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Edition 1.1 2014-08

# CONSOLIDATED VERSION

# VERSION CONSOLIDÉE

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



**Valves à convertisseur de source de tension (VSC) pour le transport d'énergie en courant continu à haute tension (CCHT) – Essais électriques**



IEC 62501:2009-06+AMD1:2014-08 CSV(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# VOLTAGE SOURCED CONVERTER (VSC) VALVES FOR HIGH-VOLTAGE DIRECT CURRENT (HVDC) POWER TRANSMISSION – ELECTRICAL TESTING

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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.**

IEC 62501 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

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# VOLTAGE SOURCED CONVERTER (VSC) VALVES FOR HIGH-VOLTAGE DIRECT CURRENT (HVDC) POWER TRANSMISSION – ELECTRICAL TESTING

## 1 Scope

This International Standard applies to self-commutated converter valves, for use in a three-phase bridge voltage sourced converter (VSC) for high voltage d.c. power transmission or as part of a back-to-back link. It is restricted to electrical type and production tests.

The scope of this standard includes the electrical type and production tests of dynamic braking valves which may be used in some HVDC schemes for d.c. overvoltage limitation.

This standard can be used as a guide for testing of STATCOM valves.

The tests specified in this standard are based on air insulated valves. For other types of valves, the test requirements and acceptance criteria ~~must~~ should be agreed between the purchaser and the supplier.



## 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 60060 (all parts), *High-voltage test techniques*

~~IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*~~

~~IEC 60071-1:2006, *Insulation co-ordination – Part 1: Definitions, principles and rules*~~

IEC 60071 (all parts), *Insulation co-ordination*

IEC 60270:2000, *High-voltage test techniques – Partial discharge measurements*

IEC 60700-1:1998, *Thyristor valves for high voltage direct current (HVDC) power transmission – Part 1: Electrical testing*[1)]

Amendment 1(2003)
Amendment (2008)

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

1) There exists a consolidated edition 1.2 (2008) that comprises IEC 60700-1, Amendment 1 and Amendment 2.

## 3.1 Insulation co-ordination terms

**3.1.1**
**test withstand voltage**
value of a test voltage of standard waveshape at which a new valve, with unimpaired integrity, does not show any disruptive discharge and meets all other acceptance criteria specified for the particular test, when subjected to a specified number of applications or a specified duration of the test voltage, under specified conditions

**3.1.2**
**internal insulation**
air external to the components and insulating materials of the valve, but contained within the profile of the valve or multiple valve unit

**3.1.3**
**external insulation**
air between the external surface of the valve or multiple valve unit and its surroundings.

## 3.2 Power semiconductor terms

~~There are several types of controllable semiconductor switch device which can be used in VSC converters for HVDC. For convenience, the term IGBT is used throughout this standard to refer to the main, controllable, semiconductor switch device. However, the standard is equally applicable to other types of controllable semiconductor switch device.~~



**3.2.1**
**turn-off semiconductor device**
controllable semiconductor device which may be turned on and off by a control signal, for example an IGBT

NOTE There are several types of turn-off semiconductor devices which can be used in VSC converters for HVDC. For convenience, the term IGBT is used throughout this standard to refer to the main turn-off semiconductor device. However, the standard is equally applicable to other types of turn-off semiconductor devices.



**~~3.2.1~~3.2.2**
**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, the load current can be controlled, i.e. turned on and turned off.

**~~3.2.2~~3.2.3**
**free-wheeling diode**
**FWD**
power semiconductor device with diode characteristic

NOTE 1 A FWD has two terminals: an anode (A) and a cathode (K). The current through FWDs is in the opposite direction to the IGBT current.

NOTE 2 FWDs are characterized by the capability to cope with high rates of decrease of current caused by the switching behaviour of the IGBT.

**~~3.2.3~~3.2.4**
**IGBT-diode pair**
arrangement of IGBT and FWD connected in inverse parallel

## 3.3 Operating states of converter

### ~~3.3.1 Operating state of an IGBT-diode pair~~

~~3.3.1.1~~
~~**blocking state**~~
~~condition in which an IGBT-diode pair is turned off~~

~~In that state, the load current does not flow through the IGBT. However, a load current can flow through the diode as the diode is not controllable.~~

~~3.3.1.2~~
~~**de-blocked state**~~
~~the condition when the load current flows either through the IGBT or diode of an IGBT-diode pair depending on the load current direction~~

### ~~3.3.2 Operating state of converter~~

~~3.3.2.1~~3.3.1
**blocking state**
condition of the converter, in which a turn-off signal is applied continuously to all IGBTs of the converter

NOTE Typically, the converter is in the blocking state condition after energization.

~~3.3.2.2~~3.3.2
**de-blocked state**
condition of the converter, in which turn-on and turn-off signals are applied repetitively to IGBTs of the converter

~~3.3.2.3~~3.3.3
**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



3.3.4
**voltage step level**
voltage step caused by switching of a valve or part of a valve during the de-blocked state of the converter

NOTE For valves of the controllable voltage source type, the voltage step level corresponds to the change of voltage caused by switching one submodule or cell. For valves of the switch type, the voltage step level corresponds to the change of voltage caused by switching the complete valve.

## 3.4 VSC construction terms

3.4.1
**VSC phase unit**
equipment used to connect the two d.c. busbars to one a.c. terminal

3.4.2
**switch type 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~~ arrangement of IGBT-diode pairs connected in series and arranged to be switched simultaneously as a single function unit

~~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.~~

**3.4.3**
**controllable voltage source type VSC valve**
complete controllable voltage source assembly, which is generally connected between one a.c. terminal and one d.c. terminal

**~~3.4.3~~3.4.4**
**diode valve**
semiconductor valve containing only diodes as the main semiconductor devices, which might be used in some VSC topologies

**3.4.5**
**dynamic braking valve**
complete controllable device assembly, which is used to control energy absorption in braking resistor

**~~3.4.4~~3.4.6**
**valve**
VSC valve, dynamic braking valve or diode valve according to the context

**3.4.7**
**submodule**
part of a VSC valve comprising controllable switches and diodes connected to a half bridge or full bridge arrangement, together with their immediate auxiliaries, storage capacitor, if any, where each controllable switch consists of only one switched valve device connected in series



**3.4.8**
**cell**
MMC building block where each switch position consists of more than one IGBT-diode pair connected in series

NOTE See Figure A.13



**~~3.4.5~~3.4.9**
**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 arrangement, together with their immediate auxiliaries, storage capacitor, if any~~
smallest indivisible functional unit of VSC valve

NOTE 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 A.13). For MMC type without IGBT-diode pairs connected in series one valve level is one submodule together with its auxiliaries (see Figure A.12).

**~~3.4.6~~3.4.10**
**diode valve level**
part of a diode valve composed of a diode and associated circuits and components, if any

**~~3.4.7~~3.4.11**
**redundant levels**
maximum number of series connected 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

NOTE 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.