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colour inside

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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

FOREWORD

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In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions and deletions are displayed in red, with deletions being struck through. A separate Final version with all changes accepted is available in this publication.

This publication has been prepared for user convenience.

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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.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site 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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

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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, modular multi-level converters and cascaded two-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.

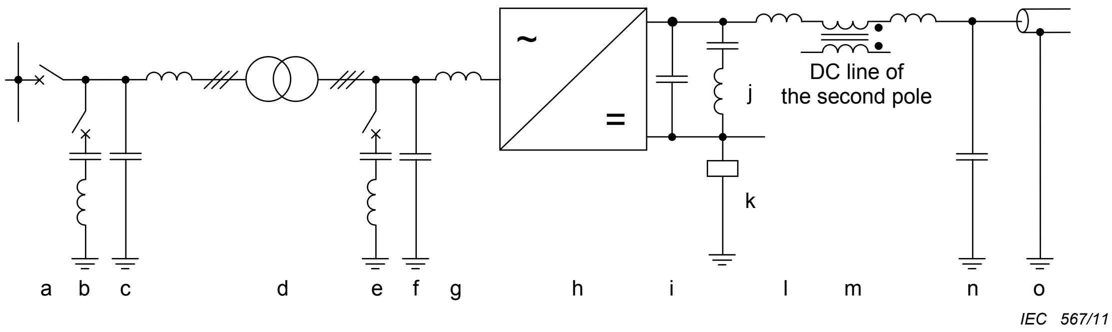

Figure 1 – Major components that may be found in a VSC substation

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. cell or 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
turn-off semiconductor ~~switched valve~~ device~~s~~
a controllable ~~valve~~ semiconductor device which may be turned on and off by a control signal, for example IGBT

NOTE There are several types of turn-off semiconductor 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 turn-off semiconductor device. However, the technical report is equally applicable to other types of devices with turn-off capability in most of the parts.

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~~ turn-off semiconductor device with three terminals: a gate terminal (G) and two load terminals emitter (E) and collector (C).

NOTE 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~~.~~

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

NOTE 2 The current through FWDs is in opposite direction to the IGBT current.

NOTE 3 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