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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Insulation co-ordination –
Part 11: Definitions, principles and rules for HVDC system

Coordination de l'isolement –
Partie 11: Définitions, principes et règles relatifs au réseau CCHT

IEC 60071-11:2022-11(en-fr)

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INSULATION CO-ORDINATION –

Part 11: Definitions, principles and rules for HVDC system

FOREWORD

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IEC 60071-11 has been prepared by IEC technical committee 99: Insulation co-ordination and system engineering of high voltage electrical power installations above 1,0 kV AC and 1,5 kV DC. It is an International Standard.

This international standard replaces, in conjunction with IEC 60071-12, IEC 60071-5 published in 2014.

This edition includes the following significant technical changes with respect to IEC 60071-5:2014:

a) This standard applies to both LCC and VSC HVDC systems whereas IEC 60071-5 only dealt with LCC HVDC system;
b) Annex C (normative) gives the recommended specified withstand voltage (LI and SI);
c) Annex C (normative) gives the minimum air clearances;
d) Annex E shows the correlation of clauses between this standard and IEC 60071-5:2014.

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

Draft	Report on voting
99/374/FDIS	99/394/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/standardsdev/publications.

A list of all parts in the IEC 60071 series, published under the general title *Insulation co-ordination*, can be found on the IEC website.

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- withdrawn,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.

INTRODUCTION

As the demand for electrical energy is growing, more and more HVDC projects have appeared, and the voltage up to ±1 100 kV so far. However, the nominal voltage, nominal current and insulation levels for HVDC system are not yet as standardized as the AC system.

In October 2016, IEC Technical Committee 28 (Insulation co-ordination) established AHG 8 (Ad hoc group 8) to make the roadmap for HVDC system insulation co-ordination standards.

After IEC TC 28 was merged into IEC TC 99 in 2017, JWG 13 (Joint working group 13) was built by IEC TC 99 and TC 115 and was responsible for making the series standards for HVDC system according to the approved roadmap, as follows:

a) Part 11: Definitions, principles and rules for HVDC system;
b) Part 12: Application guidelines for LCC HVDC converter stations;
c) Part 13: Application guidelines for VSC HVDC converter stations;
d) Part 14: Insulation co-ordination for AC/DC filters;
e) Part 15: Insulation co-ordination for DC transmission lines.

INSULATION CO-ORDINATION –

Part 11: Definitions, principles and rules for HVDC system

1 Scope

This part of IEC 60071 applies to high-voltage direct current (HVDC) systems. It specifies the principles on the procedures for the determination of the specified withstand voltages, creepage distance and air clearances for the equipment and the installations of these systems.

This document gives the insulation co-ordination principles related to line commutated converter (LCC) and voltage sourced converters (VSC) HVDC systems. The main principles of this document also apply to other special converter configurations of LCC, such as the capacitor commutated converter (CCC) as well as the controlled series compensated converter (CSCC), etc.

This document applies to insulation co-ordination of equipment connected between the converter AC bus (including the AC harmonic filters, the converter transformer, the circuit breakers) and the DC line side. The line and cable terminations in so far as they influence the insulation co-ordination of converter station equipment are also covered.

This document applies only for HVDC applications in power systems and not for industrial conversion equipment. Principles and guidance given are for insulation co-ordination purposes only. The requirements for human safety are not covered by this document.

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

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

IEC 60099-4:2014, *Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems*

IEC TS 60815-1:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

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*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC 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

NOTE Many of the following definitions refer to insulation co-ordination concepts (IEC 60071-1), or to arrester parameters (IEC 60099-4).

3.1
insulation co-ordination
selection of the dielectric strength of equipment in relation to the operating voltages and overvoltages which can appear on the system for which the equipment is intended and taking into account the service environment and the characteristics of the available preventing and protective devices

[SOURCE: IEC 60071-1:2019, 3.1, modified – The note to entry has been removed.]

3.2
nominal DC voltage
mean value of the DC voltage required to transmit nominal power at nominal current

3.3
highest DC voltage
highest value of DC voltage for which the equipment and system is designed to operate continuously, in respect of its insulation as well as other characteristics

3.4
symmetrical monopole
HVDC converter with symmetrical DC voltage outputs on the two pole terminals

Note 1 to entry: A symmetrical monopole is generally applicable only to the VSC HVDC systems.

Note 2 to entry: "Symmetrical monopole" is used even though there are two polarities with DC voltages, because only one converter is unable to provide the redundancy which is generally provided by "bipole".

Note 3 to entry: In the symmetrical monopole operation, persistent overvoltage appears at the sound (healthy) pole when a fault occurs at the opposite pole.

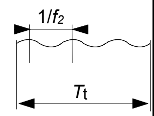
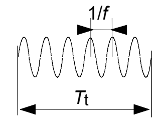
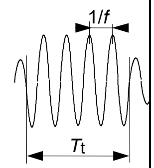
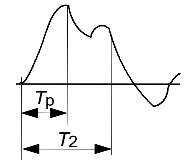
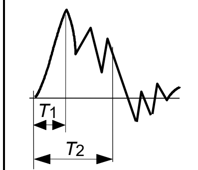
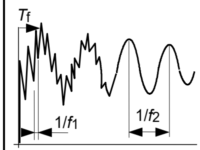
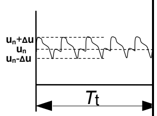
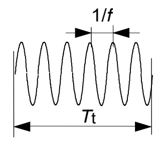
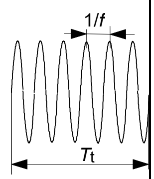
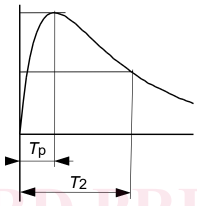
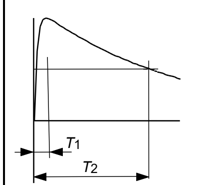
3.5
asymmetrical monopole
for the HVDC converter with asymmetrical DC voltage outputs on the two terminals, one terminal is generally earthed

3.6
bipole
in general, two asymmetrical monopoles form a bipolar DC circuit

3.7
overvoltage
voltage having a value exceeding the corresponding highest steady state voltage of the system

Note 1 to entry: Table 1 presents (as per IEC 60071-1) the classification of these voltages which are defined in 3.7.1 to 3.7.2.3.

Table 1 – Classes and shapes of overvoltages, standard voltage shapes and standard withstand voltage tests

Class	Low frequency			Transient		
	Continuous		Temporary	Slow-front	Fast-front	Very-fast-front
Voltage or over-voltage shapes						
Range of voltage or over-voltage shapes	T_t ≥ 3 600s 1/T_t = f_1= 0 Hz f_2 < 2 500 Hz	f = 50 Hz or 60 Hz T_t ≥ 3 600s	10 Hz < f < 500 Hz 0,02 s ≤ T_t ≤ 3 600 s	20 µs < T_p ≤ 5 000 µs T_2 ≤ 20 ms	0,1 µs < T_1 ≤ 20 µs T_2 ≤ 300 µs	T_f ≤ 100 ns 0,3 MHz < f_1 < 100 MHz 30 kHz < f_2 < 300 kHz
Standard voltage shapes	 $\frac{\Delta U}{U_n} \leq 3\%$ [b] T_t [a]	 f = 50 Hz or 60 Hz T_t [a]	 48 Hz ≤ f ≤ 62 Hz T_t = 60 s	 T_p = 250 µs T_2 = 2 500 µs	 T_1 = 1,2 µs T_2 = 50 µs	[a]
Standard withstand voltage test	DC voltage test [a]	[a]	Short-duration power frequency test	Switching impulse test	Lightning impulse test	[a]

[a] To be specified by the relevant apparatus committees.

[b] Unless otherwise specified by the relevant Technical Committees, standard voltage shapes should be in accordance with IEC 60060-1.

3.7.1
temporary overvoltage

overvoltages of relatively long duration (ranging from 0,02 to 3 600 s as per IEC 60071-1)

Note 1 to entry: The overvoltage can be undamped or weakly damped.

3.7.2
transient overvoltage

short-duration overvoltage of a few millisecond or less, oscillatory or non-oscillatory, usually highly damped

[SOURCE: IEC 60071-1: 2019, 3.17.2, modified – The note to entry has been removed.]

3.7.2.1
slow-front overvoltage

transient overvoltage, usually unidirectional, with time to peak 20 µs < T_p ≤ 5 000 µs, and tail duration T_2 ≤ 20 ms

Note 1 to entry: For the purpose of insulation co-ordination, slow-front overvoltages are classified according to their shape, regardless of their origin. Although considerable deviations from the standard shapes occur on actual systems, in this standard it is considered sufficient in most cases to describe such overvoltages by their classification and peak value.

3.7.2.2
fast-front overvoltage
overvoltage at a given location on a system, due to a lightning discharge or other cause, the shape of which can be regarded, for insulation co-ordination purposes, as similar to that of the standard impulse (IEC 60060-1) used for lightning impulse tests

Note 1 to entry: Fast-front overvoltage is defined as transient overvoltage, usually unidirectional, with time to peak 0,1 μs < T_1 ≤ 20 μs, and tail duration T_2 ≤ 300 μs in IEC 60071-1:2019, 3.17.2.2.

Note 2 to entry: For the purpose of insulation co-ordination, fast-front overvoltages are classified according to their shape, regardless of their origin. Although considerable deviations from the standard shapes occur on actual systems, in this standard it is considered sufficient in most cases to describe such overvoltages by their classification and peak value.

3.7.2.3
very-fast-front overvoltage
transient overvoltage, usually unidirectional, with time to peak T_f < 0,1 μs, and with or without superimposed oscillations at frequency 30 kHz < f < 100 MHz

[SOURCE: IEC 60071-1:2019, 3.17.2.3, modified – The abbreviated term VFFO has been removed.]

3.7.2.4
steep-front overvoltage
transient overvoltage classified as a kind of fast-front overvoltage with time to peak 3 ns < T_1 < 1,2 μs

Note 1 to entry: A steep-front impulse voltage for test purposes is defined in IEC 60700-1.

Note 2 to entry: The front time is decided by means of system studies.

3.7.2.5
combined overvoltage
overvoltage consisting of two voltage components simultaneously applied between each of the two-phase terminals of a phase-to-phase (or longitudinal) insulation and earth

Note 1 to entry: Combined overvoltage can include temporary, slow-front, fast-front or very-fast front overvoltages.

Note 2 to entry: It is classified by the component of higher peak value.

3.8
representative overvoltage
U_{rp}
overvoltage assumed to produce the same dielectric effect on the insulation as overvoltage of a given class occurring in service due to various origins

Note 1 to entry: In this document, it is generally assumed that the representative overvoltages are characterized by their assumed or obtained maximum values.

[SOURCE: IEC 60071-1:2019, 3.19, modified – The notes to entry have been removed and replaced by a new Note 1.]

3.8.1
representative slow-front overvoltage
RSFO
voltage value between terminals of an equipment having the shape of a standard switching impulse

3.8.2
representative fast-front overvoltage
RFFO
voltage value between terminals of an equipment having the shape of a standard lightning impulse

3.8.3
representative steep-front overvoltage
RSTO
voltage value with a standard shape having a time to crest less than that of a standard lightning impulse, but not less than that of a very-fast-front overvoltage as defined by IEC 60071-1

Note 1 to entry: A steep-front impulse voltage for test purposes is defined in Figure 1 of IEC 60700-1:2015. The front time is decided by means of system studies.

3.9
co-ordination withstand voltage
U_{cw}
for each class of voltage, value of the withstand voltage of the insulation configuration, in actual service conditions, that meets the performance criterion

[SOURCE: IEC 60071-1:2019, 3.25]

3.10
required withstand voltage
U_{rw}
test voltage that the insulation must withstand in a standard withstand voltage test to ensure that the insulation will meet the performance criterion when subjected to a given class of overvoltages in actual service conditions and for the whole service duration

Note 1 to entry: The required withstand voltage has the shape of the co-ordination withstand voltage, and is specified with reference to all the conditions of the standard withstand voltage test selected to verify it

[SOURCE: IEC 60071-1:2019, 3.28]

3.11
specified withstand voltage
U_w
test voltage suitably selected equal to or above the required withstand voltage (U_{rw})

Note 1 to entry: For AC equipment, values of withstand voltages U_w are standardized as per IEC 60071-1. For HVDC equipment, the specified withstand voltages are rounded up to convenient practical values.

Note 2 to entry: The standard impulse shapes used for withstand tests on equipment as well as the test procedures are defined in IEC 60060-1 and IEC 60071-1. For some DC equipment (e.g. the thyristor valves), the standard impulse shapes may be modified in order to more realistically reflect expected conditions.

3.11.1
switching impulse withstand voltage
SIWV
withstand voltage of insulation with the shape of the standard switching impulse

3.11.2
lightning impulse withstand voltage
LIWV
withstand voltage of insulation with the shape of the standard lightning impulse

3.11.3
steep-front impulse withstand voltage
STIWV
withstand voltage of insulation with the shape parameters in 3.7.2.4

3.12
continuous operating voltage of an arrester
U_c
permissible r.m.s. value of power frequency voltage that may be applied continuously between the terminals of the arrester

[SOURCE: IEC 60099-4:2014, 3.10, modified – The words “designated” at the beginning of the definition and “in accordance with 8.7” at the end have been removed.]

3.13
equivalent continuous operating voltage of an arrester
ECOV
r.m.s. value of the sinusoidal power frequency voltage at a metal-oxide surge arrester stressed by operating voltage of any wave-shape that generates the same power losses in the metal oxide materials as the actual operating voltage

3.14
residual voltage of an arrester
U_{res}
peak value of voltage that appears between the terminals of an arrester during the passage of a discharge current

[SOURCE: IEC 60099-4:2014, 3.58, modified – The note to entry has been removed.]

3.15
co-ordination currents of an arrester
for a given system under study and for each class of overvoltage, the current through the arrester for which the representative overvoltage is determined

Note 1 to entry: Standard shapes of co-ordination currents for steep-front, lightning and switching current impulses are given in IEC 60099-4.

Note 2 to entry: The co-ordination currents are determined by system studies.

3.16
protective levels of an arrester
for each voltage class, residual voltage that appears between the terminals of an arrester during the passage of a discharge current corresponding to the co-ordination current

Note 1 to entry: For HVDC converter equipment, the following specific definitions 3.16.1 to 3.16.3 apply.

3.16.1
switching impulse protective level
SIPL
residual voltage of a surge arrester subjected to a discharge current corresponding to the co-ordination switching impulse current

3.16.2
lightning impulse protective level
LIPL
residual voltage of a surge arrester subjected to a discharge current corresponding to the co-ordination lightning impulse current

3.16.3
steep-front impulse protective level
STIPL
residual voltage of a surge arrester subjected to a discharge current corresponding to the co-ordination steep-front impulse current

3.17
directly protected equipment
equipment connected in parallel to a surge arrester for which the separation distance can be neglected and any representative overvoltage be considered equal to the corresponding protective level

3.18
creepage distance
shortest distance, or the sum of the shortest distances, along the insulating parts of the insulator between those parts which normally have the operating voltage between them

Note 1 to entry: The surface of cement or of any other non-insulating jointing material is not considered as forming part of the creepage distance.

Note 2 to entry: If a high resistance coating, e.g. semi-conductive glaze, is applied to parts of the insulating part of an insulator, such parts are considered to be effective insulating surfaces and the distance over them is included in the creepage distance.

[SOURCE: IEC TS 60815-1: 2008, 3.1.5]

3.19
unified specific creepage distance
USCD
creepage distance of an insulator divided by the maximum operating voltage across the insulator. It is generally expressed in mm/kV

[SOURCE: IEC TS 60815-4:2016, 3.1.1, modified – The note to entry has been removed.]

3.20
separation distance
distance between the high voltage terminal of the protected equipment and the connection point of the arrester high voltage conductor

3.21
performance criterion
basis on which the insulation is selected so as to reduce to an economically and operationally acceptable level the probability that the resulting voltage stresses imposed on the equipment will cause damage to equipment insulation or affect continuity of service

Note 1 to entry: The performance criterion is usually expressed in terms of an acceptable failure rate (number of failures per year, years between failures, risk of failure, etc.) of the insulation configuration.

[SOURCE: IEC 60071-1:2019, 3.23]

4 Symbols and abbreviations

4.1 General

The list provided in 4.2 below covers only the most frequently used symbols and abbreviations, some of which are illustrated graphically in the single-line diagram of Figure A.1 and Table A.1. For a more complete list of symbols which has been adopted for HVDC converter stations, and also for insulation co-ordination, refer to the standards listed in the normative references (Clause 2) and to the Bibliography.