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IEC 61869-14: 2018

INSTRUMENT TRANSFORMERS –
Part 14: Additional requirements for current transformers for DC applications

ICS 17.220.20

Saudi Standards, Metrology and Quality Org (SASO)

Foreword

The Saudi Standards ,Metrology and Quality Organization (SASO) has adopted the International standard No. IEC 61869-14: 2018 “INSTRUMENT TRANSFORMERS – Part 14: Additional requirements for current transformers for DC applications ” issued by the international Electrotechnical Commission(IEC). The text of this international standard has been translated into Arabic so as to be approved as a Saudi standard without introducing any technical modification.

CONTENTS

INTRODUCTION

General

This document applies to current transformers intended to be used in DC applications with at least one of the following functions:

- measure DC current (with significant harmonics);
- withstand DC voltage.

Depending on the position of the current transformer on the DC system, different kinds of application exist, which are briefly described below, together with the approximate voltage or current wave shape.

Line-commutated converters (LCC)

Line-commutated converters (LCC) are based on thyristor converters (see خطأ! لم يتم العثور على مصدر المرجع.). They are characterized by a single direction of current flow, and a voltage polarity reversal possibility. Significant voltage and current harmonics exist up to frequencies of about 3 kHz to 4 kHz.

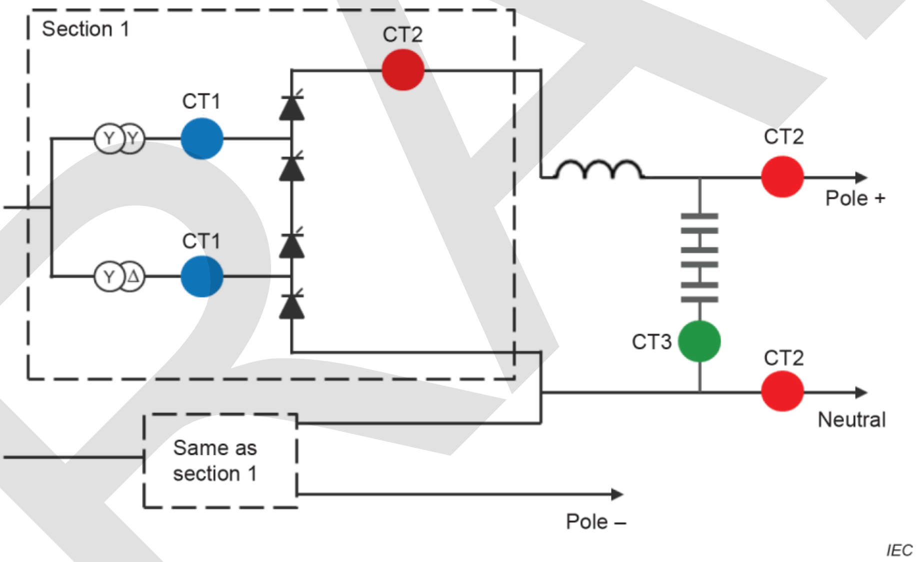


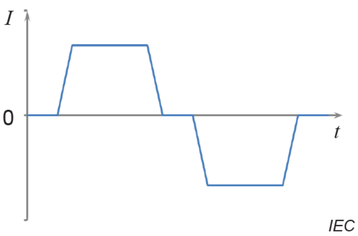
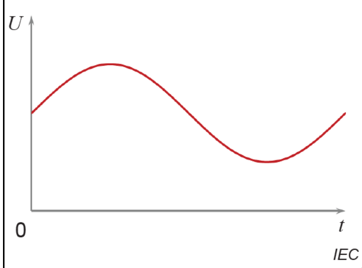
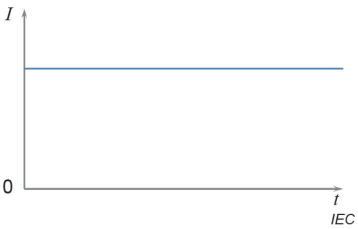
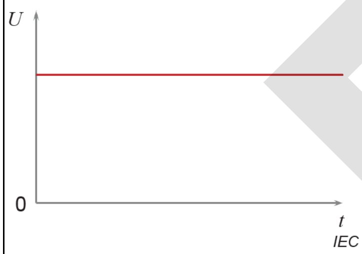
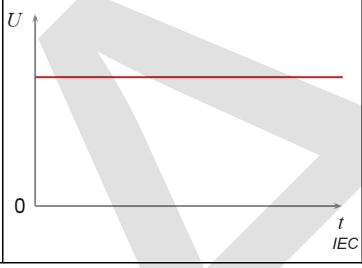
Figure 1401 – Example of LCC scheme

We distinguish three different current-measurement functions:

- CT1: measurement of the current at the AC side of the converter;
- CT2: measurement of the current at the DC side of the converter;
- CT3: measurement of the current in the DC filter.

Table 1401 gives an overview of the current and voltage waveshapes as well as the main characteristics of the different applications of the CT.

Table 1401 – Current and voltage in current transformers for LCC application

	Current	Voltage	Characteristics
CT1			AC current AC + DC voltage Large amount of current harmonics Mainly for protection purposes
CT2			Pure DC application High-accuracy measurement Harmonics measurement Metering, control and protection purposes
CT3			DC voltage stress with harmonics DC current = 0 Harmonics measurement Mainly for protection purposes

Voltage-source converters (VSC)

Voltage-source converters (VSC) are based on transistor converters. They are characterized by a bi-directional current flow and a single voltage polarity. Voltage and current harmonics exist up to frequencies of about 20 kHz.

Two variants of VSC schemes exist: symmetrical monopoles (using one single converter) and asymmetrical monopole or bipole (with one converter for each polarity).

Both schemes are shown in Figure 1402 and Figure 1403.

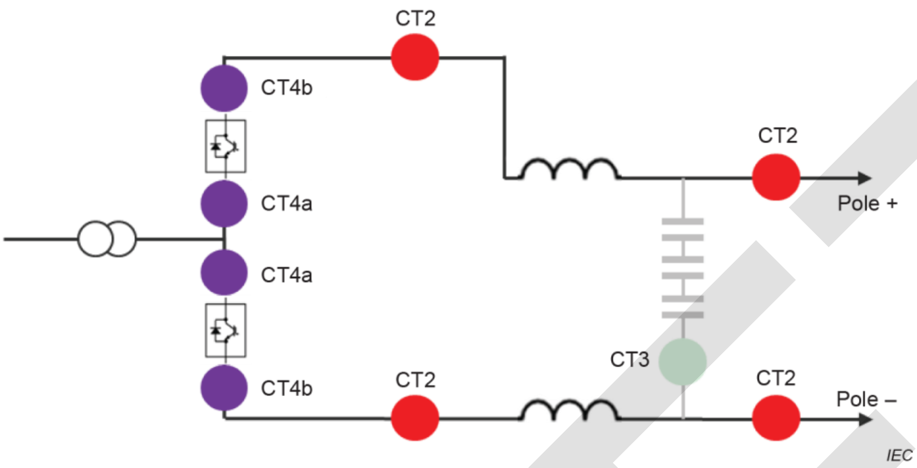


Figure 1402 – Typical scheme for VSC – symmetrical monopole

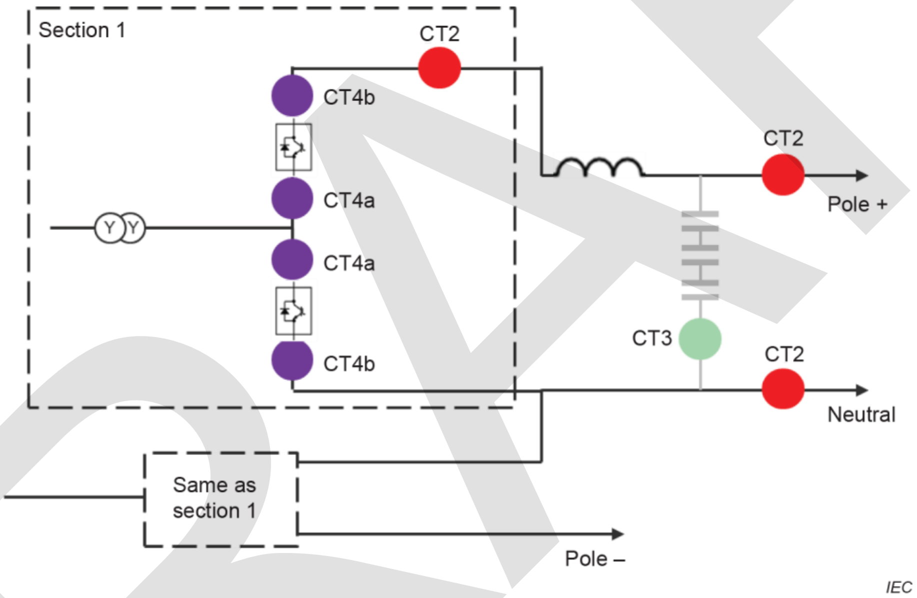


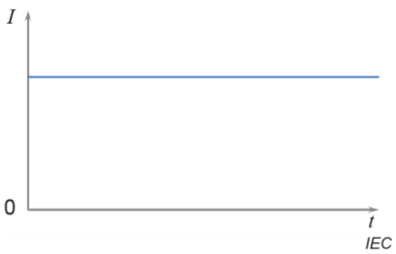
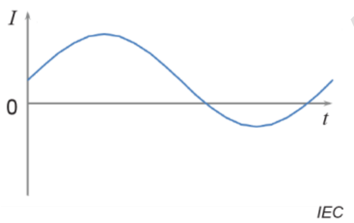
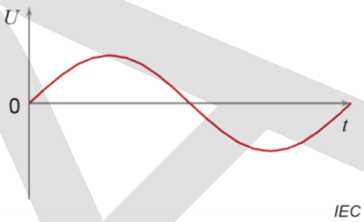
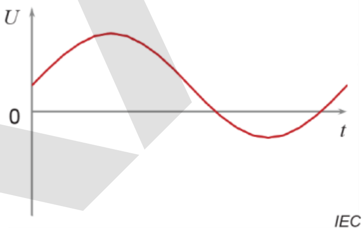
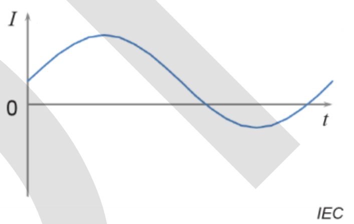
Figure 1403 – Typical scheme for VSC – asymmetrical monopole or bipole

We distinguish three different current-measurement functions:

- CT4: measurement of the current in the transistor branches of the converter.
  The CT can be placed before (CT4a) or after the transistor branch (CT4b);
- CT2: measurement of the current at the DC side of the converter;
- CT3: measurement of the current in the DC filter (not always present in this scheme).

Table 1402 gives an overview of the current and voltage waveshapes as well as the main characteristics of the different applications of the CT.

Table 1402 – Current and voltage in current transformers for VSC application

	Current	Voltage	Characteristics
CT2			Pure DC application High accuracy measurement Harmonics measurement Metering, control and protection purposes Short step response time
CT3			DC voltage stress DC current = 0 Harmonics measurement Mainly for protection purposes
CT4a		Symmetrical monopole:  Asymmetrical monopoles / bipoles: 	Pure AC voltage or DC + AC voltage DC + AC current High-accuracy measurement Short step response time
CT4b			DC voltage stress DC + AC current High-accuracy measurement Short step response time

INSTRUMENT TRANSFORMERS –

Part 14: Additional requirements for current transformers for DC applications

1 Scope

This part of IEC 61869 provides all requirements specific to current transformers to be used in DC applications (DCCTs), whatever the technology used. The output signal can be analogue or digital.

It is applicable to newly manufactured current transformers used for measuring, protection and/or control applications in DC power systems with a rated voltage above 1,5 kV.

The general configuration of a single-pole low-power instrument transformer is described in Figure 601 of IEC 61869-6:2016.

The DCCTs intended for current measurement in the transistor branch of the VSC valve (referred to as CT4a and CT4b in Figure 1403 and Table 1402) are not covered by this document, and will be considered in a future revision.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

Clause 2 of IEC 61869-6:2016 is applicable, with the following additions and modifications:

IEC TS 60815-4:2016, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 4: Insulators for DC systems*

IEC TS 61245:2015, *Artificial pollution tests on high-voltage ceramic and glass insulators to be used on DC systems*

IEC 61869-6:2016, *Instrument transformers – Part 6: Additional general requirements for low-power instrument transformers*

IEC 61869-9:2016, *Instrument transformers – Part 9: Digital interface for instrument transformers*

3 Terms and definitions

Clause 3 of IEC 61869-1:2007, of IEC 61869-6:2016 and of IEC 61869-9:2016 are applicable with the following additions and modifications.

3.1 General definitions

3.1.1401
instrument transformer for DC application
instrument transformer intended to be used in DC applications with at least one of the following functions:

- measure DC current or DC voltage (with significant harmonics);
- withstand DC voltage.

3.1.1402
current transformer for DC application
DCCT
instrument transformer for DC application in which the secondary signal, under normal conditions of use, is substantially proportional to the primary current

Note 1 to entry: The different applications are described in the introduction.

3.2 Definitions related to dielectric ratings

3.2.2
highest voltage for equipment
U_m
Definition 3.2.2 of IEC 61869-1:2007 is replaced by the following one:

highest value of DC voltage for which the equipment is designed to operate continuously, in respect of its insulation as well as other characteristics that relate to this voltage

3.3 Definitions related to current ratings

3.3.1401
DC overload current
overcurrent occurring in an electric circuit, which is not caused by a short-circuit or an earth fault

Note 1 to entry: The DC overload current is specified by the customer in terms of value and duration.

[SOURCE: IEC 60050-826:2004, 826-11-15, modified – "DC" added in the term and Note 1 to entry added.]

3.3.1402
short-time overload current
I_{sov}
DC overload current occurring for a duration shorter than one minute

3.3.1403
long-time overload current
I_{lov}
DC overload current occurring for a duration of minutes or hours

Note 1 to entry: Different values of long-time overload can be specified for different durations.

3.3.1404
maximum peak fault current
I_{sc}
maximum peak value of current occurring during a fault condition of the DC power system

3.4 Definitions related to accuracy

3.4.1401
Absolute error

ε_A

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

Note 1 to entry: The absolute error is defined by the following formula:

$$\varepsilon_A = K_r \cdot U_s - I_p$$

where

K_r is the rated transformation ratio;

I_p is the DC value of the actual primary current in steady state;

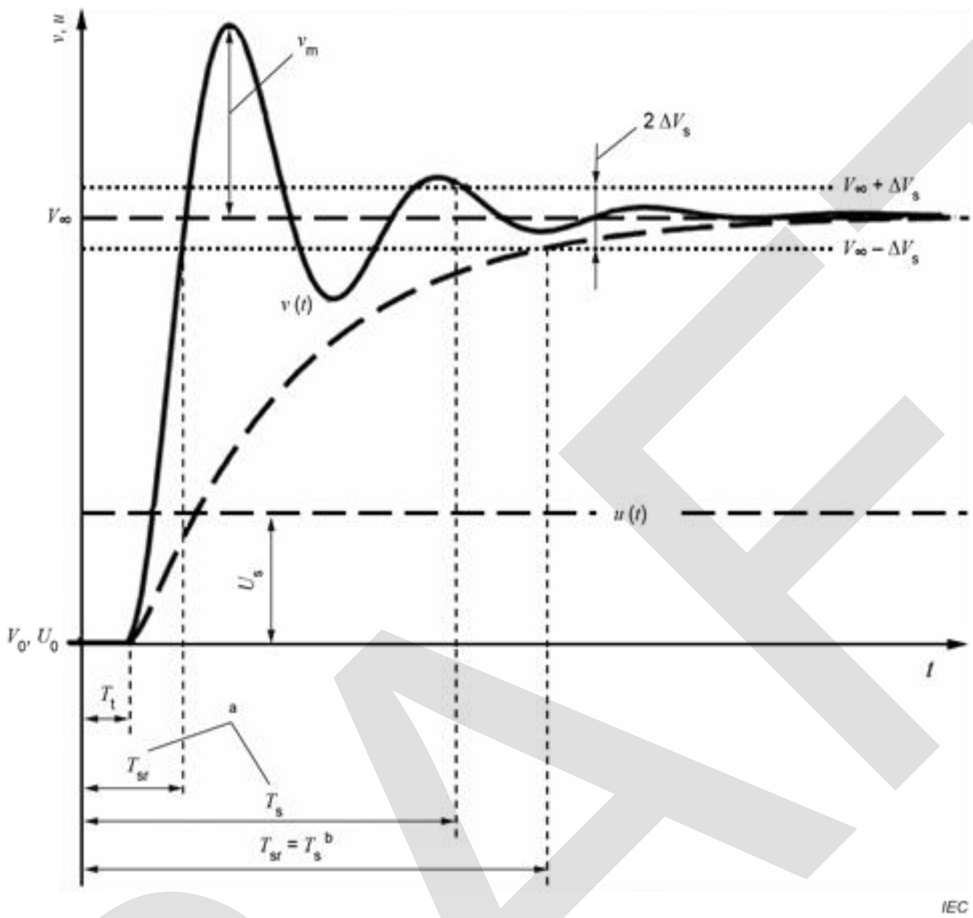
U_s is the DC value of the output voltage.

3.5 Definitions related to other ratings

3.5.1401
step response

duration between the instant when the measurand (or quantity supplied) is subjected to a specified abrupt change and the instant when the indication (or quantity supplied) reaches, and remains within specified limits of, its final steady-state value

Note 1 to entry: See graphical explanation in Figure 1404.



[a] For periodic behaviour

[b] For aperiodic behaviour

u	Input variable
U_0	Initial value of the input variable
U_s	Step height of the input variable
v	Output variable
V_0, V_∞	Steady-state values before and after application of the step
v_m	Overshoot
2 Δv_s	Specified tolerance limit
T_{sr}	Step response time
T_s	Settling time
T_t	Dead time

Figure 1404 – Typical step responses of a system

Note 2 to entry: The dead time includes the delay time.

[SOURCE: IEC 60050-311:2001, 311-06-04 and IEC 60050-351:2013, 351-45-27 modified – Note 1 to entry has been added; the notes of the sources have been deleted.]

3.5.1402
step response time
T_{sr}
for a step response, the duration of the time interval between the instant of the step change of an input variable and the instant when the output variable reaches for the first time a specified percentage of the difference between the final and the initial steady-state values

Note 1 to entry: The step response time includes the delay time of the current transformer.

[SOURCE: IEC 60050-351:2013, 351-45-36, modified – Note 1 to entry has been modified and the figure has been deleted.]

3.5.1403
settling time
T_s
for a step response, the duration of the time interval between the instant of the step change of an input variable and the instant when the difference between the step response and their steady-state value remains smaller than the transient value tolerance

Note 1 to entry: The settling time includes the delay time of the current transformer.

[SOURCE: IEC 60050-351:2013, 351-45-37, modified – Note 1 to entry has been modified and the figure has been deleted.]

3.5.1404
overshoot
v_m
for a step response of a transfer element, the maximum transient deviation from the final steady-state value of the output variable, usually expressed in percent of the difference between the final and the initial steady-state values and for reference-variable step response or disturbance-variable step response of a control system the maximum transient deviation from the desired value

[SOURCE: IEC 60050-351:2013, 351-45-38, modified – Note 1 to entry and the figure have been deleted.]

3.7 Index of abbreviations and symbols

The table in 3.7 of IEC 61869-6:2016 is replaced by the following one:

DCCT	current transformer for DC application
F	mechanical load
I_{amax}	maximum supply current
I_{ar}	rated supply current
I_{cth}	rated continuous thermal current
I_{pr}	rated primary current
I_{lov}	long-time overload current
I_{sov}	short-time overload current
I_{sc}	maximum peak fault current
IT	instrument transformer
K_{ALF}	accuracy limit factor
K_{pcr}	extended primary current factor
K_{r}	rated transformation ratio
R_{br}	rated burden
t_{d}	delay time
t_{dr}	rated delay time
T_{s}	settling time
T_{sr}	step response time
T_{t}	dead time
U_{ar}	auxiliary power supply voltage
U_{m}	highest voltage for equipment
U_{sr}	rated secondary voltage
v_{m}	overshoot
ε	ratio error
ε_{A}	absolute error

5 Ratings

5.1 General

Subclause 5.1 of IEC 61869-1:2007 is replaced by the following one:

If applicable, the ratings of DC current transformers, including their auxiliary equipment, shall be selected from the following ones:

- highest voltage for equipment (U_{m});
- rated primary current (I_{pr});
- rated delay time (t_{dr});
- rated continuous thermal current (I_{cth});
- long-time overload current (I_{lov});
- short time overload current (I_{sov});
- maximum peak fault current (I_{sc});
- rated secondary voltage (U_{sr});

- insulation level;
- rated burden (R_{br});
- rated accuracy class;
- accuracy limit factor (K_{ALF});
- rated extended primary current factor (K_{pcr});
- rated step response time (T_{sr}).

The rating applies at the standardized reference atmosphere (temperature 20 °C, pressure 101,3 kPa, and humidity 11 g/m^3) as specified in IEC 60071-1.

NOTE The ratings are specified by the purchaser depending on the characteristics of the whole DC system application.

5.2 Highest voltage for equipment

Subclause 5.2 of IEC 61869-1:2007 is replaced by the following one:

There are no standard values for highest voltage for equipment.

However, a tentative list of standard values is given in Annex 14B.

5.3 Rated insulation levels

5.3.1 General

Subclause 5.3.1 of IEC 61869-1:2007 is replaced by the following one:

The standard values of insulation level of IEC 60071-1 are not applicable to DC systems.

Methods of calculation for applied dielectric test voltages are given in the relevant clauses of this document.

Additionally, indications for impulse withstand voltage values are given in Annex 14B.

5.3.3 Other requirements for primary terminals insulation

5.3.3.1 Partial discharges

Subclause 5.3.3.1 of IEC 61869-1:2007 is replaced by the following one:

The partial discharge level measured during the power-frequency voltage withstand test, shall not exceed the limits specified in Table 3.

Table 3 – Partial discharge test voltages and permissible levels

PD test voltage (r.m.s.) kV	**Maximum permissible PD level** pC	
	Type of insulation	
	immersed in liquid or gas	**solid**
1,5 $U_m/\sqrt{2}$	10	50
1,2 $U_m/\sqrt{2}$	5	20

5.4 Rated frequency

Subclause 5.4 of IEC 61869-1:2007 is replaced by the following one:

The rated frequency is equal to 0 (which means DC).

5.5 Rated output

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

Subclause 5.5.602 of IEC 61869-6:2016 is replaced by the following one:

The standard values for rated delay time are:

5 µs – 25 µs – 100 µs

5.5.1401 Standard values of rated secondary voltage

The standard values of rated secondary DC voltage are:

150 mV – 1,66 V – 3 V – 5 V

NOTE Generally, DC current transformers are multipurpose CTs.

5.6 Rated accuracy class

5.6.1401 Accuracy class designation

The accuracy class is designated by the highest permissible percentage of the ratio error at rated primary current and with the rated burden.

5.6.1402 Standard accuracy classes

The standard accuracy classes are:

0,1 – 0,2 – 0,5 – 1

5.6.1403 Standard accuracy limit factors (K_{ALF})

The standard values for K_{ALF} are:

3 – 6 – 10 – 20

5.6.1404 Limits of ratio error

5.6.1404.1 Ratio error for DC current measurement

This is applicable for DCCT intended to measure DC current at the DC side of the converter.

NOTE They are referred as CT2 in the introduction.

The ratio error for the DC component, measured at the secondary terminals at rated or higher burden, shall not exceed the values given in Table 1403, expressed as a percentage of the measured current. A graphical representation of error limits is shown in Figure 1405.

The accuracy shall be guaranteed for the whole range of temperature, both for the outdoor and the indoor part of the current transformer and for both polarities.

Table 1403 – Limits of ratio error for DCCT (classes from 0,1 to 1)

Accuracy class	Ratio error ± %				
	at % of rated current				
	5	**20**	**100**	K_{pcr}	K_{ALF}
0,1	1	0,25	0,1	0,1	1
0,2	2	0,5	0,2	0,2	2
0,5	3,5	1	0,5	0,5	5
1	5	2	1	1	10

For current lower than 5 % of the rated current, the absolute error ε_A shall not increase above the value at 5 % of the rated current.

NOTE The purpose of this requirement is to consider a minimum value of error due to offset voltage and noise.

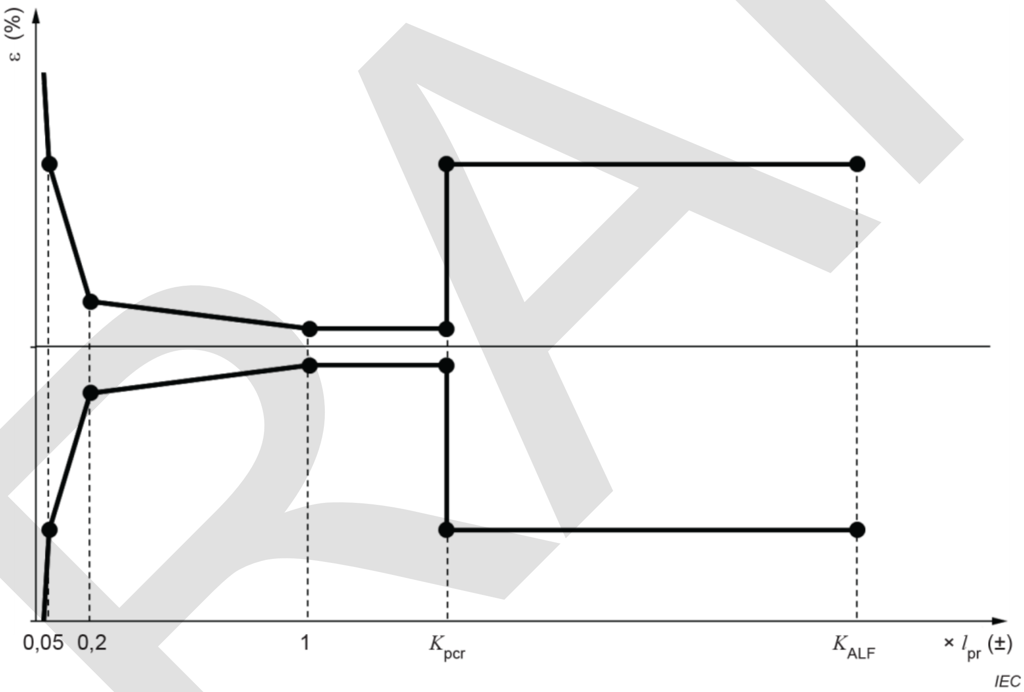


Figure 1405 – Accuracy limits of a DCCT

5.6.1404.2 Accuracy requirements for AC current measurement

These CT’s are exposed to DC voltage, but are intended to measure AC current

NOTE They are referred as CT3 in the introduction.

The error shall be specified in accordance with 5.6.201.3 or 5.6.202.2 of IEC 61869-2:2012, or both. The reference rated frequency shall be defined.

NOTE Typically, the rated frequency refers to the AC network frequency.

5.6.1405 Accuracy requirements for harmonic measurement

This subclause is applicable for the measurement of the ripple of the DC current.

Subclause 6A.4.3 of IEC 61869-6:2016 is applicable.

5.1401 Rated step response time

This subclause is not applicable to DCCT intended for AC current measurement.

The standard values for the rated step response time are:

25 µs – 250 µs – 500 µs

6 Design and construction

6.6 Requirements for the external insulation

6.6.1 Pollution

Subclause 6.6.1 of IEC 61869-1:2007 is replaced by the following.

This subclause is applicable to current transformers having U_m equal to or above 20 kV.

The purchaser shall specify the minimum creepage distance or the minimum USCD (see IEC TS 60815-4:2016) or, alternatively, the DC site pollution severity.

The necessary creepage distance may be determined from the USCD by:

$$\text{USCD} \times U_m$$

where USCD is the minimum nominal unified specific creepage distance (mm/kV), see IEC 60050-471:2007, 471-01-16.

For indoor current transformers, the minimum USCD value shall be 14 mm/kV.

For outdoor current transformers, if artificial pollution tests are required, they shall be performed in accordance with 7.4.1401.

NOTE Values for USCD for outdoor current transformers are considered in IEC TS 60815-4:2016. These values are strongly dependent on the insulator material. Additional factors relating to the insulator profile and insulator material are also specified.

6.7 Mechanical requirements

Subclause 6.7 of IEC 61869-1:2007 is replaced by the following one:

These requirements apply only to free-standing current transformers.

The required static load that current transformers shall be able to withstand is given in Table 7. The figures include loads due to wind and ice.

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

Table 7 – Static withstand test loads

Highest voltage for equipment, U_m kV	Static withstand test load, F N Current transformers with terminals
Up to 100	2 500
> 100 up to 300	3 000
> 300 up to 500	4 000
> 500	5 000

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 is agreed between the manufacturer and the purchaser.

6.8 Multiple chopped impulse on primary terminals

Subclause 6.8 of IEC 61869-1:2007 is replaced by the following one:

If additionally specified, the primary terminals of oil-immersed current transformers having U_m equal to or above 100 kV shall withstand multiple chopped impulses in accordance with 7.4.2 of IEC 61869-1:2007.

NOTE Requirements and tests relate to the behaviour of the internal shields and connections carrying high-frequency transient currents. The test can also be applied to ratings below this level.

6.9 Internal arc fault protection requirements

Subclause 6.9 of IEC 61869-1:2007 is replaced by the following one:

These requirements apply to oil-immersed and gas-insulated free-standing current transformers having U_m equal to or above 100 kV, for which an internal arc fault protection class is additionally specified.

If additionally specified, the instrument transformer shall be able to withstand an internal arc of the specified current and duration.

The applied current is a symmetrical sinusoidal current. The r.m.s. current value is

$$I_{SC}/\sqrt{2}$$

The arc fault duration shall be defined in accordance with Table 8.

It shall be considered that compliance with these requirements is achieved if the instrument transformer passes the test described in 7.4.6 of IEC 61869-1:2007.

Table 8 – Arc fault duration and performance criteria

Protection stage	Arc fault duration s	Internal arc fault protection class I	Internal arc fault protection class II
1	0,2	Fracture of the housing and fire permitted, but all projected parts to be confined within the containment area	No external effect other than the operation of suitable pressure relief device
2	0,5		No fragmentation (burn-through or fire acceptable)

6.11 Electromagnetic compatibility (EMC)

6.11.2 Requirement for radio interference voltage (RIV)

Subclause 6.11.2 of IEC 61869-1:2007 is replaced by the following one:

The RIV requirement applies to current transformers having U_m equal to or above 100 kV to be installed in air-insulated substations.

During test with power-frequency voltage, the radio interference voltage shall not exceed 2 500 µV at $1,1 \times U_m / \sqrt{2}$.

NOTE This requirement is included to meet certain electromagnetic compatibility regulations.

6.13 Markings

6.13.1401 Terminal markings

The markings shall identify

a) The primary and the secondary terminals;

b) The relative polarity of terminals.

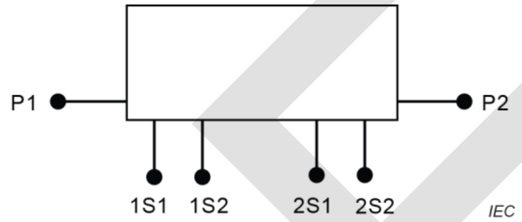
6.13.1402 Method of marking

The primary terminals shall be marked clearly and indelibly, either on their surface or in their immediate vicinity. If possible, the secondary terminals shall be identified clearly and indelibly, either on the surface of the DCCT or in the immediate vicinity of the terminals.

6.13.1403 Terminal markings

The markings of DCCT terminals shall be as indicated in Table 1404:

Table 1404 – Markings of terminals

Primary terminals Secondary terminals	 DCCT with one secondary output
Primary terminals Secondary terminals	 DCCT with two secondary outputs

6.13.1404 Rating plate markings

Subclause 6.13 of IEC 61869-1:2007 and IEC 61869-6:2016 is replaced by the following one:

All current transformers shall carry at least the following markings:

a) manufacturer's name or other mark by which the manufacturer can be readily identified;
b) year of manufacture and a serial number or a type designation, preferably both;
c) highest voltage for equipment (U_m);
d) insulation level;
e) rated primary current (I_{pr});
f) rated continuous thermal current (I_{cth});
g) long-time overload current (I_{lov}) (if specified);
h) short time overload current (I_{sov}) (if specified);
i) accuracy limit factor (K_{ALF}) (if specified);
j) extended primary current factor (K_{pcr});
k) accuracy class.

When the instrument transformer is intended for both DC and AC measurements, the accuracy for both applications shall be marked separately.

l) temperature category;
m) mass in kg (when ≥ 25 kg);
n) thermal class of insulation if different from Class A;

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

In addition, the following information shall be marked (if applicable):

o) maximum static mechanical load;
p) type of insulating fluid;
q) rated filling pressure;

r) minimum functional pressure;

s) insulating fluid volume (or mass) contained in the current transformer;

t) on transformers with secondary converters, the use of each one and its corresponding terminals.

For analogue secondary output, the following information shall be marked:

u) rated secondary output voltage;

v) rated burden (R_{br});

w) rated delay time (t_{dr});

x) on current transformers with two or more secondary terminals, the ratings of each one (e.g. transformation ratio, accuracy class).

The rating plate of all DCCTs, where practicable, shall be readable from ground level and carry the markings given in Tables 1405 to 1407.

Table 1405 – Rating plate marking for common rating plate

Rating	Abbreviation	Analogue output	Digital output
Type designation		x	x
Manufacturer's name or mark		x	x
Highest voltage for equipment	U_m	x	x
Insulation level		x	x
Rated primary current	I_{pr}	x	x
Rated continuous thermal current	I_{cth}	x	x
Long-time overload current	I_{lov}	x	x
Short time overload current	I_{sov}	x	x
Accuracy limit factor	K_{ALF}	x	x
Extended primary current factor	K_{pcr}	x	x
Temperature category		x	x
Mass in kg		x	x
Thermal class of insulation		x	x
Maximum static mechanical load		x	x
Type of insulating fluid		x	x
Rated filling pressure Minimum functional pressure		x	x
Insulating fluid volume (or mass)		x	x

Table 1406 – Rating plate marking for each secondary converter

Rating	Abbreviation	Analogue output	Digital output
Accuracy class		x	x
Rated transformation ratio	K_r		x
Rated secondary output voltage	U_{sr}	x	
Rated burden	R_{br}	x	
Rated delay time	t_{dr}	x	
Maximum delay time			x

Table 1407 – Rating plate marking for auxiliary power supply

Rating	Abbreviation	Analogue output	Digital output
Auxiliary power supply voltage	U_{ar}	x	x
Auxiliary power supply frequency		x	x
Supply current (nominal conditions)	I_{ar}	x	x
Maximum supply current (overload conditions)	I_{amax}	x	x

All information shall be marked in an indelible manner on a rating plate securely attached to the transformer (at least the common rating plate) or to the secondary auxiliary cabinet for the secondary converter and auxiliary power supply, if present.

6.602 Requirements for electrical transmitting system and electrical wires for output link

6.602.1 Connectors

Subclause 6.602.1 of IEC 61869-6:2016 is replaced by the following one:

Screw terminals are the standard interface.

For applications requesting a high bandwidth, it is preferable to use a coaxial connector. In this case, the centre pin shall correspond to the “S1” terminal.

6.1401 Digital interface

Refer to the different clauses and annexes of IEC 61869-9:2016.

NOTE Digital interfaces for DC applications are still under development, and the full adequacy of IEC 61869-9 has still to be improved.

7 Tests

7.1 General

7.1.2 List of tests

Table 10 of IEC 61869-1:2007 is replaced by the following one.

Table 10 – List of tests

Tests	Subclause
Type tests	**7.2**
Temperature rise test	7.2.2
Impulse voltage withstand test on primary terminals	7.2.3
Wet test for outdoor type transformers	7.2.4
Polarity reversal test with partial discharge measurement	7.2.1401
Electromagnetic compatibility tests	7.2.5
Test for accuracy	7.2.6
Test for accuracy versus harmonics	7.2.1402
Verification of the degree of protection by enclosures	7.2.7
Enclosure tightness test at ambient temperature	7.2.8
Pressure test for the enclosure	7.2.9
Low-voltage component voltage withstand test	7.2.601
Measurement of the step response time	7.2.1403
Routine tests	**7.3**
Power-frequency voltage withstand tests on primary terminals	7.3.1
Partial discharge measurement	7.3.2
Power-frequency voltage withstand test between sections	7.3.3
DC applied voltage withstand test with partial discharge measurement	7.3.1401
Power-frequency voltage withstand test on secondary terminals	7.3.4
Test for accuracy	7.3.5
Verification of markings	7.3.6
Enclosure tightness test at ambient temperature	7.3.7
Pressure test for the enclosure	7.3.8
Power-frequency voltage withstand test for low-voltage components	7.3.601
Special tests	**7.4**
Chopped impulse voltage withstand test on primary terminals	7.4.1
Multiple chopped impulse test on primary terminals	7.4.2
Measurement of capacitance and dielectric dissipation factor	7.4.3
Transmitted overvoltage test	7.4.4
Mechanical tests	7.4.5
Internal arc fault test	7.4.6
Enclosure tightness test at low and high temperatures	7.4.7
Gas dew point test	7.4.8
Corrosion test	7.4.9
Fire hazard test	7.4.10
Pollution tests	7.4.1401
Vibration tests	7.4.601
Test for accuracy on the composite signal	7.4.1402

7.1.3 Sequence of tests

Subclause 7.1.3 of IEC 61869-1:2007 is replaced by 7.1.3.1401 and 7.1.3.1402.

7.1.3.1401 Sequence of type tests

The sequence of tests is not specified and may be agreed between the purchaser and the supplier.

Before starting the type test sequence, the following routine tests shall be performed:

- power-frequency voltage withstand test on primary terminals;
- partial discharge measurement.

NOTE The partial discharge measurement is generally performed together with the power-frequency voltage withstand test.

After the type test sequence, the current transformer shall be subjected to all routine tests detailed in 7.3.

The DC applied voltage test may be performed before the polarity reversal test. In this case, it does not need to be repeated after the type test sequence.

7.1.3.1402 Sequence of routine tests

The sequence of tests is not specified, but the accuracy tests shall be performed after the dielectric tests.

7.2 Type tests

7.2.2 Temperature rise test

Subclause 7.2.2 of IEC 61869-6:2016 is applicable with the addition of 7.2.2.1401, 7.2.2.1402 and 7.2.2.1403.

7.2.2.1401 Duration of test

Subclause 7.2.2.203 of IEC 61869-2:2012 is applicable.

7.2.2.1402 Temperature and temperature rise

The purpose of the test is to determine the average temperature rise of the primary conductor, the secondary windings (if present), the primary and secondary converters and, for oil-immersed transformers, the temperature rise of the top oil, in steady-state conditions when the losses resulting from the specified service conditions are generated in the current transformer.

The average temperature of the secondary windings (if present) shall be determined by the resistance variation method.

Thermometers or thermocouples shall measure the temperature rise of parts other than the windings. The top-oil temperature shall be measured by sensors applied to the top of the metallic head directly in contact with the oil. The temperature rise shall be determined by the difference with respect to the ambient temperature.

7.2.2.1403 Test modalities

The current transformer shall be mounted in a manner representative of the mounting in service.

The current to be applied is the rated continuous thermal current I_{cth}. The test shall be continued until the steady-state temperature of the transformer has been reached in accordance with 7.2.2.1401.

Immediately after reaching the temperature stability, the long-time overload current for the specified duration shall be applied for the time specified.

The temperature rise shall not exceed the values of Table 5 of IEC 61869-1:2007.

This temperature rise limit does not apply to resistive shunts used as primary sensor for which the temperature limit shall be defined by the manufacturer.

If a DC source is not available, an AC 50 Hz or 60 Hz current supply may be used. In such a case, the test current shall be used with correction for the skin effect of the AC supply as calculated from:

$$I_{AC} = \sqrt{I_{DC}^2 \cdot \frac{R_{DC}}{R_{AC}}}$$

A method for the determination of the correction to be applied is proposed in Annex 14A.

The temperature rise test may be performed by applying only the long-time overload current up to the temperature stability state in accordance with 7.2.2.1401.

7.2.3 Impulse voltage withstand test on primary terminals

7.2.3.2 Lightning impulse voltage test on primary terminals

The subclause 7.2.3.2.1 of IEC 61869-1:2007 is applicable to current transformers having U_m equal to or above 20 kV.

7.2.3.3 Switching impulse voltage test

The subclause 7.2.3.3 of IEC 61869-1:2007 is applicable to current transformers having U_m equal to or above 100 kV.

7.2.4 Wet test for outdoor type transformers

The subclause 7.2.4 of IEC 61869-1:2007 is applicable with the following modifications:

For current transformers having U_m equal to or above 100 kV, the test shall be performed with switching impulse voltage test of both polarities, with the voltage corresponding to the insulation level.

For current transformers having U_m < 100 kV, the test shall be performed with power-frequency voltage defined in 7.3.1.

7.2.5 Electromagnetic compatibility (EMC) tests

7.2.5.1 RIV test

Subclause 7.2.5.1 of IEC 61869-1:2007 is applicable to current transformers having U_m equal to or above 100 kV, with the last three paragraphs replaced by the following ones:

The test shall be performed with AC power supply.

A pre-stress voltage of $1,25 \times U_m / \sqrt{2}$ shall be applied and maintained for 30 s.

The voltage shall then be decreased to $1,1 \times U_m / \sqrt{2}$ 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 / √2 is in accordance with 6.11.2.

7.2.5.2 Immunity test

Subclause 7.2.5.2 of IEC 61869-6:2016 is applicable in the case of electronic DCCTs.

7.2.6 Test for accuracy

7.2.6.1401 General

Test circuits are given in Annex 6D of IEC 61869-6:2016 for analogue outputs and Annex 9D of IEC 61869-9:2016 for digital outputs.

To prove compliance with the specified accuracy class, the test shall be carried out at each value of current given in Table 1403, at rated burden, and at ambient temperature, unless otherwise specified.

For measuring current transformers, the test shall be made up to the rated primary current (I_{pr}).

For primary current equal to zero, the measured absolute error shall not exceed the value of the absolute error allowed at 0,05 × I_{pr}.

For the test at accuracy limit primary current, the DC current source might not be available. The accuracy of the whole system may be tested using an alternative signal input method. The supplier shall supply all necessary information for the calculation of the accuracy at the specified primary input level.

For some technologies (e.g zero-flux CTs), instead of applying the primary current on the primary terminals, an auxiliary test winding may be used to supply a corresponding test current.

7.2.6.1402 Basic accuracy tests for DCCTs with analogue output

7.2.6.1402.1 DC current measurement

For analogue output with rated delay time, it is not necessary to insert a delay time device between the reference transformer and the accuracy measurement system.

7.2.6.1402.2 AC current measurement

Accuracy tests shall be performed in accordance with 7.2.6 of IEC 61869-2:2012.

7.2.6.1403 Tests for accuracy of current transformers with digital outputs

Subclause 7.2.6 of IEC 61869-9:2016 is applicable with replacement of the two last paragraphs by the following ones:

Accuracy tests shall be performed over a minimum period, during which several measurements shall be averaged. The details of the test arrangement and timing and/or bandwidth of the test system shall be provided in the accuracy test report.

The measurement period needs to be sufficient to secure the accuracy measurement considering ripple oscillations and the effect of the sampling. Time should be less than 10 s.

7.2.1401 Polarity reversal test with partial discharge measurement

This test is applicable to DCCTs having U_m equal to or above 100 kV.

During the test, the ambient temperature shall be between 10 °C and 40 °C. Before the test, the device shall be at ambient temperature.

A double polarity reversal shall be used as shown in Figure 1406.

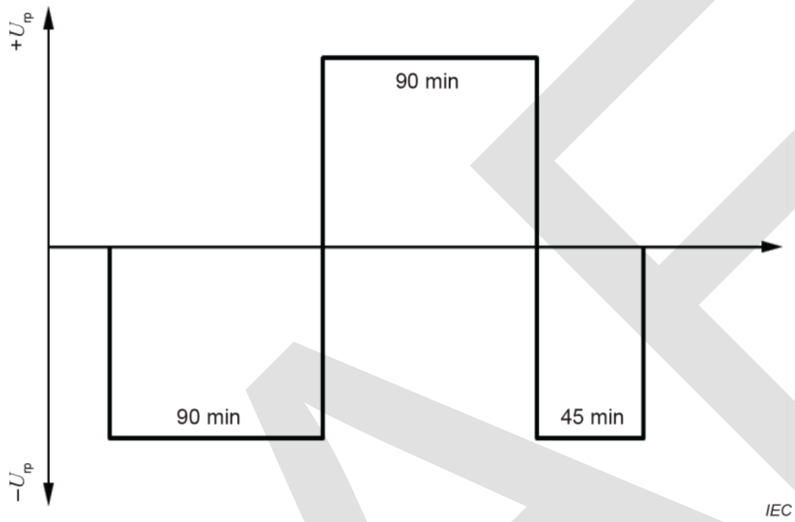


Figure 1406 – Polarity reversal test profile

No preconditioning of the insulation at lower voltage is permitted. After the DC applied voltage withstand test, the current transformer shall normally be earthed and completely discharged before the polarity reversal test is initiated. The time duration required for a complete discharge shall be agreed between the parties depending on the type of current transformer and shall be sufficient to avoid any undue influence of the trapped charges on the results of this test.

However, to save time during routine tests and upon agreement between the parties, the polarity reversal test may be initiated at any time after the DC applied voltage withstand test.

The test sequence shall include:

- 90 min at negative polarity, followed by
- 90 min at positive polarity, followed by
- 45 min at negative polarity, and
- reduction of the voltage to zero.

The time for the polarity reversal shall be as short as possible, consistent with the testing equipment, but never more than 2 min. The polarity reversal is considered as complete when the voltage has reached 100 % of the test value. The partial discharge levels shall be monitored during the entire test sequence.

Partial discharges shall be measured in accordance with IEC 60270.

The polarity reversal test voltage (U_{rp}) shall be calculated as follows:

$$U_{rp} = 1,25 \times U_m$$

The current transformer shall be considered to have passed the test if the following conditions are met:

- No more than 10 pulses of partial discharge with a magnitude equal to or greater than 2 000 pC are recorded during the last 30 min of the test time. Pulses that are proven to be external to the test object shall be disregarded.
- No disruptive discharges on the non-self-restoring insulation shall occur. If there is an internal breakdown, the current transformer shall be considered to have failed the test. For capacitance graded insulation, it is assumed that an internal breakdown has occurred if the capacitance measured after the test exceeds the capacitance measured before the test by the approximate amount attributable to the capacitance of one layer of insulation. If a flashover occurs the test shall be repeated once only. If, during the repetition of the test, no disruptive discharge occurs, the current transformer shall be considered to have passed the test.

7.2.1402 Tests for accuracy versus harmonics

Annex 6A of IEC 61869-6:2016 is applicable.

7.2.1403 Measurement of the step response time

The step response test shall be performed with the rated burden and the original transmission cable, if existing.

Testing to determine the response of a current transformer requires a current generator and instruments to measure the input signal and the output voltage.

The rise time of the generated signal shall be less than 0,2 × T_{sr}.

The primary current step-up may be replaced by a current step-down. The fall time then replaces the rise time. The positive current polarity generates a negative step-down and vice versa.

The step response time of the signal measurement systems shall be lower than 0,05 × T_{sr}.

The measurements can be performed manually with appropriate instrumentation but a transient recorder is recommended.

The test shall be performed with input current of positive and negative polarity. A test current value higher or equal to 100 A shall be used. If the rated current is lower than 100 A, the rated primary current shall be used.

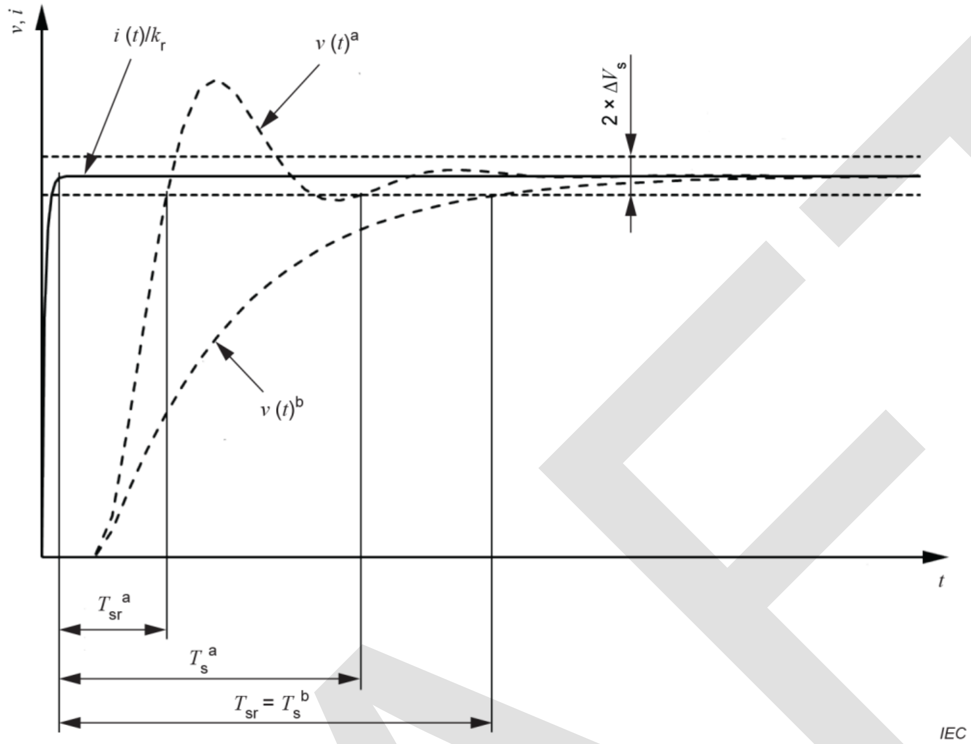
A step current shall be applied and both primary current and secondary voltage shall be recorded simultaneously (see Figure 1407).

The tolerance limit ΔV_S is defined as 5 % of the steady-state value of the output signal V_∞.

NOTE A reduced tolerance limit can be defined by agreement between the purchaser and the manufacturer.

The current transformer shall be considered to have passed the test if:

- the measured step response time is lower than the rated step response time;
- the settling time is less than 10 × T_{sr}.



Key

i(t) Input current

v(t) Output voltage of test object

[a] For periodic behaviour

[b] For aperiodic behaviour

Figure 1407 – Measurement of the step response time

In the case of difficulties generating the primary signal with the specified rise time, the test procedure may be adapted:

- inject an equivalent sensor signal on the input of the primary converter. The supplier shall supply necessary information for the calculation of the step response time at the primary input level;
- for some technologies (e.g. zero-flux CTs), instead of applying the primary current on the primary terminals, an auxiliary test winding may be used to supply a corresponding test current. The supplier shall supply information for the calculation of the step response time at the primary input level.

7.3 Routine tests

7.3.1 Power-frequency voltage withstand tests on primary terminals

Subclause 7.3.1 of IEC 61869-1:2007 is replaced by the following one:

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

The test voltage is calculated as follows:

$$U_{AC} = 1{,}5 / \sqrt{2} \times U_m$$

with a minimum value of 3 kV. The duration shall be 60 s.

Other values may be specified in case of special applications.

NOTE In some special applications (for example, some neutral current measurement applications), the specified test voltage can be insufficient.

Dielectric tests shall be made on a current transformer completely assembled, or on the insulating part in the case of separate assembly of the sensor.

The test voltage shall be applied between the primary terminals and earth.

The secondary terminals, the frame, the case (if any) and core (if existing and there is a special earth terminal) shall be connected to earth.

7.3.2 Partial discharge measurement

7.3.2.2 Partial discharge test procedure

Subclause 7.3.2.2 of IEC 61869-1:2007 is applicable with the following addition:

Partial discharge measurement shall be made on a current transformer completely assembled, or on the insulating part in the case of separate assembly of the sensor.

NOTE For a DCCT, only Procedure A is applicable.

7.3.4 Power-frequency voltage withstand tests on secondary terminals

Subclause 7.3.4 of IEC 61869-6:2016 is applicable with the following addition:

Devices for which both output terminals are insulated from ground shall be tested in accordance with 7.3.4 of IEC 61869-1:2007.

7.3.5 Test for accuracy

Subclause 7.3.5 of IEC 61869-6:2016 is replaced by the following one:

The routine test is, in principle, the same as the type test in 7.2.6. However, routine tests at a reduced number of test points are permissible if type tests on a similar DCCT have demonstrated that such a reduced number of tests is sufficient to prove compliance with a specified accuracy class.

7.3.1401 DC applied voltage withstand test with partial discharge measurement

This test is applicable to DCCTs having U_m equal to or above 20 kV.

Dielectric tests shall be performed on a current transformer completely assembled, or on the insulating part in the case of separate assembly of the sensor.

During the test, the temperature of the current transformer shall be between 10 °C and 40 °C.

No preconditioning of the current transformer at a lower voltage level is permitted and the DC voltage shall be raised to the test level within a period not exceeding 1 min. The DC voltage shall then be held for 2 h, after which the voltage shall be reduced to zero within a period not exceeding 1 min. Positive polarity shall be used.

The DC test voltage shall be calculated as follows:

$$U_{DC} = 1{,}5 \times U_m$$

The current transformer shall be considered to have passed the test if the following conditions are met.

- No more than 10 pulses of partial discharge with magnitude equal to or greater than 2 000 pC are recorded during the last 30 min of the test. Pulses that are proven to be external to the test object shall be disregarded. If this condition is not met, then the test may be extended for 30 min, with the same criteria applying. Only one 30-min extension is allowed.
- No disruptive discharges on non-self-restoring insulation shall occur. If there is an internal breakdown, the current transformer shall be considered to have failed the test. For capacitance graded insulation, it is assumed that an internal breakdown has occurred if the capacitance measured after the test exceeds the previously measured capacitance by the approximate amount attributable to the capacitance of one layer of insulation. If a flashover occurs, the test shall be repeated once only. If, during the repetition of the test, no disruptive discharge occurs, the current transformer shall be considered to have passed the test.

7.4 Special tests

7.4.1 Chopped impulse voltage withstand test on primary terminals

Subclause 7.4.1 of IEC 61869-1:2007 is replaced by the following one:

The test is applicable to current transformers having U_m equal to or above 20 kV.

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

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

The test voltage of the full impulse shall be in accordance with the rated lightning impulse withstand voltage.

The chopped impulse test voltage shall be in accordance with 5.3.3.2 of IEC 61869-1:2007.

The sequence of impulse applications shall be as follows:

- one full impulse;
- two chopped impulses;
- fourteen full impulses.

After the test, the current transformer shall pass successfully the test for accuracy in accordance with 7.3.5.

7.4.3 Measurement of capacitance and dielectric dissipation factor

Subclause 7.4.3 of IEC 61869-1:2007 is replaced by the following one:

The subclause is applicable to current transformers having U_m equal to or above 20 kV.

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

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

The measurement of capacitance (C) and dielectric dissipation factor (tanδ) shall be performed at the test voltage frequency and at a voltage level of U_m / $\sqrt{2}$.

7.4.1401 Pollution tests

7.4.1401.1 Artificial pollution test

The test is applicable to current transformers having U_m equal to or above 100 kV.

An artificial pollution test may be applied to current transformers having porcelain insulators to be used outdoors and exposed to polluted atmospheres.

If a test is deemed necessary, the specific test method to be applied and the degree of pollution severity shall be specified or agreed upon between the purchaser and the manufacturer at the time of ordering. Proposals for artificial pollution test methods are described in IEC TS 61245.

NOTE The reproducibility of artificial pollution tests on insulators, with weather sheds of silicon rubber, performed in different laboratories has not been established in a manner consistent with other standardized tests. However, further guidance will become available as research continues and when appropriate inter-laboratory comparisons are made. The problem is under consideration by IEC TC 36: Insulators.

The DC withstand test voltage shall be specified. In general, it coincides with the highest voltage for equipment. The tests are usually carried out at negative polarity.

The specified characteristics of the current transformer are confirmed if no flashover or puncture occurs during three consecutive individual tests performed in accordance with the specified or agreed procedure. If there is a puncture, the current transformer shall be considered to have failed the test. If only one flashover occurs, a fourth test shall be performed and the current transformer shall then be considered to have passed the test if no further flashover or puncture occurs.

7.4.1401.2 Even wetting DC voltage test

The even wetting test may be applied to all outdoor current transformers having U_m equal to or above 100 kV.

The current transformer shall be mounted in a manner representative of the mounting in service.

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

The standard even wetting test procedure specified in IEC 60060-1 shall be used, except for the test duration.

Rain with different characteristics representing very light or light conductive layers on the insulator surface or having different precipitation rates may be agreed between manufacturer and purchaser. The rain precipitation shall be adjusted before starting the test.

The test voltage to be applied to the current transformer shall be equal to 1,25 $\times$ U_m.

The test voltage shall be maintained at this value for 1 h.

The current transformer shall be considered to have passed the test if no flashover or puncture occurs. If there is a puncture, the current transformer shall be considered to have failed the test. If a flashover occurs, the test shall be repeated once only, after verifying the rain conditions. The current transformer shall be considered to have passed the test if no further flashover or puncture occurs.

7.4.1402 Accuracy tests on the composite signal

The purpose of the test is to measure the accuracy on the DC component and on harmonic components, when supplied simultaneously.

The accuracy on the DC current component shall comply with the specifications of 5.6.1404, while pure sinusoidal harmonic components are supplied (one at a time) to the primary side.

20-A current components shall be supplied with the following frequencies:

- for low-bandwidth DC applications: 100 Hz, 500 Hz, 1 kHz, 1,5 kHz, 3 kHz;
- for high-bandwidth DC applications: 100 Hz, 2,5 kHz, 5 kHz, 7,5 kHz, 10 kHz, 15 kHz, 20 kHz.

The accuracy on the AC current components shall comply with the specifications of Annex 6A of IEC 61869-6:2016, while the rated DC primary current is supplied to the primary side.

When applicable, the test may be applied on the current sensor only.

When possible, the DC current and the AC current may be applied to the sensor with separate conductors. But the primary configuration shall be respected. If this is not possible, suitable filtering arrangements shall be used to guarantee the accuracy of both current components applied to the sensor.

NOTE Additional frequencies can be specified depending on the application.

Annex 14A
(informative)

Equivalent thermal current in CTs for DC application

14A.1 General

Annex 14A gives the information required to deal with the test modalities for thermal tests of DCCTs:

- influence of the harmonic content of the DC current on the heating of the primary conductor in the case of HVDC applications (LCC or VSC);
- correction of the AC test current to take into consideration the skin effect.

14A.2 Current harmonic content

The current flowing in the primary conductor has the typical waveform for LCC application shown in Figure 14A.1.

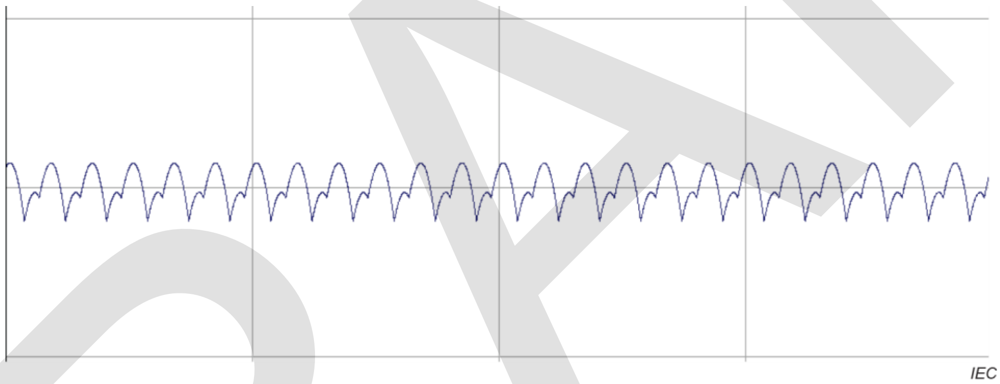


Figure 14A.1 – Typical waveform of current flowing in the primary conductor for LCC applications

The DC current waveform can be considered as consisting of the average (DC) component, and superimposed harmonic currents. Table 14A.1 gives typical values of harmonic current components at different frequencies for 800 kV applications. The values of the harmonic currents can be considered as independent of the rated (DC) component, but depend on the rated voltage.

Table 14A.1 – Typical harmonic current values (800 kV LCC)

Harmonic order	Harmonic RMS current (A)	Harmonic order	Harmonic rms current (A)	Harmonic order	Harmonic rms current (A)
2	18,2	19	0,0	36	5,6
3	3,7	20	0,3	37	0,0
4	5,3	21	1,7	38	0,1
5	0,4	22	0,3	39	1,1
6	11,5	23	0,0	40	0,1
7	0,2	24	10,9	41	0,0
8	1,7	25	0,0	42	0,3
9	0,5	26	0,3	43	0,0
10	1,0	27	0,3	44	0,2
11	0,0	28	0,3	45	0,3
12	14,9	29	0,0	46	0,2
13	0,0	30	0,6	47	0,0
14	0,7	31	0,0	48	1,5
15	0,9	32	0,2	49	0,0
16	0,3	33	1,2	50	0,1
17	0,1	34	0,2		
18	0,8	35	0,0		

In VSC applications, the harmonic content is much reduced compared to this figure.

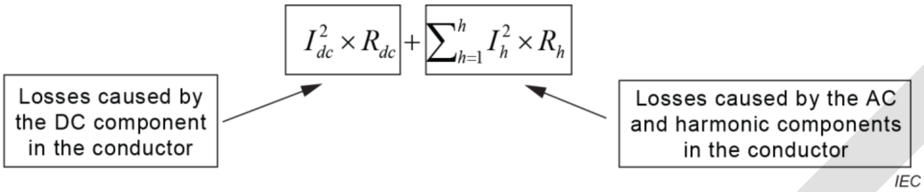
14A.3 Losses in primary conductor due to harmonic content

Most CTs for HVDC applications are designed with sensors on the top (in the head).

Consequences are:

- primary conductors are very short (typically < 1 m);
- rated current typically in the range of 1 000 A to (4 000 to 5 000) A;
- multi-turn primary windings are not used;
- mainly solid rods (or possibly thick tubes).

The total losses in the primary conductor are made up of two terms as shown in Figure 14A.2.



Key

I_{dc} DC component

R_{dc} DC resistance

I_h harmonic component of the current

R_h resistance corresponding to the harmonic h

Figure 14A.2 – The two terms that make up the total losses in the primary conductor

The calculation of the ratio between AC and AC resistance can be done for each harmonic frequency, based on the depth of penetration

$$\delta = \frac{1}{2\pi}\sqrt{\frac{10\rho}{\mu f}}$$

where:

δ: thickness of the depth of penetration in m;

ρ: resistivity in Ω/m;

μ: permeability, 4π 10^{-7} for vacuum;

f: frequency in Hz.

The ratio between DC resistance and AC resistance can be calculated using the Levasseur formula:

$$K = 0{,}25 + \sqrt[6]{0{,}75^6 + \left(\frac{D}{4\delta}\right)^6}$$

where D is the diameter of the conductor in m.

A calculation has been performed for different primary solid bar diameters from 40 mm to 100 mm, made from electrolytic copper or aluminium, considering a 2 000 A DC current and the harmonic content of Table 14A.1. See Figure 14A.3.

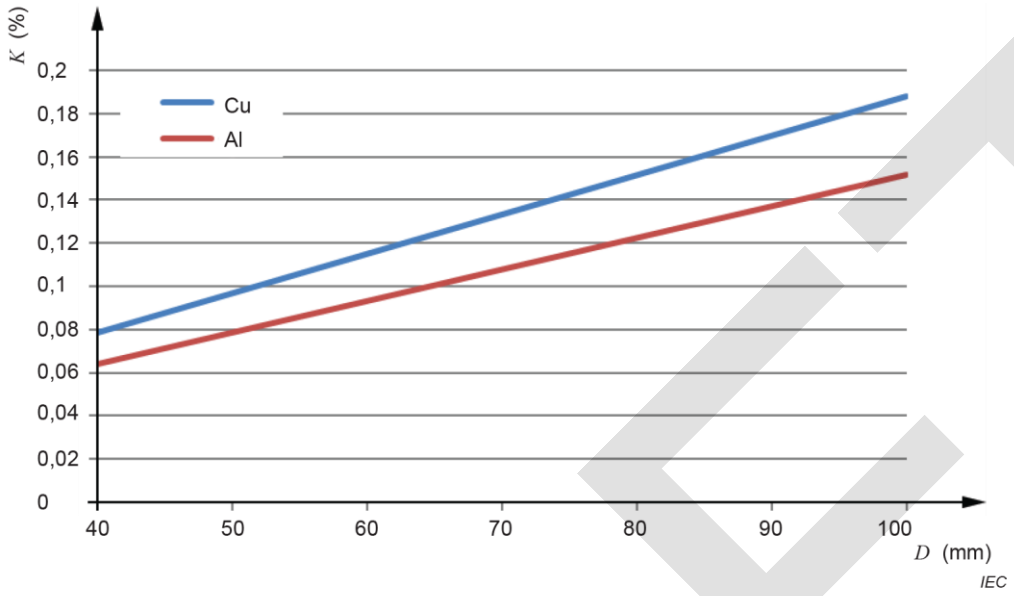


Figure 14A.3 – Additional losses in conductors due to typical current harmonics

Conclusion: the additional losses due to the harmonic content of the current is negligible, whatever the HVDC technology.

14A.4 Thermal test with AC current

Compared with the thermal losses due to the flow of DC current in the primary bar, the test with power-frequency current induces additional losses due to the skin effect in the primary bar.

Using the Levasseur formula, the additional losses can be evaluated as shown in Figure 14A.4, whatever the current value:

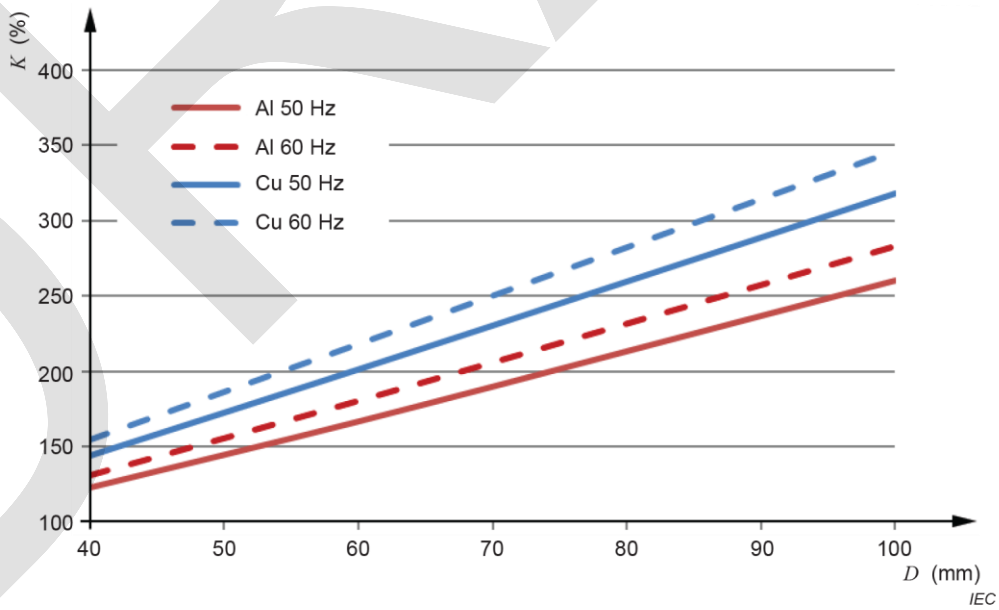


Figure 14A.4 – Power-frequency losses in conductors compared to DC losses

Annex 14B
(informative)

Proposed rated insulation level applicable to current transformers for DC application

Insulation coordination for HVDC systems is currently under consideration by the IEC.

However, instrument transformer manufacturers need references for the design and testing of their devices.

For AC and DC applied dielectric tests, test voltage is defined in 7.2 and 7.3.

The present annex proposes test voltage for impulse tests, based on generally adopted system voltages and test voltages. Table 14B.1 gives indicative values, and system designers could be forced to define other insulation levels, based on specific insulation coordination conditions.

For system voltage below 200 kV, too many applications exist and it is not possible to define any standard values. Insulation levels shall be defined by the system designer.

After publication of the rated system voltages and rated insulation levels by TC28, the present annex will be disregarded.

Table 14B.1 – Proposed rated primary terminal insulation levels for current transformers for DC application

Rated system voltage kV	Highest voltage for equipment U_m kV	Rated lightning impulse withstand voltage (peak) kV	Rated switching withstand voltage (peak) kV
200	210	500	390
250	262	750	650
320	336	900 750 660 [a]	650 612 -- [a]
400	412	1 175 790 [a]	950 760 [a]
500	515	1425 1 300 [a]	1 175
600	617	1 650 2 100	1 280 1 675
800	816	1 950 2 300	1 600 1 800
1 100	1 120	2 300	2 100

[a] cable connection

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