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Incorporating corrigendum February 2015

BSI Standards Publication

Terminology for voltage-sourced converters (VSC) for high-voltage direct current (HVDC) systems

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National foreword

This British Standard is the UK implementation of EN 62747:2014. It is identical to IEC 62747:2014, incorporating corrigendum February 2015.

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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31 March 2015	Implementation of IEC corrigendum February 2015. Modulation index equation in subclause 8.11 updated.

EUROPEAN STANDARD

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EN 62747

September 2014

ICS 29.200; 29.240

English Version

Terminology for voltage-sourced converters (VSC) for high-voltage direct current (HVDC) systems (IEC 62747:2014)

Terminologie relative aux convertisseurs de source de tension (VSC) des systèmes en courant continu à haute tension (CCHT)
(CEI 62747:2014)

Terminologie für Spannungszwischenkreis-Stromrichter (VSC) für Hochspannungsgleichstrom(HGÜ)-Systeme
(IEC 62747:2014)

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European Committee for Electrotechnical Standardization
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Foreword

The text of document 22F/301/CDV, future edition 1 of IEC 62747, 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 62747:2014.

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)	2015-05-21
– latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-08-21

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In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60146-1-1	NOTE	Harmonized as EN 60146-1-1.
IEC 60146-2	NOTE	Harmonized as EN 60146-2.
IEC 60747	NOTE	Harmonized in EN 60747 series.
IEC 60633	NOTE	Harmonized as EN 60633.
IEC 62501	NOTE	Harmonized as EN 62501.
IEC 62751-1	NOTE	Harmonized as EN 62751-1 [1)].
IEC 62751-2	NOTE	Harmonized as EN 62751-2 [1)].

1) To be published.

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	EN 60027	series
IEC 60617	-	Graphical symbols for diagrams	-	-

CONTENTS

TERMINOLOGY FOR VOLTAGE-SOURCED CONVERTERS (VSC) FOR HIGH-VOLTAGE DIRECT CURRENT (HVDC) SYSTEMS

1 Scope

This International Standard defines terms for the subject of self-commutated voltage-sourced converters used for transmission of power by high voltage direct current (HVDC).

The standard is written mainly for the case of application of insulated gate bipolar transistors (IGBTs) in voltage sourced converters (VSC) but may also be used for guidance in the event that other types of semiconductor devices which can both be turned on and turned off by control action are used.

Line-commutated and current-sourced converters for high-voltage direct current (HVDC) power transmission systems are specifically excluded from 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 60027 (all parts), *Letter symbols to be used in electrical technology*

IEC 60617, *Graphical symbols for diagrams*

3 Symbols and abbreviations

3.1 List of letter symbols

Essential terms and definitions necessary for the understanding of this standard are given here; other terminology is as per relevant parts of IEC 60747.

The list covers only the most frequently used symbols (see Figure 1). IEC 60027 shall be used for a more complete list of the symbols which have been adopted for static converters. See also other standards listed in the normative references and the bibliography.

U_{d} direct voltage

U_{dc} converter d.c. voltage

U_{dpe} pole-to-earth direct voltage

U_{dpp} pole-to-pole direct voltage

U_{dppN} rated pole-to-pole direct voltage

U_{dpeN} rated pole-to-earth direct voltage

U_{L} line-to-line voltage on line side of interface transformer, r.m.s. value including harmonics

U_{Le} line-to-earth voltage on line side of interface transformer, r.m.s. value including harmonics

U_{LN} rated value of U_L

U_v line-to-line voltage on valve side of interface transformer, r.m.s. value including harmonics

U_{ve} line-to-earth voltage on valve side of interface transformer, r.m.s. value including harmonics

U_c line-to-line converter voltage, r.m.s. value including harmonics

NOTE U_c is equal to U_v minus the voltage drop across the phase and valve reactors. However, U_c has only a clear meaning during balanced conditions (steady state).

U_{ce} line-to-earth converter voltage , r.m.s. value including harmonics

U_{valve} voltage between terminals of a valve (any defined value)

I_d direct current (any defined value)

I_{dN} rated direct current

I_L current on line side of interface transformer, r.m.s. value including harmonics

I_{LN} rated value of I_L

I_v current on valve side of interface transformer, r.m.s. value including harmonics

I_{valve} current through a valve

3.2 List of subscripts

0 (zero) at no load

e earth

p pole

N rated value or at rated load

d direct current or voltage

L line side of interface transformer

c converter

v valve side of interface transformer

valve through or across one valve

max maximum

min minimum

n pertaining to harmonic component of order n

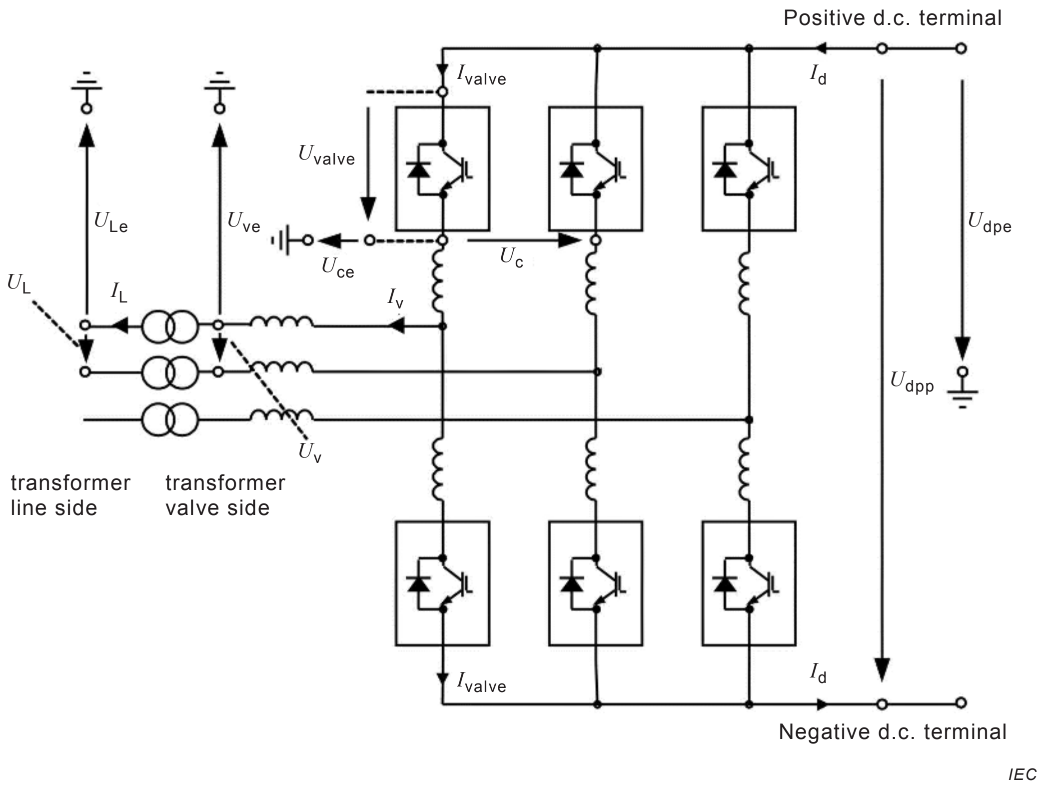


Figure 1 – Converter symbol identifications

3.3 List of abbreviations

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

CTL	cascaded two-level converter
ERTB	earth return transfer breaker
ESCR	effective short-circuit ratio
FWD	free-wheeling diode
HF	high frequency
HVDC	high-voltage direct current
IGBT	insulated gate bipolar transistor
MMC	modular multilevel converter
MRTB	metallic return transfer breaker
MTDC	multi-terminal HVDC transmission system
MVU	multiple valve (unit)
NBS	neutral bus switch
NGBS	neutral bus grounding switch
PCC	point of common coupling
PCC-DC	point of common coupling – d.c. side

SCR short-circuit ratio

VBE valve base electronics

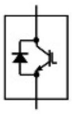
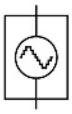
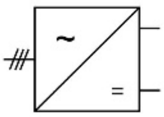
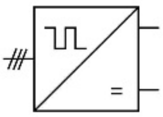
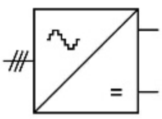
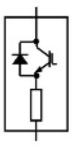
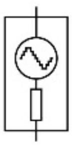
VCU valve control unit

VSC voltage-sourced converter

NOTE Even though the word “breaker” is used in the abbreviations, it does not necessarily imply the ability to interrupt fault currents.

4 Graphical symbols

Figure 2 shows the specific graphical symbols which are defined only for the purposes of this standard. IEC 60617 shall be used for a more complete list of the graphical symbols which have been adopted for static converters.

No.	Symbol	Description
1		IGBT-diode pair
2		Valve of “switch” type
3		Valve of “controllable voltage source” type
4		VSC unit (of unspecified type)
5		VSC unit using switch type valves
6		VSC unit using controllable voltage source type valves
7		Dynamic braking valve of “switch” type
8		Dynamic braking valve of “controllable voltage source” type

IEC

Figure 2 – Graphical symbols

5 General terms related to converter circuits

5.1
conversion
in the context of HVDC, the transfer of energy from a.c. to d.c. or vice versa, or a combination of these operations

5.2
converter
in the context of HVDC, the device employed to transfer of energy from a.c. to d.c. or vice versa, it connects between three a.c. terminals and two d.c. terminals

5.3
voltage-sourced converter
VSC
electronic a.c./d.c. converter having an essentially smooth d.c. voltage provided by e.g. a common d.c. link capacitor or distributed d.c. capacitors within the converter arms

5.4
arm
converter arm
part of a converter connecting the a.c. phase terminal with the d.c. pole terminal

5.5
commutation
transfer of current between any two paths with both paths carrying current simultaneously during this process

5.6
line commutation
method of commutation whereby the commutating voltage is supplied by the a.c. system

5.7
self-commutation
commutation where the commutating voltage is supplied by components within the converter or the electronic switch

5.8
commutating voltage
voltage which causes the current to commutate, provided either by the system or by a switching action of valve/semiconductor devices

5.9
commutation inductance
total inductance included in the commutation circuit, in series with the commutating voltage

Note 1 to entry: The commutation inductance is typically referred as stray inductance or loop inductance.

5.10
coupling inductance
equivalent inductance referred to the converter side of the interface transformer between the point of common coupling (PCC) and the d.c. terminal of the valve

6 VSC topologies

6.1
two-level converter
converter in which the voltage between the a.c. terminals of the VSC unit (see 7.6) and VSC unit midpoint (see 7.28) is switched between two discrete d.c. voltage levels

6.2
three-level converter
converter in which the voltage between the a.c. terminals of the VSC unit (see 7.6) and VSC unit midpoint (see 7.28) is switched between three discrete d.c. voltage levels

6.3
multi-level converter
converter in which the voltage between the a.c. terminals of the VSC unit (see 7.6) and VSC unit midpoint (see 7.28) is switched between more than three discrete d.c. voltage levels

6.4
modular multi-level converter
MMC
multi-level converter in which each VSC valve (see 7.8, 7.9) consists of a number of MMC building blocks (see 7.11) connected in series

Note 1 to entry: See also Figure 4.

6.5
cascaded two-level converter
CTL
modular multi-level converter in which each switch position consists of more than one IGBT-diode pair connected in series

Note 1 to entry: See Figure 5.

7 Converter units and valves

7.1
turn-off semiconductor device
controllable semiconductor device which may be turned on and off by a control signal, for example an IGBT

7.2
insulated gate bipolar transistor
IGBT
turn-off semiconductor device with three terminals: a gate terminal (G) and two load terminals emitter (E) and collector (C)

7.3
free-wheeling diode
FWD
power semiconductor device with diode characteristic

Note 1 to entry: A FWD has two terminals: an anode (A) and a cathode (K).

Note 2 to entry: The current through FWDs is in the opposite direction to the IGBT current.

7.4
IGBT-diode pair
arrangement of IGBT and FWD connected in inverse parallel

Note 1 to entry: An IGBT-diode pair is usually in one common package, however, it can include individual IGBTs and/or diodes packages connected in parallel.

7.5
converter unit
indivisible operative unit comprising all equipment between the point of common coupling on the a.c. side (see 9.25) and the point of common coupling – d.c. side (see 9.26), essentially one or more VSC units, together with one or more interface transformers, converter unit control equipment, essential protective and switching devices and auxiliaries, if any, used for conversion

Note 1 to entry: See Figure 3.

7.6
VSC unit
three VSC phase units, together with VSC unit control equipment, essential protective and switching devices, d.c. storage capacitors, phase reactors and auxiliaries, if any, used for conversion

Note 1 to entry: See Figure 3.

7.7
VSC phase unit
equipment used to connect the two d.c. terminals to one a.c. terminal

Note 1 to entry: In the simplest implementation, the VSC phase unit consists of two VSC valves, and in some case, it may include also valve reactors. The VSC phase unit may also include control and protection equipment, and other components.

7.8
VSC valve
<switch type> arrangement of IGBT-diode pairs connected in series and arranged to be switched simultaneously as a single function unit

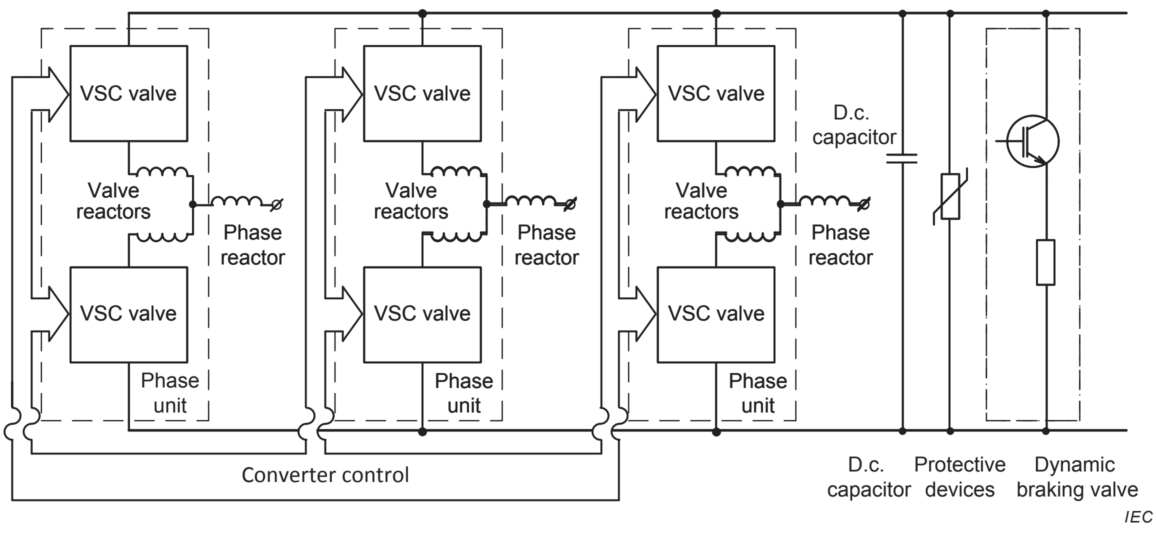


Figure 3 – Voltage-sourced converter unit

Note 1 to entry: In some designs of VSC, the phase reactors may fulfill part of the function of the converter-side high frequency filter. In addition, in some designs of VSC, part or all of the phase reactor may be built into the three “phase units” of the VSC unit, as “valve reactors”.

Note 2 to entry: In some designs of VSC, the VSC d.c. capacitor may be partly or entirely distributed amongst the three “phase units” of the VSC unit, where it is referred to as d.c. submodule capacitors.

Note 3 to entry: Valve and/or phase reactors shown above show optional configurations which may not be included in all schemes.

Note 4 to entry: Just a typical example of how a VSC unit could look like is shown in Figure 3, differences may exist at all levels.

7.9
VSC valve
<controllable voltage source type> complete controllable voltage source assembly, which is generally connected between one a.c. terminal and one d.c. terminal

7.10
VSC valve level
the smallest indivisible functional unit of VSC valve

Note 1 to entry: For any VSC valve in which IGBTs are connected in series and operated simultaneously, one VSC valve level is one IGBT-diode pair including its auxiliaries (see Figure 4). For MMC type without IGBT-diode pairs connected in series, one valve level is one submodule together with its auxiliaries (see Figure 5).

7.11
MMC building block
self-contained, two-terminal controllable voltage source together with d.c. capacitor(s) and immediate auxiliaries, forming part of a MMC

7.12
switch position
semiconductor function which behaves as a single, indivisible switch

Note 1 to entry: A switch position may consist of a single IGBT-diode pair or, in the case of the Cascaded Two Level converter, a series connection of multiple IGBT-diode pairs.

7.13
submodule
MMC building block where each switch position consists of only one IGBT-diode pair

Note 1 to entry: See Figure 4.

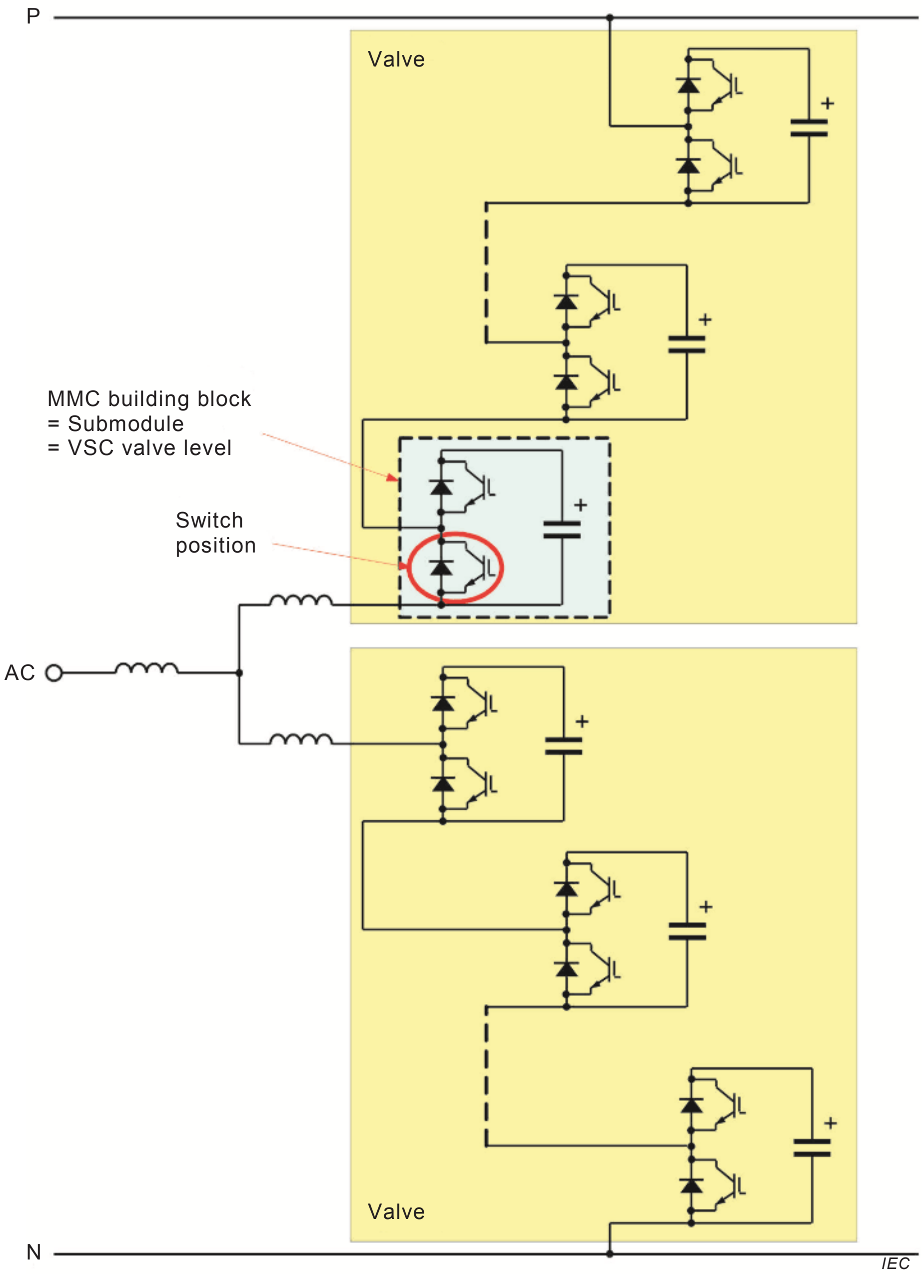


Figure 4 – Phase unit of the modular multi-level converter (MMC) in basic half-bridge, two-level arrangement, with submodules

7.14
cell
MMC building block where each switch position consists of more than one IGBT-diode pair connected in series

Note 1 to entry: See Figure 5.

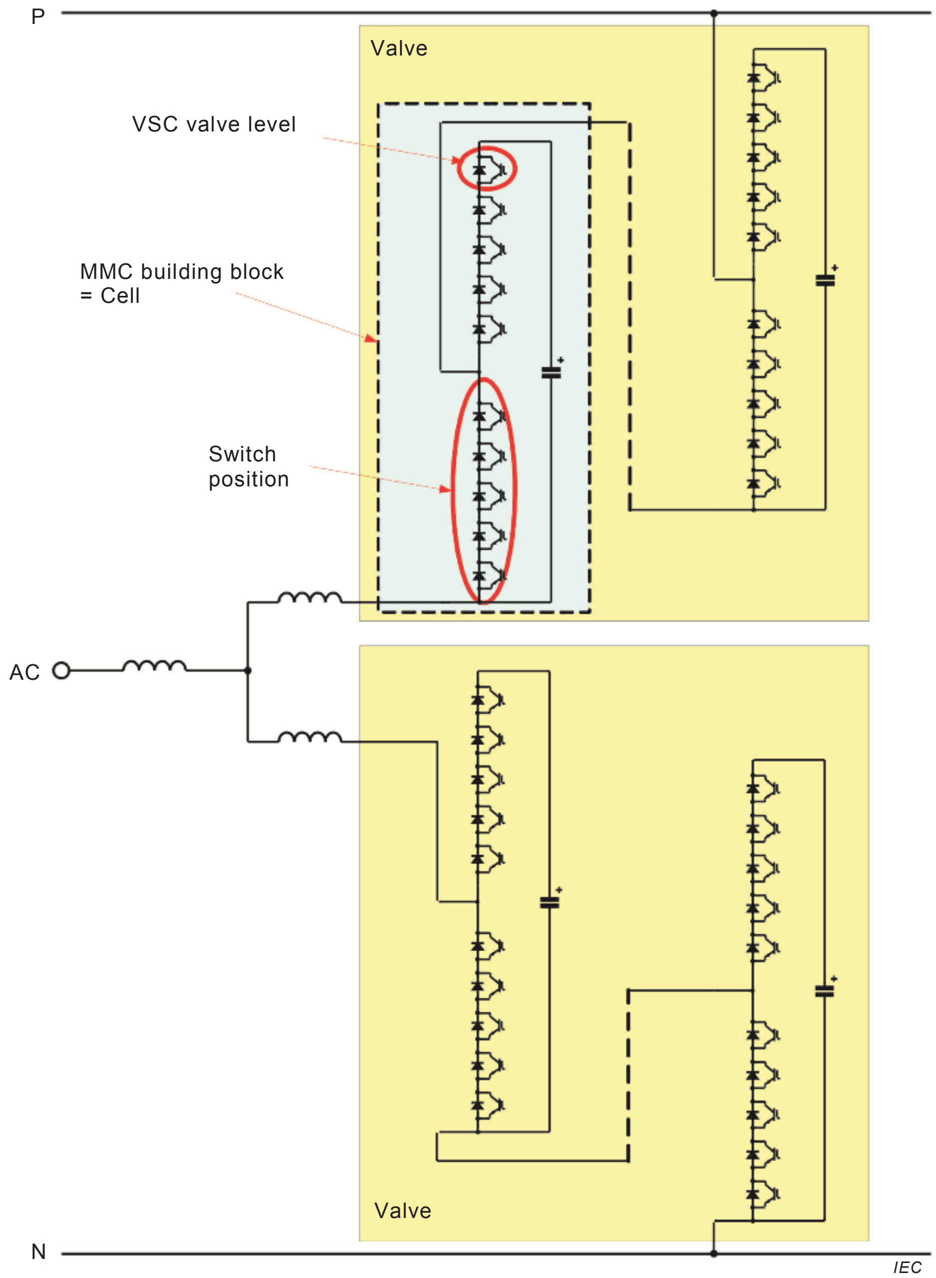


Figure 5 – Phase unit of the cascaded two-level converter (CTL) in half-bridge form

7.15
diode valve
semiconductor valve containing only diodes as the main semiconductor devices and associated circuits and components if any, which might be used in some VSC topologies

7.16
diode valve level
part of a diode valve composed of a diode and associated circuits and components, if any

7.17
dynamic braking valve
complete controllable device assembly, which is used to control energy absorption in a dynamic braking resistor

7.18
dynamic braking valve level
part of a dynamic braking valve comprising a turn-off semiconductor device and an associated diode, or controllable switches and diodes connected in parallel, or turn-off semiconductor devices and diodes connected to a half bridge arrangement, together with their immediate auxiliaries, storage capacitor, if any

7.19
valve
VSC valve, dynamic braking valve or diode valve according to the context

7.20
redundant levels
the maximum number of series connected VSC valve levels or diode valve levels in a valve that may be short-circuited externally or internally without affecting the safe operation of the valve as demonstrated by type tests, and which if and when exceeded, would require shutdown of the valve to replace the failed levels or acceptance of increased risk of failures

Note 1 to entry: In valve designs such as the cascaded two level converter, which contain two or more conduction paths within each cell and have series-connected VSC valve levels in each path, redundant levels shall be counted only in one conduction path in each cell.

7.21
d.c. capacitor
capacitor which is used as part of a voltage-sourced converter which experiences mainly d.c. voltage between its terminals

Note 1 to entry: For valves of the controllable switch type, the d.c. capacitor is usually arranged as a single device between the d.c. terminals. For valves of the controllable voltage-sourced type the d.c. capacitor is usually distributed amongst the MMC building blocks.

7.22
valve reactor
reactor (if any) which is connected in series to a VSC valve of the controllable voltage-source type

Note 1 to entry: One or more valve reactors can be associated to one VSC valve and might be connected at different positions within the valve. According to the definition, valve reactors are not part of the VSC valve. However, it is also possible to integrate the valve reactors in the structural design of the VSC valve, e.g. into each valve level.

7.23
valve module
the largest factory-assembled and tested building block of the valve, consisting of one or more VSC valve levels, submodules or cells connected electrically in series

7.24
valve structure
structural components of a valve, required in order to mechanically support the valve modules

7.25
valve support
that part of the valve which mechanically supports and electrically insulates the active part of the valve from earth

Note 1 to entry: A part of a valve which is clearly identifiable in a discrete form to be a valve support may not exist in all designs of valves.

7.26
multiple valve unit
MVU
mechanical arrangement of 2 or more valves or 1 or more VSC phase units sharing a common valve support

Note 1 to entry: A MVU might not exist in all topologies and physical arrangement of converters.

7.27
valve section
electrical assembly defined for test purposes, comprising a number valve levels and other components, which exhibits pro-rated electrical properties of a complete valve

Note 1 to entry: For valves of controllable voltage source type, the valve section includes d.c. capacitor in addition to VSC valve levels.

7.28
VSC unit midpoint
point in a VSC unit whose electrical potential is equal to the average of the potentials of the positive and negative d.c. terminals of the VSC unit

Note 1 to entry: In some applications, the VSC unit midpoint may exist only as a virtual point, not corresponding to a physical node in the circuit.

8 Converter operating conditions

8.1
rectifier operation
rectification
mode of operation of a converter or an HVDC substation when energy is transferred from the a.c. side to the d.c. side

Note 1 to entry: Phasor diagram showing a.c. system voltage, converter a.c. voltage and converter a.c. current for rectifier operation is shown in Figure 6.

8.2
inverter operation
inversion
mode of operation of a converter or an HVDC substation when energy is transferred from the d.c. side to the a.c. side

Note 1 to entry: Phasor diagram showing a.c. system voltage, converter a.c. voltage and converter a.c. current for inverter operation is shown in Figure 6.

8.3
capacitive operation
operation in which the converter feeds reactive power into the a.c. system with or without exchanging active power

8.4
inductive operation
operation in which the converter consums reactive power from the a.c. system with or without exchanging active power

8.5
STATCOM operation
mode of operation of a converter when only reactive power (capacitive or inductive) is exchanged with the a.c. system

8.6
operating state
condition in which the HVDC substation is energized and the converters are de-blocked

Note 1 to entry: Unlike line-commutated converter, VSC can operate with zero active/reactive power output.

8.7
no-load operating state
condition in which the HVDC substation is energized but the IGBTs are blocked and all necessary substation service loads and auxiliary equipment are connected

8.8
idling operating state
condition in which the HVDC substation is energized and the IGBTs are de-blocked but with no active or reactive power output at the point of common connection to the a.c. network

Note 1 to entry: The “idling operating” and “no-load” conditions are similar but from the no-load state, several seconds may be needed before power can be transmitted, while from the idling operating state, power transmission may be commenced almost immediately (less than 3 power frequency cycles).

Note 2 to entry: In the idling operating state, the converter is capable of actively controlling the d.c. voltage, in contrast to the no-load state, where the behavior of the converter is essentially “passive”.

Note 3 to entry: Losses will generally be slightly lower in the no-load state than in the idling operating state, therefore this operating mode is preferred where the arrangement of the VSC system permits it.

8.9
blocked state
condition in which all valves of the VSC unit are blocked

8.10
converter charging
transitional condition of the converter when the a.c. system voltage is applied to the converter via a pre-insertion resistor

Note 1 to entry: Pre-insertion resistor may not be necessary in all applications.

8.11
modulation index
M
ratio of the peak line to ground a.c. converter voltage, to half of the converter d.c. terminal to terminal voltage

$$M = \frac{\sqrt{2} \cdot U_{\mathrm{c1}}}{\sqrt{3} \cdot \frac{U_{\mathrm{dc}}}{2}}$$

where

U_{c1} is the r.m.s value of the fundamental frequency component of the line-to-line voltage U_{c};

U_{c} is the output voltage of one VSC phase unit at its a.c. terminal;

U_{dc} is the output voltage of one VSC phase unit at its d.c. terminals.

Note 1 to entry: Some sources define modulation index in a different way such that a modulation index of 1 refers to a square-wave output, which means that the modulation index can never exceed 1. The modulation index according to that definition is given simply by M·(π/4). However, that definition is relevant mainly to two-level converters using pulse width modulation (PWM).

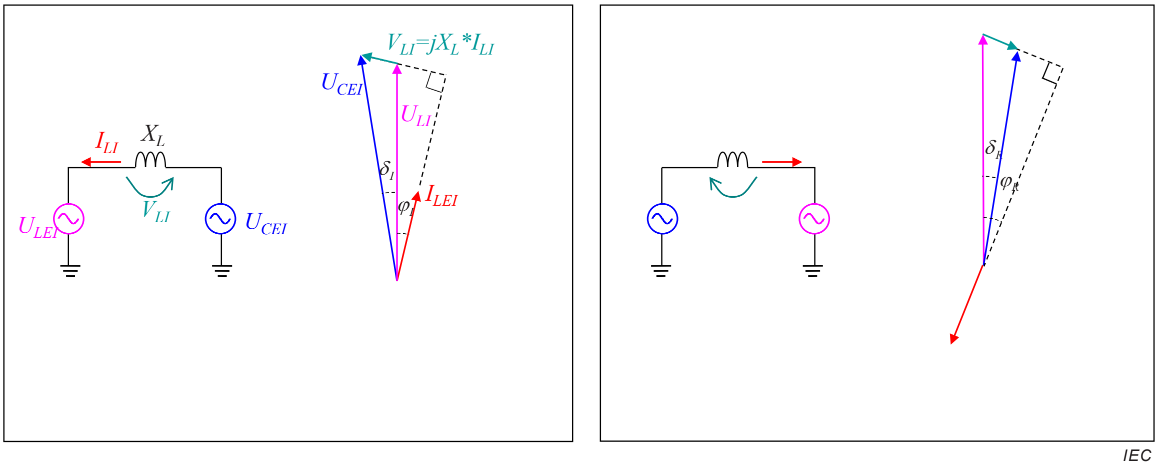


Figure 6 – Phasor diagram showing a.c. system voltage, converter a.c. voltage and converter a.c. current

8.12
positive conducting state
condition of an IGBT-diode pair in which load current flows through the IGBT from collector to emitter

8.13
negative conducting state
condition of an IGBT-diode pair in which load current flows through the free-wheeling diode from anode to cathode

8.14
positive valve current
direction of current flow through the valve from positive d.c. terminal to negative d.c. terminal or, in case of a diode valve, in the direction that forward biases the diode valve

8.15
negative valve current
direction of current flow through the valve from negative d.c. terminal to positive d.c. terminal

8.16
positive valve terminal
terminal of the valve that is closest to the positive d.c. terminal of the VSC unit

8.17
negative valve terminal
terminal of the valve that is closest to the negative d.c. terminal of the VSC unit

8.18
valve voltage
potential difference between the positive valve terminal and negative valve terminal

8.19
valve blocking state
condition of a valve when all IGBTs are turned off

8.20
IGBT gating
control action carried out to establish a current or interrupt a current in an IGBT

8.21
short-circuit failure mode
condition of an IGBT in which it is no longer capable of withstanding voltage but can safely conduct current in either direction

8.22
MMC building block operating states
possible states under which MMC building blocks can be operated

8.22.1
bypassed
operating state where the IGBT(s) of one or more switch positions are turned on such that the valve current does not flow through the cell/submodule d.c. capacitor

8.22.2
active
operating state where the IGBT(s) of one or more switch positions are turned on such that the valve current flows through the cell/submodule d.c. capacitor

8.22.3
protectively bypassed
emergency operating state where the valve current flows through a protective device other than the IGBT(s)/diode(s) in order to prevent damage to the MMC building block or its components

Note 1 to entry: Protective bypassing may be used for either permanent or temporary conditions depending on the type of fault.

8.22.4
converter blocking
operation to initiate a mode change from operating state to blocked state of a VSC unit

8.23
valve protective blocking
means of protecting the valve or converter from excessive electrical stress by the emergency turn-off of all IGBTs in one or more valves

8.24
converter deblocking
operation to initiate a mode change from blocked state to operating state of a VSC unit

8.25
short-circuit ratio
SCR
ratio of the a.c network short-circuit level (in MVA) at 1 p.u. voltage at the point of connection to the HVDC substation a.c. bus, to the rated d.c. power of the HVDC substation (in MW)

8.26
effective short-circuit ratio
ESCR
ratio of the a.c. network short-circuit level (in MVA) at 1 p.u. voltage at the point of connection to the HVDC substation a.c. bus, reduced by the reactive power of the shunt capacitor banks and a.c. filters, if any, connected to this point (in MVAr), to the rated d.c. power of the HVDC substation (in MW)

9 HVDC systems and substations

9.1
HVDC system
electrical power system which transfers energy in the form of high-voltage direct current between two or more a.c. buses

9.2
HVDC transmission system
HVDC system which transfers energy between two or more geographic locations

9.3
two-terminal HVDC transmission system
HVDC transmission system consisting of two HVDC transmission substations and the connected HVDC transmission line(s)

9.4
multiterminal HVDC transmission system
MTDC
HVDC transmission system consisting of more than two separated HVDC substations and the interconnecting HVDC transmission lines

9.5
symmetrical monopole
single VSC converter with symmetrical d.c. voltage output on the two terminals

Note 1 to entry: The term "symmetrical monopole" is used even though there are two polarities with d.c. voltages, because with only one converter it is not possible to provide the redundancy which is normally associated with the term "bipole".

9.6
asymmetrical monopole
single VSC converter with asymmetrical d.c. voltage output on the two terminals, normally with one terminal earthed

9.7
bipole
two or more VSC asymmetrical monopoles forming a bipolar d.c. circuit

9.8
parallel converter configuration
two or more converters located in the same substation and connected to the same a.c. and d.c. transmission system connected in parallel

9.9
series converter configuration
two or more converters located in the same substation and connected to the same a.c. and d.c. transmission systems, connected in parallel on the a.c. side and in series in the d.c. side

9.10
bi-directional HVDC system
HVDC system for the transfer of energy in either direction

9.11
uni-directional HVDC system
HVDC system for the transfer of energy in only one direction

Note 1 to entry: Most HVDC systems are inherently bi-directional. However, some systems may be optimized to transmit power in only one preferred direction. Such systems may still be considered as "bi-directional".

9.12
HVDC back-to-back system
HVDC system which transfers energy between a.c. buses at the same location

9.13
(HVDC) (system) pole
part of an HVDC system consisting of all the equipment in the HVDC substations and the interconnecting transmission lines, if any, which during normal operation exhibit a common direct voltage polarity with respect to earth

Note 1 to entry: See Figure 7.

9.14
(HVDC) (system) bipole
part of an HVDC system consisting of two HVDC system poles, which during normal operation, exhibit opposite direct voltage polarities with respect to earth

9.15
bipolar (HVDC) system
HVDC system with two independently operable poles of opposite polarity with respect to earth

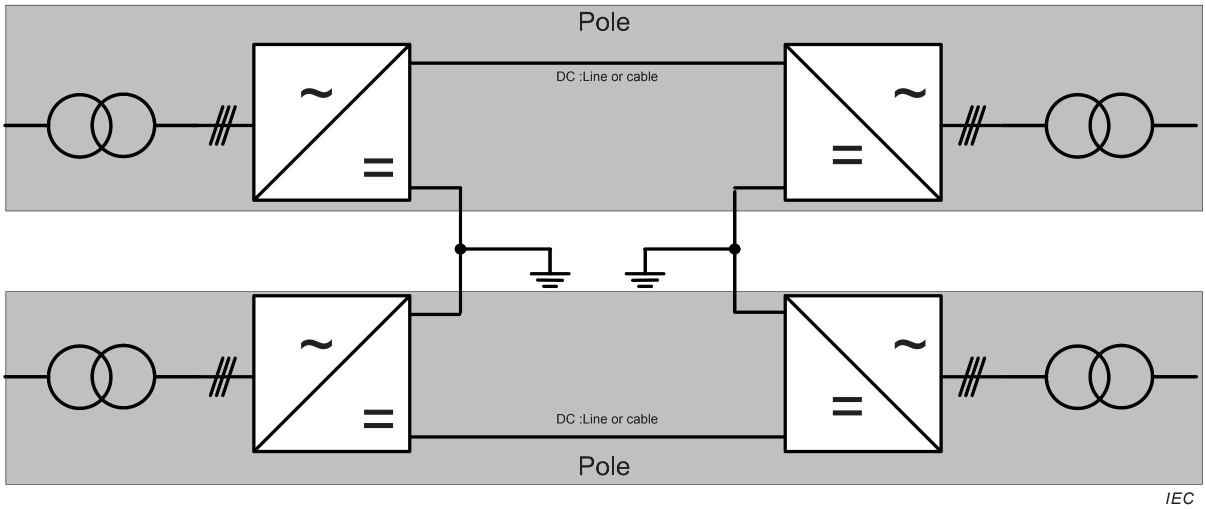


Figure 7 – Example of bipolar VSC transmission with earth return

9.16
earth return
operation mode in which the return current path between neutrals of the HVDC substations is through the earth

9.17
metallic return
operation mode in which the return current path between neutrals of the HVDC substations is through a dedicated conductor

Note 1 to entry: The metallic return conductor may be either a dedicated neutral conductor or another high voltage conductor.

9.18
monopolar (HVDC system)
HVDC system with only one pole

9.19
symmetrical monopolar HVDC system
HVDC system consisting of a single converter unit or a parallel connection of two or more converter units at each substation operated such that the two d.c. output terminals are at symmetrical voltages with respect to earth

Note 1 to entry: See Figure 8.

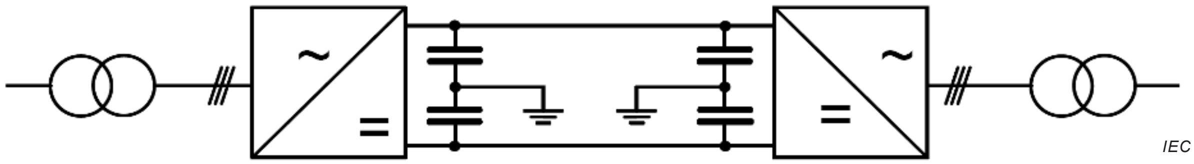


Figure 8 – VSC transmission with a symmetrical monopole illustrated with capacitive earthing on the d.c. side

9.20
asymmetrical monopolar HVDC system
HVDC system consisting of a single converter unit or a parallel connection of two or more converter units at each substation operated such that one of the two d.c. output terminals of at least one substation is earthed

Note 1 to entry: See Figures 9 and 10.

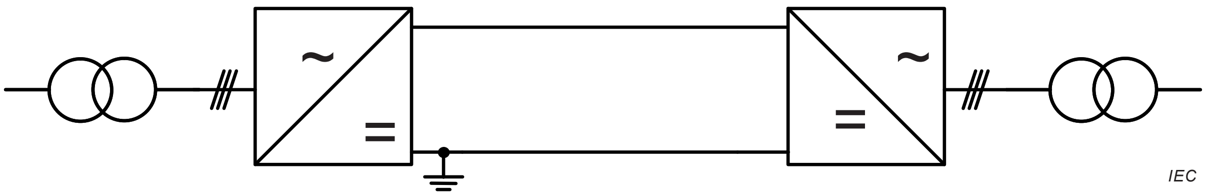


Figure 9 – VSC transmission with an asymmetrical monopole with metallic return

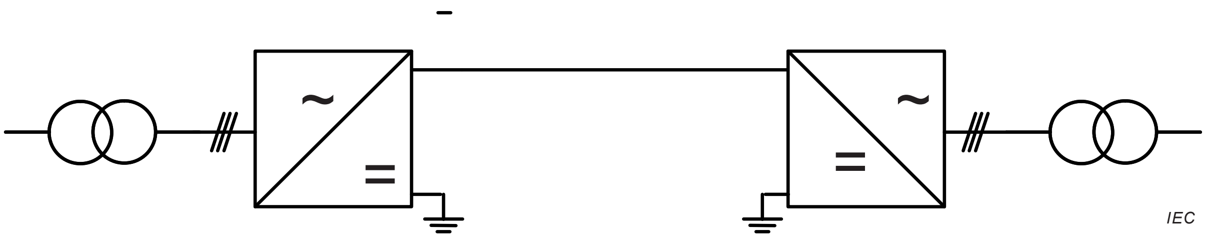


Figure 10 – VSC transmission with an asymmetrical monopole with earth return

9.21
HVDC substation
HVDC converter station
part of an HVDC system which consists of one or more converter units installed in a single location together with buildings, reactors, filters, reactive power supply, control, monitoring, protective, measuring and auxiliary equipment

Note 1 to entry: An HVDC substation forming part of an HVDC transmission may be referred to as an HVDC transmission substation.

9.22
HVDC transmission line
part of a pole consisting of overhead lines and/or cables connecting two HVDC substations

9.23
earth electrode
array of conducting elements placed in the earth, or the sea, which provides a low resistance path between a point in the d.c. circuit and the earth and is capable of carrying continuous current for some expected period

9.24
earth electrode line
insulated line between the HVDC substation d.c. neutral bus and the earth electrode

9.25
point of common coupling
PCC
point of interconnection of the HVDC converter station to the adjacent a.c. system

9.26
point of common coupling – d.c. side
PCC-DC
point of interconnection of the HVDC converter station to the d.c. transmission line

10 HVDC substation equipment

NOTE Major components that can be found in a VSC substation are shown in Figure 11.

10.1
HVDC substation circuit breaker
circuit breaker located at the feeder from the a.c. transmission system to connect and disconnect the HVDC substation

10.2
pre-insertion resistor
during energization of the HVDC substation, temporarily inserted resistor to reduce charging currents of the d.c. circuit

Note 1 to entry: The pre-insertion resistor could be integrated within the substation circuit breaker.

10.3
a.c. harmonic filters
filter circuits to prevent VSC-generated harmonics – if applicable – from penetrating into the a.c. system or to prevent amplification of background harmonics on the a.c. system

Note 1 to entry: AC harmonic filters can be installed on either the line side or the converter side of the interface transformer.

10.4
high frequency filters
HF filters
filter circuits to prevent VSC-generated high frequency (HF) harmonics – if applicable – from penetrating into the a.c. system

Note 1 to entry: High frequency filters can be installed on either the line side or the converter side of the interface transformer.

10.5
interface transformer
transformer (if any) through which power is transmitted between the a.c. system connection point and one or more VSC units

Note 1 to entry: The term “converter transformer” is also used for this equipment.

10.6
phase reactor
a reactor connected directly to the a.c. terminal of the VSC phase unit forming part of the coupling inductance

10.7
VSC d.c. capacitor
capacitor bank (s) (if any) connected between two d.c. terminals of the VSC

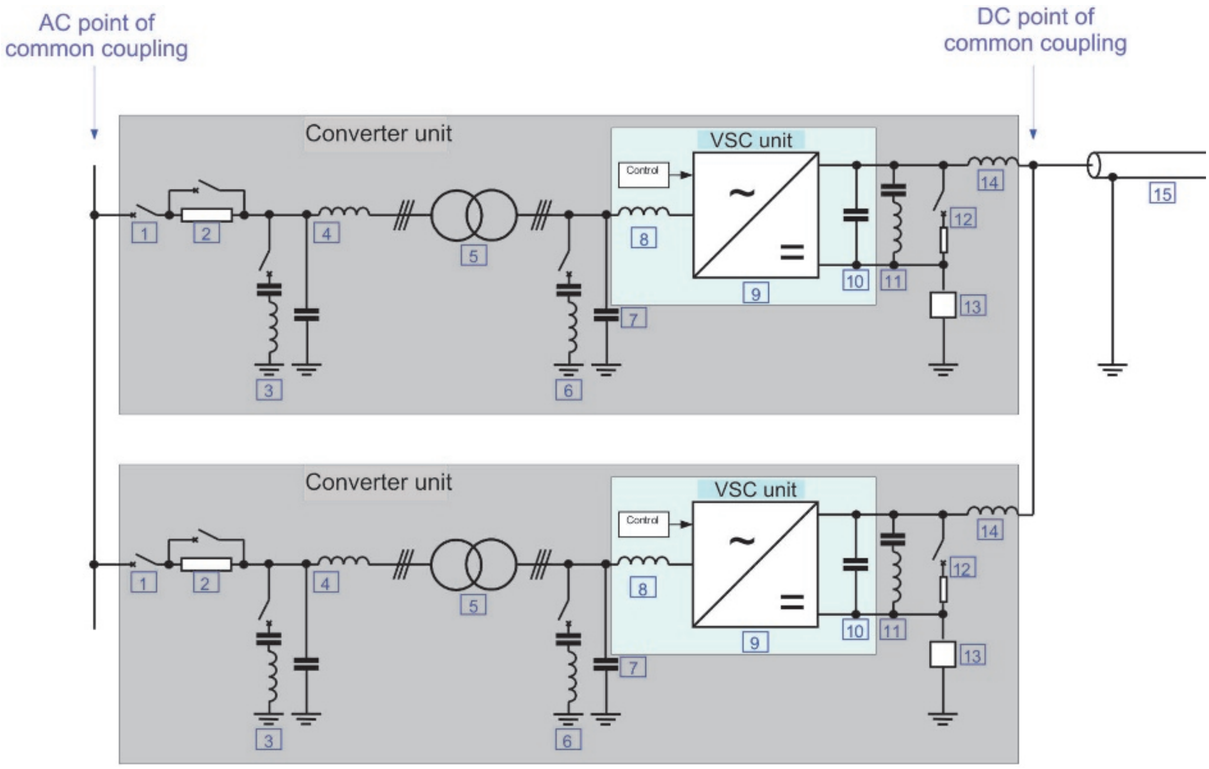
10.8
common mode blocking reactor
reactor (if any) used to reduce common mode alternating currents flowing into a d.c. overhead line or cable of an HVDC transmission scheme

10.9
d.c. harmonic filter
d.c. filters (if any) used to prevent harmonics generated by VSC valve from penetrating into the d.c. system

10.10
d.c. reactor
a reactor (if any) connected in series to a d.c. busbar

10.11
converter unit arrester
arrester connected across the d.c. terminals of a converter unit

10.12
converter unit d.c. bus arrester
arrester connected from the high voltage d.c. bars of the converter unit to substation earth



Key

1	Circuit breaker	9	VSC unit [b]
2	Pre-insertion resistor	10	VSC d.c. capacitor [c]
3	Line side harmonic filter	11	DC harmonic filter
4	Line side high frequency filter	12	Dynamic braking system
5	Interface transformer	13	Neutral point grounding branch [d]
6	Converter side harmonic filter	14	DC reactor
7 + 8	Converter side high frequency filter[a]	15	DC cable or overhead transmission line
8	Phase reactor [a]		

[a] In some designs of VSC, the phase reactor may fulfill part of the function of the converter-side high frequency filter.

[b] In some VSC topologies, each valve of the VSC unit may include a “valve reactor”, which may be built in to the valve or provided as a separate component.

[c] In some designs of VSC, the VSC d.c. capacitor may be partly or entirely distributed amongst the three phase units of the VSC unit, where it is referred to as the d.c. submodule capacitors.

[d] The philosophy and location of the neutral point grounding branch may be different depending on the design of the VSC unit.

Figure 11 – Major components that may be found in a VSC substation

10.13
metallic return transfer breaker
MRTB
switching device used to transfer d.c. current from an earth return path to a metallic return path

10.14
earth return transfer breaker
ERTB
switching device used to transfer d.c. current from a metallic return path to an earth return path

10.15
neutral bus switch
NBS
switching device used to transfer d.c. current from a fault on the neutral bus into the metallic or earth return path

10.16
neutral bus grounding switch
NBGS
switching device used to transfer d.c. current from a fault on the neutral bus or neutral conductor into station ground

11 Modes of control

11.1
control mode
manner in which a converter unit, pole or HVDC substation is controlled in order to maintain one or more electrical quantities at desired values

Note 1 to entry: The desired values may change with time or as a function of measured quantities and defined priorities.

11.2
d.c. voltage control mode
control of the d.c. voltage in an HVDC substation

11.3
active power control mode
control of the active power exchanged between an HVDC substation and the connected a.c. network

11.4
a.c.voltage control mode
control of the a.c. voltage of the a.c. network connected to an HVDC substation

11.5
reactive power control mode
control of the reactive power exchanged between an HVDC substation and the connected a.c. network

11.6
islanded network operation mode
control mode in which the HVDC substation controls the frequency and the voltage of the connected islanded a.c. network

11.7
frequency control mode
control of the frequency of the connected a.c. network by varying the active power exchanged between an HVDC substation and the connected a.c. network

11.8
damping control mode
control mode providing the damping of power oscillations or sub-synchronous oscillations in a connected a.c. network

12 Control systems

12.1
integrated a.c./d.c. system control
control system which governs the integrated operation of a.c. and HVDC systems of a power system

Note 1 to entry: This control system is under the responsibility of the system operator.

12.2
control system
HVDC control system
function of, or the equipment used for, controlling, monitoring or protection of main plant equipment, such as circuit breakers, valves, interface transformers and their tap changers, forming part of an HVDC system

Note 1 to entry: An example illustrating a typical HVDC control system hierarchy is shown in Figure 12.

12.3
HVDC system control
control system which governs the operation of an entire HVDC system consisting of more than one HVDC substation and performs those functions of controlling, monitoring and protection which require information from more than one substation

Note 1 to entry: See Figure 12.

12.4
multiterminal control
HVDC system control for more than two HVDC substations

12.5
(HVDC system) bipole control
control system of a bipole

Note 1 to entry: See Figure 12.

12.6
(HVDC system) pole control
control system of a pole

Note 1 to entry: See Figure 12.

Note 2 to entry: When the HVDC system has no bipole(s) but one or more poles, the pole control interfaces with the HVDC system control.

12.7
(HVDC) station control
control system used for the controlling, monitoring and protection within an HVDC substation

Note 1 to entry: HVDC station control may be implemented at the bipole and/or pole level and may be referred to as local control.

12.8
converter control
control system used for the controlling, monitoring and protection of a single converter unit

Note 1 to entry: See Figure 12.

12.9
valve base electronics
VBE
electronic unit, at earth potential, providing the electrical to optical conversion between the converter control system and the VSC valves

12.10
valve control unit
VCU
electronic unit, at earth potential, providing the control and protection functions for individual valves

Note 1 to entry: VBE and VCU functions could be combined in one unit.

12.11
valve electronics
electronic circuits at valve potential(s) which perform control and protection functions for one or more valve levels

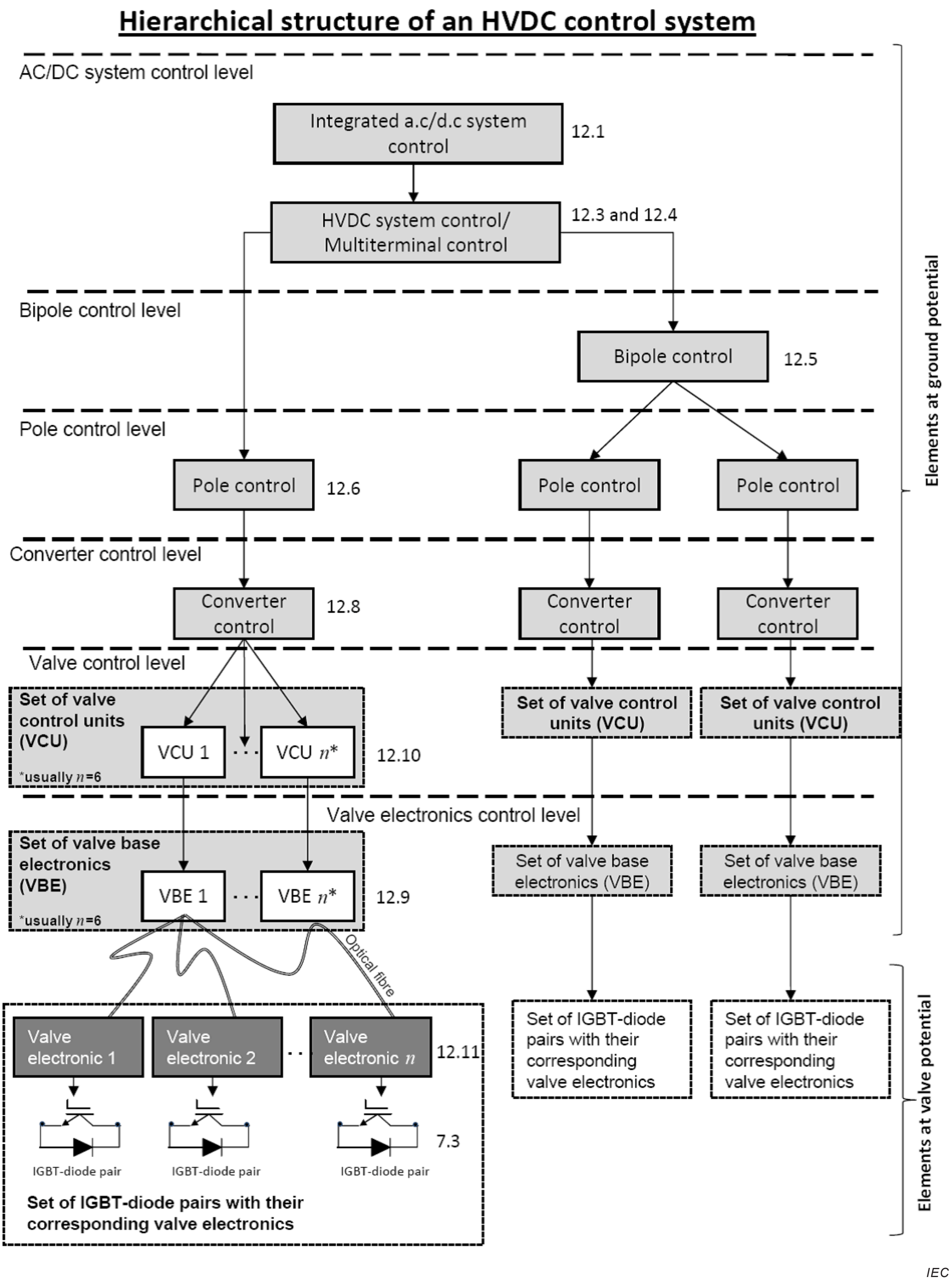


Figure 12 – Hierarchical structure of an HVDC control system

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