TECHNICAL SPECIFICATION

IEC TS 60071-5

First edition
2002-06

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 CCHT

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International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

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INSULATION CO-ORDINATION –

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FOREWORD

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 60071-5, which is a technical specification, has been prepared by IEC technical committee 28: Insulation co-ordination.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
28/139/CDV	28/144A/RVC

Full information on the voting for the approval of this technical specification 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 3.

This technical specification is published in English only.

Annexes A, B and C are for information only.

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

- transformed into an International standard
- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

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.

The guide 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 application guide.

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 guide 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 is 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 guide 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 guide 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 guide 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.

2 Normative references

The following referenced documents are indispensable for the application 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 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1:1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*

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

IEC 60099-4:1991, *Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems*

IEC 60633:1998, *Terminology for high-voltage direct current (HVDC) transmission*

IEC 60700-1:1998,*Thyristor valves for high-voltage direct current (HVDC) power transmission – Part 1: Electrical testing*

IEC 60815:1986, *Guide for the selection of insulators in respect of polluted conditions*

3 Definitions

For the purposes of this part of IEC 60071, the following terms and definitions apply.

Many of the following definitions refer to actual insulation co-ordination concepts, or to actual arrester parameters. For more information on these, please refer to IEC 60071-1 or to IEC 60099-4, respectively.

3.1
d.c. system voltage
highest mean or average operating voltage to earth, excluding harmonics and commutation overshoots (IEC 123 pollution test of HVDC insulator)

3.2
peak value of continuous operating voltage (PCOV)
highest continuously occurring crest value of the voltage at the equipment on the d.c. side of the converter station including commutation overshoots and commutation notches (see figure 6)

3.3
crest value of continuous operating voltage (CCOV)
highest continuously occurring crest value of the voltage at the equipment on the d.c. side of the converter station excluding commutation overshoots (see figure 6)

3.4
overvoltage
voltage between one phase conductor and earth or between phase conductors having a peak value exceeding the corresponding peak of the highest voltage of the system on the a.c. side and the PCOV on the d.c. side of the HVDC converter station

3.4.1
temporary overvoltage (TOV)
power frequency overvoltage of relatively long duration (IEC 60071-1)

NOTE The overvoltage may be undamped or weakly damped. In some cases its frequency may be several times smaller or higher than power frequency.

3.4.2
slow-front overvoltage
transient overvoltage, usually unidirectional, with time to peak 20 µs < Tp < 5 000 µs, and tail duration T2 < 50 ms (IEC 60071-1)

NOTE 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.

3.4.3
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.

Transient overvoltage, usually unidirectional, with time to peak 0,1 µs < T1 < 20 µs, and tail duration T2 < 300 µs (IEC 60071-1).

NOTE For the purpose of insulation co-ordination, slow-front and 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.

3.4.4
very fast-front overvoltage
transient overvoltage, usually unidirectional, with time to peak T_f < 0,1 µs, total duration < 3 ms, and with superimposed oscillations at frequency 30 kHz < f < 100 MHz (IEC 60071-1)

3.4.5
steep-front overvoltage
transient overvoltage classified as a kind of fast-front overvoltage with time to peak 3 ns < T1 < 1,2 µs). A steep-front impulse voltage for test purposes is defined in figure 1 of IEC 60700-1

NOTE The front time is decided by means of system studies.

3.4.6
combined overvoltage (temporary, slow-front, fast-front, very fast-front)
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. It is classified by the component of higher peak value

3.5
representative overvoltages
overvoltages assumed to produce the same dielectric effect on the insulation as overvoltages of a given class occurring in service due to various origins (IEC 60071-1)

NOTE In this specification it is generally assumed that the representative overvoltages are characterized by their assumed or obtained maximum values.

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

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

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 A steep-front impulse voltage for test purposes is defined in figure 1 of IEC 60700-1. The front time is decided by means of system studies.

3.6
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 in accordance with IEC 60099-4.

3.7
continuous operating voltage of an arrester including harmonics (U_{ch})
r.m.s. value of the combination of power frequency voltage and harmonics that may be applied continuously between the terminals of the arrester

3.8
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

3.9
residual voltage of an arrester
peak value of voltage that appears between the terminals of an arrester during the passage of a discharge current (IEC 60099-4)

3.10
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. Standard shapes of co-ordination currents for steep-front, lightning and switching current impulses are given in IEC 60099-4

NOTE The co-ordination currents are determined by system studies.

3.11
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

3.12
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

For HVDC converter equipment the following specific definitions 3.12.1 to 3.12.3 apply.

3.12.1
switching impulse protective level (SIPL)
residual voltage of a surge arrester subjected to a discharge current corresponding to the co-ordination switching impulse current

3.12.2
lightning impulse protective level (LIPL)
residual voltage of a surge arrester subjected to a discharge current corresponding to the co-ordination lightning impulse current

3.12.3
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

3.13
co-ordination withstand voltage
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)

3.14
required withstand voltage
test voltage that the insulation withstands in a standard withstand test to ensure that the insulation will meet the co-ordination withstand voltage in actual service

(IEC 60071-1 modified)

3.15
specified withstand voltage
test voltage suitably selected equal or above the required withstand voltage (see 3.14)

NOTE 1 For a.c. equipment, values of specified withstand voltages are standardized as per IEC 60071-1. For HVDC equipment, there is no standardized values for the specified withstand voltages which are rounded up to convenient practical values.

NOTE 2 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.

3.15.1
specified switching impulse withstand voltage (SSIWV)
withstand voltage of insulation with the shape of the standard switching impulse

3.15.2
specified lightning impulse withstand voltage (SLIWV)
withstand voltage of insulation with the shape of the standard lightning impulse

3.15.3
specified steep-front impulse withstand voltage (SSFIWV)
withstand voltage of insulation with the shape specified in IEC 60700-1

3.16
thyristor valve protective firing (PF)
method of protecting the thyristors from excessive voltage in the forward direction by firing them at a pre-determined voltage

4 Symbols and abbreviations

The list covers only the most frequently used symbols and abbreviations some of which are illustrated graphically in the single-line diagram of figure 1 and table 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 and to the bibliography.

4.1 Subscripts

0 (zero)	at no load (IEC 60633)
d	direct current or voltage (IEC 60633)
i	ideal (IEC 60633)
max	maximum (IEC 60633)
n	pertaining to harmonic component of order n (IEC 60633)

4.2 Letter symbols

K_a	atmospheric correction factor (IEC 60071-1)
K_c	co-ordination factor (IEC 60071-1)
K_s	safety factor (IEC 60071-1)
U_{ch}	continuous operating voltage of an arrester including harmonics
U_{dio}	ideal no-load direct voltage (IEC 60633)
U_{dim}	maximum value of U_{dio} taking into account a.c. voltage measuring tolerances, and transformer tap-changer offset by one step
U_s	highest voltage of an a.c. system (IEC 60071-1 and 60071-2)
U_{v0}	no-load phase-to-phase voltage on the valve side of converter transformer, r.m.s. value excluding harmonics
α	delay angle (IEC 60633); “firing angle” also used in this standard
β	advance angle (IEC 60633)
γ	extinction angle (IEC 60633)
μ	overlap angle (IEC 60633)

4.3 Abbreviations

CCC	capacitor commutated converter
CSCC	controlled series compensated converter
CCOV	crest value of continuous operating voltage
ECOV	equivalent continuous operating voltage
LIPL	lightning impulse protective level
PCOV	peak continuous operating voltage
PF	protective firing
RFAO	representative fast-front overvoltage (the maximum voltage stress value)
RSLO	representative slow-front overvoltage (the maximum voltage stress value)
RSTO	representative steep-front overvoltage (the maximum voltage stress value)
RLIWV	required lightning impulse withstand voltage
RSIWV	required switching impulse withstand voltage
RSFIWV	required steep-front impulse withstand voltage
SIPL	switching impulse protective level