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Station Service Voltage Transformers (SSVT)

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STATION SERVICE VOLTAGE TRANSFORMERS (SSVT)

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IEC/IEEE 63253-5713-8 has been prepared by IEC technical committee 38: Instrument Transformers, in cooperation with Transformers Committee of the IEEE Power and Energy Society, under the IEC/IEEE Dual Logo Agreement.

It is published as an IEC/IEEE dual logo standard.

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

Draft	Report on voting
38/788/FDIS	38/789/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 the rules given in the ISO/IEC Directives, Part 2, 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/.

The IEC Technical Committee and IEEE Technical Committee have 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- withdrawn, or
- revised.

STATION SERVICE VOLTAGE TRANSFORMERS (SSVT)

1 Scope

This document describes electrical and mechanical requirements of single-phase station service voltage transformers with system voltages of 46 kV or higher and with the maximum rated voltage of the power winding of 1 000 V.

This document is a basis for the establishment of performance and limited electrical and mechanical interchangeability requirements of the equipment are described. It is also a basis for assistance in the proper selection of such equipment.

A station service voltage transformer (SSVT) is a single-phase transformer to be connected line-to-earth on an effectively earthed system. It can be used either as an individual unit for supplying single-phase loads, or in a three-phase bank to support three-phase loads. A typical application is to supply substation power such as lighting, pump and motor loads. The SSVT can be provided with a measuring winding when requested by the user.

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 60060-1:2010, *High-voltage testing techniques – Part 1: General definitions and test requirements*

IEC 60060-2, *High-voltage testing techniques – Part 2: Measuring systems*

IEC 60071-2:2023, *Insulation co-ordination – Part 2: Application guidelines*

IEC 60076-1:2011, *Power transformers – Part 1: General*

IEC 60076-5, *Power transformers – Part 5: Ability to withstand short circuit*

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

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

IEC 60475, *Method of sampling insulating liquids*

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

IEC 60567, *Oil-filled electrical equipment – Sampling of free gases and analysis of free and dissolved gases in mineral oils and other insulating liquids – Guidance*

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

IEC 60867, *Insulating liquids – Specifications for unused liquids based on synthetic aromatic hydrocarbons*

IEC 60836, *Specifications for used silicon insulating liquids for electrotechnical purposes*

IEC 60944, *Guide for the maintenance of silicon transformer liquids*

IEC 61099, *Insulating liquids – Specifications for unused synthetic organic esters for electrical purposes*

IEC 61869-1:2023, *Instrument transformers – Part 1: General requirements*

IEC 61869-3:2011, *Instrument transformers – Part 3: Additional requirements for inductive voltage transformers*

IEC 61869-99:2022, *Instrument transformers – Part 99: Glossary*

IEC 62262, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK Code)*

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

ASTM D2225, *Standard Test Methods for Silicone Liquids Used for Electrical Insulation*

ASTM D3487, *Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus*

ASTM D5222, *Standard Specification for High Fire-Point Mineral Electrical Insulating Oils*

ASTM D6871, *Standard Specification for Natural (Vegetable Oil) Ester Fluids Used in Electrical Apparatus*

CISPR TR 18-2:2017, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits*

IEEE Std 4™-2013, *High-Voltage Testing Techniques*

IEEE Std C57.12.70™, *IEEE Standard Terminal Markings and Connections for Distribution and Power Transformers*

IEEE Std C57.12.80™-2010, *IEEE Standard Terminology for Power and Distribution Transformers*

IEEE Std C57.12.90™-2015, *IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*

IEEE Std C57.13™-2016, *IEEE Standard for Requirements for Instrument Transformers*

IEEE Std C57.13.5™, *IEEE Standard of Performance and Test Requirements for Instrument Transformers of a Nominal System Voltage of 115 kV and Above*

IEEE Std C57.19.100™, *IEEE Guide for Application of Power Apparatus Bushings*

IEEE Std 693™, *IEEE Recommended Practice for Seismic Design of Substations*

NEMA 107-2016, *Methods of measurement of radio influence voltage (RIV) of high-voltage apparatus*

NEMA 250, *Enclosures for Electrical Equipment (1000 Volts Maximum)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61869-99, IEEE Std C57.12.80™, and the following apply.

ISO, IEC and IEEE maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>
- IEEE Standards Dictionary Online: available at <http://dictionary.ieee.org>

3.1 General definitions

3.1.1

station service voltage transformer SSVT

line-to-earth connected single-phase transformer that can be used either as an individual unit for supplying single-phase loads, or in a three-phase bank to supply three-phase loads and can be provided with a measuring winding

EXAMPLE A typical application is to supply power to the control house and yard loads inside a substation.

3.1.2

enclosure

housing affording the type and degree of protection suitable for the intended application

Note 1 to entry: This definition needs the following explanations under the scope of this document:

- 1) enclosure provides protection for persons or animals against access to hazardous parts;
- 2) enclosure provides protection for equipment against the harmful effects of mechanical impact;
- 3) barriers, shapes of openings or other means – whether attached to the enclosure or formed by the enclosed equipment – suitable to prevent or limit penetration, are considered as part of the enclosure, except when they can be removed without the use of a key or tool.

[SOURCE: IEC 60050-151:2001, 151-13-08, modified – the Note to entry has been added.]

3.1.3

primary terminal

terminal to which the voltage to be transformed is applied

3.1.4

secondary terminal

terminal which transfers the power to the secondary circuit or transmits the secondary signal to measuring instruments, meters and protective or control devices or similar apparatus

3.1.5

neutral terminal

terminal intended for connection to a neutral point of a network

3.1.6

secondary circuit

external circuit connected to the secondary terminals

[SOURCE: IEC 61869-99:2022, 3.1.4]

3.1.7

pressure relief device

device suitable to limit dangerous over-pressures inside the SSVT

[SOURCE: IEC 61869-99:2022, 3.2.61, modified – Reference to "instrument transformer" replaced with "SSVT".]

3.1.8

zero period acceleration

ZPA

acceleration level of the high-frequency, non-amplified portion of the response spectrum, corresponding to the maximum (peak) acceleration of the time history used to derive the spectrum

Note 1 to entry: The ZPA is assumed to be the acceleration at 33 Hz or greater.

[SOURCE: IEEE Std 693™-2018- 3.1, modified – second part of the definition moved to a Note.]

3.1.9

IEC profile

iteration of this document where the user of this document follows the IEC references

3.1.10

IEEE profile

iteration of this document where the user of this document follows the IEEE references

3.2 Definitions related to voltage and dielectric aspects

3.2.1

nominal system voltage

suitable approximate value of voltage used to designate or identify a system

[SOURCE: IEC 60050-601:1985, 601-01-21, modified – the term "nominal voltage of a system" has been replaced with "nominal system voltage", which is the common term in North America.]

3.2.2

highest voltage of a system

maximum system voltage

U_{sys}

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

Note 1 to entry: Transient overvoltages due e.g. to switching operations and unusual temporary variations of voltage, are not taken into account.

[SOURCE: IEC 60050-601:1985, 601-01-23, modified – the term "maximum system voltage" and symbol have been added; the word "abnormal" replaced with "unusual" in the definition.]

3.2.3

highest voltage for equipment

maximum equipment voltage

U_m

highest value of line-to-line voltage (RMS value) for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standards under normal operating conditions

[SOURCE: IEC 60050-614:2016, 614-03-01, modified – the term "maximum equipment voltage" and symbol have been added; in the definition "greatest" has been replaced with "highest" and "service conditions" replaced with "operating conditions".]

3.2.4

rated primary voltage

U_{pr}

value of the primary line-to-earth voltage of the SSVT on which its performance is based

3.2.5

rated secondary voltage

U_{sr}

value of the secondary voltage of the SSVT to be developed at no-load between the secondary terminals with rated primary voltage

3.2.6

harmonic factor

ratio of the RMS value of harmonic content to the RMS value of an alternating quantity

[SOURCE: IEC 60050-161:1990, 161-02-23, modified – "total" has been omitted from the term.]

3.2.7

rated voltage factor

F_v

multiplying factor to be applied to the rated primary voltage to determine the maximum voltage at which an SSVT must comply with the relevant thermal and optional accuracy requirements for a specific time

3.2.8

rated insulation level

test voltages, under specified conditions, that the insulation is designed to withstand

Note 1 to entry: These test voltages can be for instance:

- a) rated lightning impulse and short duration power frequency withstand voltages;
- b) rated lightning and switching impulse withstand voltages (phase-to-earth).

[SOURCE: IEC 60050-421:1990, 421-09-02]

3.2.9

earth fault factor

at a given location of a three-phase system, and for a given system configuration, ratio of the highest RMS value of line-to-earth power frequency voltage on a healthy line conductor during an earth fault affecting one or more line conductors at any point on the system, to the RMS value of line-to-earth power frequency voltage which would be obtained at the given location in the absence of such earth fault

[SOURCE: IEC 60050-614:2016, 614-03-06, modified – The term "ground fault factor, US" has been omitted.]

3.2.10 effectively earthed neutral system

system on which the neutral is connected to earth solidly or through an impedance of sufficiently low value to reduce transient oscillations and to give a current sufficient for selective earth fault protection

Note 1 to entry: A three-phase system with effectively earthed neutral at a given location is a system characterized by an earth fault factor at this point which does not exceed 1,4. This condition 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 one.

Note 2 to entry: A three-phase system with non-effectively earthed neutral at a given location is a system characterized by an earth fault factor at this point that may exceed 1,4.

3.2.11 solidly earthed neutral system

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

[SOURCE: IEC 60050-601:1985, 601-02-25]

3.3 Definitions related to windings

3.3.1 winding

assembly of turns forming an electric circuit associated with one of the voltages assigned to the SSVT

[SOURCE: IEC 60050-421:1990, 421-03-01, modified – Reference to transformer or reactor replaced with SSVT.]

3.3.2 primary winding

winding to which is applied the voltage to be transformed

[SOURCE: IEC 60050-321:1986, 321-01-05, modified – removed "(of a voltage transformer)" from the term.]

3.3.3 secondary winding

winding which supplies power to the secondary circuit or voltage to measuring instruments, meters, protective or control devices

3.3.4 power winding

secondary winding that supplies power to the secondary circuit

3.3.5 measurement winding

additional winding that supplies the voltage circuits of measuring instruments, meters, relays or similar apparatus

Note 1 to entry: The accuracy of measuring windings depends not only on the load and the power factor of the winding itself, but also on the load and power factor of the power windings.

3.3.6 section

electrically conductive part of an SSVT insulated from other similar parts and equipped with terminals

EXAMPLE Primary or secondary reconnectable windings, shielding to be externally earthed, temperature sensors

3.3.7

tap

connection made at some intermediate point in a winding to permit changing of the ratio

[SOURCE: IEC 60050-421:1990, 421-05-01, modified – The term "tapping" removed, and "to permit changing the ratio" added to the definition.]

3.4 Definitions related to ratings

3.4.1

rating

numerical values assigned to the quantities which define the operation of the SSVT in the condition specified in this document and on which the manufacturer's guarantee and tests are based

3.4.2

rated value

value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

Note 1 to entry: Voltages and currents are always expressed by their RMS values, unless otherwise specified.

[SOURCE: IEC 60050-151:2001, 151-16-08, modified – Note to entry added.]

3.4.3

rated frequency

f_r

frequency at which the SSVT is designed to operate and on which the requirements of this document are based

[SOURCE: IEC 60050-421:1990, 421-04-03, modified – symbol added, and "and on which the requirements of this document are based" added, and changed "transformer or reactor" to "SSVT".]

3.4.4

rated output power

S_r

conventional value of apparent power assigned to a winding which, together with its rated voltage, determines its rated current

3.4.5

rated current

I_r

current flowing through terminals of a winding which is derived by dividing the rated output power S_r by the rated voltage of the winding

3.4.6

reference temperature

temperature defined as 20 °C plus the rated average winding temperature rise

[SOURCE: IEEE C57.12.80-2010, 3.368, modified – removed "unless otherwise stated" and the second sentence.]

3.4.7**temperature rise**

difference between the temperature of the part under consideration and ambient air temperature

[SOURCE IEC 60050-151:2001, 151-16-26, modified – "a reference temperature" replaced by "ambient air temperature" and the note deleted.]

3.4.8**rated arc-proof current**

I_{arc}

maximum current, within a specified withstand duration, for which the internal arc classification applies

3.5 Definitions related to losses**3.5.1****no-load loss**

active power absorbed when the rated primary voltage U_{pr} at rated frequency f_r is applied to the primary winding with the other windings open-circuited

3.5.2**no-load current**

current flowing through a line terminal of a winding when a given voltage is applied at rated frequency, the other winding(s) being open-circuited

Note 1 to entry: Normally the applied voltage is the rated voltage and the energized winding, if fitted with taps, is connected on its principal tapping.

Note 2 to entry: The no-load current of a winding is often expressed as a percentage of the rated current of the same winding.

3.5.3**load loss**

absorbed active power at rated frequency f_r and reference temperature associated with a pair of windings when rated current is flowing through the terminals of one of the windings, and the terminals of the other winding are short-circuited

Note 1 to entry: Other windings, if existing, are open circuited.

3.5.4**total loss**

sum of the no-load loss and the load loss

Note 1 to entry: For a two-winding SSVT there is only one winding combination and one value of load loss. For a multi-winding SSVT there are several values of load loss corresponding to the different two-winding combinations (see IEC 60076-8:1997, Clause 7). A combined load loss figure for the complete SSVT is referred to a specified winding load combination.

3.5.5**short-circuit impedance**

percent impedance, US

equivalent series impedance $Z = R + jX$, in ohms, at rated frequency and reference temperature, across the terminals of one winding of a pair, when the terminals of the other winding are short-circuited and other windings, if existing, are open-circuited

Note 1 to entry: In an SSVT having a tapped winding the short-circuit impedance is referred to a particular tapping. Unless otherwise specified the rated voltage tap applies.

Note 2 to entry: This quantity can be expressed as a fraction z of the reference impedance Z_{ref} , of the same winding of the pair and expressed in percent, hence the term "percent impedance".

In percentage notation:

$$z(\%) = 100 \frac{Z}{Z_{\text{ref}}} \quad (1)$$

where:

$$Z_{\text{ref}} = \frac{U^2}{S_r} \quad (2)$$

U is the voltage (rated voltage or tapping voltage) of the winding to which Z and Z_{ref} belong;

S_r is value of rated output power.

The relative value is also equal to the ratio between the applied voltage during a short-circuit measurement which causes the relevant rated current (or tapping current) to flow, and rated voltage (or tapping voltage). This applied voltage is referred to as the short-circuit voltage of the pair of windings.

3.5.6

short circuit voltage

impedance voltage

voltage required to be applied at rated frequency to the line terminals of a winding of a single-phase transformer, to cause the rated current to flow through these terminals when the terminals of the other winding are short-circuited

Note 1 to entry: The value is normally related to the appropriate reference temperature.

Note 2 to entry: The impedance voltage is usually expressed as a percentage of the rated voltage of the winding to which the voltage is applied.

Note 3 to entry: When expressed in relative form (in %) the short circuit voltage has the same value as the short circuit impedance in %.

3.5.7

voltage drop or rise for a specified load condition

voltage regulation for a specified load condition

arithmetic difference between the no-load voltage of a power winding and the voltage developed at terminals of the same winding at a specified load and power factor, the voltage supplied to the power winding being equal to:

- its rated value if the SSVT is connected to the rated voltage tap (the no-load voltage of the power winding then being equal to its rated value)
- the tap voltage if the SSVT is connected to another tap

Note 1 to entry: The difference is generally expressed as a percentage of the no-load voltage of the power winding.

Note 2 to entry: For SSVTs with multiple windings (also applicable to measuring windings) the voltage drop depends not only on the load and power factor of the winding itself, but also on the load and power factor of the other windings.

[SOURCE: IEC 60050-421:1990, 421-07-03, modified – In the definition, "winding" has been replaced with "power winding", "transformer" has been replaced with "SSVT" and "tapping" replaced with "tap"; the existing note to entry deleted and replaced with two new notes to entry.]

3.6 Definitions related to gas insulation

3.6.1

closed pressure system

volume that is replenished only when needed by manual connection to an external gas source

3.6.2**rated filling pressure**

pressure referred to the standard atmospheric air conditions (20 °C and 101,3 kPa) to which the gas-insulated SSVT is filled before being put in service, or replenished as needed

[SOURCE: IEC 61869-99:2022, 3.6.7, modified – changed "instrument transformer" to "SSVT" and "periodically replenished" to "replenished as needed".]

3.6.3**minimum functional pressure**

pressure referred to the standard atmospheric air conditions (20 °C and 101,3 kPa) at which, and above which, rated insulation and other characteristics of the gas-insulated SSVT are maintained and at which gas replenishment becomes necessary

[SOURCE: IEC 61869-99:2022, 3.6.8, modified – "instrument transformer" replaced with "SSVT".]

3.6.4**absolute leakage rate**

amount of gas escaped by time unit under standard atmospheric conditions (20 °C and 101,3 kPa)

Note 1 to entry: The absolute leakage rate is typically expressed in pascal meter cubed per second (Pa·m³/s).

[SOURCE: IEC 61869-99:2022, 3.6.9]

3.6.5**relative leakage rate**

F_{rel}

absolute leakage rate related to the total amount of gas in the SSVT at rated filling pressure (or density)

Note 1 to entry: Relative leakage rate is typically expressed in per cent per year (%/y).

[SOURCE: IEC 61869-99:2022, 3.6.10, modified – "instrument transformer" replaced with "SSVT".]

3.7 Index of abbreviated terms

The abbreviated terms are given in Table 1.

Table 1 – Index of abbreviated terms

Abbreviated term	Full term
F_{rel}	Relative leakage rate
F_v	Rated voltage factor
f_r	Rated frequency
GNAN	Gas natural air natural (cooling method)
I_{arc}	Rated arc-proof current
I_r	Rated current
KNAN	K-fluid ^a natural air natural (cooling method)
ONAN	Oil natural air natural (cooling method)
SSVT	Station service voltage transformer
S_r	Rated power

Abbreviated term	Full term
U_m	Highest voltage for equipment / Maximum equipment voltage
U_{pr}	Rated primary voltage
U_{sr}	Rated secondary voltage
U_{sys}	Highest voltage of a system / Maximum system voltage
^a K-type cooling medium is a fluid with fire point greater than 300 °C	

4 Profiles and use of normative references

This document can be used with either IEC or IEEE normative references but the references shall not be mixed. For the IEC profile (3.1.9), IEC references are used; for the IEEE profile (3.1.10), IEEE references are used. The purchaser shall include in the enquiry and order which normative references are to be used. By default, if the choice of normative references is not specified, IEC references shall be used. For SSVTs intended for installation in North America, IEEE references are used.

See Annex C for technical information exchange during contracting stage.

5 Environmental conditions

5.1 Normal (usual) environmental conditions

5.1.1 General

SSVTs conforming to this document shall be suitable for operation at rated power under the following normal environmental conditions.

5.1.2 Temperature

The temperature of the cooling air (ambient temperature) does not exceed 40 °C, and the average temperature of the cooling air for any 24 h period does not exceed 30 °C.

The minimum ambient air temperature is –30 °C.

5.1.3 Altitude

The altitude does not exceed 1 000 m (3 300 ft).

5.1.4 Other environmental conditions

Other environmental conditions are as follows:

- solar radiation up to a level of 1 000 W/m² should be considered;
- the ambient air may be polluted by dust, smoke, corrosive gases, vapours or salt. The pollution or contamination does not exceed the medium level defined in IEC 60815-1 or IEEE C57.19.100™;
- the wind speed does not exceed 34 m/s (76 mph);
- the presence of condensation or precipitation;
- the ice coating does not exceed 20 mm (0,79 in).

NOTE These environmental conditions are consistent with normal environmental conditions for outdoor instrument transformers according to IEC 61869-1.

5.1.5 Primary voltage

The primary voltage wave shape is approximately sinusoidal. The harmonic factor of the primary voltage does not exceed 0,05 per unit.

5.1.6 Load current

The load current is approximately sinusoidal. The harmonic factor of the load current does not exceed 0,05 per unit.

5.1.7 Step-down operation

Unless otherwise specified, an SSVT shall be utilized in a step-down operation in which the outgoing power from the SSVT is at a lower voltage than the incoming power.

5.1.8 Operation above rated voltage or below rated frequency

5.1.8.1 Capability

SSVTs shall be capable of the following:

- a) Operating continuously above rated voltage or below rated frequency, at maximum rated power for any tap, without exceeding the limits of observable temperature rise in accordance with 6.18 when all of the following conditions are present:
 - 1) Secondary voltage and the ratio of secondary voltage over frequency do not exceed 105 % of rated values
 - 2) Load power factor is 80 % or higher
 - 3) Frequency is at least 95 % of rated value.
- b) Operating continuously above rated voltage or below rated frequency, on any tap at no load, without exceeding limits of observable temperature rise in accordance with 6.18, when neither the voltage nor the ratio of secondary voltage over frequency exceed 110 % of rated values.

5.1.8.2 Maximum continuous SSVT operating voltage

The primary voltage shall not exceed the specified highest voltage for equipment (U_m). Preferential values of U_m are listed in Table 4. System conditions may require voltage transformation ratios involving tap voltages higher than the maximum system voltage for regulation of the secondary voltage.

The current associated with the power rating on the nameplate shall not be exceeded at any operating voltage.

NOTE Normal load power factor is 80 % or higher. A lower power factor may affect secondary voltage drop (or rise). The voltage drop (or rise) can be calculated as instructed in 6.5.4.

5.1.8.3 Rated voltage factor (F_v)

The SSVT shall be capable of operating at a line-to-earth overvoltage according to Table 2 without any damage. When specified by the user, the following F_v and time duration options can be selected:

Table 2 – Standard values of rated voltage factor

F_V	Duration	Applicability	Source
1,1	Continuous	Default for all voltage levels	IEEE
1,2	Continuous		IEC
1,25	60 s		IEEE/IEC
1,4	60 s	Optional	IEEE
1,5	30 s	Optional	IEC

5.2 Special (unusual) environmental conditions

5.2.1 General

Conditions other than those described in 5.1 are considered special environmental conditions and, when prevalent, shall be brought to the attention of those responsible for the design and application of the SSVT. Examples of some of these conditions are listed in 5.2.2 and in 5.2.4.

5.2.2 Special (unusual) temperature

For installations located in a place where the ambient temperature can be significantly outside the normal environmental condition range stated in 5.1.2, the preferred ranges of minimum and maximum temperature to be specified should be:

- a) –50 °C to 40 °C for very cold climates;
- b) –5 °C to 50 °C for very hot climates.

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

5.2.3 Altitude correction factor for altitudes greater than 1 000 m

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 at the environmental 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.

The altitude correction factor shall be determined in accordance with IEC 60071-2:2023, 7.2.2, using Formula H.11 from Annex H of IEC 60071-2:2023 as follows:

$$K_a = e^{m \left(\frac{H - 1000}{8150} \right)} \quad (3)$$

where

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

m is as follows:

- $m = 1,0$ for co-ordination lightning impulse withstand voltages;
- $m = 1,0$ for power-frequency withstand voltages in the case of wet tests;
- m is in accordance with Figure 1 for co-ordination switching impulse withstand voltages.

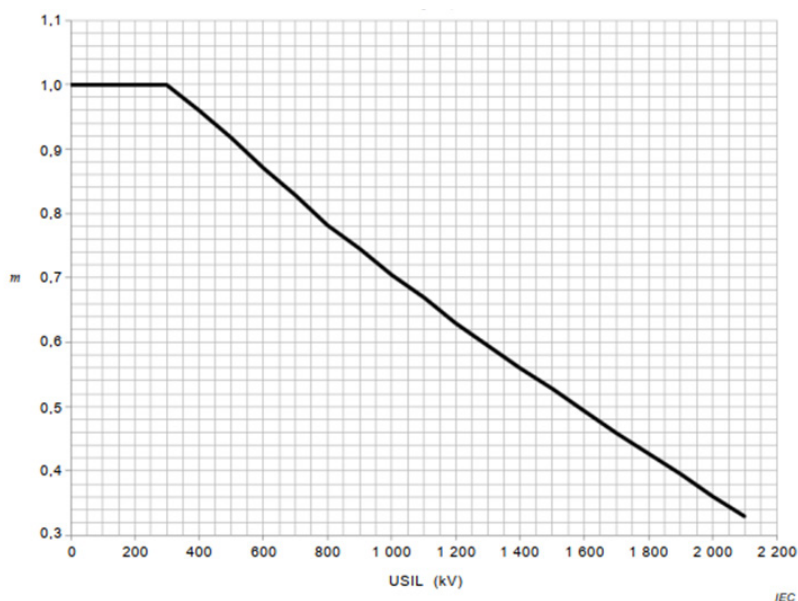


Figure 1 – Factor m for the switching impulse withstand test

To withstand a voltage at an altitude greater than 1 000 m, it can be necessary to increase the arcing distance of the SSVT's insulator. If the increase of 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 60071-2:2023.

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

5.2.4 Loading beyond rated power

Any overload rating, if needed, shall be defined by the user.

5.2.5 Other special (unusual) environmental conditions

Other special environmental conditions include the following:

- a) Damaging fumes or vapours, excessive or abrasive dust, explosive mixtures of dust or gases, steam, salt spray, etc.
- b) Special vibration, tilting, shock, or seismic conditions.
- c) Special transportation or storage conditions.
- d) Special space limitations.
- e) Special maintenance problems.
- f) Special duty or frequency of operation, or high-current short-duration loading.
- g) Unbalanced AC voltages, or departure of AC system voltages from a substantially sinusoidal wave form.
- h) Conditions exceeding those listed in 5.1.
- i) Special voltage conditions (transient overvoltages, resonance, switching surges, etc.) can require special consideration in insulation design.
- j) Unusually strong magnetic fields. It should be noted that solar magnetic disturbances may result in the flow of telluric currents in transformer neutral(s).

6 Ratings

6.1 Secondary voltage

The maximum rated voltage of the power winding shall be 1 000 V.

The rated voltage of a secondary winding is equal to the no-load secondary voltage and may be higher than the nominal secondary voltage. This is to compensate for the voltage drop due to loading which occurs with unity or lagging load power factors.

The rated voltage of the secondary winding is equal to the rated voltage of the primary winding divided by the turns ratio. At least two of the following shall be known in order to design an SSVT:

- 1) rated voltage of the primary winding;
- 2) rated voltage of the secondary winding;
- 3) turns ratio.

The values in the above list may be established based on a calculation of voltage drop as described in 6.5.4 if the necessary parameters are known. Alternatively, they may be based on the maximum secondary voltage allowed by standards or operating practices applicable to the installation.

The rated secondary voltage shall be shown on the SSVT nameplate.

6.2 Cooling classes of SSVTs

SSVTs shall use the ONAN or KNAN mode of cooling for liquid-immersed SSVTs and GNAN mode of cooling for gas-filled SSVTs.

6.3 Frequency

Unless otherwise specified, SSVTs shall be designed for operation at a frequency of 50 Hz or 60 Hz.

6.4 Rated power

Power ratings are for continuous duty and are based on not exceeding the limits of temperature rise. The temperature rise shall not exceed the temperature rise class or insulation class as given in 6.18.

Preferred power ratings for SSVTs are:

25 – 50 – 75 – 100 – 167 – 250 – 333 – 500 kVA

These ratings are based on the normal temperature and altitude environmental conditions specified in 5.1.

6.5 Voltage ratings and taps

6.5.1 General

Standard nominal system voltages and maximum system voltages are listed in Table 4.

6.5.2 Voltage ratings

The voltage ratings are at no load.

6.5.3 Ratings of SSVT taps

Whenever an SSVT is provided with taps from a winding for de-energized operation, they shall be full power taps.

6.5.4 Voltage drop or rise (voltage regulation) for a specified load condition

The voltage drop or rise (voltage regulation) for a specified load condition may need to be calculated to help ensure compliance with system standards or operating practices.

Examples of formulae for calculating regulation are shown in Formula (4) and Formula (5):

a) When the load is lagging:

$$U_{\text{reg}} = \sqrt{(R + F_p)^2 + (X + q)^2} - 1 \quad (4)$$

b) When the load is leading:

$$U_{\text{reg}} = \sqrt{(R + F_p)^2 + (X - q)^2} - 1 \quad (5)$$

where:

U_{reg} is the voltage drop or rise (voltage regulation)

F_p is power factor of load

$$q = \sqrt{1 - F_p^2}$$

R is resistance factor of SSVT, which is equal to the load loss in kilowatts divided by the rated power in kilovoltamperes

X is reactance factor of SSVT: $X = \sqrt{Z^2 - R^2}$

Z is impedance factor of SSVT, which is equal to the short circuit impedance in percentage multiplied by 100.

The quantities F_p , q , R , X , and Z are on a per-unit basis. Results shall be multiplied by 100 to obtain the percentage of regulation.

6.6 Connections

Standard connection arrangements shall be in accordance with IEEE Std C57.12.70™ or IEC 60076-1, however the arrangement may be varied by the manufacturer when design conditions so dictate. The connection arrangements for measuring are as specified in IEEE Std C57.13™ or IEC 61869-3.

6.7 Markings

6.7.1 Polarity of single-phase SSVTs

The polarity of SSVTs covered by this document shall be as follows: the voltage at terminals A or H1 shall be in phase with the voltage at terminal a or X1.

6.7.2 Terminal markings

Terminal markings shall be in accordance with IEEE Std C57.13 or IEC 61869-3.

6.7.3 Nameplates

A durable weatherproof nameplate designed to be legible for the life of the equipment shall be affixed to the outside of each SSVT by the manufacturer. Unless otherwise specified, it shall be made of corrosion-resistant material. It shall bear the rating and other essential operating data as specified in Table 3. This document recognizes the use of metric (SI) and imperial (U.S. customary) units for data appearing on SSVT nameplates. It should be noted that although this document recognizes the possibility of using SI units as an alternative to the U.S. customary units used in the past, it is not intended that both appear on the specific nameplate. However, units used shall be explicitly shown.

Table 3 – Nameplate information

1	Serial number ^a
2	Month/year of manufacture
3	Model / Style number
4	Cooling class (ONAN, GNAN, KNAN)
5	Frequency
6	Rated output power ^a
7	Rated primary and secondary voltages ^a
8	Voltage factor
9	Insulation levels (BIL, BSL)
10	Temperature rise class or insulation class
11	Polarity (Subtractive)
12	Highest voltage for equipment and rated voltage factor
13	Short-circuit impedance
14	Short-circuit voltage [%] (alias impedance voltage)
15	Arc-proof current and duration (if applicable)
16	Approximate total mass in kg or weight in lb
17	Winding and connection diagram (optional placement on separate nameplate)
18	Name and location (country) of manufacturer
19	The abbreviation SSVT
20	Type of insulating liquid (generic name preferred) ^b or gas type
21	Conductor material (of each winding)
22	Liquid volume or mass of gas
23	Measuring accuracy class (if applicable)
24	Rated burden of the measuring winding (if applicable)
25	Power winding load range for rated measuring winding accuracy
26	Rated filling pressure, minimal functional pressure and alarm pressure (if applicable)
27	Standard reference number including edition
^a The letters and numerals showing kVA, serial number, and voltage ratings shall have a minimum height of 4,00 mm (0,157 in) whether engraved or stamped. The height of other letters and numerals shall be optional with the manufacturer. ^b For liquid filled units, the nameplate shall state: "Contains no detectable level of PCB at the time of manufacture".	