

AS 61869.1:2024
IEC 61869-1:2023



Instrument transformers

Part 1: General requirements (IEC 61869-1:2023 (ED 2.0) MOD)



AS 61869.1:2024

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Instrument transformers

Part 1: General requirements (IEC 61869-1:2023 (ED 2.0) MOD)

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Preface

This Standard was prepared by the Australian members of Standards Australia Committee EL-013, Measurement And Protection Transformers to supersede AS 61869.1:2021.

The objective of this document is to provide general requirements for newly manufactured instrument transformers intended for applications where the nominal voltage is higher than 1 kV AC or 1,5 kV DC, with an analogue or a digital secondary signal for measuring, protection and control purposes, with rated frequencies from 15 Hz to 400 Hz, or for DC applications.

NOTE 1 A bushing type current transformer, although having no primary insulation level for itself is often placed on a system with a nominal voltage > 1 kV AC or > 1,5 kV DC and therefore falls within the scope of this document. Example: CT placed around an HV bushing or a cable.

This document is identical with national modifications, and has been reproduced from, IEC 61869-1:2023, *Instrument transformers — Part 1: General requirements*.

The modifications are additional requirements and are set out in [Appendix ZZ](#), which has been added at the end of the source text.

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- (a) In the source text “this part of IEC 61869” should read “this document”.
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The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

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FOREWORD

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IEC 61869-1 has been prepared by IEC technical committee 38: Instrument transformers. It is an International Standard.

This second edition cancels and replaces the first edition published in 2007 and IEC 61869-6:2016. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) merger with IEC 61869-6:2016;
- b) new scope: equipment for HV applications with a nominal voltage > 1 kV AC or 1,5 kV DC;
- c) new classification of some special tests as type tests or routine test;

- d) additional type tests, additional special tests and new clause for commissioning tests;
- e) new [annexes E, F, G](#) and [I](#).

The text of this International Standard is based on the following documents:

Draft	Report on voting
38/718/FDIS	38/722/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61869 series, published under the general title *Instrument transformers*, can be found on the IEC website. An overview of the planned or existing set of standards at the date of publication of this document is given below.

The updated list of standards issued by IEC TC 38 is available at the website: <https://www.iec.ch>

Product family standard	Product standard	Title
61869-1 General requirements	61869-2	Additional requirements for current transformers
	61869-3	Additional requirements for inductive voltage transformers
	61869-4	Additional requirements for combined transformers
	61869-5	Additional requirements for capacitor voltage transformers
	61869-7	Additional requirements for low-power voltage transformers
	61869-8	Additional requirements for low-power current transformers
	61869-9	Digital interface for instrument transformers
	61869-10	Additional requirements for current sensors
	61869-11	Additional requirements for voltage sensors
	61869-12	Additional requirements for combined low-power instrument transformers
	61869-13	Stand-alone merging unit (SAMU)
	61869-14	Additional requirements for current transformers for DC applications
	61869-15	Additional requirements for voltage transformers for DC applications
	61869-16	TEDS (transducer electronic data sheet) for instrument transformers
	61869-99	Glossary

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or

- amended.

IMPORTANT — The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document is the first revision of IEC 61869-1, defining common requirements for instrument transformers, applicable to all types or technologies.

Furthermore, the document is the result of a merger of IEC 61869-1:2007 (*General requirements*) and IEC 61869-6:2016 (*Additional general requirements for low-power instrument transformers*) with the aim of having one single document and simplify the comprehension for the reader of [LPIT](#) product-specific standards.

The main modifications of this revision are listed below:

- new scope: equipment for HV applications with a nominal voltage > 1 kV AC or 1,5 kV DC;
- transfer of the definitions to the TC 38 Glossary IEC 61869-99;
- ratings:
 - addition of HV insulation levels above 800 kV;
 - new DC insulation resistance requirements for secondary terminals;
 - additional accuracy class extensions for harmonics;
- design and construction:
 - additional mechanical requirements for EHV applications;
 - clarification of the altitude correction for external insulation and dielectric tests;
 - multiple chopped impulse test: definition of maximum gas-in-oil level before test;
 - internal arc fault protection: simplification of the acceptance criteria;
 - new requirements for storage climatic conditions withstand capability for [LPIT](#);
- type tests:
 - temperature rise test: more accurate definition of the test duration;
 - lightning impulse test: new test procedure (15 impulses) for gas-insulated and resin-insulated instrument transformers, for $U_m \geq 300$ kV;
 - switching impulse test: to be performed in both polarities in case of gas-insulated instrument transformers;
 - chopped wave impulse test: moved from special test to type test;
 - test for accuracy: to be performed with regard to the temperature range and frequency;
 - mechanical test: moved from special test to type test;
 - new specification for storage climatic environmental tests;
- routine tests:
 - partial discharge measurement: addition of record of [PD](#) inception voltage and extinction voltage;

- measurement of capacitance and $\tan\delta$: moved from special test to routine test;
- special tests:
 - transmitted overvoltage test: improved test procedure;
 - internal arc fault test: clarified test procedure;
 - new insulation resistance measurement on secondary terminals;
 - new test for resin insulated instrument transformers operating at low temperature;
 - vibration test: improvement and addition of a shock test for parts mechanically coupled to a circuit-breaker;
 - optional tests for accuracy versus harmonics and for anti-aliasing;
- commissioning tests (new clause):
 - new installation inspection;
 - gas dew point test moved from special test to commissioning tests;
 - new recommended insulation test on LV connection up to the LV cubicle;
- rules for transport, storage, erection, operation and maintenance:
 - new mandatory rules for user and manufacturer;
 - new conditions for transportation and storage;
- new annexes:
 - [Annex E](#) (informative): technique used in temperature rise test of transformers to determine the thermal time constant by an experimental estimation;
 - [Annex F](#) (informative): guidance for the extension of validity of type tests and special tests;
 - [Annex G](#) (informative): guidance for the calculation of equivalent diameter in case of irregular shape of insulating part;
 - [Annex I](#) (normative): seismic qualification of instrument transformers.

NOTES

Australian Standard®

Instrument transformers

Part 1: General requirements (IEC 61869-1:2023 (ED 2.0) MOD)

1 Scope

This part of IEC 61869 is applicable to newly manufactured instrument transformers intended for applications where the nominal voltage is higher than 1 kV AC or 1,5 kV DC, with an analogue or a digital secondary signal for measuring, protection and control purposes, with rated frequencies from 15 Hz to 400 Hz, or for DC applications.

NOTE 1 A bushing type current transformer, although having no primary insulation level for itself is often placed on a system with a nominal voltage > 1 kV AC or > 1,5 kV DC and therefore falls within the scope of this document. Example: [CT](#) placed around an HV bushing or a cable.

The general requirements for instrument transformers for applications in LV systems (nominal voltage ≤ 1 kV AC or $\leq 1,5$ kV DC) are covered by IEC 61869-201.

This part of IEC 61869 is a product family standard and covers general requirements only. For each type of instrument transformer, the product standard is composed of this document and the relevant specific product standard.

This part of IEC 61869 contains the requirements for the limits of the errors both for analogue and digital secondary signals. The other characteristics of a digital interface for instrument transformer are standardised in IEC 61869-9 as an application of the IEC 61850 horizontal standard series, covering communication networks and systems for power utility automation.

This part of IEC 61869 considers bandwidth requirements. The accuracy requirements on harmonics and requirements for the anti-aliasing filter are specified in [5.7](#).

In the case of an [LPIT](#), the general block diagram of single-phase devices is given in [Figure 1](#).

According to the technology, it is not always necessary that all parts described in [Figure 1](#) be included in the instrument transformer.

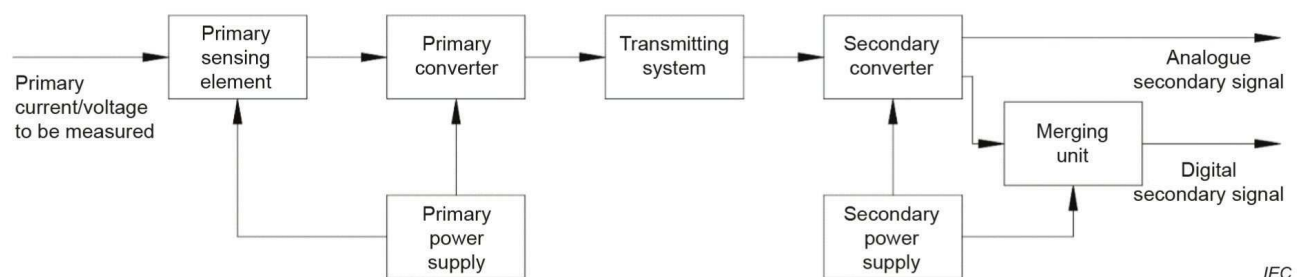


Figure 1 — General block diagram of single-phase LPITs

NOTE 2 A secondary power supply can be combined with a primary power supply or with a power supply of other instrument transformers.

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.

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

IEC 60068-2-1, *Environmental testing - Part 2-1: Tests - Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing - Part 2-2: Tests - Test B: Dry heat*

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

IEC 60068-2-11, *Environmental testing - Part 2-11: Tests - Test Ka: Salt mist*

IEC 60068-2-17, *Basic environmental testing procedures - Part 2-17: Tests - Test Q: Sealing*

IEC 60068-2-27:2008, *Environmental testing - Part 2-27: Tests - Test Ea and guidance: Shock*

IEC 60068-2-47, *Environmental testing - Part 2-47: Tests - Mounting of specimens for vibration impact and similar dynamic tests*

IEC 60068-2-57:2013, *Environmental testing - Part 2-57: Tests - Test Ff: Vibration - Time-history and sine-beat method*

IEC 60068-2-75, *Environmental testing - Part 2-75: Tests - Test Eh: Hammer tests*

IEC 60068-2-78:2012, *Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state*

IEC 60068-3-3:2019, *Environmental testing - Part 3-3: Supporting documentation and guidance - Seismic test methods for equipment*

IEC 60071-1:2019, *Insulation co-ordination - Part 1: Definitions, principles and rules*

IEC 60071-2:2018, *Insulation co-ordination - Part 2: Application guidelines*

IEC 60085, *Electrical insulation - Thermal evaluation and designation*

IEC 60270:2000, *High-voltage test techniques - Partial discharge measurements*

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IEC 60296, *Fluids for electrotechnical applications - Mineral insulating oils for electrical equipment*

IEC 60376, *Specification of technical grade sulphur hexafluoride (SF₆) and complementary gases to be used in its mixtures for use in electrical equipment*

IEC 60455 (all parts), *Resin based reactive compounds used for electrical insulation*

IEC 60475, *Method of sampling insulating liquids*

IEC 60480, *Specifications for the re-use of sulphur hexafluoride (SF₆) and its mixtures in electrical equipment*

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IEC TS 60815-2:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions - Part 2: Ceramic and glass insulators for a.c. systems*

IEC TS 60815-3:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions - Part 3: Polymer insulators for a.c. systems*

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IEC TR 61000-4-1, *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, *Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test*

IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test*

IEC 61000-4-5:2014/AMD1:2017

IEC 61000-4-6, *Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields*

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 - Impulse 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 for equipment with input current up to 16 A per phase*

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

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IEC 61000-4-17, *Electromagnetic compatibility (EMC) - Part 4-17: Testing and measurement techniques - Ripple on DC input power port immunity test*

IEC 61000-4-18:2019, *Electromagnetic compatibility (EMC) - Part 4-18: Testing and measurement techniques - Damped oscillatory wave immunity test*

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IEC 61083-1, *Instruments and software used for measurement in high-voltage and high-current tests - Part 1: Requirements for instruments for impulse tests*

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IEC 61181, *Mineral oil-filled electrical equipment - Application of dissolved gas analysis (DGA) to factory tests on electrical equipment*

IEC 61462, *Composite hollow insulators - Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V - Definitions, test methods and acceptance criteria and design recommendations*

IEC 61850-7-4, *Communication networks and systems for power utility automation - Part 7-4: Basic communication structure - Compatible logical node classes and data object classes*

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

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IEC 62217:2012, *Polymeric HV insulators for indoor and outdoor use - General definitions, test methods and acceptance criteria*

IEC 62271-4:2022, *High-voltage switchgear and controlgear - Part 4: Handling procedures for gases for insulation and/or switching*

IEC 62271-100, *High-voltage switchgear and controlgear - Part 100: Alternating-current circuit-breakers*

IEC 62271-203:2022, *High-voltage switchgear and controlgear - Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

IEC 62770, *Fluids for electrotechnical applications - Unused natural esters for transformers and similar electrical equipment*

IEC 63012, *Insulating liquids - Unused modified or blended esters for electrotechnical applications*

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

ISO/IEC/IEEE 21451-4, *Information technology - Smart transducer interface for sensors and actuators - Part 4: Mixed-mode communication protocols and Transducer Electronic Data Sheet (TEDS) formats*

ISO 4628-3, *Paints and varnishes - Evaluation of degradation of coatings - Designation of quantity and size of defects, and of intensity of uniform changes in appearance - Part 3: Assessment of degree of rusting*

ISO 22479, *Corrosion of metals and alloys - Sulfur dioxide test in a humid atmosphere (fixed gas method)*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions of IEC 61869-99 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>;

- ISO Online browsing platform: available at <https://www.iso.org/obp>.

3.2 Symbols and abbreviated terms

ADC	analogue-to-digital converter
AIS	air-insulated switchgear
CT	current transformer
CVT	capacitor voltage transformer
EIT	electronic IT
EMC	electromagnetic compatibility
F	mechanical load
f_r	rated frequency
F_{rel}	relative leakage rate
F_V	rated voltage factor
GIS	gas-insulated switchgear
I_{arc}	rated internal arc fault current
I_{cth}	rated continuous thermal current
I_{dyn}	rated dynamic current
I_{pr}	rated primary current
I_{psc}	rated short-circuit current
I_{sr}	rated secondary current
I_{th}	rated short-time thermal current
IED	intelligent electronic device
IT	instrument transformer
K_r	rated transformation ratio
k_{se}	superelevation factor
LPCT	low-power current transformer
LPIT	low-power instrument transformer
LPVT	low-power voltage transformer
MU	merging unit
PD	partial discharge
RMS	root-mean-square
SAMU	stand-alone merging unit
S_r	rated output - rated output power
t_{dr}	rated delay time
U_m	highest voltage for equipment
U_{pr}	rated primary voltage
U_{sr}	rated secondary voltage
U_{sys}	highest voltage of the system
VT	voltage transformer
Z_{br}	rated burden
ZPA	zero period acceleration
$\Delta\phi$	phase displacement
ε	ratio error
ε_c	composite error
φ_e	phase error

4 Normal and special environmental conditions

4.1 General

Unless otherwise specified, instrument transformers are intended to be used at their rated characteristics under the normal environmental conditions listed in 4.2.

If the actual environmental conditions differ from these normal environmental conditions, instrument transformers shall be designed to comply with special environmental conditions as required by the purchaser.

4.2 Normal environmental conditions

4.2.1 Ambient air temperature

Instrument transformers are classified in three operating temperature categories, as given in Table 1.

Table 1 — Operating ambient temperature categories

Category	Minimum temperature °C	Maximum temperature °C
–5/40	–5	40
–25/40	–25	40
–40/40	–40	40

In the case of instrument transformers integrated within other equipment (e.g. GIS, circuit-breaker), the instrument transformer should be specified for the temperature conditions for the respective equipment.

The lower limit for storage temperature shall be selected from the following values:

–5 °C, –25 °C or – 40 °C.

The upper limit for storage temperature shall be selected from the following values:

+40 °C, +55 °C or + 70 °C.

4.2.2 Altitude

The altitude does not exceed 1 000 m.

4.2.3 Vibrations or earth tremors

Vibrations occurring after switching operations of circuit-breakers shall be regarded as normal environmental conditions. Vibrations due to earth tremors are considered as special environmental conditions.

4.2.4 Exposure to pollution

For degrees of severity of environmental conditions under condensation and pollution, refer to IEC TS 60815-1:2008, Clause 8:

- for instrument transformers to be used in an enclosed switchgear, minimum site pollution severity (SPS) class is "Very Light";
- for AIS indoor instrument transformers, minimum SPS class is "Light";

- for [AIS](#) outdoor instrument transformers, minimum SPS class is "Heavy".

For [GIS](#) applications, no pollution severity is defined.

4.2.5 Other environmental conditions for indoor instrument transformers

Other considered environmental conditions applicable to indoor ITs are as follows:

- a) the influence of solar radiation can be neglected;
- b) the conditions of humidity are as follows:
 - the average value of the relative humidity measured for a period of 24 h does not exceed 95 %;
 - the average value of the relative humidity for a period of one month does not exceed 90 %.

For these conditions, condensation can occasionally occur.

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

NOTE 2 Condensation can be prevented by special design of the housing, by suitable ventilation and heating, or using a dehumidifying device.

4.2.6 Other environmental conditions for outdoor instrument transformers

Other considered environmental conditions applicable to outdoor [IT](#) 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) shall be considered;
- c) the wind pressure does not exceed 700 Pa (corresponding to a 34 m/s wind speed);
- d) the presence of condensation or precipitation should be considered;
- e) the ice coating does not exceed 20 mm.

4.2.7 [IT](#) with outdoor parts

In the case of an [IT](#) with indoor and outdoor parts, the manufacturer shall indicate which parts of the equipment are located indoors and which parts are located outdoors.

4.3 Special environmental conditions

4.3.1 General

When instrument transformers are intended to be used under conditions different from the normal environmental conditions given in [4.2](#), the purchaser's requirements should refer to standardised criteria given in [4.3.2](#) to [4.3.5](#).

4.3.2 Altitude

4.3.2.1 Influence of altitude on external insulation

At an altitude >1 000 m, the disruptive discharge voltage for external insulation is affected by the reduction of air density. Considering the reduced withstand capability of the air, the required insulation withstand level of the external insulation is specified in [6.6.2](#).

4.3.2.2 Influence of altitude on temperature rise

At an altitude $>1\,000$ m, the thermal behaviour of an instrument transformer is affected by the reduction of air density. The reduction of the temperature rise limits is specified in [6.4.2](#).

4.3.3 Ambient temperature

For installations located in a place where the ambient temperature can be significantly outside the normal environmental condition range stated in [4.2.1](#), the preferred ranges of minimum and maximum temperature to be specified should be:

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

NOTE 1 In certain regions with a frequent occurrence of warm humid atmosphere, sudden changes of temperature can occur, resulting in condensation, even indoors.

For the electronic part of an instrument transformer mounted inside an indoor or outdoor cabinet, the preferred maximum temperature for very hot climates is increased to $+55\text{ °C}$. Temperatures up to $+70\text{ °C}$ may also be specified.

NOTE 2 $+55\text{ °C}$ is consistent with IEC 62271-1 and $+70\text{ °C}$ is consistent with IEC 60255-1.

NOTE 3 Under certain conditions of solar radiation, appropriate measures (e.g. roofing, forced ventilation) are sometimes necessary in order not to exceed the specified temperature rises. Alternatively, derating can be used.

For storage located in a place where the minimum ambient temperature can be significantly outside the normal environmental condition range stated in [4.2.1](#), the lower limit for storage temperature can be -50 °C .

4.3.4 Vibrations or earth tremors

Vibration levels that are likely to occur shall be specified by the purchaser.

NOTE Earth tremors are not to be confused with earthquakes.

4.3.5 Earthquakes

For installations at locations where earthquakes are likely to occur, the relevant severity level shall be specified by the purchaser in accordance with [1.2.2](#).

5 Ratings

5.1 General

The ratings of instrument transformers, including their auxiliary equipment if existing, shall be selected from the following ones (when applicable):

- a) highest voltage for equipment (U_m);
- b) rated insulation level;
- c) rated primary current (I_{pr}) or rated primary voltage (U_{pr});
- d) rated secondary current (I_{sr}) or rated secondary voltage (U_{sr}) or rated transformation ratio (K_r);
- e) rated extended primary current (I_{epr}) and rated extended primary current factor (K_{epr});
- f) rated short-time thermal current (for [CT](#)) (I_{th});

- g) rated dynamic current (for [CT](#)) (I_{dyn});
- h) rated continuous thermal current (for [CT](#)) (I_{cth});
- i) rated short-circuit current (for [CT](#)) (I_{psc});
- j) rated voltage factor (for [VT](#)) (F_V);
- k) rated frequency (f_r);
- l) rated output (S_r) or rated burden (Z_{br});
- m) accuracy class.

5.2 Voltage ratings

5.2.1 Highest voltage for equipment (U_m)

[Table 2](#) contains a list of standard values for the highest voltage for equipment.

For exposed installations (which are subject to overvoltage of atmospheric origin), it is recommended to choose the highest coordinated insulation level.

The highest voltage for equipment (U_m) shall be higher or equal to the highest voltage of the system (U_{sys}).

For bushing types [CT](#), no primary insulation level is applicable.

NOTE A bushing type [CT](#) has no primary insulation for itself. The insulation is part of the HV equipment on which it is mounted.

Guidance for the selection of the rated AC insulation level, is given in IEC 60071-1:2019, 5.5. This should also take into account the overvoltage during the disconnector operations. For DC applications, refer to product-specific standards.

Table 2 — Rated primary terminal insulation levels for instrument transformers for AC applications

Highest voltage for equipment U_m (RMS) kV	Rated power-frequency withstand voltage (RMS) kV	Rated lightning impulse withstand voltage (peak) kV	Rated switching impulse withstand voltage (peak) kV
3,6	10	20 40	
7,2	20	40 60	
12	28	60 75	
17,5	38	75 95	
24	50	95 125	
36	70	145 170	
52	95	250	
72,5	140	325	
100	185	450	

Table 2 (continued)

Highest voltage for equipment U_m (RMS) kV	Rated power-frequency withstand voltage (RMS) kV	Rated lightning impulse withstand voltage (peak) kV	Rated switching impulse withstand voltage (peak) kV
123	185 230	450 550	
145	230 275	550 650	
170	275 325	650 750	
245	395 460	950 1 050	
300	395 460	950 1 050	750 850
362	460 510	1 050 1 175	850 950
420	570 630	1 300 1 425	950 1 050
550	630 680	1 425 1 550	1 050 1 175
800	880 975	1 950 2 100	1 425 1 550
1 100	1 100	2 250 2 400 2 550	1 550 1 675 1 800
1 200	1 200	2 250 2 400 2 700	1 675 1 800 1 950

5.2.2 Power system earthing

The considered power system earthing can be:

- a) isolated neutral system;
- b) earthed neutral system:
 - 1) solidly earthed neutral system;
 - 2) impedance earthed neutral system:
 - effectively earthed neutral characterized by an earth fault factor $\leq 1,4$;
 - non-effectively earthed neutral characterized by an earth fault factor $> 1,4$;
 - 3) resonant earthed neutral system.

NOTE The condition to be effectively earthed is obtained approximately when, for all system configurations, the ratio of zero-sequence reactance to the positive sequence reactance is less than 3 and the ratio of zero-sequence resistance to positive sequence reactance is less than 1.

5.2.3 Standard values for rated primary voltage (U_{pr})

See product-specific standards.

5.2.4 Standard values for rated secondary voltage (U_{sr})

See product-specific standards.

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

5.2.5.1 General

The rated auxiliary power supply voltage is the voltage value on which the requirements of a specification are based. It is measured at the power supply terminals.

The manufacturer may specify an auxiliary power supply voltage range.

5.2.5.2 Rated AC auxiliary voltage

The standard values of AC voltages are given below:

110 V - 120 V - 220 V - 230 V

Preferential values are those underlined.

The preferred operating range is 80 % to 110 % of the rated voltage.

The preferred values of the AC power supply frequency are:

50 Hz or 60 Hz

The manufacturer may specify an auxiliary power supply frequency range.

5.2.5.3 Rated DC auxiliary voltage

Standard values for the rated DC voltages are given below:

24 V - 48 V - 110 V - 125 V - 220 V - 250 V

The preferred operating range is 80 % to 110 % of the rated voltage.

In the case of a long distance between the control room and the instrument transformer electronics, a lower minimum supply voltage may be specified.

For LPITs with a DC power supply provided by the associated [IED](#), the maximum power consumption shall be limited to 0,5 W. This includes the primary converter and the secondary converter. If the [LPIT](#) has phase-segregated components, this limitation applies to each phase. The standard value of the rated power supply voltage for this application is 24 V DC.

5.2.5.4 Insulation requirements for power supply terminals

Insulation requirements for the power supply terminals are given in [Table 3](#). Requirements apply from the input terminals to any grounded part, and/or neighbouring circuit terminals (if present).

Table 3 — Insulation requirements for power supply terminals

Overvoltage category	Insulation type	Rated insulation voltage (RMS or DC)	Power-frequency voltage withstand capability (1 min)	Impulse voltage withstand capability (1,2/50 μ s)
III	Basic insulation	300 V	2,2 kV	4 kV
III	Basic insulation	600 V	3,25 kV	6 kV

NOTE The overvoltage category III and the basic insulation concept are described in IEC 60664-1. [Table 3](#) requirements assume that the protection from electrical shock is implemented using basic insulation plus grounding.

5.3 Current ratings

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

See product-specific standards.

5.3.2 Standard values for rated secondary current (I_{sr})

See product-specific standards.

5.3.3 Standard values for rated continuous thermal current (I_{cth})

See product-specific standards.

5.3.4 Short-time current ratings

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

See product-specific standards.

5.3.4.2 Rated dynamic current (I_{dyn})

See product-specific standards.

5.3.4.3 Rated internal arc fault current (I_{arc})

If optionally specified, the value of the rated internal arc fault current (I_{arc}) shall be declared by the manufacturer.

If not otherwise specified, an internal arc fault current equal to 60 % of the switchgear rated short-time withstand current is suitable for most of applications.

NOTE 1 Experience has shown that selection of internal arc fault currents equal to 100 % system fault current statistically requires a degree of over-design of the transformer, since local phase-to-earth fault levels are significantly lower.

NOTE 2 Values higher than 60 % of the system fault current could be required based on the phase-to-earth fault current calculation at a given location where the transformer will be installed.

5.4 Dielectric ratings

5.4.1 General

For most of the values of highest voltage for equipment (U_m), several rated insulation levels exist to allow application of different performance criteria or overvoltage patterns. The choice should be made

considering the degree of exposure to fast-front and slow-front overvoltage, the type of neutral earthing of the system, and the type of overvoltage limiting devices.

For the bushing type [CT](#), the primary insulation is not provided by the [CT](#) of its own, but through the HV device on which it is mounted (e.g. [GIS](#), HV cable, HV bushing). No primary insulation level is applicable for these devices.

5.4.2 Rated primary terminal insulation level

The rated primary terminal insulation level of an instrument transformer shall be based on its highest voltage for equipment U_m in accordance with [Table 2](#).

The [VT](#) primary terminal intended to be earthed in operation shall have a power-frequency withstand voltage of 3 kV.

For instrument transformers mounted on [GIS](#), the rated insulation levels shall be in accordance with IEC 62271-203:2022, Table 2 and Table 3, phase-to-earth insulation.

5.4.3 Other requirements for primary terminal insulation

5.4.3.1 Partial discharges

The partial discharge level for AC application shall not exceed the limits specified in [Table 4](#). The test procedure is specified in [7.3.2.2](#).

The partial discharge level for DC application is defined in the product-specific standards.

Table 4 — Partial discharge test voltages and permissible levels for AC applications

Type of earthing of the neutral system ^a	Instrument transformer type	PD test voltage (RMS) kV	Maximum permissible PD level ^b pC	
			insulated in liquid or gas	solid
Earthed neutral system (earth fault factor $\leq 1,4$)	CT and earthed VT	U_m $1,2 U_m/\sqrt{3}$	10 5	50 20
	Unearthed VT	$1,2 U_m$	5	20
Isolated or non-effectively earthed neutral system (earth fault factor $> 1,4$)	CT and earthed VT	$1,2 U_m$ $1,2 U_m/\sqrt{3}$	10 5	50 20
	Unearthed VT	$1,2 U_m$	5	20

^a If the neutral system is not defined, the values given for isolated or non-effectively earthed neutral systems are applicable.

^b The maximum permissible PD level is also applicable for test frequencies different from rated frequency.

5.4.3.2 Chopped lightning impulse

Instrument transformers with $U_m \geq 72,5$ kV, other than [GIS](#) devices, shall be capable to withstand a chopped lightning impulse voltage of negative polarity applied to its primary terminals with a peak value of 115 % of the rated lightning impulse withstand voltage.

5.4.3.3 Capacitance and dielectric dissipation factor (tanδ)

This requirement applies only to the following instrument transformers with $U_m \geq 72,5$ kV:

- with liquid-insulated primary insulation;
- with solid insulation;
- free-standing gas-insulated with capacitance grading insulation system.

NOTE The main purpose of this measurement is to check the water content and the purity of the insulating material.

Capacitance and tanδ measurement can be not applicable for certain types of voltage transformers. For the measuring procedure, refer to the relevant product standard.

The dielectric dissipation factor (tanδ) is dependent on the type of insulation, and on both voltage and temperature. Its value at ambient temperature shall not exceed the values indicated in .

Table 5 — Maximum values of tanδ

Type of insulation	Maximum value of tanδ measured at $U_m / \sqrt{3}$
Oil-impregnated paper	0,005
Oil-impregnated film	0,001
Oil-impregnated mixed film-paper	0,002
Gas-impregnated paper	0,003
Gas-impregnated film	0,001
Solid insulation	a
Other (e.g.: new technologies)	a
a To be indicated and justified by the manufacturer	

5.4.4 Between-section insulation requirements

For terminals of each section, the rated power-frequency withstand voltage of the insulation between sections shall be 3 kV.

The insulation requirement between sections of secondary windings is covered by [5.4.5](#).

5.4.5 Insulation requirements for secondary terminals and low-voltage components

5.4.5.1 General requirements

For inductive instrument transformers and [CVT](#), the rated power-frequency withstand voltage between secondary terminals and earth shall be 3 kV.

5.4.5.2 Special requirements for LPITs

In the case of LPITs, insulation requirements for secondary terminals and low-voltage component terminals are given in [Table 6](#).

Table 6 — LPIT secondary terminal and low-voltage component terminal withstand capability

Transmitting system of the LPIT	Power-frequency voltage withstand capability	Impulse voltage withstand capability
Electrical cable length ≤ 10 m	820 V	1,5 kV - 1,2/50 μ s
Electrical cable length > 10 m	3 kV	5 kV - 1,2/50 μ s
Optical connectors	NA	NA
NOTE In cases where the total electrical cable length of the transmitting system up to the secondary equipment does not exceed 10 m, and the associated earthing impedance is sufficiently low, the common mode voltage is not supposed to exceed a safe value. The levels indicated in the first row are reduced to a value consistent with the requirements defined in IEC 60255-27:2013, Table C.3. The insulation level meets PEB (protection by equipotential bonding) system requirements for 150 V working voltage.		

5.4.5.3 DC insulation resistance requirement

If requested, the insulation resistance between the short-circuited terminals of each secondary winding and earth shall be higher or equal to 200 M Ω when measured at a voltage of 1 kV DC. If the power-frequency voltage withstand capability is below 1 kV according to Table 6, the insulation measurement voltage shall be reduced to 500 V DC.

NOTE The on-site measurement of insulation resistance can present a lower value owing to ambient humidity.

5.5 Rated frequency (f_r)

The standard values of the rated frequency for AC applications are

16,7 Hz - 50 Hz - 60 Hz - 400 Hz.

5.6 Output ratings

5.6.1 Rated output for inductive instrument transformers and CVTs

5.6.1.1 General

For inductive instrument transformers and CVTs, the rated output (S_r) is expressed in volt-amperes absorbed in the secondary circuit connected with the rated burden (Z_{br}), at a specified power factor and at the rated secondary voltage or current.

5.6.1.2 Rated output values

See specific product standards.

5.6.2 Rated burden for LPITs

For LPITs, the standard value of rated burden is defined by a resistance of 2 M Ω in parallel with a capacitance of 50 pF. This specification assumes that the transmitting cable is part of the LPIT. The rated burden represented by the measuring and/or protection device is connected at the end of the transmitting cable.

For use on devices backward compatible with IEC 60044-8 or applications which require increased electromagnetic immunity, 2 k Ω /5 000 pF and 20 k Ω /500 pF are acceptable.

NOTE When necessary, an impedance converter can be integrated into the LPIT to adapt it to the standard rated burden.

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

The standard values for rated delay time are:

0 μ s - 50 μ s - 100 μ s - 500 μ s

In the case of a digital signal in accordance with IEC 61869-9, the rated delay time is zero, because the merging unit provides an absolute time reference for signal measurement.

5.7 Accuracy requirements

5.7.1 General

The limits of error for steady-state and transient performance related to each accuracy class as well as the related tests are defined in the product-specific standards.

For very low current or very low voltage, the maximum absolute error is defined in the product-specific standard.

For measuring accuracy classes, the limits of error shall be granted from 99 % to 101 % of the rated frequency (f_r). For protection accuracy classes, the limits of error shall be granted from 96 % to 102 % of the rated frequency (f_r). For the majority of the instrument transformers, no additional tests are needed. In the case of specific technologies having known issues, this will be covered by the product-specific standard.

5.7.2 Rated accuracy classes

See specific product standards.

5.7.3 Accuracy class extension for harmonics

Owing to the use of specific devices (e.g. non-linear loads, railways), harmonics can be generated on the network. The amount of harmonics depends on the network and the voltage level. Harmonics are of interest for measuring applications, power quality measurements and protection purposes. Specific accuracy requirements for each class are given in [5.7.4](#), [5.7.5](#) and [5.7.6](#).

To give a brief indication of the performance of a piece of equipment in terms of harmonics response, an accuracy class extension identifier may be used for each accuracy class.

Accuracy class extensions for harmonics are:

- WB0 extension for harmonic frequencies up to the 13th harmonic;
- WB1 extension for harmonic frequencies up to 3 kHz;
- WB2 extension for harmonic frequencies up to 20 kHz;
- WB3 extension for harmonic frequencies up to 150 kHz;
- WB4 extension for wide bandwidth applications up to 500 kHz.

Requirements for accuracy on harmonics are defined in [5.7.4](#).

This accuracy class extension identifier may be appended to the rated accuracy class, separated by a dash.

EXAMPLE 1 Accuracy class 0,5-WB1.

Extensions can be freely combined with all accuracy classes to indicate better performances at high frequencies.

For all LPITs and [SAMU](#), the accuracy class extension shall be at least WB0, while the extensions WB1, WB2, WB3 and WB4 are optional.

For other instrument transformers, all extensions are optional.

Some extensions may be not applicable to a specific instrument transformer.

Where applicable, multiple extensions may be claimed for the same [IT](#).

EXAMPLE 2 Class 0,2-WB1 and class 0,5-WB2.

The extensions apply to both voltage transformers and current transformers.

5.7.4 Accuracy requirements for harmonics

5.7.4.1 Accuracy class extension for measuring applications

[Table 7](#) provides the limit of errors for the accuracy class extension WB0.

Table 7 — WB0 extension for harmonics

Accuracy class	Ratio error at low frequency		Ratio error at harmonics based on f_r				Phase error at low frequency	Phase error at harmonics based on f_r			
	%		%				Degrees	Degrees			
	DC ^a	1 Hz	2 nd to 4 th	5 th and 6 th	7 th to 9 th	10 th to 13 th	1 Hz	2 nd to 4 th	5 th and 6 th	7 th to 9 th	10 th to 13 th
0,1	+1 -100	+1 -30	±1	±2	±4	±8	±45	±1	±2	±4	±8
0,2 - 0,2 S ^b	+2 -100	+2 -30	±2	±4	±8	±16	±45	±2	±4	±8	±16
0,5 - 0,5 S ^b	+5 -100	+5 -30	±5	±10	±20	±20	±45	±5	±10	±20	±20
1 - 3 - 5	+10 -100	+10 -30	±10	±20	±20	±20	±45	±10	±20	±20	±20
^a DC coupling is allowed but not required.											
^b The accuracy classes 0,2 S and 0,5 S apply only for current transformers.											

The transition between points defined in [Table 7](#) shall be a straight line when shown in a diagram with logarithmic scales on both axes.

5.7.4.2 Accuracy class extensions for wide bandwidth applications

According to EN 50160 and IEC 61000-4-7, for such purposes, harmonics up to the 40th order are measured (in some cases even to the 50th order). IEC 61000-4-7 specifies a limit for quality measuring applications. The limits of accuracy for wide bandwidth application are given in [Table 8](#).

Table 8 — Accuracy class extensions for wide bandwidth applications

Accuracy class	Ratio error at frequencies shown below			Phase error at frequencies shown below		
	%			Degrees		
WB1	$f_r < f \leq 1 \text{ kHz}$	$1 < f \leq 1,5 \text{ kHz}$	$1,5 < f \leq 3 \text{ kHz}$	$f_r < f \leq 1 \text{ kHz}$	$1 < f \leq 1,5 \text{ kHz}$	$1,5 < f \leq 3 \text{ kHz}$

Table 8 (continued)

Accuracy class	Ratio error at frequencies shown below			Phase error at frequencies shown below		
	%			Degrees		
WB2	$f_r < f \leq 5 \text{ kHz}$	$5 < f \leq 10 \text{ kHz}$	$10 < f \leq 20 \text{ kHz}$	$f_r < f \leq 5 \text{ kHz}$	$5 < f \leq 10 \text{ kHz}$	$10 < f \leq 20 \text{ kHz}$
WB3	$f_r < f \leq 20 \text{ kHz}$	$20 < f \leq 50 \text{ kHz}$	$50 < f \leq 150 \text{ kHz}$	$f_r < f \leq 20 \text{ kHz}$	$20 < f \leq 50 \text{ kHz}$	$50 < f \leq 150 \text{ kHz}$
WB4	$f_r < f \leq 50 \text{ kHz}$	$50 < f \leq 150 \text{ kHz}$	$150 < f \leq 500 \text{ kHz}$	$f_r < f \leq 50 \text{ kHz}$	$50 < f \leq 150 \text{ kHz}$	$150 < f \leq 500 \text{ kHz}$
0,1	± 1	± 2	± 5	± 1	± 2	± 5
0,2 - 0,2 S	± 2	± 4	± 5	± 2	± 4	± 5
0,5 - 0,5 S	± 5	± 10	± 10	± 5	± 10	± 20
1	± 10	± 20	± 20	± 10	± 20	± 20
Protection	± 10	± 20	± 30	-	-	-

The accuracy classes 0,2 S and 0,5 S apply only for current transformers.

NOTE 1 Accuracy class extension WB4 is intended for very wide bandwidth applications like travelling-wave protections and fault locators where signal frequencies reach as high as 500 kHz. The use of relays based on travelling-wave analysis is a promising solution offering very accurate fault location. For instance, new devices based on such principles claim to be much more accurate than conventional reactance-based fault locators. This field is still evolving, but CTs and VTs suitable for these relays need a very large frequency range, hence the "extended" range up to 500 kHz. No consensus for general requirements for this kind of application is available at the date of the publication.

NOTE 2 Travelling wave relays are designed especially for this purpose and are very special (very large bandwidth, etc.). Although WB4 compliant ITs are very desirable, inductive CTs and CVTs often have not a sufficient bandwidth allowing relays and fault locators to accurately measure the traveling wave arrival times.

NOTE 3 Owing to the high bandwidth, the classes WB3 and WB4 are not compatible with digital signals in accordance with IEC 61869-9 and its standardized sampling rates.

IEC 61850-7-4 introduces a mechanism which allows the [IT](#) frequency response compensation factors to be exposed to the [IED](#) by using the frequency correction setting "CorCrv" contained within the logical nodes for current and voltage transformers (TCTR and TVTR). Correction factors are provided in the form of "curve shape setting" (CSG).

It is recommended that manufacturers of SAMUs and LPITs with digital interfaces provide device-specific frequency correction factors supporting the IEC 61850-7-4 "CorCrv" correction mechanism.

When the frequency correction factors are provided, the manufacturer shall specify the accuracy at harmonics after correction according to [Table 8](#).

5.7.5 Harmonic requirements for [LPIT](#) protection accuracy classes

For all protective accuracy classes, the harmonic requirements of [Table 9](#) are mandatory, and harmonic requirements of [Table 8](#) are optional. Frequencies of 16,7 Hz or 20 Hz are relevant to cover possible influences coming from railway power frequencies (for electrical networks with rated frequencies of 50 Hz or 60 Hz).

Table 9 — Harmonic requirements for protection accuracy classes

Ratio error at low frequency		Ratio error at frequencies and harmonics shown below, based on f_r		Phase error at low frequency	Phase error at frequencies and harmonics shown below, based on f_r	
%				Degrees		
DC	1 Hz	1/3 rd component (16,7 Hz or 20 Hz)	2 nd to 5 th harmonic	1 Hz	1/3 rd component (16,7 Hz or 20 Hz)	2 nd to 5 th harmonic
+10	+10	±10	±10	-	±10	±10
-100	-30					

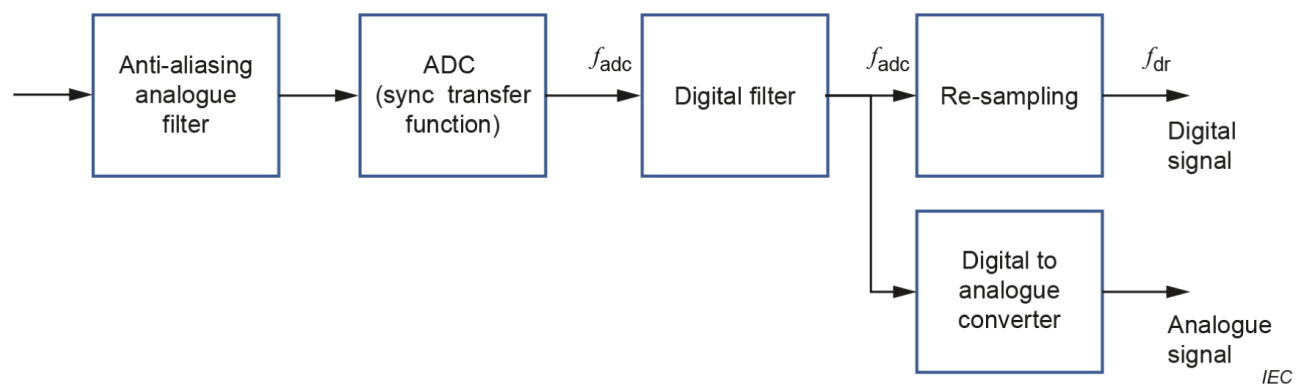
The above limits apply equally to both low-power voltage and low-power current transformers.

5.7.6 Anti-aliasing filter for EIT using digital data processing

Digital and discrete time data processing limits the bandwidth to less than one half the digital sampling rate f_s (Nyquist criterion). If different sampling rates along the signal processing path are used, the lowest rate is the limiting factor. For instrument transformers with digital signal, the lowest rate is usually the output sampling rate. Frequencies above $f_s / 2$ are mirrored to frequencies below $f_s / 2$. From the point of view of accuracy, the most critical frequencies are those mapped onto the power system frequency f_r . The first frequency mapped on f_r is

$$f_s - f_r$$

An example of data acquisition system is illustrated in Figure 2 which shows that a single system can use multiple sampling frequencies f_s marked in this case as f_{adc} and f_{dr} .



Key

f_{adc} [ADC](#) sampling rate
 f_{dr} output sampling rate

Figure 2 — Example of digital data acquisition system

If f_{adc} is larger than f_{dr} , the useable signal bandwidth is less than $f_{dr} / 2$, otherwise the signal bandwidth is less than $f_{adc} / 2$.

Hence, a so-called anti-aliasing filter shall be used. Minimum anti-aliasing filter attenuation requirements are specified as a function of the instrument transformer accuracy class and given in Table 10.

Table 10 — Anti-aliasing filter requirements

Accuracy class	Anti-aliasing filter attenuation guarding frequencies up to 13 th harmonic ($f_s - 13 \times f_r \leq f < f_s - f_r$)	Anti-aliasing filter attenuation guarding the fundamental ($f_s - f_r \leq f$)
0,1	≥ 17 dB	≥ 34 dB
0,2	≥ 14 dB	≥ 28 dB
0,5	≥ 10 dB	≥ 20 dB
1	≥ 10 dB	≥ 20 dB
Protection classes	≥ 10 dB	≥ 20 dB

The attenuation, expressed in decibels (dB), is calculated in accordance with the following formula in the case of current transformers with an analogue secondary signal:

$$\alpha = 20 \lg \left(\frac{I_p}{I_{pr}} \times \frac{U_{sr}}{U_s} \right)$$

where

α is the attenuation;

I_p is the [RMS](#) value of the primary current at frequency f , with $f \geq f_s - f_r$;

U_s is the [RMS](#) value of the secondary voltage at the mirrored frequency ($f_s - f_r$);

I_{pr} is the rated primary current;

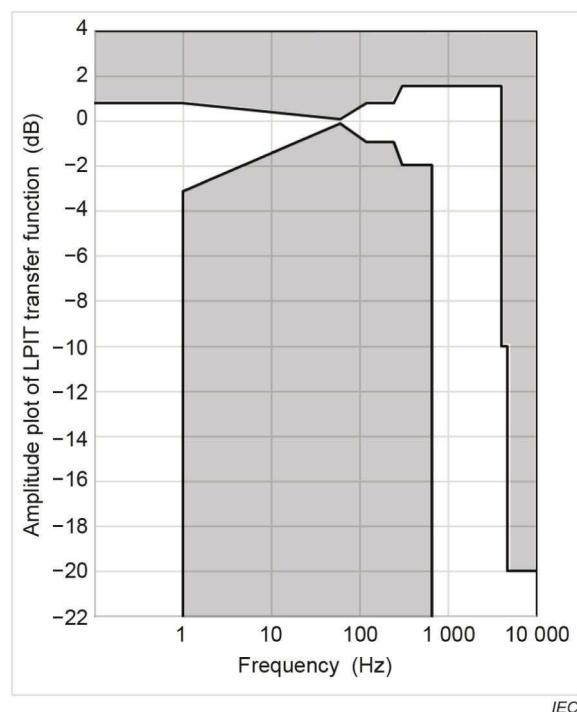
U_{sr} is the rated secondary voltage.

For a digital secondary signal, the attenuation is defined by

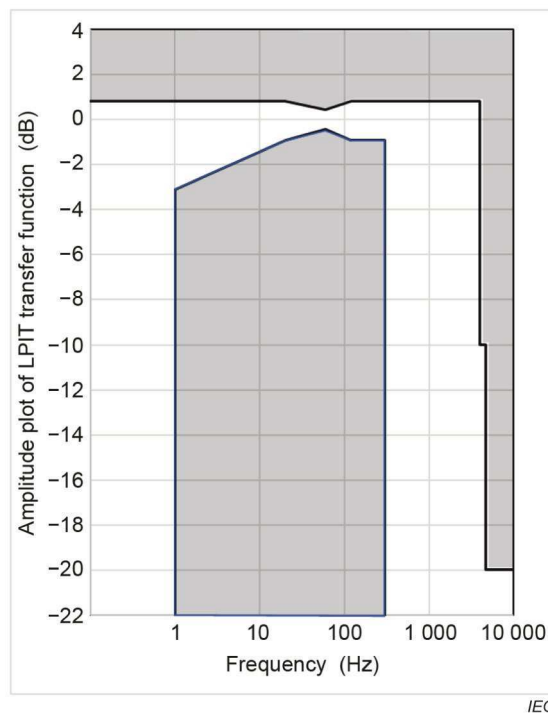
$$\alpha = 20 \lg \frac{I_p}{I_s}$$

For low-power voltage transformers, replace current I_p by voltage U_p and current I_s by voltage U_s .

[Figure 3](#) illustrates the combined harmonic and anti-aliasing frequency response magnitude requirements for measuring accuracy class 1, WB0 and protection accuracy class 5P where $f_r = 60$ Hz and $f_s = 4\,800$ Hz.



Measuring class

**Key**

Grey zone: prohibit region for response

Protection class

Figure 3 — Example of frequency response mask for EIT with digital output

It is recommended that a typical frequency response plot (phase and magnitude) be provided with the documentation. The frequency response plot may be obtained by simulation.

6 Design and construction

6.1 Requirements for liquids used in equipment

6.1.1 General

The manufacturer shall specify the type and the required quantity and quality of the liquid to be used in equipment.

6.1.2 Liquid quality

For mineral oil-filled equipment, new insulating oil shall comply with IEC 60296.

For synthetic liquid-filled equipment, new insulating liquid shall comply with IEC 60867.

For natural ester liquid-filled equipment, new insulating liquid shall comply with IEC 62770.

For synthetic ester liquid-filled equipment, new insulating liquid shall comply with IEC 61099.

For modified or blended ester liquid-filled equipment, new insulating liquid shall comply with IEC 63012.

6.1.3 Liquid level indicator

If supplied, the device for checking the liquid level shall indicate whether the liquid level is within the permissible range during operation.

6.1.4 Liquid tightness

No liquid leakage is permitted. Any liquid leakage represents a danger for insulation dielectric performance and can be harmful for the environment.

6.2 Requirements for gases used in equipment

6.2.1 General

The manufacturer shall specify the type and the required quantity and quality of the gas to be used in equipment.

6.2.2 Gas quality

New SF₆ (sulphur hexafluoride) shall comply with IEC 60376. Used SF₆ shall comply with IEC 60480.

SF₆ handling shall be in accordance with IEC 62271-4:2022, Clauses 4 and 5.

The maximum allowed moisture content within instrument transformers filled with gas at rated filling pressure shall be such that the dew point is not higher than $-5\text{ °C}^{1)}$ for a measurement at 20 °C. Adequate correction shall be applied for measurement at other temperatures. For the measurement and determination of the dew point, refer to IEC 60376 for new SF₆ and IEC 60480 for used SF₆. This is applicable at any time in the life of the instrument transformer.

NOTE New insulating gases are being introduced and used today. The standardization is under consideration, but the maturity is not yet sufficient to be considered.

6.2.3 Gas monitoring device

Gas-insulated instrument transformers with a minimum functional pressure above 0,2 MPa shall be provided with a pressure or density monitoring device. Gas monitoring devices can be provided alone or together with the associated equipment.

6.2.4 Gas tightness

6.2.4.1 General

The specifications of [6.2.4.2](#) apply to all instrument transformers that use gas as an insulating medium, other than air at atmospheric pressure.

6.2.4.2 Closed pressure systems for gas

The tightness characteristic of a closed pressure system and the time between replenishments under normal environmental conditions shall be stated by the manufacturer. This time shall be at least 10 years for maintenance planning purposes.

The tightness of closed pressure systems for gas is specified by the relative leakage rate F_{rel} of each compartment.

Standardized values of the relative leakage rate are:

- 0,5 % per year for SF₆ and SF₆ mixtures;

1) This value is consistent with other high-voltage equipment standards.

- 1 % per year for other gases.

An increased leakage rate at extreme temperatures (if such tests are required in the relevant standards) is acceptable, provided that this rate resets to a value not higher than the maximum permissible value at normal ambient air temperature (F_p). The permissible temporary leakage rate shall not exceed the values given in [Table 11](#).

Table 11 — Permissible temporary leakage rates for gas systems

Temperature class °C	Permissible temporary leakage rate
+40 and +50	$3 F_p$
ambient temperature	F_p
-5 /-10 /-15 /-25 /-40	$3 F_p$
-50	$6 F_p$

6.2.5 Pressure-relief device

For safety reasons, each compartment of instrument transformers shall be equipped with a pressure-relief device.

The pressure-relief device shall be equipped with a deflector in order to control the direction of emission in such a way to minimize the danger to an operator working in accessible places or normal operation.

In order to avoid any pressure-relief operation under normal conditions, a sufficient difference is necessary between the operation pressure of the pressure relief device and the design pressure.

NOTE The requirement is consistent with IEC 62271-203.

6.3 Requirements for solid materials used in equipment

Specifications for organic material used for instrument transformers (i.e. epoxy resin, polyurethane resin, epoxy-cycloaliphatic resin, composite material, etc.) either for indoor or outdoor installations, are given in the IEC 60455 series.

NOTE Tests on complete instrument transformers considering phenomena such as flammability and ageing are not yet standardized. IEC 62217 can be used as guidance for polymeric HV insulators.

6.4 Requirements for temperature rise of parts and components

6.4.1 General

The temperature rise of windings, magnetic circuits and any other parts of instrument transformers shall not exceed the appropriate value given in [Table 12](#), when operating under the specified rated conditions. These values are based on the environmental conditions given in [4.2.1](#).

The temperature rise of the windings is limited by the lowest thermal class either of the winding itself or of the surrounding medium in which it is embedded.

If the instrument transformers are used within enclosures, attention shall be paid to the temperature reached by the surrounding cooling media within the enclosure.

If ambient temperatures exceeding the values given in [4.2.1](#) are specified, the permissible temperature rise given in [Table 12](#) shall be reduced by an amount equal to the excess ambient temperature.

Table 12 — Limits of temperature and temperature rise for various parts, materials and dielectrics of instrument transformers

Part of instrument transformers	Maximum value	
	Temperature T °C	Temperature rise ΔT at ambient air temperature not exceeding 40 °C K
1) Liquid-insulated instrument transformers		
- top oil	90	50
- top oil, hermetically sealed	95	55
- winding average	100	60
- winding average, hermetically sealed	105	65
- other metallic parts in contact with oil	as for windings	as for windings
2) Solid-insulated or gas-insulated instrument transformers		
- winding (average) in contact with insulating materials of the following thermal classes (°C) ^a		
• 90 (Y)	85	45
• 105 (A)	100	60
• 120 (E)	115	75
• 130 (B)	125	85
• 155 (F)	150	110
• 180 (H)	175	135
- other metallic parts in contact with insulation materials of the above thermal classes	as for windings	as for windings
3) Connection (including terminals), bolted or the equivalent		
Bare-copper, bare-copper alloy or bare-aluminium alloy		
- in OG ^b	100	60
- in NOG ^c	115	75
- in oil	100	60
Silver-coated or nickel-coated		
- in OG ^b	115	75
- in NOG ^c	115	75
- in oil	100	60
Tin-coated		
- in OG ^b	105	65
- in NOG ^c	105	65
- in oil	100	60
NOTE Compared to IEC 60085, the maximum temperature of windings has been reduced by 5 K to consider the difference between the average temperature given by the method of resistance increase and the hot spot temperature. ^a Thermal class definitions are in accordance with IEC 60085. ^b OG (oxidizing gas): reactive gas that can accelerate ageing of contacts either by corrosion phenomena (presence of humidity) or by oxidation phenomena (mostly due to an ambient air medium like oxygen). Typical insulating OG gases are ambient air and dry air.		

Table 12 (continued)

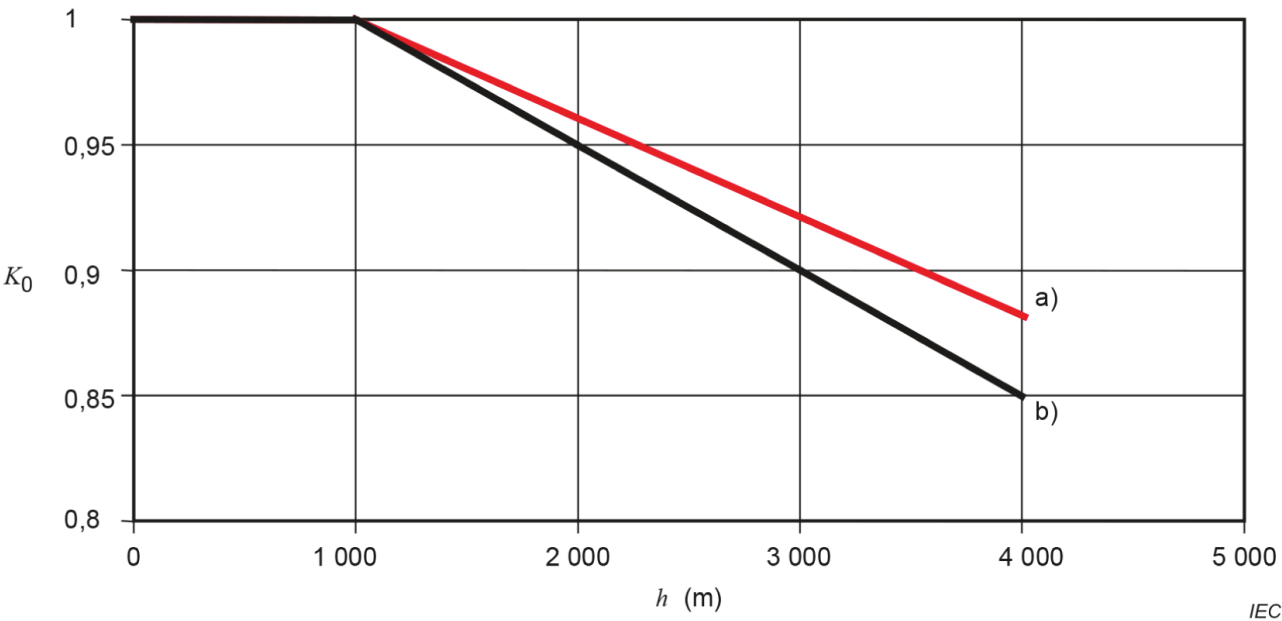
Part of instrument transformers	Maximum value	
	Temperature <i>T</i> °C	Temperature rise ΔT at ambient air temperature not exceeding 40 °C K
^c NOG (not oxidizing gas): non-reactive gas that does not accelerate ageing of contacts by corrosion or oxidation, as purity of these gases is controlled. Typical NOG gases used today are SF ₆ , N ₂ , CO ₂ , CF ₄ . They can be used pure or as a mixture of various NOGs.		

When connections have different coatings or one connection part is of bare material, the permissible temperatures and temperature rises shall be those of the surface material having the highest value permitted in item 3 of [Table 12](#).

NOTE This is in accordance with IEC TR 60943.

6.4.2 Influence of altitude on temperature rise

If an instrument transformer is specified for operation at an altitude higher than 1 000 m and tested at an altitude below 1 000 m, the limits of temperature rise ΔT given in [Table 12](#) shall be reduced by the altitude correction factor K_0 indicated in [Figure 4](#).



Key:

- a) liquid-insulated instrument transformers: $K_0 = 1 - (h - 1000) \times 0,000\,04$
- b) solid-insulated and gas-insulated instrument transformers: $K_0 = 1 - (h - 1000) \times 0,000\,05$

Figure 4 — Altitude correction factor for the temperature rise

The altitude correction for the temperature rise is $\Delta T_h = K_0 \Delta T_{h0}$ with

- ΔT_h is the temperature rise at altitude *h*;
- ΔT_{h0} is the limit of temperature rise ΔT specified in [Table 12](#) for altitudes $h_0 \leq 1\,000$ m.

6.5 Requirements for earthing of equipment

6.5.1 General

The frame of each equipment, if intended to be earthed, shall be provided with a reliable earthing terminal for connection to an earthing conductor suitable for phase-to-earth fault conditions. The point

of connection shall be marked with the "earth" symbol, as indicated by symbol IEC 60417-5019



6.5.2 Earthing of the enclosure

6.5.2.1 GIS enclosure

The enclosure of instrument transformers for gas-insulated switchgear (GIS) shall be connected to earth. All metal parts which do not belong to a main or an auxiliary circuit shall be earthed.

6.5.2.2 Enclosure of low-voltage components

All LPIT low-voltage components (e.g. converters) installed at ground potential shall be provided with a reliable earthing connection.

6.5.3 Electrical continuity

The continuity of the earthing circuits shall be ensured considering the thermal and electrical stresses caused by the maximum expected fault current.

For the interconnection of enclosures, frames, etc., fastening (e.g. bolting or welding) is acceptable for providing electrical continuity.

6.6 Requirements for the external insulation

6.6.1 Pollution

For AIS instrument transformers, the reference unified specific creepage distance (RUSCD) shall be selected according to the site pollution severity class (SPS); see Table 13.

The necessary creepage distances are determined by multiplying the RUSCD by a value as follows:

$$\frac{U_m}{\sqrt{3}} \times K_{ad} \text{ (for CT and phase-to-earth VT)}$$

$$U_m \times K_{ad} \text{ (for phase-to-phase VT)}$$

where K_{ad} is the correction factor depending on the average diameter of the insulator (refer to IEC TS 60815-2:2008, 10.3 for ceramic insulators, or IEC TS 60815-3:2008, 10.2 for polymeric insulators).

In the case of an irregular shape of the insulating part, an equivalent average diameter shall be considered to determine K_{ad} . For the calculation of this equivalent average diameter, refer to Annex G.

Table 13 — Specific creepage distances by site pollution severity class, as defined in the former publication

SPS class	RUSCD based on $U_m/\sqrt{3}$ mm/kV	Pollution level	Minimum SCD based on U_m mm/kV
IEC TS 60815-1	IEC TS 60815-2 IEC TS 60815-3	IEC TR 60815:1986 Table II	IEC TR 60815:1986 Table II
a - Very light	22,0	-	12,7
b - Light	27,8	I	16
c - Medium	34,7	II	20
d - Heavy	43,3	III	25
e - Very heavy	53,7	IV	31

6.6.2 Altitude

The coordination withstand voltages are considered valid up to an altitude of 1 000 m. To consider the reduced withstand capability of the air at an installation site with an altitude above 1 000 m, the required type test insulation withstand level of external insulation at standard reference atmospheric conditions shall be determined by multiplying the withstand voltage required on site by an altitude correction factor K_a . The correction factor shall not be applied for routine tests, because a routine test validates the quality of the internal insulation only.

For AC applications, the altitude correction factor shall be determined in accordance with IEC 60071-2:2018, 6.2.2, using Formula H.13 from IEC 60071-2:2018, Annex H, as follows:

$$K_a = e^{m \frac{(H-1000)}{8150}}$$

where

H is the altitude above sea level (in metres);

m is as follows:

$m = 1,0$ for co-ordination lightning impulse withstand voltages;

$m = 1,0$ for power-frequency withstand voltages in case of wet tests;

m is in accordance with [Figure 5](#) for co-ordination switching impulse withstand voltages.

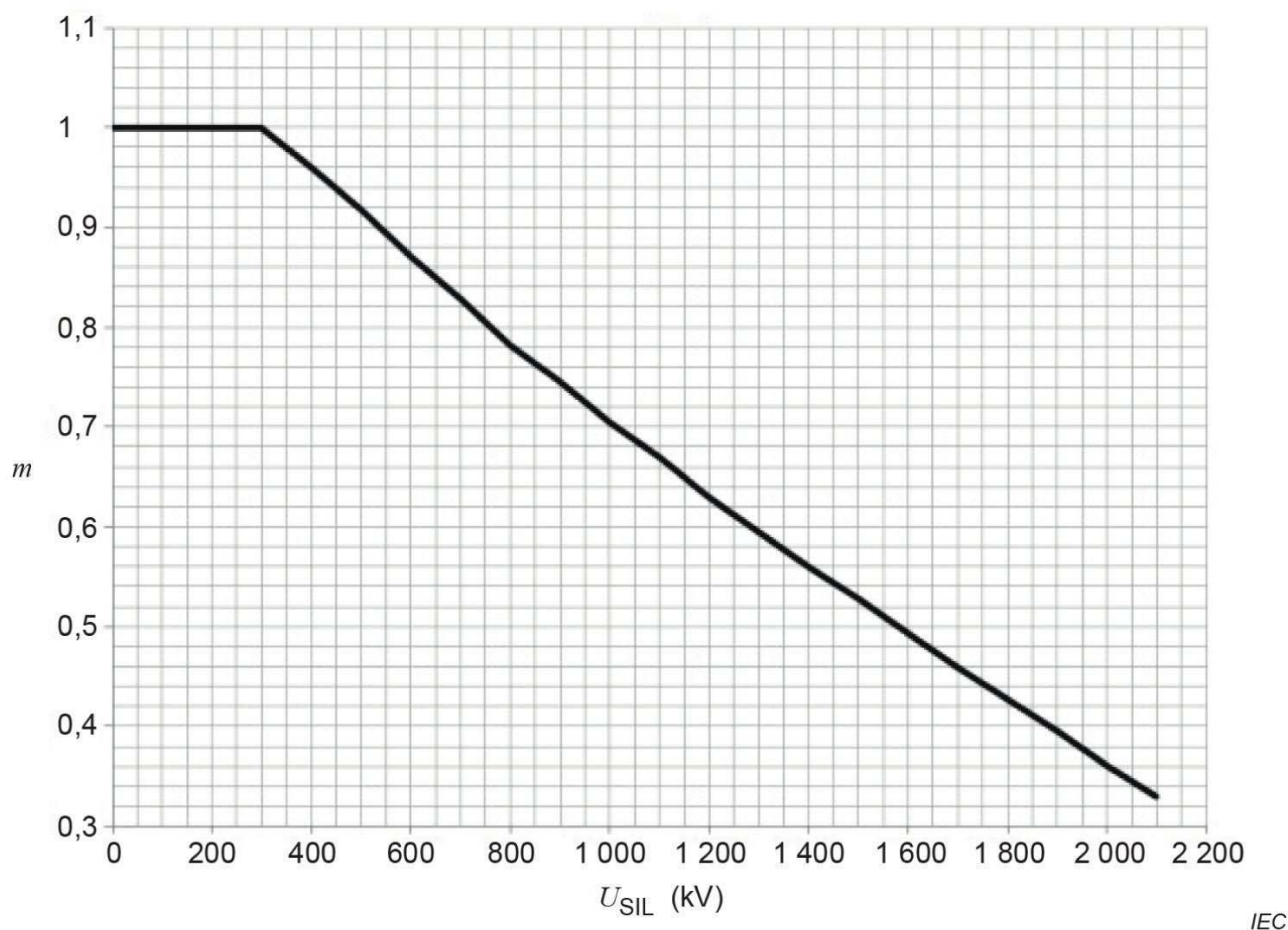


Figure 5 — Factor m for the switching impulse voltage (U_{SIL}) withstand test

For DC applications, refer to product-specific standards.

To verify the withstand voltages corrected for altitude, the arcing distance of the instrument transformer needs to be increased. If increasing the arcing distance is based on a verified arcing distance of a similar product, it can be considered valid without further testing.

If the withstand voltages corrected for altitude cannot be validated by an increased arcing distance of a similar product, external insulation shall be tested in accordance with IEC 60071-2:2018, 7.3.7.

NOTE It is considered that the altitude does not affect the internal insulation.

6.7 Mechanical requirements

These requirements apply to free-standing instrument transformers with $U_m \geq 72,5$ kV.

In the case of instrument transformers mounted on [GIS](#), no external force is considered to be applied to the HV terminals. These devices are not subject to these mechanical requirements.

Instrument transformers shall be capable of withstanding the static withstand loads indicated in [Table 14](#).

The test values defined in [Table 14](#) include a safety margin with respect to static forces due to line connections. This safety margin is intended to cover other non-permanent external loads of various nature (e.g. wind, ice, short-circuits) that can occur in operation, taking into account that a combination of the extreme values of all electrical and environmental loads would lead to unnecessarily high margins.