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TECHNICAL REPORT

colour inside

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

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INTERNATIONAL
ELECTROTECHNICAL
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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 has been prepared by subcommittee 22F: Power electronics for electrical transmission and distribution systems, of IEC technical committee 22: Power electronic systems and equipment. It is a Technical Report.

This second edition cancels and replaces the first edition published in 2011, Amendment 1:2013 and Amendment 2:2017. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) in Clause 3, some redundant definitions which were identical to those listed in IEC 62747 have been deleted;
b) in 4.3.4, description and diagrams have been added for the cases of a bipole with dedicated metallic return and a rigid bipole;
c) in 4.4, mention is made of the bi-mode insulated gate transistor (BiGT) and injection enhanced gate transistor (IEGT) as possible alternatives to the IGBT;
d) in 5.6, the reference to common-mode blocking reactors has been deleted since these are very rarely used nowadays.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
22F/649/DTR	22F/669/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

1 Scope

This document gives general guidance on the subject of voltage sourced converters (VSC) 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 DC 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 this document, 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 document.

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

IEC 62501, *Voltage sourced converter (VSC) valves for high-voltage direct current (HVDC) power transmission – Electrical testing*

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

~~IEC 62751 (all parts), *Power losses in voltage sourced converter (VSC) valves for high voltage direct current (HVDC) systems*~~

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62747, IEC 62501 and the following apply.

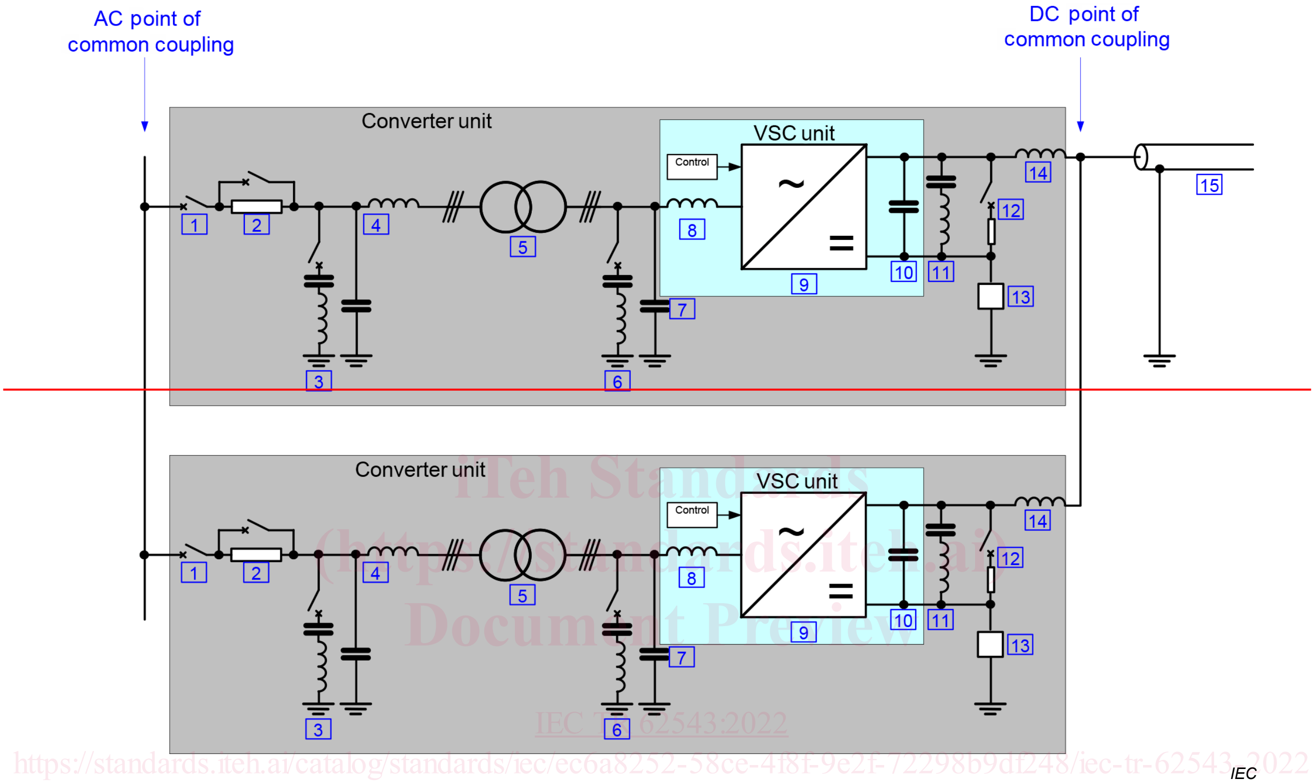
ISO and IEC maintain terminological databases for use in standardization at the following addresses:

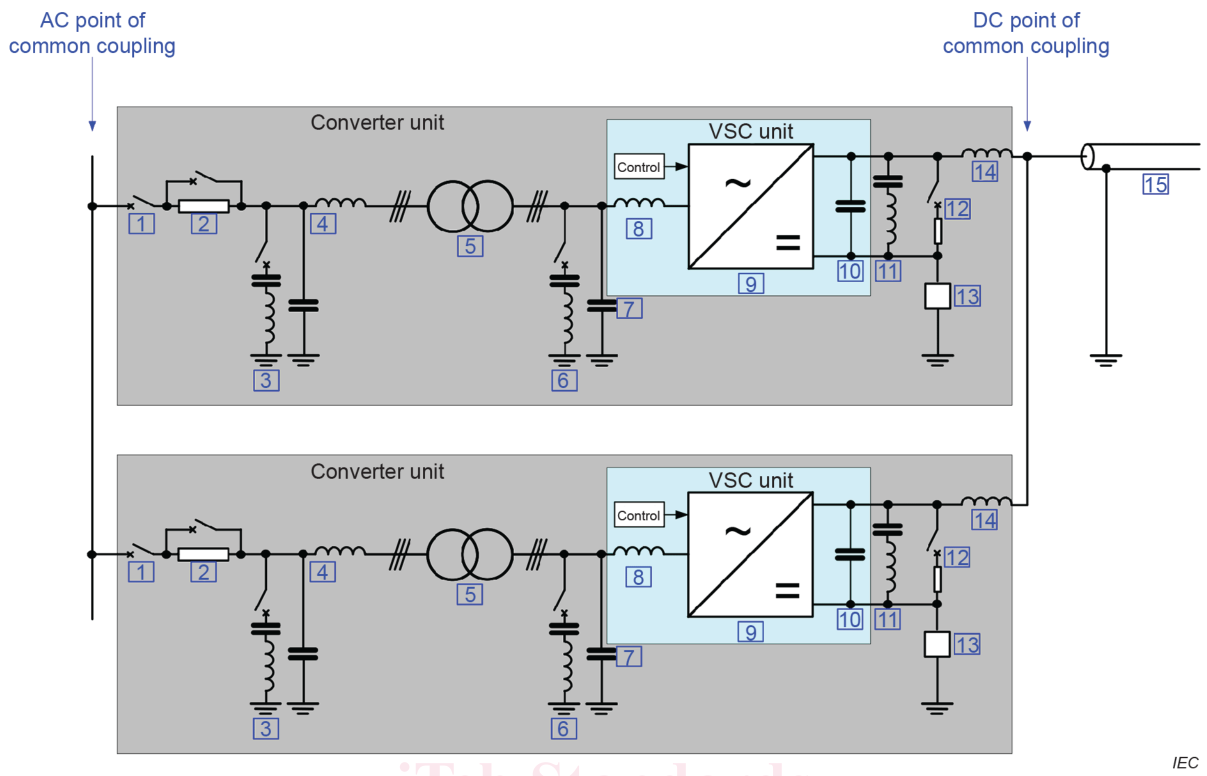
- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 General

Basic terms and definitions for voltage sourced converters used for HVDC transmission are given in IEC 62747. Terminology on electrical testing of VSC valves for HVDC transmission is given in IEC 62501.

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.





Key

1	circuit breaker	9	VSC unit [3)]
2	pre-insertion resistor	10	VSC DC capacitor [4)]
3	line side harmonic filter [1)]	11	DC harmonic filter [1)]
4	line side high frequency filter [6)]	12	dynamic braking system [7)]
5	interface transformer	13	neutral point grounding branch [5)]
6	converter side harmonic filter [1)]	14	DC reactor [8)]
7 + 8	converter side high frequency filter [2)]	15	DC cable or overhead transmission line
8	phase reactor [2)]		

[1)] In some designs of VSC based on controllable voltage source valves, it is possible the harmonic filter~~s may~~ is not ~~be~~ required.

[2)] In some designs of VSC, the phase reactor ~~may fulfill~~ can fulfil part of the function of the converter-side high frequency filter.

[3)] In some VSC topologies, each valve of the VSC unit ~~may~~ can include a "valve reactor", which ~~may~~ can be built into the valve or provided as a separate component.

[4)] In some designs of VSC, the VSC DC capacitor ~~may~~ can be partly or entirely distributed amongst the three-phase units of the VSC unit, where it is referred to as the DC submodule capacitors.

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

[6)] In some designs of VSC, the interface transformer ~~may fulfill~~ can fulfil part of the function of the line-side high frequency filter.

[7)] Optional.

[8)] Optional~~, if phase reactors are located on the d.c. side of the converter~~.

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

3.2 Letter symbols

U_{conv}	line-to-line AC voltage of the converter unit(s), RMS value, including harmonics
I_{conv}	alternating current of the converter unit(s), RMS value, including harmonics
U_{L}	line-to-line AC voltage of the AC system, RMS value, including harmonics
I_{L}	alternating current of the AC system, RMS value, including harmonic
~~U_{d}~~	~~d.c. line-to-line voltage of the d.c. bus of the VSC transmission system;~~
U_{dc}	DC terminal-to-terminal voltage of one converter unit
I_{d}	DC current of the DC bus of the VSC transmission system

3.3 VSC transmission

3.3.1
VSC DC capacitor
capacitor bank(s) (if any) connected between two DC terminals of the VSC, used for energy storage and/or filtering purposes

3.3.2
AC side radio frequency interference filter
RFI filter
filters (if any) used to reduce penetration of radio frequency interference (RFI) into the AC system to an acceptable level

3.3.3
~~**valve side harmonic filter**~~ **converter side high frequency filter**
filters (if any) used to mitigate the HF stresses of the interface transformer

~~**3.5.10**~~
~~**d.c. harmonic filter**~~
~~d.c. filters (if any) used to prevent harmonics generated by VSC valve from penetrating into the d.c. system.~~

~~NOTE The filter can consist of a tuned shunt branch, smoothing reactor or common mode blocking reactor or combinations thereof.~~

~~**3.5.11**~~
~~**d.c. reactor**~~
~~a reactor (if any) connected in series to a d.c. busbar~~

~~NOTE DC reactor is used to reduce harmonic currents flowing in the d.c. line or cable and to detune critical resonances within the d.c. circuit. A d.c. reactor might also be used for protection purposes.~~

3.3.4
DC side radio frequency interference filter
filters (if any) used to reduce penetration of radio frequency (RF) into the DC system to acceptable limits

3.3.5
type tests
tests carried out to verify that the components of VSC transmission system design will meet the requirements specified

Note 1 to entry: In this document, type tests are classified under two major categories: dielectric tests and operational tests.

3.3.6
dielectric tests
tests carried out to verify the high voltage withstanding capability of the components of VSC transmission system

3.3.7
operational tests
tests carried out to verify the turn-on (if applicable), turn-off (if applicable), and current related capabilities of the components of VSC transmission system

3.3.8
production tests
tests carried out to verify proper manufacture, so that the properties of the certain component of VSC transmission system correspond to those specified

3.3.9
sample tests
production tests which are carried out on a small number of certain VSC transmission components, for example valve sections or special components taken at random from a batch

3.4 Power losses

3.4.1
auxiliary losses
electric power required to feed the VSC substation auxiliary loads

Note 1 to entry: The auxiliary losses depend on whether the substation is in no-load or carrying load, in which case the auxiliary losses depend on the load level.

3.4.2
no-load operating losses
losses produced in an item of equipment with the VSC substation energized but with the VSCs blocked and all substation service loads and auxiliary equipment connected as required for immediate pick-up of load

3.4.3
idling operating losses
losses produced in an item of equipment with the VSC substation energized and with the VSCs de-blocked but with no real or reactive power output

3.4.4
operating losses
losses produced in an item of equipment at a given load level with the VSC substation energized and the converters operating

3.4.5
total system losses
sum of all operating losses, including the corresponding auxiliary losses

3.4.6
station essential auxiliary load
loads whose failure will affect the conversion capability of the HVDC converter station (e.g. valve cooling), as well as the loads that ~~shall~~ need to remain working in case of complete loss of AC power supply (e.g. battery chargers, operating mechanisms)

Note 1 to entry: Total "operating losses" minus "no-load operating losses" ~~may~~ can be considered as being quantitatively equivalent to "load losses" as in conventional AC substation practice.