IEC 60071-12

Edition 1.0 2022-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

**Coordination de l'isolement –
Partie 12: Lignes directrices en matière d'application pour stations de conversion à courant continu haute tension (CCHT) équipées de convertisseurs commutés par le réseau (LCC)**

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INSULATION CO-ORDINATION –

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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.

On the basis of technical experience gained and the development of HVDC, sufficient consensus has emerged to establish a series insulation co-ordination standard for HVDC system. The standard series for HVDC system belongs to IEC 60071 standard series, and 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.

This International Standard replaces, in conjunction with IEC 60071-11 [1], IEC 60071-5 published in 2014. IEC 60071-5 provides basic principles and guidance for insulation coordination of high-voltage direct current (HVDC) converter stations. IEC 60071-11 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. IEC 60071-12 provides 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.

IEC 60071-12 retains the technical content of IEC 60071-5 of the guidelines on the procedures for insulation coordination of LCC converter stations, and there are no essentially technical amendments. An example for LCC HVDC converter station in a pole with two 12-pulse converters in series is provided in annex. Examples of insulation co-ordination for controlled series capacitor converter (CSCC) and capacitor commutated converters (CCC) in IEC 60071-5 are no longer dealt with in this document.

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

Draft	Report on voting
99/368/FDIS	99/379/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.

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.

[1] Under preparation. Stage at the time of publication: IEC/CFDIS 60071-11:2022.

INSULATION CO-ORDINATION –

Part 12: Application guidelines for LCC HVDC converter stations

1 Scope

This part of IEC 60071 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 evaluating the overvoltage stresses on the converter station equipment subjected to combined DC, AC power frequency, harmonic and impulse voltages, and determining the specified withstand voltages for equipment.

This document deals only with metal-oxide surge arresters, without gaps, which are used in modern HVDC converter stations. The criteria for determining the protective levels of series and/or parallel combinations of surge arresters used to ensure optimal protection are also presented. Typical arrester protection schemes and stresses of arresters are presented.

Annex A 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.

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 60071-11[2], *Insulation co-ordination – Part 11 : Definitions, principles and rules for HVDC system*

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

IEC 60633, *High-voltage direct current (HVDC) transmission – Vocabulary*

3 Terms, definitions, symbols and abbreviated terms

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

[2] Under preparation. Stage at the time of publication: IEC/CFDIS 60071-11:2022.

3.1.1
crest value of continuous operating voltage
CCOV
highest continuously occurring crest value of the voltage at the equipment on the DC 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 DC side of the converter station including commutation overshoots and commutation notches

3.1.3
valve protective firing
means of protecting the thyristors from excessive forward voltage, rate of change of voltage or forward voltage applied during the reverse recovery time, by firing the thyristors into conduction

3.2 Symbols and abbreviated terms

3.2.1 General

The list covers only the most frequently used symbols and abbreviated terms, 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_ccov	crest value of continuous operating voltage
U_ch	continuous operating voltage of an arrester including harmonics
U_di0	ideal no-load direct voltage (IEC 60633)
U_di0max	maximum value of U_di0 taking into account AC voltage measuring tolerances, and transformer tap-changer offset by one step
U_s	highest voltage of an AC system (IEC 60071-1 and IEC 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 alternating current)
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 Abbreviated terms

LCC	line commutated converter
VSC	voltage sourced converter
HVDC	high voltage direct current
HV	high voltage
LV	low voltage
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
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 can be noted that Figure 1 shows possible arrester locations covered in this document. Some of these arresters can 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, can change accordingly.

The AC and DC filter configurations could be more complex than those shown in these figures.

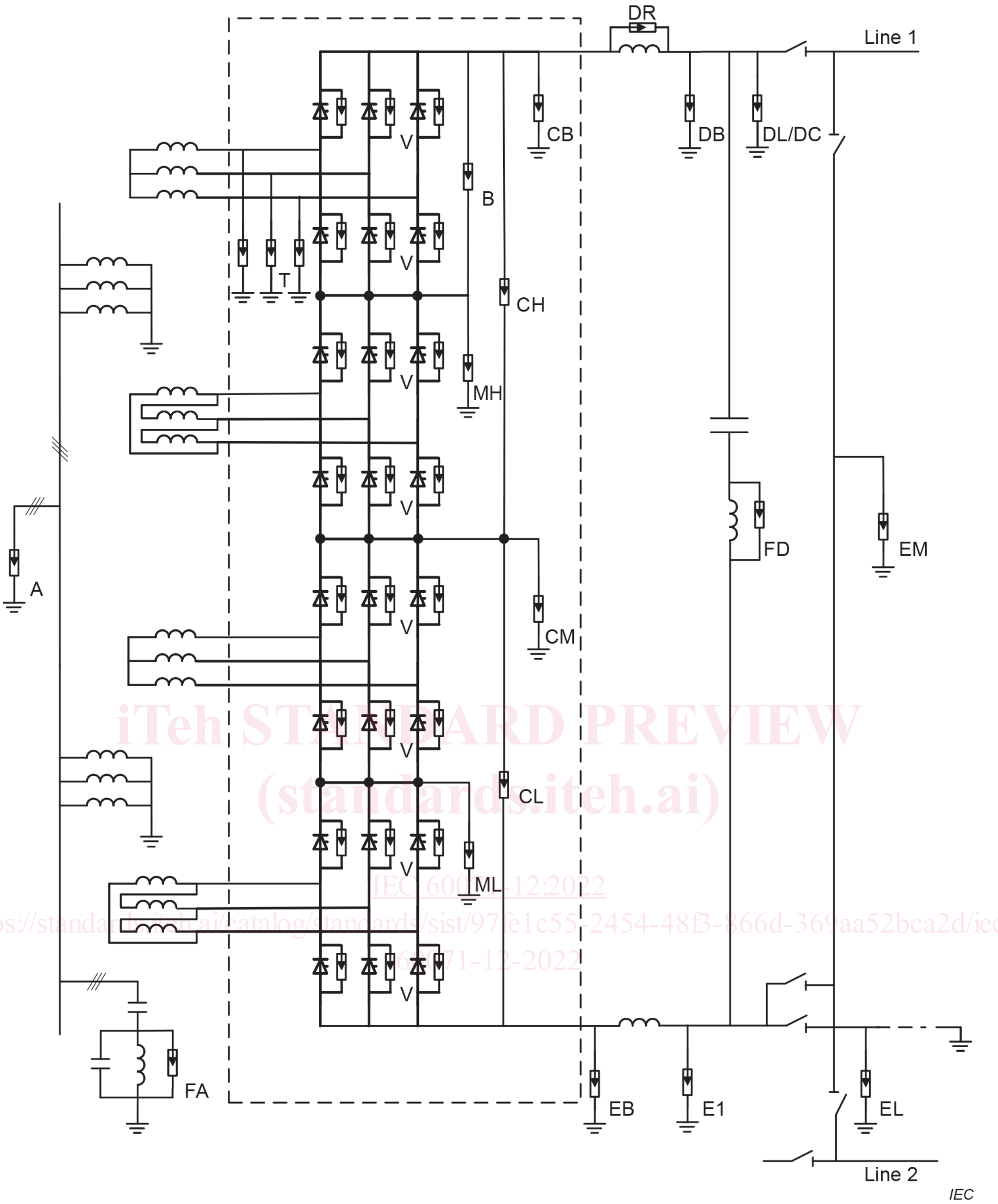
Table 1 presents the graphical symbols used in this document.

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 can 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.

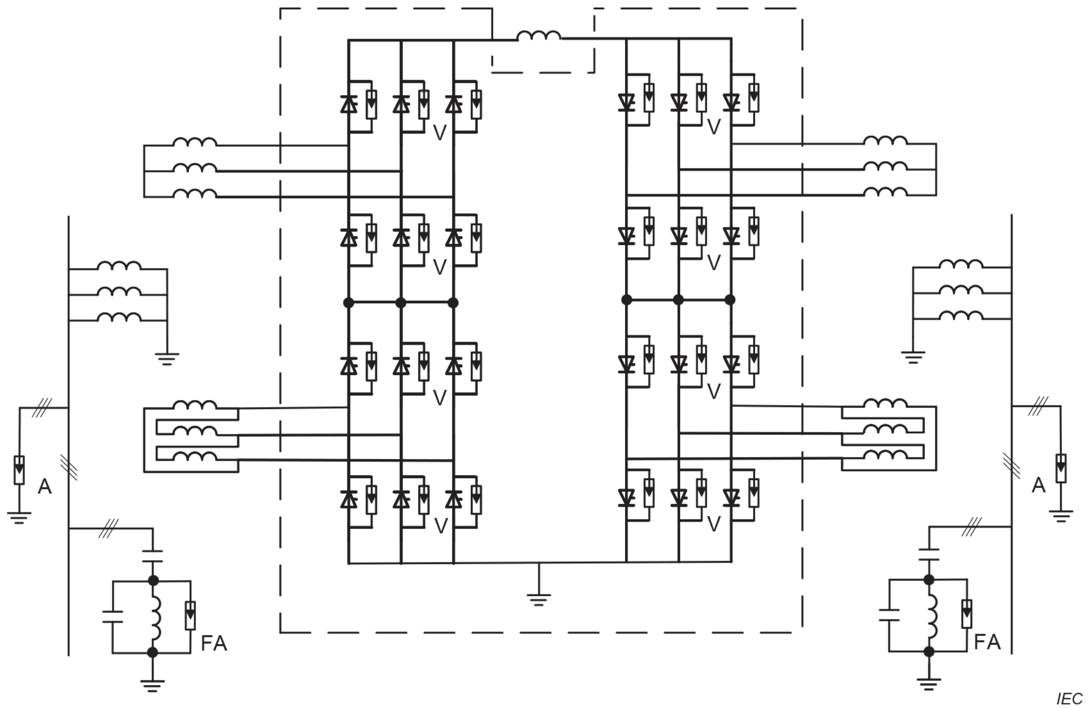
Arrester designations and details on their design and specific roles are presented in Clause 6.



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

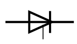
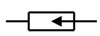
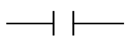
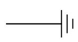
A: AC bus arrester

V: valve arrester

FA: AC filter arrester

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

Table 1 – Symbol description

Symbol	Description
	Single valve (thyristor) IEC 60617-S00057:2001-07
	Arrester IEC 60617-S00373:2001-07
	Reactor IEC 60617-S00849:2001-07
	Capacitor IEC 60617-S00567:2001-07
	Earth IEC 60617-S00200:2001-07

5 Voltages and overvoltages in service

5.1 Continuous operating voltages at various locations in the converter station

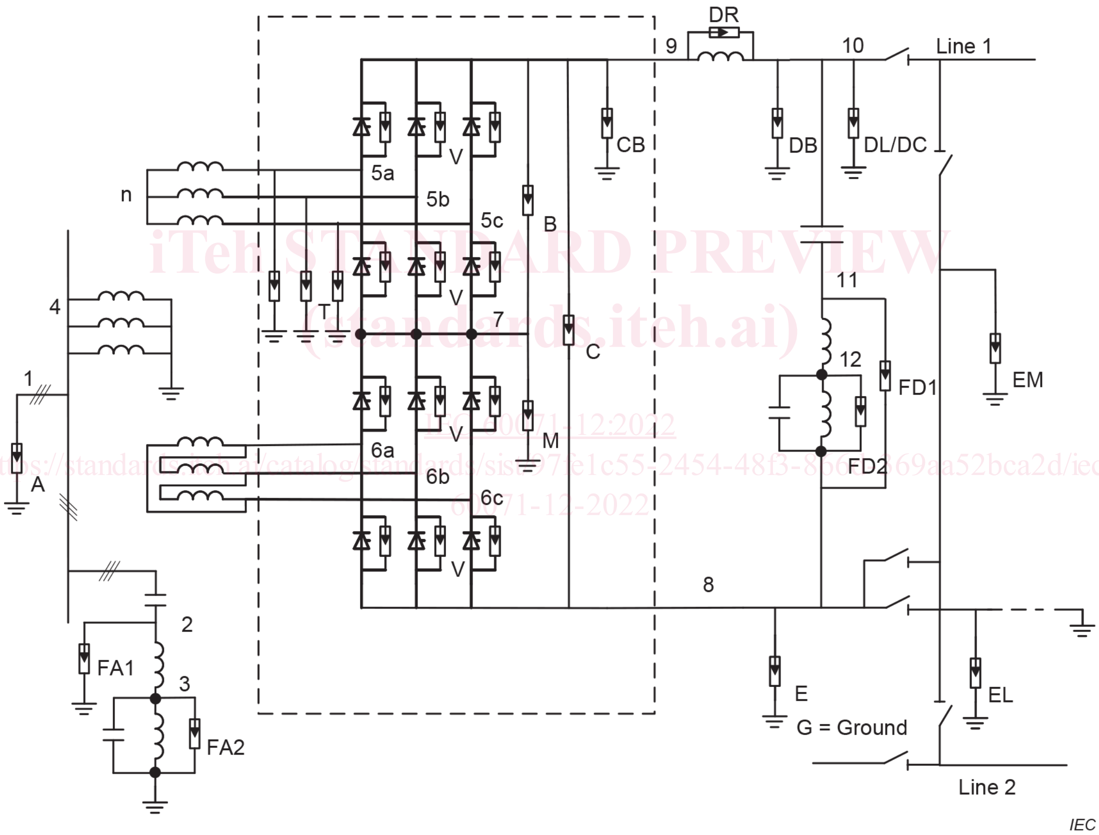
The continuous operating voltages at various locations in an LCC HVDC converter station differ from the AC system in that they consist of not simply the fundamental frequency voltages. They could be a combination of direct voltage, fundamental frequency voltage, harmonic voltages, and high frequency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

Table 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 some 800 kV schemes.

Figure 4 shows typical waveforms of continuous operating voltages excluding commutation overshoots at various locations in the LCC HVDC converter station either to earth (G) or to another point for the typical configuration of Figure 3. The numbers and alphabetical designations, in Figure 3, identify node numbers and arrester designations respectively. These waveforms have been produced with a simulation tool considering typical DC parameters.

Note that Figure 1, Figure 2 and Figure 3 show possible arrester locations, and some of them can be eliminated because of specific designs.



Key

A:	AC bus arrester	CB:	converter unit DC bus arrester
M:	mid-point bridge arrester	EM:	metallic return arrester
E:	DC neutral bus arrester	EL:	electrode line arrester
V:	valve arrester	B:	bridge arrester (6-pulse)
T:	transformer valve winding arrester	C:	converter unit arrester
DR:	smoothing reactor arrester	DB:	DC bus arrester
DL:	DC line arrester	DC:	DC cable arrester
FA1, FA2:	AC filter arresters	FD1, FD2:	DC filter arresters

Figure 3 – LCC HVDC converter station in a pole with one 12-pulse converter