IEC 60071-5

Edition 1.0 2014-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Insulation co-ordination –
Part 5: Procedures for high-voltage direct current (HVDC) converter stations

Coordination de l'isolement –
Partie 5: Procédures pour les stations de conversion à courant continu haute tension (CCHT)

IEC 60071-5:2014-10(en-fr)

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INSULATION CO-ORDINATION –

Part 5: Procedures for high-voltage direct current (HVDC) converter stations

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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International Standard IEC 60071-5 has been prepared by IEC technical committee 28: Insulation co-ordination.

This International Standard cancels and replaces IEC TS 60071-5 published in 2002. On the basis of technical experience gained since the Technical Specification was published, sufficient consensus has emerged for transformation of the Technical Specification into an International Standard.

The technical content is essentially the same as that contained in the Technical Specification with amendments mainly for user convenience. The structure of the document has been changed to allow division and subdivision into complete integral parts to facilitate comprehension and ease of referencing.

In addition to the high level revisions above, the following main technical changes have been made with respect to the previous edition:

– arresters have been added to several locations to reflect some recent 800 kV HVDC scheme practice, along with their justifications, expected voltages, overvoltages and arrester stresses in service;
– significant changes have been made in Clause 8 – all subclauses on the characteristics, schemes, stresses and specification of arresters have been consolidated into a single entity, Clause 8;
– the implications of a smoothing reactor and of a neutral blocking filter located on the neutral bus (as on some recent 800 kV schemes), on coordination of arresters connected to the neutral end have been added;
– possible use of sacrificial arresters on the neutral bus is introduced to cater for excessive arrester energy in the rather unlikely event of a particular rare fault;
– all subclauses dealing with study tools and modelling details have been consolidated into Clause 10;
– creepage distances and clearances have been consolidated into Clauses 11 and 12, respectively, with more details added.

The text of this standard is based on the following documents:

FDIS	Report on voting
28/218/FDIS	28/221/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 600071 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 publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

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INTRODUCTION

The IEC 60071 series consists of the following parts under the general title *Insulation co-ordination:*

Part 1: Definitions, principles and rules

Part 2: Application guide

Part 4: Computational guide to insulation co-ordination and modelling of electrical networks

Part 5: Procedures for high-voltage direct current (HVDC) converter stations

INSULATION CO-ORDINATION –

Part 5: Procedures for high-voltage direct current (HVDC) converter stations

1 General

1.1 Scope

This part of IEC 60071 provides guidance on the procedures for insulation co-ordination of high-voltage direct current (HVDC) converter stations, without prescribing standardized insulation levels.

This standard applies only for HVDC applications in high-voltage a.c. 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 standard.

1.2 Additional background

The use of power electronic thyristor valves in a series and/or parallel arrangement, along with the unique control and protection strategies employed in the conversion process, has ramifications requiring particular consideration of overvoltage protection of equipment in converter stations compared with substations in a.c. systems. This standard outlines the procedures for evaluating the overvoltage stresses on the converter station equipment subjected to combined d.c., a.c. power frequency, harmonic and impulse voltages. The criteria for determining the protective levels of series and/or parallel combinations of surge arresters used to ensure optimal protection are also presented.

The basic principles and design objectives of insulation co-ordination of converter stations, in so far as they differ from normal a.c. system practice, are described.

Concerning surge arrester protection, this standard deals only with metal-oxide surge arresters, without gaps, which are used in modern HVDC converter stations. The basic arrester characteristics, requirements for these arresters and the process of evaluating the maximum overvoltages to which they may be exposed in service, are presented. Typical arrester protection schemes and stresses of arresters are presented, along with methods to be applied for determining these stresses.

This standard includes insulation co-ordination of equipment connected between the converter a.c. bus (including the a.c. harmonic filters, the converter transformer, the circuit breakers) and the d.c. line side of the smoothing reactor. The line and cable terminations in so far as they influence the insulation co-ordination of converter station equipment are also covered.

Although the main focus of the standard is on conventional HVDC systems where the commutation voltage bus is at the a.c. filter bus, outlines of insulation co-ordination for the capacitor commutated converter (CCC) as well as the controlled series compensated converter (CSCC) and some other special converter configurations are covered in the annexes.

This standard discusses insulation co-ordination related to line commutated converter (LCC) stations. The insulation coordination of voltage sourced converters (VSC) is not part of this standard.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 60071-1:2006, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guide*

IEC 60099-4:2004, *Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems*

IEC 60633, *Terminology for high-voltage direct current (HVDC) transmission*

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.

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: 2006, 3.1]

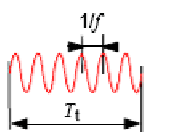
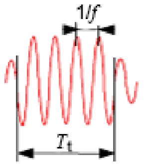
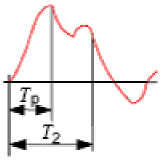
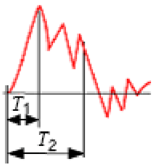
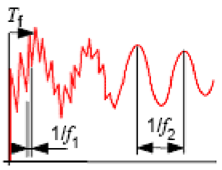
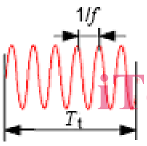
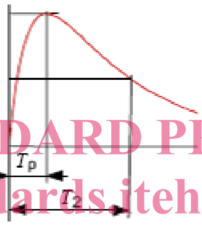
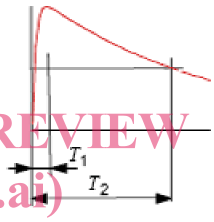
3.2
nominal d.c. voltage
mean value of the direct voltage required to transmit nominal power at nominal current

3.3
highest d.c. voltage
highest value of d.c. voltage for which the equipment is designed to operate continuously, in respect of its insulation as well as other characteristics

3.4
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 3.4.1 to 3.4.2.3.

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	f = 50 Hz or 60 Hz $T_t \geq$3 600s	10 Hz < f < 500 Hz 0,02 s $\leq T_t \leq$ 3 600 s	20 µs < $T_p \leq$ 5 000 µs $T_2 \leq$ 20 ms	0,1 µs < $T_1 \leq$ 20 µs $T_2 \leq$ 300 µs	$T_f \leq$ 100 ns 0,3 MHz < f_1 < 100 MHz 30 kHz < f_2 < 300 kHz
Standard voltage shapes	 f = 50 Hz or 60 Hz T_t [a]	 48 Hz $\leq f \leq$ 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	[a]	Short-duration power frequency test	Switching impulse test	Lightning impulse test	[a]

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

3.4.1
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 may be undamped or weakly damped.

3.4.2
transient overvoltage
short-duration overvoltage of a few millisecond or less, oscillatory or non-oscillatory, usually highly damped

[SOURCE: IEC 60071-1: 2006, 3.17.3]

3.4.2.1
slow-front overvoltage
transient overvoltage, usually unidirectional, with time to peak 20 µs < $T_p \leq$ 5 000 µs, and tail duration $T_2 \leq$ 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.

[SOURCE: IEC 60071-1:2006, 3.17.3.1]

3.4.2.2
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 60071-1:2006, 3.17.3.2.

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.

3.4.2.3
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 60071-1:2006, 3.17.3.3]

3.4.2.4
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.

3.4.2.5
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.

3.5
representative overvoltages
U_{rp}
overvoltages assumed to produce the same dielectric effect on the insulation as overvoltages of a given class occurring in service due to various origins

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

[SOURCE: IEC 60071-1:2006, 3.19]

3.5.1
representative slow-front overvoltage
RSFO
voltage value between terminals of an equipment having the shape of a standard switching impulse

Note 1 to entry: This note applies to the French language only.

3.5.2
representative fast-front overvoltage
RFFO
voltage value between terminals of an equipment having the shape of a standard lightning impulse

Note 1 to entry: This note applies to the French language only.

3.5.3
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 60700-1:2008. The front time is decided by means of system studies.

Note 2 to entry: This note applies to the French language only.

3.6
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 (IEC 60071-1)

3.7
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. 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 60071-1:2006, 3.27]

3.8
withstand voltage
U_w
test voltage suitably selected equal to or above the required withstand voltage (U_{rw})

Note 1 to entry: For a.c. equipment, values of withstand voltages U_w are standardized as per IEC 60071-1. For HVDC equipment, there are no standardized values for the withstand voltages which 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 d.c. equipment (e.g. the thyristor valves), the standard impulse shapes may be modified in order to more realistically reflect expected conditions.

3.8.1
switching impulse withstand voltage
SIWV
withstand voltage of insulation with the shape of the standard switching impulse

Note 1 to entry: This note applies to the French language only.

3.8.2
lightning impulse withstand voltage
LIWV
withstand voltage of insulation with the shape of the standard lightning impulse

Note 1 to entry: This note applies to the French language only.