

# FINAL VERSION

# VERSION FINALE



**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**

## CONTENTS

FOREWORD.....	5
1 Scope.....	7
2 Normative references .....	7
3 Terms and definitions .....	7
3.1 Insulation co-ordination terms .....	7
3.2 Power semiconductor terms .....	8
3.3 Operating states of converter .....	8
3.4 VSC construction terms.....	9
3.5 Valve structure terms .....	10
4 General requirements.....	10
4.1 Guidelines for the performance of type tests.....	10
4.1.1 Evidence in lieu .....	10
4.1.2 Selection of test object .....	11
4.1.3 Test procedure .....	11
4.1.4 Ambient temperature for testing.....	11
4.1.5 Frequency for testing.....	11
4.1.6 Test reports.....	11
4.1.7 Conditions to be considered in determination of type test parameters.....	12
4.2 Atmospheric correction factor.....	12
4.3 Treatment of redundancy.....	12
4.3.1 Operational tests .....	12
4.3.2 Dielectric tests.....	12
4.4 Criteria for successful type testing .....	13
4.4.1 General .....	13
4.4.2 Criteria applicable to valve levels .....	13
4.4.3 Criteria applicable to the valve as a whole.....	14
5 List of type tests .....	14
6 Operational tests .....	15
6.1 Purpose of tests .....	15
6.2 Test object .....	15
6.3 Test circuit .....	16
6.4 Maximum continuous operating duty test.....	16
6.5 Maximum temporary over-load operating duty test.....	17
6.6 Minimum d.c. voltage test.....	17
7 Dielectric tests on valve support structure .....	17
7.1 Purpose of tests .....	17
7.2 Test object .....	18
7.3 Test requirements .....	18
7.3.1 Valve support d.c. voltage test.....	18
7.3.2 Valve support a.c. voltage test.....	19
7.3.3 Valve support switching impulse test.....	20
7.3.4 Valve support lightning impulse test .....	20
8 Dielectric tests on multiple valve unit.....	20
8.1 Purpose of tests .....	20
8.2 Test object .....	20

8.3	Test requirements .....	21
8.3.1	MVU d.c. voltage test to earth .....	21
8.3.2	MVU a.c. voltage test .....	21
8.3.3	MVU switching impulse test .....	22
8.3.4	MVU lightning impulse test .....	23
9	Dielectric tests between valve terminals .....	24
9.1	Purpose of the test .....	24
9.2	Test object .....	24
9.3	Test requirements .....	24
9.3.1	Valve a.c. – d.c. voltage test .....	24
9.3.2	Valve impulse tests (general) .....	26
9.3.3	Valve switching impulse test .....	26
9.3.4	Valve lightning impulse test .....	27
9.4	Test methods .....	28
9.4.1	General .....	28
9.4.2	Method one .....	28
9.4.3	Method two .....	28
10	IGBT overcurrent turn-off test .....	28
10.1	Purpose of test .....	28
10.2	Test object .....	29
10.3	Test requirements .....	29
11	Short-circuit current test .....	29
11.1	Purpose of tests .....	29
11.2	Test object .....	29
11.3	Test requirements .....	29
12	Tests for valve insensitivity to electromagnetic disturbance .....	30
12.1	Purpose of tests .....	30
12.2	Test object .....	30
12.3	Test requirements .....	30
12.3.1	General .....	30
12.3.2	Approach one .....	31
12.3.3	Approach two .....	31
12.3.4	Acceptance criteria .....	31
13	Production tests .....	32
13.1	Purpose of tests .....	32
13.2	Test object .....	32
13.3	Test requirements .....	32
13.4	Production test objectives .....	32
13.4.1	Visual inspection .....	32
13.4.2	Connection check .....	32
13.4.3	Voltage-grading circuit check .....	33
13.4.4	Control, protection and monitoring circuit checks .....	33
13.4.5	Voltage withstand check .....	33
13.4.6	Partial discharge tests .....	33
13.4.7	Turn-on / turn-off check .....	33
13.4.8	Pressure test .....	33
14	Presentation of type test results .....	33
15	Tests for dynamic braking valves .....	31

Annex A (informative) Overview of VSC converters in HVDC power transmission .....	34
Annex B (informative) Valve component fault tolerance .....	46
Bibliography.....	47
Figure A.1 – A single VSC phase unit and its idealized output voltage .....	35
Figure A.2 – Output voltage of a VSC phase unit for a 2-level converter .....	35
Figure A.3 – Output voltage of a VSC phase unit for a 15-level converter, without PWM .....	36
Figure A.4 – Basic circuit topology of one phase unit of a 2-level converter .....	37
Figure A.5 – Basic circuit topology of one phase unit of a 3-level diode-clamped converter .....	38
Figure A.6 – Basic circuit topology of one phase unit of a 5-level diode-clamped converter .....	38
Figure A.7 – Basic circuit topology of one phase unit of a 3-level flying capacitor converter .....	39
Figure A.8 – A single VSC phase unit with controllable voltage source type VSC valve.....	40
Figure A.9 – The half-bridge MMC circuit.....	41
Figure A.10 – The full-bridge MMC circuit .....	41
Figure A.11 – The half-bridge CTL circuit.....	43
Figure A.12 – Construction terms in MMC valves .....	44
Figure A.13 – Construction terms in CTL valves.....	44
Table 1 – Minimum number of valve levels to be operational type tested as a function of the number of valve levels per valve .....	11
Table 2 – Valve level faults permitted during type tests.....	14
Table 3 – List of type tests.....	15

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

**DISCLAIMER**

**This Consolidated version is not an official IEC Standard and has been prepared for user convenience. Only the current versions of the standard and its amendment(s) are to be considered the official documents.**

This Consolidated version of IEC 62501 bears the edition number 1.2. It consists of the first edition (2009-06) [documents 22F/185/FDIS and 22F/193/RVD], its amendment 1 (2014-08) [documents 22F/299/CDV and 22F/316A/RVC] and its amendment 2 (2017-09) [documents 22F/438/CDV and 22F/457/RVC]. The technical content is identical to the base edition and its amendments.

This Final version does not show where the technical content is modified by amendments 1 and 2. A separate Redline version with all changes highlighted is available in this publication.

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 amendments 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.

**IMPORTANT – The “colour inside” logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.**

# 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.

The tests specified in this standard are based on air insulated valves. For other types of valves, the test requirements and acceptance criteria 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 60071 (all parts), *Insulation co-ordination*

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

IEC 60700-1:2015, *Thyristor valves for high voltage direct current (HVDC) power transmission – Part 1: Electrical testing*

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

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

## 3 Terms and definitions

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

### 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