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Insulation co-ordination - Part 12: Application guidelines for LCC HVDC converter stations

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TITLE:

Insulation co-ordination - Part 12: Application guidelines for LCC HVDC converter stations

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INSULATION CO-ORDINATION

Part 12: Application guidelines for LCC HVDC converter stations

FOREWORD

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IEC 60071-12 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 and IEC 60071-11 'Definitions, principles and rules for HVDC system' jointly replace IEC 60071-5 published in 2014.

The sections arrangement of this standard and corresponding section of IEC 60071-5: 2014 are as follows,

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Annex A (informative) Example of insulation co-ordination for LCC HVDC converter stations	Annex A (informative) Example of insulation co-ordination for conventional HVDC converters

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

FDIS	Report on voting
xx/xx/FDIS	xx/xx/RVD

Full information on the voting for the approval of this International Standard 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 http://www.iec.ch/standardsdev/publications.

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- withdrawn,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.

INSULATION CO-ORDINATION

Part 12: Application guidelines for LCC HVDC converter stations

1 General

1.1 Scope

This standard applies guidelines on the procedures for insulation co-ordination of line commutated converter (LCC) stations for high-voltage direct current (HVDC) project, whose aim is to give guidance for the determination of the specified withstand voltages for equipment.

The content of this document strictly follows the flow chart of the insulation co-ordination process and give detailed information on the concepts governing the insulation co-ordination process which leads to the establishment of the specified withstand voltage levels.

This document emphasizes the necessity of considering, at the very beginning, all origins, all classes and all types of voltage stresses in service. At the end of the process, when the selection of the specified withstand voltages takes place, does the principle of covering a particular service voltage stress by a specified withstand voltage apply.

The annex contains examples of insulation co-ordination for LCC HVDC converters which support the concepts described in the main text, and the basic analytical techniques used.

1.2 Additional background

The use of power semi-conductor device 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.

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

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 guide*

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

IEC 60099-9:2014, *Surge arresters – Part 9: Metal-oxide surge arresters without gaps for HVDC converter stations*

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, definitions, symbols and abbreviations

3.1 Terms and definition

For the purposes of this document, the terms and definitions given in IEC 60071-11 and the following 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

3.1.1
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

3.1.2
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

3.1.3
thyristor valve protective firing

method of protecting the individual thyristors from excessive forward voltage stresses across individual thyristors, by firing them

3.2 Symbols and abbreviation

3.2.1 General

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 Figure 2. For a more complete list of symbols which has been adopted for LCC HVDC converter stations, and also for insulation co- ordination, refer to the standards listed in the normative references (Clause 2) and to the Bibliography.

3.2.2 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)

3.2.3 Letter symbols

K_a	altitude correction factor (IEC 60071-1)
K_c	co-ordination factor (IEC 60071-1)
K_s	safety factor (IEC 60071-1)
U_c	continuous operating voltage of an arrester
U_{ch}	continuous operating voltage of an arrester including harmonics
U_{di0}	ideal no-load direct voltage (IEC 60633)
U_{di0m}	maximum value of U_{di0} 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_m	highest voltage for the equipment
U_{v0}	no-load phase-to-phase voltage on the valve side of converter transformer, r.m.s. value excluding harmonics
U_{rp}	representative overvoltage
U_{cw}	co-ordination withstand voltage
U_{rw}	required withstand voltage
U_w	specified withstand voltage (standard withstand voltage in a.c.)
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)

3.2.4 Abbreviations

LCC	line commutated converter
VSC	voltage sourced converter
CCOV	crest value of continuous operating voltage
GIS	gas-insulated switchgear
PCOV	peak continuous operating voltage

ECOV	equivalent continuous operating voltage
RSFO	representative slow-front overvoltage (the maximum voltage stress value)
RFFO	representative fast-front overvoltage (the maximum voltage stress value)
RSTO	representative steep-front overvoltage (the maximum voltage stress value)
RSIWV	required switching impulse withstand voltage
RLIWV	required lightning impulse withstand voltage
RSTIWV	required steep-front impulse withstand voltage
SIPL	switching impulse protective level
LIPL	lightning impulse protective level
STIPL	steep-front impulse protective level
SIWV	switching impulse withstand voltage
LIWV	lightning impulse withstand voltage
STIWV	steep-front impulse withstand voltage
AC (a.c.)	alternating current
DC (d.c.)	direct current
p.u.	per unit

4 Typical LCC HVDC converter station schemes

Figure 1 shows the single line diagram of typical LCC HVDC converter stations equipped with two 12-pulse converters in series. It may be noted that Figure 1 shows possible arrester locations covered in this standard. Some of these arresters may be redundant and could be excluded depending on the specific design.

Figure 2 shows an example for a single line diagram and arrester arrangement of a back-to back converter station. Other arrangements with different earthing connections are also common, e.g., earthing at the mid-point between the two six-pulse bridges. The location of the smoothing reactor, if applicable, may change accordingly.

The a.c. and d.c. filter configurations could be more complex than those shown in these figures.

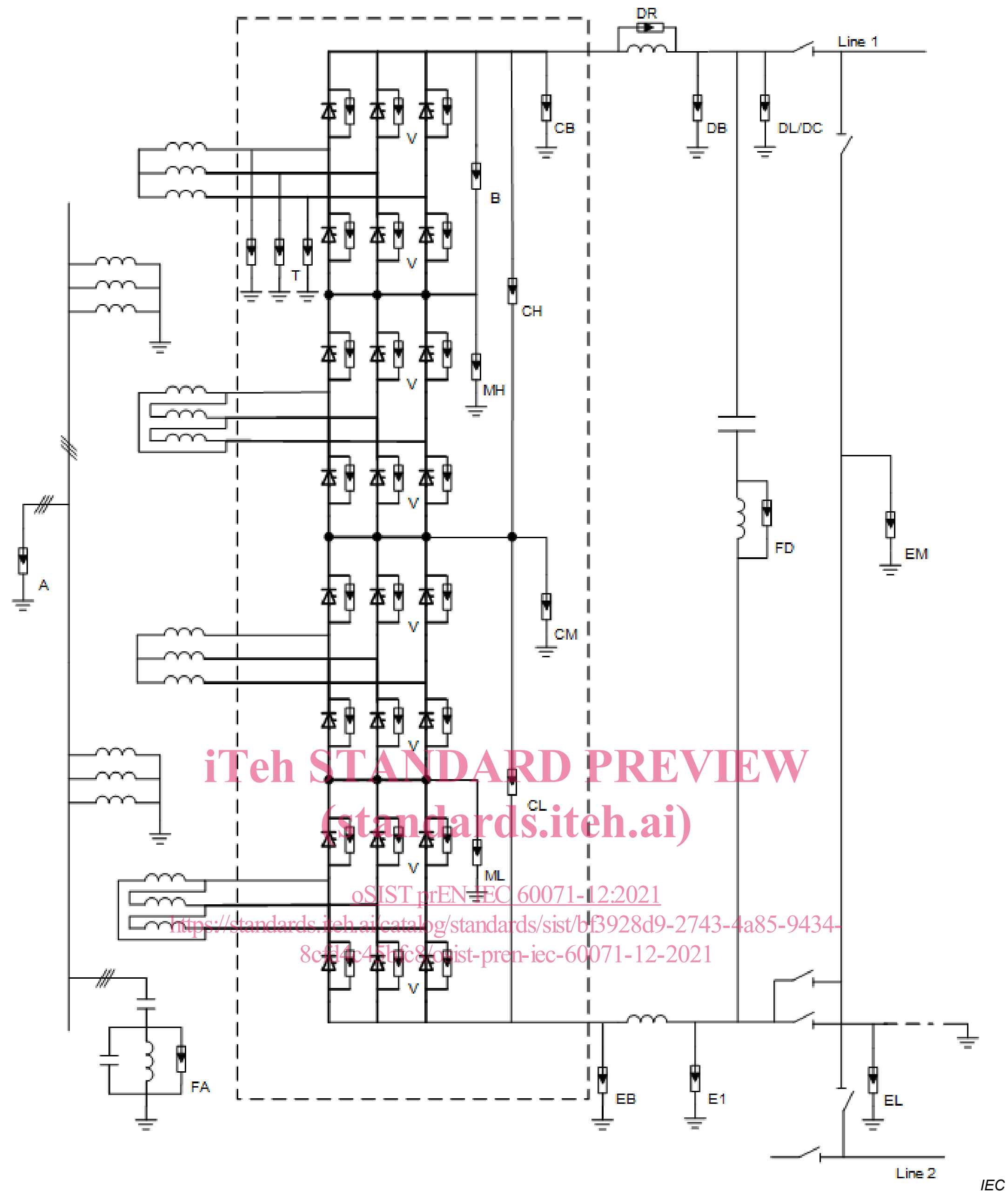
Table 1 presents the graphical symbols used in this standard.

The thyristor valves being voltage sensitive require strict overvoltage protection, which is provided by valve arresters that are connected directly across the valve terminals.

The valve arresters in combination with other arresters typically provide protection to transformer valve windings and in general separate phase-phase and phase-earth arresters are not provided. Transformer valve winding phase-to-earth arresters may be considered at 800 kV and above to lower the insulation levels especially to the top valve group.

Each voltage level and component are protected by either a single arrester or a combination of series or parallel connected arresters.

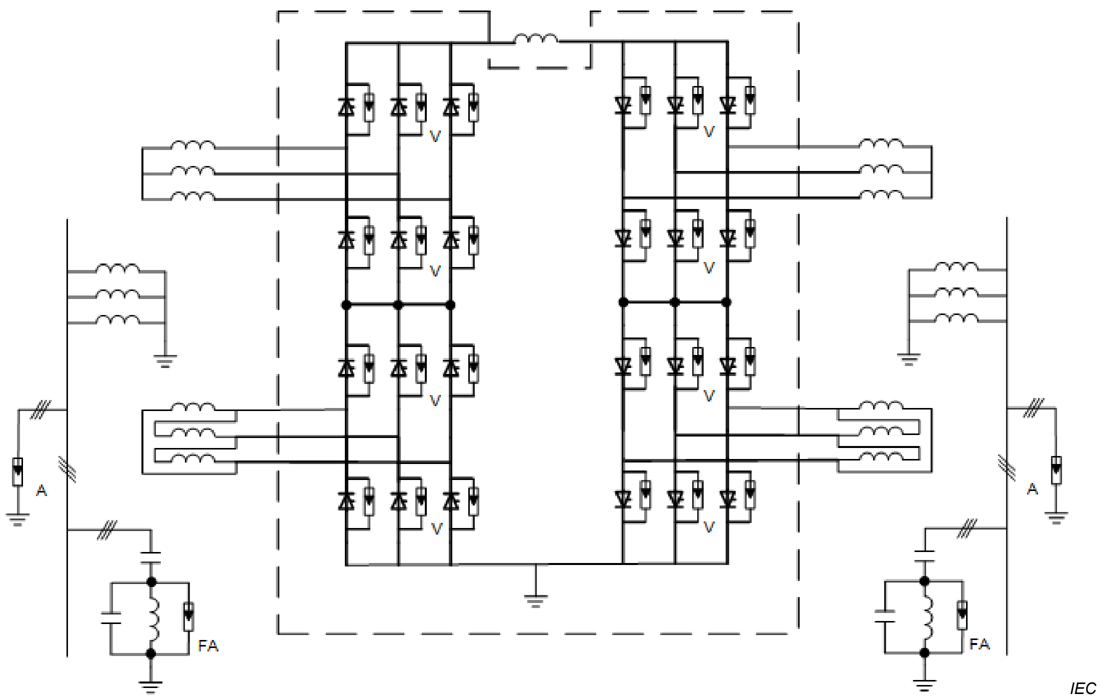
Arrester designations and details on their design and specific roles are presented in Clause 6.



Key

A:	AC bus arrester	FA:	AC filter arrester
FD:	DC filter arrester	EL:	Electrode line arrester
E1:	DC neutral bus arrester	EM:	Metallic return arrester
EB:	Converter neutral arrester	B:	Bridge arrester (6-pulse)
V:	Valve arrester	CB:	Converter unit DC bus arrester
T:	Transformer valve winding arrester	DB:	DC bus arrester
DR:	Smoothing reactor arrester	DC:	DC cable arrester
DL:	DC line arrester	CM:	Arrester between converters unit
CL:	LV converter unit arrester	MH:	Mid-point bridge arrester (HV bridge)
CH:	HV converter unit arrester	ML:	Mid-point bridge arrester (LV bridge)

Figure 1 – Possible arrester locations in a pole with two 12-pulse converters in series



Key

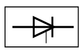
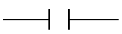
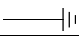
A: AC bus arrester

FA: AC filter arrester

V: Valve arrester

Figure 2 – Possible arrester locations for a back-to-back converter station

Table 1 – Symbol description

Symbol	Description
	Valve (commutation group)
	Valve (one arm)
	Arrester
	Reactor
	Capacitor
	Earth

5 Voltages and overvoltages in service

5.1 Continuous operating voltages at various locations in the converter station

The continuous operating voltages at various locations in an LCC HVDC converter station differ from the a.c. system in that they consist of not simply the fundamental frequency voltages. They could be a combination of direct voltage, fundamental frequency voltage, harmonic voltages, and high frequency transients, depending upon the location.

Figure 3 shows an LCC HVDC converter station in a pole with one 12-pulse converter configuration. In general phase-earth arresters on the valve side of the converter transformer (T) are not provided for LCC HVDC schemes up to 600 kV.

Figure 1 shows an LCC HVDC scheme with two 12-pulse converters in series per pole configuration, which has been used for the early 600 kV scheme and the recent 800 kV schemes.