

TECHNICAL REPORT



High-voltage direct current (HVDC) power transmission using voltage sourced converters (VSC)

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CONTENTS

FOREWORD.....	6
1 Scope.....	8
2 Normative references	8
3 Terms and definitions	8
3.1 General	8
3.2 Letter symbols.....	9
3.3 Power semiconductor terms	9
3.4 VSC topologies	10
submodule d.c. capacitor.....	12
3.5 VSC transmission.....	12
3.6 Operating states.....	14
3.7 Type tests	15
3.8 Production tests	15
3.9 Sample tests	15
3.10 Insulation co-ordination terms	16
3.11 Power losses.....	16
4 VSC transmission overview	17
4.1 Basic operating principles of VSC transmission.....	17
4.1.1 The voltage sourced converter as a black box.....	17
4.1.2 The principles of active and reactive power control.....	18
4.1.3 Operating principles of a VSC transmission scheme.....	19
4.1.4 Applications of VSC transmission.....	20
4.2 Design life	20
4.3 VSC transmission configurations	20
4.3.1 General	20
4.3.2 D.C. circuit configurations.....	21
4.3.3 Monopole configuration	21
4.3.4 Bipolar configuration.....	22
4.3.5 Parallel connection of two converters	22
4.3.6 Series connection of two converters	23
4.3.7 Parallel and series connection of more than two converters.....	23
4.4 Semiconductors for VSC transmission.....	23
5 VSC transmission converter topologies	25
5.1 General	25
5.2 Converter topologies with VSC valves of “switch” type	25
5.2.1 General	25
5.2.2 Operating principle	26
5.2.3 Topologies.....	26
5.3 Converter topologies with VSC valves of the “controllable voltage source” type.....	29
5.3.1 General	29
5.3.2 MMC topology with VSC levels in half-bridge topology.....	30
5.3.3 MMC topology with VSC levels in full-bridge topology.....	31
5.4 VSC valve design considerations	32
5.4.1 Reliability and failure mode	32
5.4.2 Current rating	33

5.4.3	Transient current and voltage requirements	33
5.4.4	Diode requirements	33
5.4.5	Additional design details	34
5.5	Other converter topologies	34
5.6	Other equipment for VSC transmission schemes	35
5.6.1	General	35
5.6.2	Power components of a VSC transmission scheme	35
5.6.3	VSC substation circuit breaker	35
5.6.4	A.C. system side harmonic filters	35
5.6.5	Radio frequency interference filters	36
5.6.6	Interface transformers and phase reactors	36
5.6.7	Valve reactor	37
5.6.8	D.C. capacitors	37
5.6.9	D.C. reactor	39
5.6.10	Common mode blocking reactor	39
5.6.11	D.C. filter	39
6	Overview of VSC controls	39
6.1	General	39
6.2	Operational modes and operational options	40
6.3	Power transfer	41
6.3.1	General	41
6.3.2	Telecommunication between converter stations	42
6.4	Reactive power and a.c. voltage control	42
6.4.1	A.C. voltage control	42
6.4.2	Reactive power control	42
6.5	Black start capability	43
6.6	Supply from a wind farm	43
7	Steady state operation	44
7.1	Steady state capability	44
7.2	Converter power losses	45
8	Dynamic performance	45
8.1	A.C. system disturbances	45
8.2	D.C. system disturbances	46
8.2.1	D.C. cable fault	46
8.2.2	D.C. overhead line fault	46
8.3	Internal faults	46
9	HVDC performance requirements	47
9.1	Harmonic performance	47
9.2	Wave distortion	48
9.3	Fundamental and harmonics	48
9.3.1	Three-phase 2-level VSC	48
9.3.2	Selective harmonic elimination modulation	50
9.3.3	Multi-pulse and multi-level converters	51
9.4	Harmonic voltages on power systems due to VSC operation	51
9.5	Design considerations for harmonic filters (a.c. side)	52
9.6	D.C. side filtering	52
10	Environmental impact	52
10.1	General	52

10.2 Audible noise	52
10.3 Electric and magnetic fields (EMF)	53
10.4 Electromagnetic compatibility (EMC)	53
11 Testing and commissioning	54
11.1 General	54
11.2 Factory tests	54
11.2.1 Component tests	54
11.2.2 Control system tests	54
11.3 Commissioning tests / System tests	55
11.3.1 General	55
11.3.2 Precommissioning tests	55
11.3.3 Subsystem tests	55
11.3.4 System tests	56
Annex A (informative) Functional specification requirements for VSC transmission systems	60
Annex B (informative) Determination of VSC valve power losses	68
Bibliography	77
Figure 1 – Major components that may be found in a VSC substation	9
Figure 2 – Diagram of a generic voltage source converter (a.c. filters not shown)	17
Figure 3 – The principle of active power control	18
Figure 4 – The principle of reactive power control	19
Figure 5 – A point-to-point VSC transmission scheme	19
Figure 6 – VSC transmission with a symmetrical monopole	21
Figure 7 – VSC transmission with an asymmetrical monopole with metallic return	22
Figure 8 – VSC transmission with an asymmetrical monopole with earth return	22
Figure 9 – VSC transmission in bipolar configuration	22
Figure 10 – Parallel connection of two converter units	23
Figure 11 – Symbol of a controllable switch and associated free-wheeling diode	24
Figure 12 – Symbol of an IGBT	24
Figure 13 – Diagram of a three-phase 2-level converter and associated a.c. waveform for one phase	26
Figure 14 – Single-phase a.c. output for 2-level converter with PWM switching at 21 times fundamental frequency	27
Figure 15 – Diagram of a three-phase 3-level NPC converter and associated a.c. waveform for one phase	28
Figure 16 – Single-phase a.c. output for 3-level NPC converter with PWM switching at 21 times fundamental frequency	29
Figure 17 – Electrical equivalent for a converter with VSC valves acting like a controllable voltage source	30
Figure 18 – VSC valve level arrangement and equivalent circuit in MMC topology in half-bridge topology	30
Figure 19 – Converter block arrangement with MMC topology in half-bridge topology	31
Figure 20 – VSC valve level arrangement and equivalent circuit in MMC topology with full-bridge topology	32
Figure 21 – Typical SSOA for the IGBT	33
Figure 22 – A 2-level VSC bridge with the IGBTs turned off	33

Figure 23 – Representing a VSC unit as an a.c. voltage of magnitude U and phase angle δ behind reactance.....	40
Figure 24 – Concept of vector control	41
Figure 25 – VSC power controller	41
Figure 26 – A.C. voltage controller.....	42
Figure 27 – A typical simplified PQ diagram.....	44
Figure 28 – Protection concept of a VSC substation.....	47
Figure 29 – Waveforms for three-phase 2-level VSC.....	49
Figure 30 – Voltage harmonics spectra of a 2-level VSC with carrier frequency at 21st harmonic.....	50
Figure 31 – Phase output voltage for selective harmonic elimination modulation (SHEM).....	50
Figure 32 – Equivalent circuit at the PCC of the VSC.....	51
Figure B.1 – On state voltage of an IGBT or free-wheeling diode.....	69
Figure B.2 – Piecewise-linear representation of IGBT or FWD on-state voltage	70
Figure B.3 – IGBT switching losses as a function of collector current.....	73
Figure B.4 – Free-wheeling diode recovery loss as a function of current.....	74

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**HIGH-VOLTAGE DIRECT CURRENT (HVDC) POWER TRANSMISSION
USING VOLTAGE SOURCED CONVERTERS (VSC)**

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IEC/TR 62543, which is a technical report, 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 present technical report cancels and replaces IEC/PAS 62543:2008 (Ed.1) which was published by IEC and CIGRÉ jointly, and combined with engineering experience.

The present IEC/TR 62543 bears the edition number 1.

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

Enquiry draft	Report on voting
22F/230/DTR	22F/239A/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

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HIGH-VOLTAGE DIRECT CURRENT (HVDC) POWER TRANSMISSION USING VOLTAGE SOURCED CONVERTERS (VSC)

1 Scope

This technical report gives general guidance on the subject of voltage-sourced converters used for transmission of power by high voltage direct current (HVDC). It describes converters that are not only voltage-sourced (containing a capacitive energy storage medium and where the polarity of d.c. voltage remains fixed) but also self-commutated, using semiconductor devices which can both be turned on and turned off by control action. The scope includes 2-level and 3-level converters with pulse-width modulation (PWM), along with multi-level converters, but excludes 2-level and 3-level converters operated without PWM, in square-wave output mode.

HVDC power transmission using voltage sourced converters is known as “VSC transmission”.

The various types of circuit that can be used for VSC transmission are described in the report, along with their principal operational characteristics and typical applications. The overall aim is to provide a guide for purchasers to assist with the task of specifying a VSC transmission scheme.

Line-commutated and current-sourced converters are specifically excluded from this report.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 61975, *High-voltage direct current (HVDC) installations – System tests*

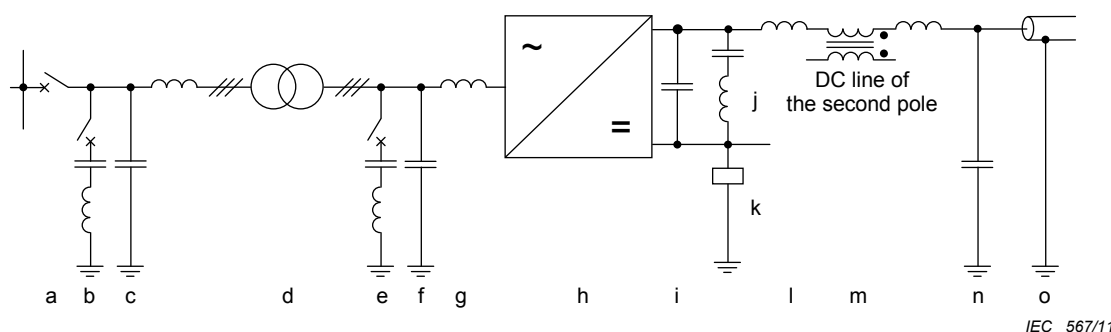
3 Terms and definitions

For the purpose of this document, the following definitions apply.

3.1 General

NOTE This report uses the terminology established by IEC 60633 and IEC 61803 for line-commutated HVDC. Only terms which are specific to HVDC transmission using voltage sourced converters are defined in this clause. Those terms that are either identical to or obvious extensions of IEC 60633 or IEC 61803 terminology have not been defined.

To support the explanations, Figure 1 presents the basic diagram of a VSC system. Dependent on the converter topology and the requirements in the project, some components can be omitted or can differ.



IEC 567/11

Figure 1 – Major components that may be found in a VSC substation

a	circuit breaker	i	VSC d.c. capacitor ^b
b	line side harmonic filter	j	d.c. harmonic filter
c	line side high frequency filter	k	neutral point grounding branch ^c
d	interface transformer	l	d.c. reactor ^d
e	converter side harmonic filter	m	common mode blocking reactor ^d
f + g	converter side high frequency filter ^a	n	d.c. side high frequency filter ^d
g	phase reactor ^a	o	d.c. cable or overhead transmission line ^b
h	VSC unit		

^a In some designs of VSC, the phase reactor may fulfil part of the function of the converter-side high frequency filter. In addition, in some designs of VSC, part of or all of the phase reactor may be built into the three "Phase units" of the VSC unit, as "Valve reactors".

^b 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.

^c The location of the neutral point grounding branch may be different depending on the design of the VSC unit.

^d Not normally required for back-to-back systems.

3.2 Letter symbols

U_{conv} line-to-line a.c. voltage of the converter unit(s), r.m.s. value, including harmonics;

I_{conv} alternating current of the converter unit(s), r.m.s. value, including harmonics;

U_L line-to-line a.c. voltage of the a.c. system, r.m.s. value, including harmonics;

I_L alternating current of the a.c. system, r.m.s. value, including harmonics;

U_d d.c. line-to-line voltage of the d.c. bus of the VSC transmission system;

I_d d.c. current of the d.c. bus of the VSC transmission system.

3.3 Power semiconductor terms

NOTE There are several types of switched valve devices which can be used in voltage sourced converters (VSC) for HVDC and currently the IGBT is the major device used in such converters. The term IGBT is used throughout this technical report to refer to the switched valve device. However, the technical report is equally applicable to other types of devices with turn-off capability in most of the parts.

3.3.1

switched valve devices

a controllable valve device which may be turned on and off by a control signal, for example IGBT

3.3.2

insulated gate bipolar transistor

IGBT

a controllable switch with the capability to turn-on and turn-off a load current. An IGBT has three terminals: a gate terminal (G) and two load terminals emitter (E) and collector (C).

By applying appropriate gate to emitter voltages, current in one direction can be controlled, i.e. turned on and turned off.

3.3.3

free-wheeling diode

FWD

power semiconductor device with diode characteristic. A FWD has two terminals: an anode (A) and a cathode (K). The current through FWDs is in opposite direction to the IGBT current.

FWDs are characterized by the capability to cope with high rates of decrease of current caused by the switching behaviour of the IGBT.

3.3.4

IGBT-diode pair

arrangement of IGBT and FWD connected in inverse parallel

3.4 VSC topologies

3.4.1

symmetrical monopole

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

3.4.2

asymmetrical monopole

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

3.4.3

bipole

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

3.4.4

two-level converter

a converter in which the voltage at the a.c. terminals of the VSC unit is switched between two discrete d.c. voltage levels

3.4.5

three-level converter

a converter in which the voltage at the a.c. terminals of the VSC unit is switched between three discrete d.c. voltage levels

3.4.6

multi-level converter

a converter in which the voltage at the a.c. terminals of the VSC unit is switched between more than three discrete d.c. voltage levels

3.4.7**modular multi-level converter****MMC**

multi-level converter in which each VSC valve consists of a number of self-contained, single-phase voltage sourced converters connected in series

3.4.8**VSC unit**

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

3.4.9**VSC phase unit**

the equipment used to connect the two d.c. busbars to one a.c. terminal

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

3.4.10**VSC valve**

complete controllable device assembly, which represents a functional unit as part of a VSC phase unit and characterized by switching actions of the power electronic devices upon control signals of the converter base electronics

NOTE Dependent on the converter topology, a valve can either have the function to act like a controllable switch or to act like a controllable voltage source.

3.4.11**diode valve**

a semiconductor valve containing diodes but no switched semiconductor devices, which might be used in some VSC topologies

3.4.12**valve**

refers to VSC valve or diode valve according to the context

3.4.13**VSC valve level**

part of a VSC valve comprising a controllable switch and an associated diode, or controllable switches and diodes connected in parallel, or controllable switches and diodes connected to a half bridge or full bridge arrangement, together with their immediate auxiliaries, storage capacitor, if any

NOTE In the context of modular multi-level converters, the term “submodule” is also used to refer to a VSC valve level.

3.4.14**diode valve level**

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

3.4.15**redundant levels**

the maximum number of VSC valve levels or diode valve levels in a valve that may be short-circuited externally or internally during service 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

3.4.16

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

3.4.17

submodule d.c. capacitor

a capacitor (if any) used as part of a certain VSC valve level, which is used as energy storage d.c. source

3.4.18

valve reactor

a reactor (if any) which is connected in series to the VSC valve. 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.

NOTE At present valve reactors are used in converter topologies with valves acting like a controllable voltage source only.

3.4.19

valve structure

physical structure holding the levels of a valve which is insulated to the appropriate voltage above earth potential

3.4.20

valve support

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

NOTE 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.

3.4.21

multiple valve unit MVU

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

NOTE A MVU might not exist in all topologies and physical arrangement of converters.

3.4.22

valve section

electrical assembly, composing a number of VSC or diode valve levels and other components, which exhibits pro-rated electrical properties of a complete valve

3.4.23

valve base electronics

VBE

electronic unit, at earth potential, which is the interface between the converter control system and the VSC valves

3.5 VSC transmission

3.5.1

VSC substation

part of a VSC transmission scheme, consisting of one or more VSC unit(s) installed in a single location together with buildings, VSC d.c. capacitors, reactors, transformers, filters, control, monitoring, protective, measuring and auxiliary equipment, as applicable