

FINAL VERSION

VERSION FINALE



**Power losses in voltage sourced converter (VSC) valves for high-voltage direct current (HVDC) systems –
Part 2: Modular multilevel converters**

**Pertes de puissance dans les valves à convertisseur de source de tension (VSC) des systèmes en courant continu à haute tension (CCHT) –
Partie 2: Convertisseurs multiniveaux modulaires**

CONTENTS

FOREWORD.....	5
1 Scope.....	7
2 Normative references	7
3 Terms, definitions, symbols and abbreviated terms.....	7
3.1 Terms and definitions.....	8
3.2 Symbols and abbreviated terms	9
3.2.1 Valve and simulation data.....	9
3.2.2 Semiconductor device characteristics	10
3.2.3 Other component characteristics.....	10
3.2.4 Operating parameters	10
3.2.5 Loss parameters.....	11
4 General conditions.....	11
4.1 General.....	11
4.2 Principles for loss determination	12
4.3 Categories of valve losses	12
4.4 Loss calculation method.....	13
4.5 Input parameters.....	13
4.5.1 General	13
4.5.2 Input data for numerical simulations	13
4.5.3 Input data coming from numerical simulations	14
4.5.4 Converter station data	14
4.5.5 Operating conditions.....	15
4.6 Contents and structure of valve loss determination report	15
5 Conduction losses	15
5.1 General.....	15
5.2 IGBT conduction losses	18
5.3 Diode conduction losses	19
5.4 Other conduction losses.....	20
6 DC voltage-dependent losses	20
7 Losses in d.c. capacitors of the valve	21
8 Switching losses	21
8.1 General.....	21
8.2 IGBT switching losses.....	21
8.3 Diode switching losses.....	22
9 Other losses	23
9.1 Snubber circuit losses.....	23
9.2 Valve electronics power consumption.....	23
9.2.1 General	23
9.2.2 Power supply from off-state voltage across each IGBT	24
9.2.3 Power supply from the d.c. capacitor	25
10 Total valve losses per HVDC substation	25
Annex A (informative) Description of power loss mechanisms in MMC valves	27
A.1 Introduction to MMC Converter topology	27
A.2 Valve voltage and current stresses	30
A.2.1 Simplified analysis with voltage and current in phase.....	30

A.2.2	Generalised analysis with voltage and current out of phase	31
A.2.3	Effects of third harmonic injection	32
A.3	Conduction losses in MMC building blocks	33
A.3.1	Description of conduction paths	33
A.3.2	Conduction losses in semiconductors	39
A.3.3	MMC building block d.c. capacitor losses	43
A.3.4	Other conduction losses	43
A.4	Switching losses	43
A.4.1	Description of state changes	43
A.4.2	Analysis of state changes during cycle	45
A.4.3	Worked example of switching losses	45
A.5	Other losses	48
A.5.1	Snubber losses	48
A.5.2	DC voltage-dependent losses	48
A.5.3	Valve electronics power consumption	51
A.6	Application to other variants of valve	53
A.6.1	General	53
A.6.2	Two-level full-bridge MMC building block	53
A.6.3	Multi-level MMC building blocks	54
Annex B (informative)	Recommended data to be supplied with the loss calculation report	56
Bibliography	58
Figure 1	– Two basic versions of MMC building block designs	16
Figure 2	– Conduction paths in MMC building blocks	17
Figure A.1	– Phase unit of the modular multi-level converter (MMC) in basic half-bridge, two-level arrangement, with submodules	28
Figure A.2	– Phase unit of the cascaded two-level converter (CTL) in half-bridge form	29
Figure A.3	– Basic operation of the MMC converters	30
Figure A.4	– MMC converters showing composition of valve current	31
Figure A.5	– Phasor diagram showing a.c. system voltage, converter a.c. voltage and converter a.c. current	32
Figure A.6	– Effect of third harmonic injection on converter voltage and current	33
Figure A.7	– Two functionally equivalent variants of a “half-bridge”, two-level MMC building block	34
Figure A.8	– Conducting states in “half-bridge”, two-level MMC building block	35
Figure A.9	– Typical patterns of conduction for inverter operation (left) and rectifier operation (right), based on the submodule configuration of Figure A.7 a)	36
Figure A.10	– Example of converter with only one MMC building block per valve to illustrate switching behaviour	37
Figure A.11	– Inverter operation example of switching events	37
Figure A.12	– Rectifier operation example of switching events	38
Figure A.13	– Valve current and mean rectified valve current	40
Figure A.14	– IGBT and diode switching energy as a function of collector current	44
Figure A.15	– Valve voltage, current and switching behaviour for a hypothetical MMC valve consisting of 5 submodules	46
Figure A.16	– Power supply from IGBT terminals	51
Figure A.17	– Power supply from IGBT terminals in cell	52

Figure A.18 – Power supply from d.c. capacitor..... 53
Figure A.19 – One “full-bridge”, two-level MMC building block 54
Figure A.20 – Four possible variants of three-level MMC building block 55

Table 1 – Contributions to valve losses in different operating modes 26
Table A.1 – Hard switching events 44
Table A.2 – Soft switching events 45
Table A.3 – Summary of switching events from Figure A.15 47
Table B.1 – Valve loss data 56
Table B.2 – Other data..... 57

Currently in preview, click buy full version

INTERNATIONAL ELECTROTECHNICAL COMMISSION

POWER LOSSES IN VOLTAGE SOURCED CONVERTER (VSC) VALVES FOR HIGH-VOLTAGE DIRECT CURRENT (HVDC) SYSTEMS –

Part 2: Modular multilevel converters

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 62751-2 bears the edition number 1.1. It consists of the first edition (2014-08) [documents 22F/303/CDV and 22F/322A/RVC] and its amendment 1 (2019-08) [documents 22F/479/CDV and 22F/488B/RVC]. The technical content is identical to the base edition and its amendment.

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

International Standard IEC 62751-2 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.

A list of all parts in the IEC 62751series, published under the general title *Power losses in voltage sourced converter (VSC) valves for high-voltage direct current (HVDC) systems*, can be found on the IEC website.

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.

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 document using a colour printer.

POWER LOSSES IN VOLTAGE SOURCED CONVERTER (VSC) VALVES FOR HIGH-VOLTAGE DIRECT CURRENT (HVDC) SYSTEMS –

Part 2: Modular multilevel converters

1 Scope

This part of IEC 62751 gives the detailed method to be adopted for calculating the power losses in the valves for an HVDC system based on the “modular multi-level converter”, where each valve in the converter consists of a number of self-contained, two-terminal, controllable voltage sources connected in series. It is applicable both for the cases where each modular cell uses only a single turn-off semiconductor device in each switch position, and the case where each switch position consists of a number of turn-off semiconductor devices in series (topology also referred to as “cascaded two-level converter”). The main formulae are given for the two-level “half-bridge” configuration but guidance is also given in Annex A as to how to extend the results to certain other types of MMC building block configurations.

The standard is written mainly for insulated gate bipolar transistors (IGBTs) but may also be used for guidance in the event that other types of turn-off semiconductor devices are used.

Power losses in other items of equipment in the HVDC station, apart from the converter valves, are excluded from the scope of this standard.

This standard does not apply to converter valves for line-commutated converter HVDC systems.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 61803, *Determination of power losses in high-voltage direct current (HVDC) converter stations*

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

IEC 62751-1:2014, *Power losses in voltage sourced converter (VSC) valves for high-voltage direct current (HVDC) systems – Part 1: General requirements*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the terms and definitions given in IEC 60633, IEC 62747, IEC 62751-1, as well as the following apply.