



NSAI
Standards

Irish Standard
I.S. EN 62751-2:2014

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

I.S. EN 62751-2:2014

Incorporating amendments/corrigenda/National Annexes issued since publication:

The National Standards Authority of Ireland (NSAI) produces the following categories of formal documents:

I.S. xxx: Irish Standard — national specification based on the consensus of an expert panel and subject to public consultation.

S.R. xxx: Standard Recommendation — recommendation based on the consensus of an expert panel and subject to public consultation.

SWiFT xxx: A rapidly developed recommendatory document based on the consensus of the participants of an NSAI workshop.

This document replaces/revises/consolidates the NSAI adoption of the document(s) indicated on the CEN/CENELEC cover/Foreword and the following National document(s):

NOTE: The date of any NSAI previous adoption may not match the date of its original CEN/CENELEC document.

This document is based on:

EN 62751-2:2014

Published:

2014-10-31

*This document was published
under the authority of the NSAI
and comes into effect on:*

2014-11-26

ICS number:

NOTE: If blank see CEN/CENELEC cover page

NSAI
1 Swift Square,
Northwood, Santry
Dublin 9

T +353 1 807 3800
F +353 1 807 3838
E standards@nsai.ie
W NSAI.ie

Sales:
T +353 1 857 6730
F +353 1 857 6729
W standards.ie

Údarás um Chaighdeáin Náisiúnta na hÉireann

EUROPEAN STANDARD

EN 62751-2

NORME EUROPÉENNE

EUROPÄISCHE NORM

October 2014

ICS 29.200; 29.240

English Version

**Power losses in voltage sourced converter (VSC) valves for
high-voltage direct current (HVDC) systems - Part 2: Modular
multilevel converters
(IEC 62751-2:2014)**

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
(CEI 62751-2:2014)

Bestimmung der Leistungsverluste in
Spannungszwischenkreis-Stromrichtern (VSC) für
Hochspannungsgleichstrom(HGÜ)-Systeme - Teil 2:
Modulare Mehrstufen-Stromrichter
(IEC 62751-2:2014)

This European Standard was approved by CENELEC on 2014-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Foreword

The text of document 22F/303/CDV, future edition 1 of IEC 62751-2, prepared by SC 22F "Power electronics for electrical transmission and distribution systems", of IEC/TC 22 "Power electronic systems and equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62751-2:2014.

The following dates are fixed:

- latest date by which the document has to be implemented at (dop) 2015-07-01
national level by publication of an identical national
standard or by endorsement
- latest date by which the national standards conflicting with (dow) 2017-10-01
the document have to be withdrawn

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62751-2:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 61803:1999	NOTE	Harmonised as EN 61803:1999.
----------------	------	------------------------------

Annex ZA

(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60633	-	Terminology for high-voltage direct current (HVDC) transmission	EN 60633	-
IEC 62747	-	Terminology for voltage-sourced converters (VSC) for high-voltage direct current (HVDC) systems	EN 62747	-
IEC 62751-1	2014	Determination of power losses in voltage sourced converter (VSC) valves for high-voltage direct current (HVDC) systems -- Part 1: General requirements	EN 62751-1	2014
ISO/IEC Guide 98-3 -		Uncertainty of measurement -- Part-3: Guide to the expression of uncertainty in measurement (GUM:1995)	-	-

This page is intentionally left blank



IEC 62751-2

Edition 1.0 2014-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**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**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2014 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in 14 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

More than 55 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue

Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 14 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary

Plus de 55 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.



IEC 62751-2

Edition 1.0 2014-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**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**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX

XA

ICS 29.200; 29.240

ISBN 978-2-8322-1836-5

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

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
5 Conduction losses	15
5.1 General	15
5.2 IGBT conduction losses	16
5.3 Diode conduction losses	17
5.4 Other conduction losses	18
6 DC voltage-dependent losses	19
7 Losses in d.c. capacitors of the valve	19
8 Switching losses	20
8.1 General	20
8.2 IGBT switching losses	20
8.3 Diode switching losses	21
9 Other losses	21
9.1 Snubber circuit losses	21
9.2 Valve electronics power consumption	22
9.2.1 General	22
9.2.2 Power supply from off-state voltage across each IGBT	23
9.2.3 Power supply from the d.c. capacitor	23
10 Total valve losses per HVDC substation	24
Annex A (informative) Description of power loss mechanisms in MMC valves	26
A.1 Introduction to MMC Converter topology	26
A.2 Valve voltage and current stresses	29
A.2.1 Simplified analysis with voltage and current in phase	29
A.2.2 Generalised analysis with voltage and current out of phase	30

A.2.3	Effects of third harmonic injection	31
A.3	Conduction losses in MMC building blocks	32
A.3.1	Description of conduction paths	32
A.3.2	Conduction losses in semiconductors	38
A.3.3	MMC building block d.c. capacitor losses	42
A.3.4	Other conduction losses	42
A.4	Switching losses	42
A.4.1	Description of state changes	42
A.4.2	Analysis of state changes during cycle	44
A.4.3	Worked example of switching losses	44
A.5	Other losses	47
A.5.1	Snubber losses	47
A.5.2	DC voltage-dependent losses	47
A.5.3	Valve electronics power consumption	50
A.6	Application to other variants of valve	52
A.6.1	General	52
A.6.2	Two-level full-bridge MMC building block	52
A.6.3	Multi-level MMC building blocks	53
	Bibliography	55
	Figure 1 – Two basic versions of MMC building block designs	15
	Figure 2 – Conduction paths in MMC building blocks	16
	Figure A.1 – Phase unit of the modular multi-level converter (MMC) in basic half- bridge, two-level arrangement, with submodules	27
	Figure A.2 – Phase unit of the cascaded two-level converter (CTL) in half-bridge form	28
	Figure A.3 – Basic operation of the MMC converters	29
	Figure A.4 – MMC converters showing composition of valve current	30
	Figure A.5 – Phasor diagram showing a.c. system voltage, converter a.c. voltage and converter a.c. current	31
	Figure A.6 – Effect of 3 rd harmonic injection on converter voltage and current	32
	Figure A.7 – Two functionally equivalent variants of a “half-bridge”, two-level MMC building block	33
	Figure A.8 – Conducting states in “half-bridge”, two-level MMC building block	34
	Figure A.9 – Typical patterns of conduction for inverter operation (left) and rectifier operation (right)	35
	Figure A.10 – Example of converter with only one MMC building block per valve to illustrate switching behaviour	36
	Figure A.11 – Inverter operation example of switching events	36
	Figure A.12 – Rectifier operation example of switching events	37
	Figure A.13 – Valve current and mean rectified valve current	39
	Figure A.14 – IGBT and diode switching energy as a function of collector current	43
	Figure A.15 – Valve voltage, current and switching behaviour for a hypothetical MMC valve consisting of 5 submodules	45
	Figure A.16 – Power supply from IGBT terminals	50
	Figure A.17 – Power supply from IGBT terminals in cell	51
	Figure A.18 – Power supply from d.c. capacitor in submodule	52
	Figure A.19 – One “full-bridge”, two-level MMC building block	52

Figure A.20 – Four possible variants of three-level MMC building block	54
Table 1 – Contributions to valve losses in different operating modes	25
Table A.1 – Hard switching events	42
Table A.2 – Soft switching events	44
Table A.3 – Summary of switching events from Figure A.15	46

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.

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.

The text of this standard is based on the following documents:

CDV	Report on voting
22F/303/CDV	22F/322A/RVC

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

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 this publication 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 configuration.

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 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.

This is a free preview. Purchase the entire publication at the link below:

[Product Page](#)

-
- Looking for additional Standards? Visit Intertek Inform Infostore
 - Learn about LexConnect, All Jurisdictions, Standards referenced in Australian legislation
-