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BSI Standards Publication

Thyristor valves for high voltage direct current (HVDC) power transmission

Part 2: Terminology

bsi.

National foreword

This British Standard is the UK implementation of EN 60700-2:2016. It is identical to IEC 60700-2:2016.

The UK participation in its preparation was entrusted to Technical Committee PEL/22, Power electronics.

A list of organizations represented on this committee can be obtained on request to its secretary.

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European foreword

The text of document 22F/373/CDV, future edition 1 of IEC 60700-2, prepared by SC 22F “Power electronics for electrical transmission and distribution systems” of IEC/TC 22 “Power electronic systems and equipment” was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60700-2:2016.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2017-05-25
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In the official version, for Bibliography, the following note has to be added for the standard indicated :

IEC 60700-1	NOTE	Harmonized as EN 60700-1.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60027	Series	Letter symbols to be used in electrical technology	-	-
IEC 60633	-	Terminology for high-voltage direct current (HVDC) transmission	EN 60633	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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THYRISTOR VALVES FOR HIGH VOLTAGE DIRECT CURRENT (HVDC) POWER TRANSMISSION –

Part 2: Terminology

FOREWORD

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International Standard IEC 60700-2 has been prepared by subcommittee 22F: Power electronics for electrical transmission and distribution systems, of IEC technical committee 22: Power electronic systems and equipment.

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

CDV	Report on voting
22F/373/CDV	22F/395A/RVC

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 60700 series, published under the general title *Thyristor valves for high voltage direct current (HVDC) power transmission*, 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 website 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.

THYRISTOR VALVES FOR HIGH VOLTAGE DIRECT CURRENT (HVDC) POWER TRANSMISSION –

Part 2: Terminology

1 Scope

This part of IEC 60700 defines terms for thyristor valves for high-voltage direct current (HVDC) power transmission with line commutated converters most commonly based on three-phase bridge connections for the conversion from AC to DC and vice versa.

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 60027(all parts), *Letter symbols to be used in electrical technology*

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

3 Symbols and abbreviations

3.1 General

The lists in 3.2 and 3.3 cover only the most frequently used symbols. The lists of symbols of the IEC 60027 series and IEC 60633 apply.

3.2 List of letter symbols

α (trigger/firing) delay angle

β (trigger/firing) advance angle

μ commutation overlap angle

γ extinction angle

3.3 List of abbreviations

The following abbreviations are always in capital letters and without dots:

ETT electrically triggered thyristor

LTT light triggered thyristor

TCU thyristor control unit

HVDC high-voltage direct current

VBE valve base electronics

MVU multiple valve (unit)

BOD breakover diode

4 General terms related to converter circuits

4.1
converter arm
part of a bridge connecting two points of different potentials within a bridge, for example between an AC terminal and a DC terminal

Note 1 to entry: The main function of a converter arm is conversion.

4.2
converter bridge
equipment used to implement the bridge converter connection, if used

SEE: Figure 1

Note 1 to entry: The term "bridge" may be used to describe either the circuit connection or the equipment implementing that circuit.

[SOURCE: IEC 60633: 2015, 6.2, modified – The expression "and the by-pass arm" has been deleted from the definition.]

4.3
converter unit
indivisible operative unit comprising all equipment between the point of common coupling on the AC side and the point of common coupling on the DC side, essentially one or more converter bridges, together with one or more converter transformers, converter unit control equipment, essential protective and switching devices and auxiliaries, if any, used for conversion

SEE: Figure 1

Note 1 to entry: If a converter unit comprises two converter bridges with a phase displacement of 30 degrees, then the converter unit forms a 12-pulse unit.

5 Converter performance

5.1
forward direction
conducting direction
direction of current through a valve, when current flows from the anode terminal to the cathode terminal

5.2
reverse direction
non-conducting direction
direction of current through a valve, when current flows from the cathode terminal to the anode terminal

6 Thyristor valve design

6.1
thyristor
bi-stable semiconductor device comprising three or more junctions which can be switched from the off-state to the on-state

Note 1 to entry: Devices having only three layers but having switching characteristics similar to those of four-layers devices may also be called thyristors.

Note 2 to entry: The term "thyristor" is used as a generic term to cover the whole range of PNPN type devices. It may be used by itself for any member of the thyristor family when such use does not result in ambiguity or

misunderstanding. In particular, the term "thyristor" is widely used for reverse blocking triode thyristor, formerly called "silicon controlled rectifier".

Note 3 to entry: Thyristors may either be electrically triggered thyristor (ETT） or light triggered thyristor (LTT).

6.2
electrically triggered thyristor
ETT
thyristor triggered by applying electrical pulses to the thyristor gate

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

6.3
light triggered thyristor
LTT
thyristor triggered by applying light pulses to a photosensitive area within the thyristor gate area

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

6.4
damping circuit
snubber circuit
circuit (usually consisting of a series connected resistor and capacitor) connected in parallel to a thyristor to reduce the amplitude of the extinction overshoot voltage

6.4.1
damping capacitor
snubber capacitor
capacitor connected in parallel to a thyristor (usually in series with a resistor) to reduce the amplitude of the extinction overshoot voltage

6.4.2
damping resistor
snubber resistor
resistor connected in parallel to a thyristor (in series with a capacitor) to limit the amplitude of discharge current of the snubber capacitor after thyristor turn-on

6.5
DC grading resistor
resistor connected in parallel to the thyristor to equalize DC voltage unbalance caused by tolerances of thyristor blocking currents

Note 1 to entry: In some designs, DC grading resistor also acts as high voltage arm of the voltage divider for monitoring voltage across the thyristor level.

6.6
heat sink
separable cooling element, usually through which a heat transfer agent flows, that contributes to the dissipation of the heat produced within the thyristors and other components, if any, in the valve

6.7
thyristor control unit
TCU
electronic unit at thyristor level potential used to trigger, protect and monitor the thyristor

Note 1 to entry: Some other terms are used for this unit: thyristor electronics (TE), thyristor firing and monitoring unit (TFM) or (thyristor) gating unit.

Note 2 to entry: In some designs, a thyristor voltage monitoring unit (TVM) is used which performs monitoring functions only.

Note 3 to entry: This note applies to the French language only.

6.8
thyristor stack
thyristor clamped assembly
mechanical arrangement of more than one thyristor, stacked in an alternating series with heat sinks and clamped within an insulating mechanical support unit

Note 1 to entry: The clamping force is usually exerted by a disk spring arrangement.

6.9
single valve unit
single structure comprising only one valve

[SOURCE: IEC 60633:2015, 6.3.1]

6.10
multiple valve unit
MVU
single structure comprising more than one valve

EXAMPLE Double valves, quadrivalves and octovalves with two, four and eight series-connected valves respectively.

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

[SOURCE: IEC 60633:2015, 6.3.2]

6.11
thyristor valve
complete operative controllable valve device assembly, normally conducting in only one direction (the forward direction), which can function as a converter arm in a converter bridge

SEE: Figure 5

6.12
valve thyristor level
part of a valve comprising a thyristor, or thyristors connected in parallel, together with their immediate auxiliaries, and reactor, if any

[SOURCE: IEC 60633:2015, 6.9]

6.13
valve section
electrical assembly, comprising a number of thyristors and other components, which exhibits prorated electrical properties of a complete valve

Note 1 to entry: This term is mainly used to define a test object for valve testing purposes.

[SOURCE: IEC 60633:2015, 6.8]

6.14
redundant thyristor levels
maximum number of thyristor levels in a thyristor valve that may be short-circuited externally or internally during service without affecting the safe operation of the thyristor valve as demonstrated by type tests, and which if and when exceeded, would require shutdown of the valve to replace the failed thyristors or acceptance of increased risk of failures

6.15
valve reactor
reactor contained within the valve and connected directly in series with one or more thyristor levels to control d*i*/d*t* at turn-on and d*u*/d*t* in the off-state

Note 1 to entry: d*i*/d*t* is rate of rise of on-state current.

Note 2 to entry: d*u*/d*t* is rate of rise of off-state voltage.

6.16
valve section capacitor
capacitor connected across two or more thyristor levels and at least one valve reactor, for the purpose of ensuring voltage sharing in fast transient conditions (for example lightning and steep-front impulse)

Note 1 to entry: Term “grading capacitor” is also used.

6.17
fast grading circuit
surge distribution circuit
capacitor, or resistor-capacitor circuit with a time constant of less than 5 μs, connected directly across each thyristor level (or across the thyristor level plus level reactor) for the purpose of ensuring voltage sharing in fast transient conditions (for example lightning and steep-front impulse)

6.18
fast grading capacitor
surge distribution capacitor
capacitive part of the fast grading circuit

6.19
fast grading resistor
surge distribution resistor
resistive part (if any) of the fast grading circuit

6.20
valve electronics
electronic circuits at valve potential(s) which perform control and protection functions for one or more valve levels

6.21
valve base electronics
VBE
electronic unit, at earth potential, providing the electrical to optical conversion between the converter control system and the valves

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

[SOURCE: IEC 60633:2015, 6.12]

6.22
trigger system
firing system
means to provide firing pulses to the thyristors at high potential

Note 1 to entry: In case of electrically triggered thyristor (ETT) valves, the trigger circuit consists of light emitting devices in the VBE, the fibre optics which transmit the trigger pulses to the individual thyristor levels and the electrical circuits on the TCUs which convert the optical pulses to electrical trigger pulses applied to the thyristors. In light triggered thyristor (LTT) valves, the optical trigger pulses may be split to the individual thyristors directly inside the valve using a multimode star coupler.

6.23
recovery protection circuit
electronic circuit or device to protect the thyristor against excessive positive rate of voltage change during the recovery period by measuring the d*u*/d*t* rate and firing the thyristor in case a limit value is exceeded

Note 1 to entry: The recovery protection circuit may be implemented at the thyristor control unit or as a separate unit per valve section.

Note 2 to entry: The recovery protection function may also be implemented in the thyristor's silicon structure rendering any external electronics unnecessary.

6.24
multimode star coupler
passive optical device which splits a number of incoming optical signals to a larger number of outgoing optical signals

Note 1 to entry: In some valve designs it is used to distribute the trigger impulses received by a few fibre optics from the valve base electronics (VBE) to the number of thyristors in a valve section.

6.25
valve cooling circuit
arrangement of tubes for transporting the heat transfer agent from ground potential into the valve arrangement, distributing it to the valve components, and transporting it back

6.26
valve cooling system
all equipment needed for removing heat from the valves and rejecting it to the environment, including the valve cooling circuit plus circulating pumps or fans, de-ionisation and filtering equipment, heat exchangers, interconnecting pipework and control system at ground potential

6.27
grading electrodes
electrodes of non corrosive metal inserted into the cooling circuit at appropriate locations and connected to appropriate electrical potentials to control leakage current flow through the cooling medium in order to avoid partial discharge due to potential mismatch

6.28
thyristor module
part of a valve comprising a mechanical assembly of thyristors with their immediate auxiliaries but without valve reactors

Note 1 to entry: Thyristor modules may be elements of a valve and/or be interchangeable for maintenance purposes.

6.29
valve module
part of a valve comprising a mechanical assembly of thyristors with their immediate auxiliaries and valve reactor(s)

Note 1 to entry: Valve module may be interchangeable for maintenance purpose.

6.30
reactor module
mechanical assembly of one or more valve reactors used in some valve designs

Note 1 to entry: Reactor modules may be elements in the construction of a valve.

[SOURCE: IEC 60633:2015, 6.7, modified – The definition has been rephrased.]

6.31
valve support
part of the valve which mechanically supports and electrically insulates from earth the active part of the valve

6.32
valve structure
structural components of a valve, required in order to physically support the valve modules

6.33
valve tier
one physical layer of a single or a multiple valve unit comprising one or more valve module(s)

6.34
corona shield
conductive surface on the external profile of a single or a multiple valve unit for the purpose of minimising the surface electrical field strength and preventing corona

7 Thyristor valve performance

7.1
valve blocking
operation preventing further firing of a valve

[SOURCE: IEC 60633:2015, 7.17, modified – The adjective "controllable" has been deleted.]

7.2
valve deblocking
operation permitting firing of a valve

[SOURCE: IEC 60633:2015, 7.18, modified – The adverb "further" and the adjective "controllable" have been deleted.]

7.3
on-state
conducting state
condition of a valve when the valve exhibits a low resistance

SEE: Figure 4

[SOURCE: IEC 60633:2015, 7.9]

7.4
off-state
non-conducting state
condition of a valve when all thyristors are turned off

7.5
forward blocking state
non-conducting state of a valve when forward voltage is applied between its main terminals

[SOURCE: IEC 60633:2015, 7.11.1, modified – The adjective "controllable" has been deleted.]

7.6
reverse blocking state
non-conducting state of a valve when reverse voltage is applied between its main terminals

[SOURCE: IEC 60633:2015, 7.11.2]

7.7
firing failure
failure to achieve firing of a valve during the entire forward voltage interval

[SOURCE: IEC 60633:2015, 7.30]

7.8
commutation failure
failure to commutate the forward current from the conducting converter arm to the succeeding converter arm

[SOURCE: IEC 60633:2015, 7.31]

7.9
false firing
misfiring
firing of a valve at an unintended instant

8 Thyristor valve voltages, currents and other parameters

8.1
valve forward voltage
voltage applied between the anode and cathode terminals of a valve or an arm when the anode is positive with respect to the cathode

SEE: Figure 4

[SOURCE: IEC 60633:2015, 7.7, modified – The noun "valve" has been added to the term.]

8.2
valve forward current
current which flows through a valve in the forward direction

[SOURCE: IEC 60633:2015, 7.5, modified – The noun "valve" has been added to the term.]

8.3
valve reverse voltage
voltage applied between the anode and cathode terminals of a valve or an arm when the anode is negative with respect to the cathode

SEE: Figure 4

[SOURCE: IEC 60633:2015, 7.8, modified – The noun "valve" has been added to the term.]

8.4
valve reverse current
current which flows through a valve in the reverse direction

[SOURCE: IEC 60633:2015, 7.6, modified – The noun "valve" has been added to the term.]

8.5
valve on-state
conducting state
state of a thyristor valve when all thyristors are turned-on

8.6
valve on-state voltage
voltage drop
forward voltage which, during the on-state, appears across the valve terminals

8.7
valve off-state voltage
forward voltage which, during the non-conducting state, appears across the valve terminals

8.8
valve on-state current
current which flows through a valve during the on-state

8.9
valve conduction interval
part of a cycle during which a valve is in the conducting state

SEE: Figure 4

[SOURCE: IEC 60633:2015, 7.25]

8.10
valve blocking interval
part of a cycle during which a valve is in the non-conducting state

SEE: Figure 4

[SOURCE: IEC 60633:2015, 7.26, modified – The noun "valve" has been added to the term, and the second preferred term "idle interval" has been deleted.]

8.11
valve forward blocking interval
part of the blocking interval during which a controllable valve is in the forward blocking state

SEE: Figure 4

[SOURCE: IEC 60633:2015, 7.27, modified – The noun "valve" has been added to the term.]

8.12
valve reverse blocking interval
part of the blocking interval during which a valve is in the reverse blocking state

SEE: Figure 4

[SOURCE: IEC 60633:2015, 7.28, modified – The noun "valve" has been added to the term.]

8.13
valve hold-off interval
time from the instant when the forward current of a controllable valve has decreased to zero to the instant when the same valve is subjected to forward voltage

SEE: Figure 3

[SOURCE: IEC 60633:2015, 7.24, modified – The noun "valve" has been added to the term, and the note to entry has been deleted.]

8.14
valve critical hold-off interval
minimum hold-off interval for which inverter operation can be maintained

[SOURCE: IEC 60633:2015, 7.24.1, modified – The noun "valve" has been added to the term.]

8.15
valve crest working reverse voltage
highest instantaneous value of the reverse voltage developed across a reverse blocking valve device or an arm consisting of such devices, excluding all repetitive and non-repetitive transient voltages

Note 1 to entry: The repetitive voltage is usually a function of the circuit and increases the power loss of the device. A non-repetitive transient voltage is usually due to an external cause, and it is assumed that its effect has completely disappeared before the next transient arrives.

[SOURCE: IEC 60050-551:1998, 551-16-56, modified – The noun "circuit" has been replaced by "valve" in the term, and the note to entry has been added.]

8.16
valve repetitive peak reverse voltage
highest instantaneous value of a reverse voltage developed across a reverse blocking valve device or an arm consisting of such devices, including all repetitive transient voltages but excluding all non-repetitive transient voltages

[SOURCE: IEC 60050-551:1998, 551-16-57, modified – The noun "circuit" has been replaced by "valve" in the term.]

8.17
valve non-repetitive peak reverse voltage
highest instantaneous value of any non-repetitive transient reverse voltage developed across a reverse blocking valve device or an arm consisting of such devices

[SOURCE: IEC 60050-551:1998, 551-16-58, modified – The noun "circuit" has been replaced by "valve" in the term.]

8.18
valve crest working off-state voltage
highest instantaneous value of the off-state voltage developed across a controllable valve device or an arm consisting of such devices, excluding all repetitive and non-repetitive transients

[SOURCE: IEC 60050-551:1998, 551-16-53, modified – The noun "circuit" has been replaced by "valve" in the term.]

8.19
valve repetitive peak off-state voltage
highest instantaneous value of the off-state voltage developed across a controllable valve device or an arm consisting of such devices, including all repetitive transient voltages but excluding all non-repetitive transient voltages

[SOURCE: IEC 60050-551:1998, 551-16-54, modified – The noun "circuit" has been replaced by "valve" in the term.]

8.20
valve non-repetitive peak off-state voltage
highest instantaneous value of any non-repetitive transient off-state voltage developed across a controllable valve device or an arm consisting of such devices

[SOURCE: IEC 60050-551:1998, 551-16-55, modified – The noun "circuit" has been replaced by "valve" in the term.]

9 Thyristor valve control

9.1
firing
establishment of current in the forward direction in a valve

[SOURCE: IEC 60633:2015, 7.12]

9.2
valve control pulse
pulse which, during its entire duration, allows the firing of the valve

[SOURCE: IEC 60633:2015, 7.13]

9.3
valve firing pulse
pulse which initiates the firing of the valve, normally derived from the valve control pulse

[SOURCE: IEC 60633:2015, 7.14]

9.4
trigger delay angle
firing delay angle
α
time, expressed in electrical angular measure, from the zero crossing of the idealized sinusoidal commutating voltage to the starting instant of forward current conduction

SEE: Figure 2

[SOURCE: IEC 60633:2015, 7.20]

9.5
trigger advance angle
firing advance angle
β
time, expressed in electrical angular measure, from the starting instant of forward current conduction to the next zero crossing of the idealized sinusoidal commutating voltage

Note 1 to entry: The advance angle β is related to the delay angle α by $\beta = \pi - \alpha$.

SEE: Figure 2

[SOURCE: IEC 60633:2015, 7.21]

9.6
overlap angle
μ
duration of commutation between two converter arms, expressed in electrical angular measure

SEE: Figures 2 and 3

[SOURCE: IEC 60633:2015, 7.22]

9.7
extinction angle
γ
time, expressed in electrical angular measure, from the end of current conduction to the next zero crossing of the idealized sinusoidal commutating voltage

Note 1 to entry: γ depends on the advance angle β and the angle of overlap μ and is determined by the relation $\gamma = \beta - \mu$ (see figures 2 and 3).

[SOURCE: IEC 60633:2015, 7.23]

9.8
phase control
process of controlling the instant within the cycle at which forward current conduction in a controllable valve begins

[SOURCE: IEC 60633:2015, 7.19]

10 Thyristor valve protection

10.1
valve arrester
arrester connected across a valve

SEE: Figure 1

[SOURCE: IEC 60633:2015, 6.14]

10.2
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

10.3
forward overvoltage protection
valve protective firing in response to forward overvoltage

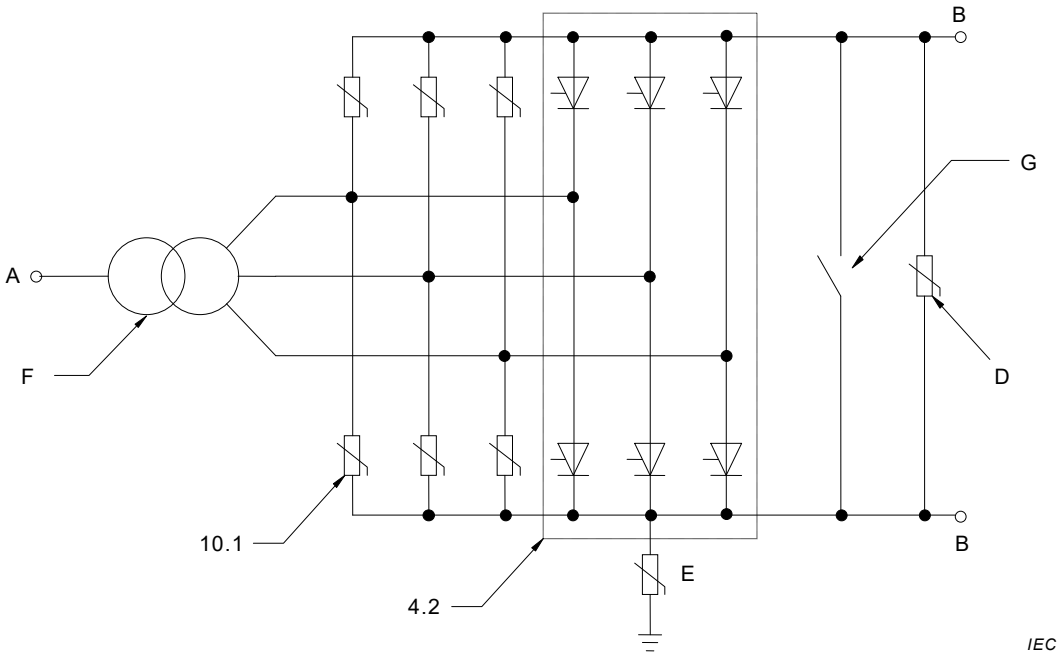
Note 1 to entry: Some thyristors have integrated protection function against forward overvoltage by means of controlled self-firing.

10.4
electronic forward overvoltage protection
forward overvoltage protection where the protective gate pulses are produced by the thyristor control unit

10.5
breakover diode (BOD) protection
forward overvoltage protection where the protective gate pulses are provided by a physical breakover diode assembly that is independent of the thyristor control unit

10.6
d*u*/d*t* protection
valve protective firing in response to excessive rate of rise of off-state voltage

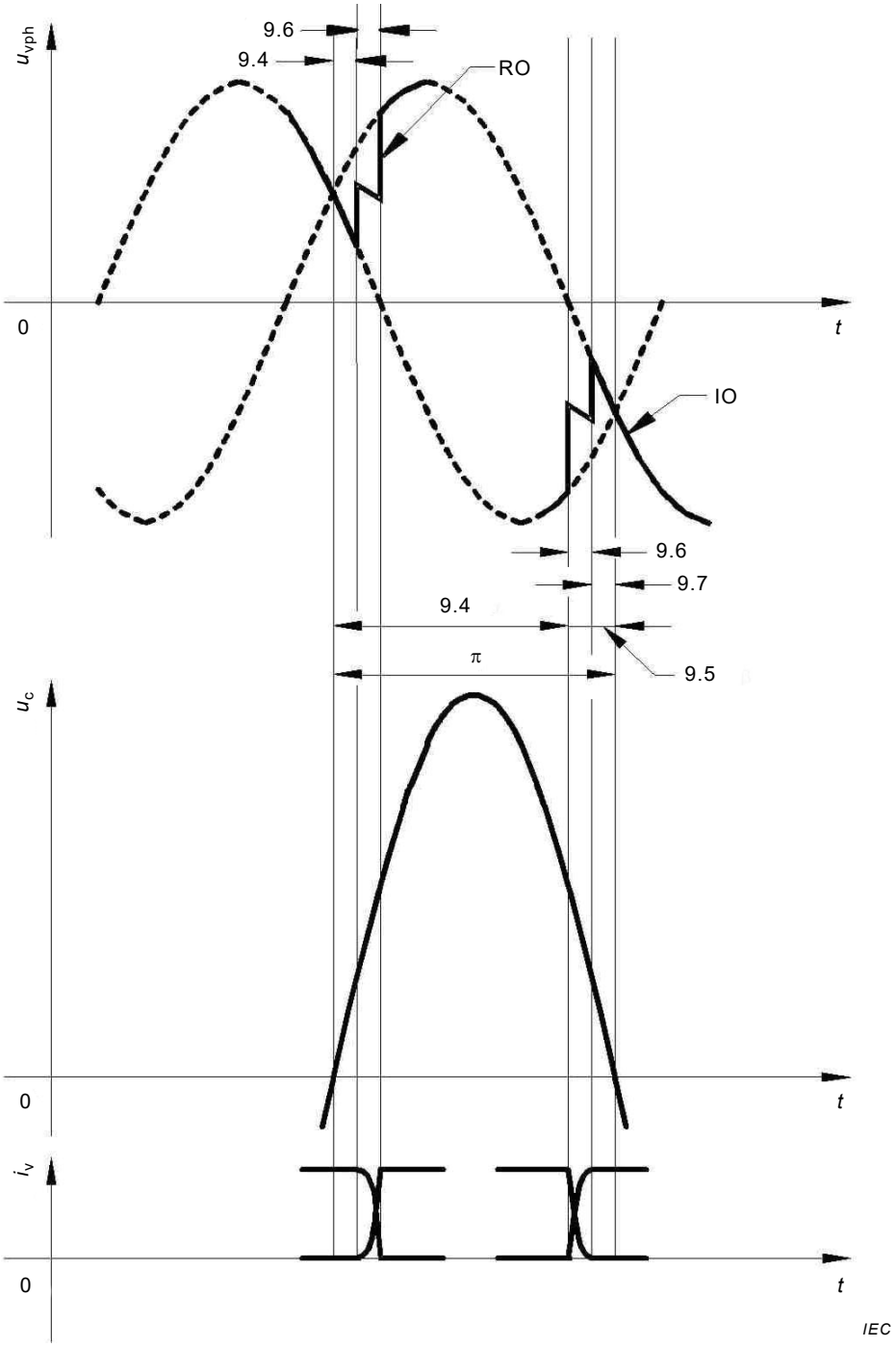
10.7
forward recovery protection
valve protective firing in response to forward voltage applied during the reverse recovery time



Key

A	AC terminals	D	converter unit arrester
B	DC terminals	E	converter unit DC bus arrester
4.2	bridge	F	converter transformer
10.1	valve arrester	G	by-pass switch

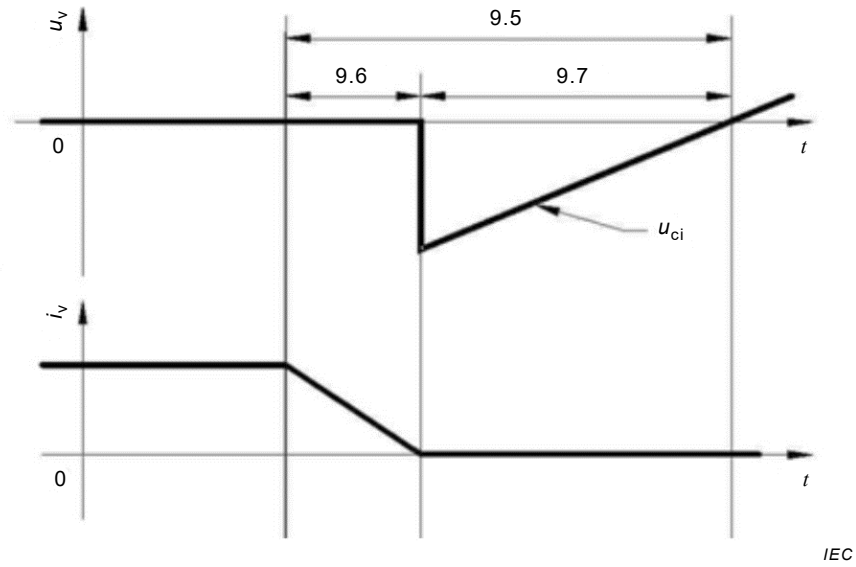
Figure 1 – Example of a converter unit



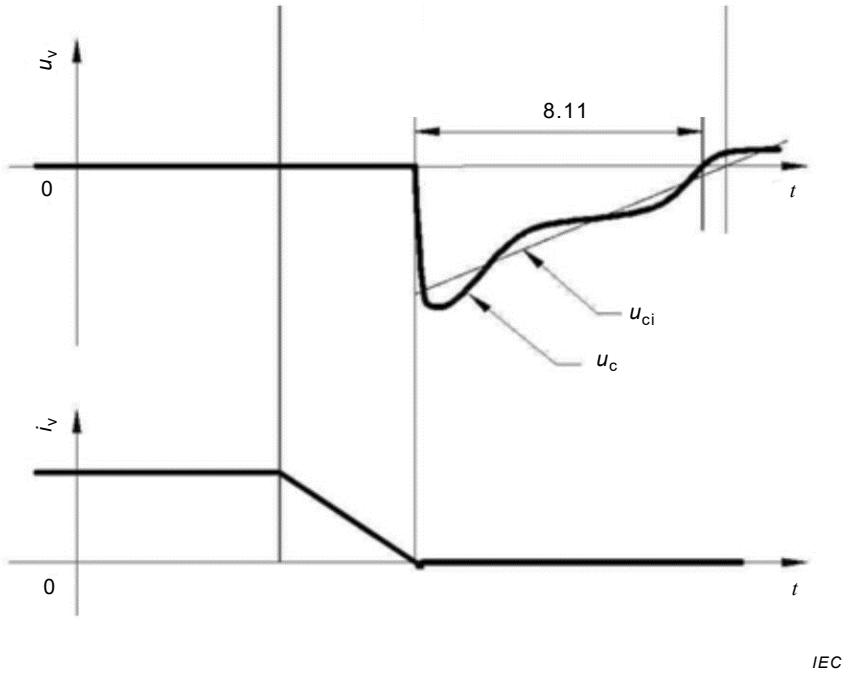
Key

u_{vph}	phase voltage	IO	inverter operation
u_c	commutating voltage	9.4	delay angle α
i_v	valve currents	9.5	advance angle β
t	time	9.6	overlap angle μ
RO	rectifier operation	9.7	extinction angle γ

Figure 2 – Commutation process at rectifier and inverter modes of operation



a) Valve idealized

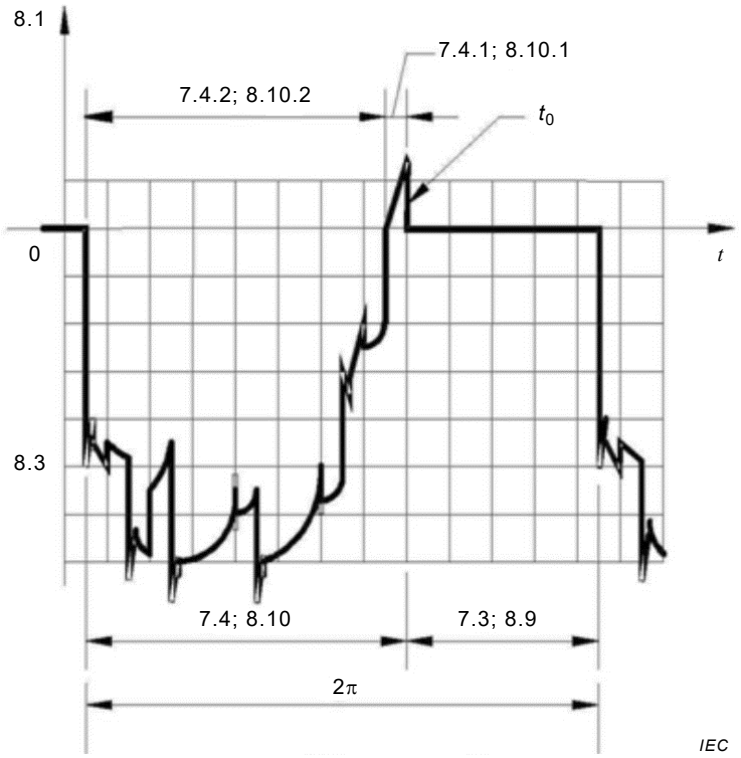


b) Real valve

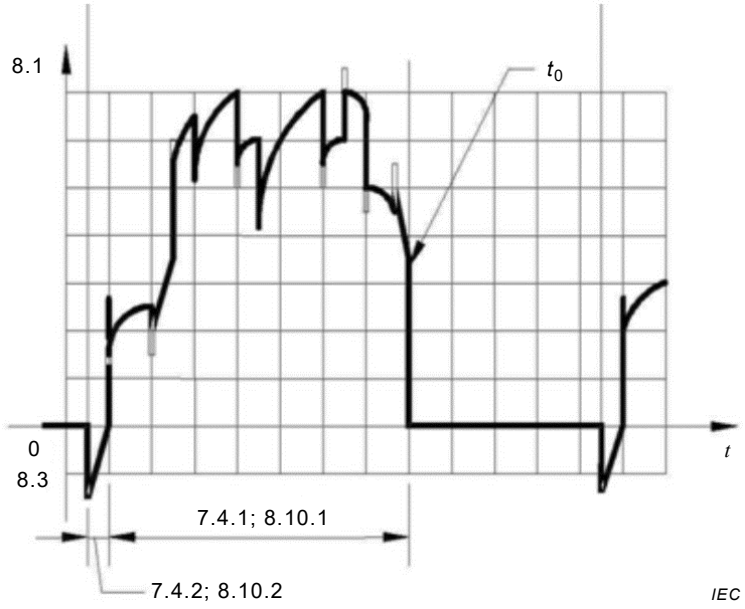
Key

u_v	voltage across outgoing valve	9.5	advance angle β
i_v	current in outgoing valve	9.6	overlap angle μ
u_{ci}	idealized commutating voltage	9.7	extinction angle γ
u_c	actual commutating voltage	8.11	hold-off interval
t	time		

Figure 3 – Illustrations of commutation in inverter operation



a) Rectifier operation



b) Inverter operation

Key

t	time	7.4.1	forward blocking state
t_0	firing instant	7.4.2	reverse blocking state
8.1	forward voltage	8.9	conduction interval
8.3	reverse voltage	8.10	blocking interval
7.3	conducting state	8.10.1	forward blocking interval
7.4	non-conducting state	8.10.2	reverse blocking interval

Figure 4 – Typical valve voltage waveforms

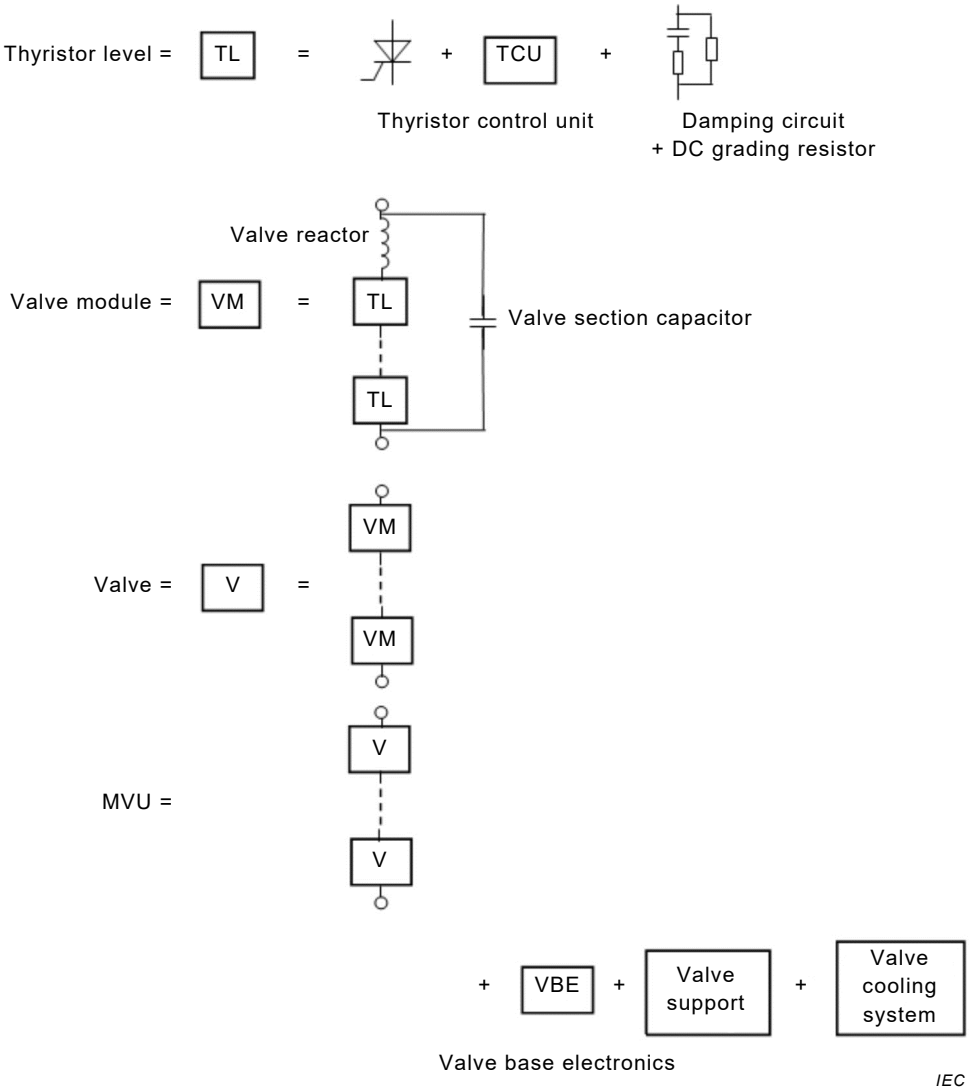


Figure 5 – An example of thyristor valve composition

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