definition 3.3.5
I_{p}	r.m.s. value of primary current when $i_{\text{p res(t)}} = 0$, definition 3.1.19
I_{pr}	rated primary current, definition 3.1.20
$i_{\text{p(t)}}$	primary current, definitions 3.1.19 and 3.3.11
$i_{\text{p res(t)}}$	primary residual current including harmonic and subharmonic components, definition 3.1.19
$i_{\text{e}}(t), i_{\text{e}}(n)$	instantaneous error current for transient conditions, definition 3.3.12
φ	phase displacement, definition 3.1.26
φ_{or}	rated phase offset, definition 3.1.28
φ_{e}	phase error, definition 3.1.29
$\varepsilon \%$	current error for steady state conditions, definition 3.1.25
ε_{c}	composite error, definition 3.3.4
$\hat{\varepsilon}$	maximum peak instantaneous error, definition 3.3.13
τ_{pr}	rated primary time constant, definition 3.3.7
$p_{\text{re}}, \rho_{\text{re}}$	rated filling pressure or density, definition 3.1.48
$p_{\text{ae}}, \rho_{\text{ae}}$	alarm pressure or density, definition 3.1.49
$p_{\text{me}}, \rho_{\text{me}}$	minimum functional pressure or density, definition 3.1.50

4 Normal and special service conditions

4.1 General

Unless otherwise specified, high-voltage electronic current transformers are intended to be used at their rated characteristics under the normal service conditions listed in 4.2

If the actual service conditions differ from these normal service conditions, high-voltage electronic current transformers shall be designed to comply with any special service conditions required by the user, or appropriate arrangements shall be made (see 4.3).

NOTE 1 In order to ensure proper operation of electronic components, these components should comply with the environmental requirements of IEC 60068-2.

NOTE 2 Detailed information concerning classification for environmental conditions is given in IEC 60721-3-3 (indoor) and IEC 60721-3-4 (outdoor).

4.2 Normal service conditions

4.2.1 Ambient air temperature

Electronic current transformers are classified into 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 When choosing the temperature category, storage and transportation conditions should also be considered.		

4.2.2 Altitude

The altitude does not exceed 1 000 m.

4.2.3 Vibrations or earth tremors

Vibrations may occur due to switchgear operations or short-circuit forces. It should be recognized that vibrations due to causes external to the electronic current transformer (for example, switching operations of circuit-breakers, etc.) must be regarded as normal service conditions. Tests should be performed to prove the correct operations of the ECT when subjected to such events (see 8.13). Vibrations due to earth tremors are considered as special service conditions.

4.2.4 Other service conditions for indoor electronic current transformers

Other service conditions considered are as follows.

- 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 In order to withstand the effects of high humidity and condensation, such as the breakdown of insulation or the corrosion of metallic parts, electronic voltage transformers designed for such conditions should be used.

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

4.2.5 Other service conditions for outdoor electronic current transformers

Other service conditions considered are as follows.

- a) The 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 1 000 W/m² (on a clear day at noon) should be considered.
- c) The ambient air may be polluted by dust, smoke, corrosive gases, vapours or salt. The pollution does not exceed the pollution levels given in table 7.
- d) The wind pressure does not exceed 700 Pa (corresponding to a 34 m/s wind speed).
- e) The presence of condensation or precipitation should be taken into account.

4.2.5.1 Partially outdoor electronic current transformers

In the case of an electronic current transformer of the type which is partially indoors, partially outdoors, the manufacturer shall indicate which part of the equipment is indoors and which part of the equipment is outdoors.

4.3 Special service conditions

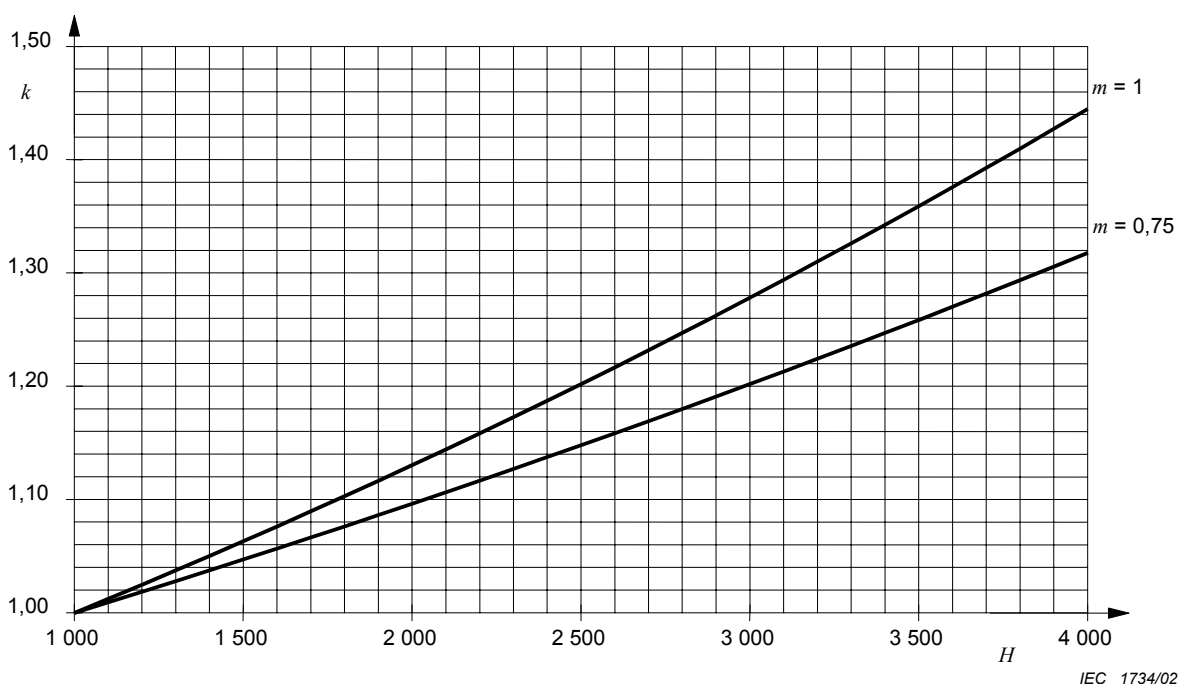
4.3.1 General

When electronic current transformers may be used under conditions different from the normal service conditions given in 4.2, the user's requirements should refer to the standardized steps given hereafter.

4.3.2 Altitude

For installations at an altitude higher than 1 000 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 3.

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



These factors can be calculated using the following equation:

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

where

H is the altitude in meters;

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

$m = 0,75$ for the switching impulse voltage.

Figure 3 – Altitude correction factor

4.3.3 Influence of altitude on temperature rise

For installation at an altitude higher than 1 000 metres, temperature rises of parts in air at atmospheric pressure shall be corrected as follows:

$$\Delta\Theta_c = \Delta\Theta_m \left[1 - 0.03 \frac{(H - 1000)}{1000} \right]$$

where:

$\Delta\Theta_c$ is the corrected value of temperature rise;

$\Delta\Theta_m$ is the value of temperature-rise measured at low altitude;

H is the altitude of the service location, in metres.

NOTE For low-voltage auxiliary and control equipment, no special precautions need to be taken if the altitude is lower than 2 000 m. For higher altitude, see IEC 60664-1.

4.3.4 Ambient temperature

For installations located in a place where the ambient temperature can be significantly outside the normal service condition range stated in 4.2.1, the preferred ranges of minimum and maximum temperature to be specified should be

- a) $-50\text{ }^{\circ}\text{C}$ and $40\text{ }^{\circ}\text{C}$ for very cold climates;
- b) $-5\text{ }^{\circ}\text{C}$ and $50\text{ }^{\circ}\text{C}$ for very hot climates.

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

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

4.3.5 Earthquakes

Requirements and testing are under consideration (future edition of IEC 60044-1).

NOTE For installations where earthquakes are likely to occur, the relevant severity level in accordance with IEC 61166 shall be specified by the user.

4.4 System earthing

The considered system earthings are:

- a) isolated neutral system (see 3.1.33);
- b) resonant earthed system (see 3.1.34);
- c) earthed neutral system (see 3.1.38);
 - 1) solidly earthed neutral system (see 3.1.36);
 - 2) impedance earthed neutral system (see 3.1.37).

5 Ratings

5.1 General ratings

5.1.1 Standard values for rated primary current (I_{pr})

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 underlined.

5.1.2 Standard values for rated extended primary current factor (K_{pcr})

The standard values for K_{pcr} are:

1,2 – 1,5 – 2 – 5 – 10 – 20 – 50 – 100

The preferred value is underlined.

5.1.3 Rated continuous thermal current (I_{cth})

The rated continuous thermal current shall not be lower than the rated primary current or the rated extended primary current if specified.

5.1.4 Short-time current ratings

5.1.4.1 Standard values for symmetrical short-circuit current

5.1.4.1.1 Standard accuracy limit factors (K_{alf})

The standard accuracy limit factors are:

$$3 - 5 - 7,5 - 10 - 12,5 - 15 - 17,5 - 20 - 25 - 30 - 40 - 63 - 80,$$

and their decimal multiples.

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

The standard r.m.s. values, expressed in kiloamperes, are in accordance with IEC 60044-6:

$$6,3 - 8 - 10 - 12,5 - 16 - 20 - 25 - 31,5 - 40 - 50 - 63 - 80 - 100$$

5.1.4.1.3 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 3.1.42).

5.1.4.2 Standard values for transient performance

5.1.4.2.1 Standard values for rated symmetrical short-circuit current factor (K_{ssc})

The standard values of K_{ssc} are:

$$3 - 5 - 7,5 - \underline{10} - 12,5 - \underline{15} - 17,5 - \underline{20} - 25 - 30 - 40 - 63 - 80,$$

and their decimal multiples. The preferred values are underlined.

5.1.4.2.2 Rated primary short-circuit current (I_{psc})

The preferred values are derived from the product of I_{pr} and K_{ssc} selected from the values given in the above subclauses. The rated primary short-circuit current shall be lower than, or equal to, I_{th} (IEC 60044-6).

5.1.4.2.3 Standard values for rated primary time constant (τ_{pr})

The standard values of the rated primary time constant expressed in milliseconds are:

$$40 - 60 - 80 - 100 - 120 \quad (\text{IEC 60044-6})$$

NOTE For some applications, higher values of rated primary time constant may be required. An example is large turbo-generator circuits.

5.1.5 Standard frequency range

The ECT fulfils its accuracy class requirements inside the standard frequency range. The standard frequency range shall be from 99 % to 101 % of the rated frequency (f_r) for accuracy classes for measurement, and from 96 % to 102 % of the rated frequency for the accuracy classes for protection (IEC 60044-7).

The accuracy outside the standard frequency range, if specified, is defined in annex D.

5.1.6 Limits of temperature rise

The temperature rise of a ECT with a primary current equal to the rated continuous thermal current flowing through its terminals and with rated burden (for analogue voltage output), shall not exceed the appropriate value given in table 2. These values are based on the service conditions given in clause 4.

If ambient temperature in excess of the values given in 4.2 are specified, the permissible temperature rise in table 2 shall be reduced by an amount equal to the excess ambient temperature.

If a electronic current transformer is specified for service at an altitude in excess of 1 000 m, and tested at an altitude below 1 000 m, the limits of temperature rise given in table 2 shall be reduced by the amounts given in 4.3.3.

The temperature rise of the ECT is limited by the lowest class of insulation according to the technology used. The maximum temperature rises of the insulation classes are as given in table 2.

Table 2 – Limits of temperature rise of the transformer

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 (for example, resin) the manufacturer should specify the relevant insulation class.	

A representative measurement of the temperature rise of the expected hottest part of the ECT should be made. This measurement depends on the technology used (i.e. resistive measurement of the windings, thermal measurement of the primary conductor).

5.1.7 Rated auxiliary power supply voltage (U_{ar})

The rated auxiliary power supply voltage means the voltage measured at the power ports of the apparatus itself during its operation, including, if necessary, the auxiliary resistors or accessories supplied or required by the manufacturer to be installed in series with it, but not including the conductors for the connection to the electricity supply.

The rated auxiliary power supply voltage should be selected from the standard values given in tables 3 and 4.

Table 3 – DC voltage

V
24
<u>48</u>
60
<u>110</u> or 125
<u>220</u> or 250
NOTE The preferred values are underlined.

Table 4 – AC voltage

Three-phase, three-wire or four-wire systems	Single-phase three-wire systems	Single-phase two-wire systems
V	V	V
-	120/240	120
(220/380)	-	(220)
230/400	-	230
(240/415)	-	(240)
277/480	-	277
NOTE 1 The lower values in the first column are voltages to neutral and the higher values are voltages between phases. The lower value in the second column is the voltage to neutral and the higher value is the voltage between lines. NOTE 2 The value 230/400 V will be, in the future, the only IEC standard voltage and its adoption is recommended in new systems. The voltage variations of existing systems at 220/380 V and 240/415 V should be brought within the range 230/400 V $\pm$ 10 %. The reduction of this range will be considered in a later stage of standardization.		

5.1.8 Rated auxiliary power supply frequency

The standard values of rated supply frequency are d.c., 50 Hz and 60 Hz.

5.1.9 Standard reference range of auxiliary power supply voltage

The standard reference range of auxiliary power supply is defined by slow voltage variations given in table 8.

5.1.10 Standard reference range of temperature

Unless otherwise specified, the standard reference range of temperature shall be from the lower limit to the upper limit of ambient air temperature given in clause 4.

5.1.11 Standard reference range for wake-up time

The standard maximum values for wake-up time at rated primary current are:

none – 1 ms – 2 ms – 5 ms

During wake-up time the output shall be zero for analogue output and invalid for digital output. Care shall be taken so that protection relay takes no tripping decision during this delay.

5.2 Standard values for rated phase offset

The standard values for rated phase offset are:

0° and 90° (for example, for stand-alone air-core coils).

5.3 Rating for digital output

5.3.1 Rated value for a digital output

Standard r.m.s. values of rated secondary output are given in table 5.

Table 5 – Rated values for digital output

	Measuring ECT (scaling factor SCM)	Protective ECT (scaling factor SCP)	EVT (scaling factor SV)
Rated value (range-flag = 0)	2D41 H (Decimal: 11 585)	01CF H (Decimal: 463)	2D41 H (Decimal: 11 585)
Rated value for scaled range (range-flag = 1)	2D41 H (Decimal: 11 585)	00E7 H (Decimal: 231)	2D41 H (Decimal: 11 585)

NOTE 1 The values given are hexadecimal numbers representing the rated primary current on the digital side (both are r.m.s. values).

NOTE 2 Protective ECT can measure currents up to 50 times the rated primary current (0 % offset) or 25 times the rated primary current (100 % offset) without any overflow. Measuring ECT and EVT can measure up to twice the rated primary range without any overflow.

NOTE 3 If the output of the transformer is the derivative of the primary current, the dynamic range is different from the dynamic range of a current output. The full scale of current transformers is related to the d.c. component induced by certain transient conditions. After derivation, the amplitude of this low-frequency component is reduced. Consequently, a protective ECT delivering the derivative of the current can be able to measure, for example with range-flag = 0, either 50 times the rated primary current with no d.c. component (0 % offset) or 25 times the rated primary current with full d.c. component (100 % offset).

NOTE 4 For protective ECT, the maximum primary current measurable without overflow is doubled when the range-flag is set.

5.3.2 Standard values for the rated delay time (t_{dr})

Standard values for rated delay time are:

$2 * T_s, 3 * T_s$ (T_s being the inverse of the digital data rate).

NOTE 1 If the data frame contains only metering data, higher delay times, but limited to a maximum of 3.3 ms, are allowed to achieve optimum anti-aliasing filtering.

NOTE 2 If the merging unit is intended to be used with synchronization pulses, the rated delay time is 3 ms (+10 % – 100 %) for all data rates, since it is not relevant for phase error.

5.3.3 Rated values for the digital data rate ($1/T_s$)

Rated values for digital data rate are

$80*f_r - 48*f_r - 20*f_r$ with $f_r = 50$ Hz or 60 Hz,

and $48*f_r$ with $f_r = 16 \frac{2}{3}$ Hz.

NOTE 1 For $20*f_r$ and for $48*f_r$ not all accuracy requirements on harmonics are fulfilled for all accuracy classes (see annex D).

NOTE 2 In case of a system fed with higher data rate than needed, under-sampling techniques described in IEC 60255-24 (common format for transient data exchange for power systems) should be implemented within the secondary equipment.

5.4 Rating for analogue voltage output

5.4.1 Standard values for the rated delay time (t_{dr})

The standard values for rated delay time are:

none, 50 μ s, 100 μ s, 200 μ s, 500 μ s

5.4.2 Standard values of rated secondary voltage (U_{sr})

The standard r.m.s. values of rated secondary voltage, U_{sr} at rated primary current are:

22,5 mV – 150 mV – 200 mV – 225 mV – 4 V

For application without secondary converter (transmitting system directly connected to the low-voltage equipment – see figure 1) used in general in medium-voltage range, the standard rated values are:

- 22,5 mV and 225 mV for ECTs delivering an output voltage proportional to the current (e.g. transformer with iron core and integrated burden),
- 150 mV for ECTs delivering an output voltage proportional to the derivative of the current (e.g. air core coils).

NOTE The rated secondary voltages 40 mV, 100 mV and 1 V may be used for existing design.

For applications using electronic secondary converter (see figure 1), the standard rated value for protective application is 200 mV and is 4 V for measurement application.

NOTE 7The rated secondary voltages 200 mV is also recommended by ANSI for analogue protection output. For measurement output, 2 V is recommended by ANSI due to a measurement range of four times I_{pr} . With a clever choice of the specified value of I_{pr} , these standard values are compatible.

5.4.3 Rated burden (R_{br})

The standard values of rated burden in ohms are:

2 k Ω – 20 k Ω – 2 M Ω

The total burden has to be equal to, or higher than, the rated burden.

NOTE Attention should be paid to the parallel capacitance of electrical measuring instruments or electrical protective devices.

6 Design requirements

6.1 General design requirements

6.1.1 Insulation requirements

6.1.1.1 Rated insulation levels for primary terminals (IEC 60044-1, 5.1.1)

6.1.1.2 Other requirements for primary terminals insulation (IEC 60044-1, 5.1.2)

6.1.1.2.1 Power-frequency withstand voltage (IEC 60044-1, 5.1.2.1)

6.1.1.2.2 Partial discharges (IEC 60044-1, 5.1.2.2)

6.1.1.2.3 Chopped lightning impulse (IEC 60044-1, 5.1.2.3)

6.1.1.2.4 Capacitance and dielectric dissipation factor (IEC 60044-1, 5.1.2.4)

6.1.1.2.5 Multiple chopped impulses (IEC 60044-1, 5.1.2.5)

6.1.1.3 Low-voltage components voltage withstand capability

The low-voltage components like the merging unit and the secondary converters generally include several separated circuits with galvanic insulation between them. This insulation shall be capable of meeting the following requirements.

Table 6 – Low-voltage withstand capability

Ports to be tested	Designs and reference standards	Power-frequency voltage withstand capability	Impulse voltage withstand capability
Power supply inputs	In accordance with 6.2.10 of IEC 60694	2,0 kV a.c., 1 min for a.c. power supply input or 2,8 kV d.c., 1 min for d.c. power supply input	5 kV, 1,2/50 μ s
Inputs and outputs connected to a galvanic link between the switchgear area and control cubicle (see figure 15)	<i>Design 1:</i> Double-shielded twisted paired cable when one or both of the shields and the signal wires are connected to the secondary devices with a plug assembled to the cable and only one shield is connected to the transformer	1,5 kV a.c., 1 min or 2,1 kV d.c., 1 min	5 kV, 1,2/50 μ s
	<i>Other designs:</i> (in accordance with 6.2.10 of IEC 60694 clause 8 of IEC 60255-5)	2,0 kV a.c., 1 min or 2,8 kV d.c., 1 min	5 kV, 1,2/50 μ s
Other inputs and outputs (see figure 15)	(in accordance with clause 6 of IEC 60255-5 and IEC 61850-3)	500 V a.c., 1 min or 700 V d.c., 1 min	
NOTE The d.c. test is recommended only for electronic devices.			

6.1.1.4 Requirements for the external insulation

6.1.1.4.1 General

If the ECT is equipped with a porcelain insulator, the insulator should be according to IEC 60815. If the ECT is equipped with a composite hollow type insulator, the insulator should comply with IEC 61462.

6.1.1.4.2 Pollution

For outdoor electronic current transformers with ceramic high-voltage insulator, susceptible to contamination, the creepage distances for given pollution levels are given in table 7.

Table 7 – Creepage distances for given pollution levels

Pollution level	Minimum nominal specific creepage distance mm/kV a, b	Creepage distance/ arcing distance
I Light	16	≤ 3,5
II Medium	20	
III Heavy	25	≤ 4,0
IV Very heavy	31	
a Ratio of the leakage 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). b 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 being the lower limit. NOTE 3 In case of exceptional pollution severity, a specific nominal creepage distance of 31 mm/kV may not be adequate. Depending on service experience and/or laboratory test results, a higher value of specific creepage distance can be used, but in some cases the practicability of washing may have to be considered.		

6.1.2 General requirements for temperature rise

The electronic current transformer shall be designed and constructed to withstand, without exceeding the specified limit for temperature rise and without damage, the thermal effects caused by the following conditions:

- maximum specified ambient temperature;
- rated frequency;
- rated continuous thermal current;
- the combination of auxiliary power supply voltage and secondary burden which causes the maximum internal power dissipation of the secondary converter.

6.1.3 Radio interference voltage requirements

The purpose of the radio interference voltage requirement is to verify the emission of corona discharges created by the electronic transformer. The main cause of corona discharges are HV parts and partial discharges at the surface of the insulator housing. This test is relevant for electronic transformers having $U_m \geq 123$ kV.

The requirement and test procedure are described in IEC 60044-1.

6.1.4 Transmitted overvoltage requirements

The purpose of the transmitted overvoltage requirement is to verify the transmission of overvoltages transmitted from the primary of the electronic transformer to the secondary output, the merging unit or to the power supply.

The main cause of overvoltages is the switching of HV equipment. This requirement is not applicable if a transmitting system providing galvanic insulation is used (see figure 1).

The requirement and test procedure are described in IEC 60044-1.

6.1.5 Electromagnetic compatibility requirements

6.1.5.1 General

EMC is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment (IEV 161-01-07). In order to assess the behaviour of an electronic transformer in this specific electromagnetic environment, it is necessary to set appropriate limits for emission and immunity. The purpose of each of the relevant tests is described in the following subclauses.

6.1.5.2 Emission requirements

Besides the emission requirements considered to be covered with a radio interference voltage test (RIV test) and transmitted overvoltage test, for electronic transformers also emission limits considered in CISPR 11 are relevant and shall be tested accordingly.

6.1.5.3 Immunity requirements.

Table 8 gives a list of type tests which can be considered relevant for electronic transformers with the associated severity class and assessment criteria. Other tests which can be of interest for this application are still under consideration.

6.1.5.3.1 Harmonic and interharmonic disturbance

The purpose is to verify the immunity of the electronic transformer against harmonic and interharmonic components of the low-voltage power supply of the electronic transformer. This test is only applicable for electronic transformers using a.c. power supply.

6.1.5.3.2 Slow voltage variation

The purpose is to verify the immunity of the electronic transformer against slow voltage variations of the low-voltage power supply of the electronic transformer. The requirement is relevant for a.c. or d.c. power supply.

6.1.5.3.3 Voltage dips and short interruption

The purpose of this test is to verify the immunity of the electronic transformer against voltage dips or voltage interruption of the low-voltage power supply of the electronic transformer. The requirement is relevant for a.c. or d.c. power supply.

6.1.5.3.4 Surge immunity

The purpose of this test is to verify the immunity of the electronic transformer against unidirectional transient caused by overvoltages from switching in the power network and lightning strokes (direct or indirect). This test is very important for HV and MV installations because of the high probability of lightning exposure.

Table 8 – Immunity requirements and tests

Test	Reference standard	Severity class	Assessment criteria
Harmonic and interharmonic test ^a	IEC 61000-4-13	2	A
Slow voltage variation test ^a	IEC 61000-4-11	From +10 % to –20 %	A
Slow voltage variation test ^b	IEC 61000-4-29	From +20 % to –20 %	A
Voltage dips and short interruption test ^a	IEC 61000-4-11	30 % dip × 0,1s ^c interruption × 0,02s ^c	A
Voltage dips and short interruption test ^b	IEC 61000-4-29	50 % dip × 0,1s ^c interruption × 0,05s ^c	A
Surge immunity test	IEC 61000-4-5	4	B
Electrical fast transient/burst test	IEC 61000-4-4	4	B
Oscillatory waves immunity test	IEC 61000-4-12	3	B
Electrostatic discharge test	IEC 61000-4-2	2	B
Power frequency magnetic field immunity test	IEC 61000-4-8	5	A
Pulse magnetic field immunity test	IEC 61000-4-9	5	B
Damped oscillatory magnetic field immunity test	IEC 61000-4-10	5	B
Radiated, radiofrequency, electro-magnetic field immunity test	IEC 61000-4-3	3	A
^a Only applicable to electronic transformer with a.c. power port. ^b Only applicable to electronic transformer with d.c. power port. ^c Values are adapted to common protective devices. A: Normal performance within the accuracy specification limits (steady-state conditions at rated primary current or lower). B: Temporary degradation of performances of measurements, which are not relevant for protection or self-diagnosis which are self-recovered is allowed. A reset or restart is not allowed. No output overvoltage greater than 500 V is allowed. No degradation of performance causing false trips of protective devices is allowed for electronic protective transformers.			

6.1.5.3.5 Electrical fast transient/burst

The purpose of this test is to verify the immunity of the electronic transformer against bursts of very short transients generated by the switching of small inductive loads, relay contact bouncing (conducted interference) or switching of HV switchgear – particularly SF6 or vacuum switchgear (radiated interferences).

6.1.5.3.6 Oscillatory wave immunity

The purpose of this test is to verify the immunity of the electronic transformer against repetitive damped oscillatory waves occurring in low-voltage circuits in HV and MV stations due to switching phenomena (isolators in HV/MV open-air stations, particularly HV busbar switching) or faults in HV or MV networks.

6.1.5.3.7 Electrostatic discharge

The purpose of this test is to verify the immunity of the electronic transformer against electrostatic discharges (ESD) generated by an operator touching (directly or with a tool) the equipment or its vicinity. In general, this is not of great concern because electronic parts of electronic transformers are located outdoors or indoors, generally standing on a bare concrete floor, without any synthetic carpet or furniture nearby. Moreover, the electronic parts are generally mounted inside a metallic cabinet well bonded to a well-controlled earthing network, for safety reasons. This makes the probability of ESD very low.

6.1.5.3.8 Power-frequency magnetic field immunity

The purpose of this test is to verify the immunity of the electronic transformer when subjected to power-frequency magnetic fields related to the proximity of power conductors, transformers, etc. in normal or faulted conditions; this test is important because of the expected vicinity of electronic parts of the electronic transformer to main circuits.

6.1.5.3.9 Pulse magnetic field immunity

The purpose of this test is to verify the immunity of the electronic transformer when subjected to impulse magnetic field generated by lightning strokes on buildings, metal structures and earth networks; this test is relevant to HV and MV installations because of the increased lightning exposition.

6.1.5.3.10 Damped oscillatory magnetic field immunity

The purpose of this test is to verify the immunity of the electronic transformer when subjected to damped oscillatory magnetic field generated the switching of HV busbars by isolators. This test is mainly applicable to electrical equipment installed in HV substations.

6.1.5.3.11 Radiated, radiofrequency, electromagnetic field immunity

The purpose of this test is to verify the immunity of the electronic transformer against electromagnetic fields generated by radio transmitters or any other device emitting wave-radiated electromagnetic energy. The most important concern in HV and MV installations comes from the possibility of the use of walkie-talkie and portable phones, as the probability of vicinity of broadcasting stations or amateur radios is, in general, very low.

6.1.6 Signal-to-noise ratio

The minimum signal-to-noise ratio of the ECT output shall be 30 dB (relative to rated secondary output) over the bandwidth specified by the manufacturer.

6.1.7 Wake-up current

If relevant, the wake-up current shall be specified by the manufacturer.

6.1.8 Mechanical requirements

These requirements generally only apply to free-standing electronic current transformers having $U_m \geq 72,5$ kV and above.

In table 9, guidance is given on the static loads that electronic current transformers shall be capable of withstanding. The figures include loads due to wind and ice.

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