

TECHNICAL SPECIFICATION



**High voltage direct current (HVDC) power transmission – System requirements
for DC-side equipment
Part 1: Using line-commutated converters**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2018 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.

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

Tel.: +41 22 919 02 11
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 - webstore.iec.ch/advsearchform

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 It also gives information on projects, replaced and withdrawn publications.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 21 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

67 000 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: sales@iec.ch.



TECHNICAL SPECIFICATION



**High voltage direct current (HVDC) power transmission – System requirements
for DC-side equipment
Part 1: Using line-commutated converters**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.200; 29.240.01

ISBN 978-2-8322-5451-6

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	6
1 Scope.....	8
2 Normative references	8
3 Terms and Definitions.....	10
3.1 DC switching devices.....	10
3.1.1 Types of DC switching device.....	10
3.1.2 Applications of DC switching devices.....	11
3.2 Filter components	12
3.2.1 Filter capacitors.....	12
3.2.2 Filter resistors	12
3.3 Surge arresters.....	12
4 General	13
4.1 Overview.....	13
4.2 Environmental conditions	16
4.3 Choice of indoor versus outdoor DC yard.....	16
5 DC smoothing reactors	17
6 DC switching devices.....	17
6.1 High-speed DC switches	17
6.1.1 General	17
6.1.2 Comparison of operating duties	18
6.1.3 Ratings.....	19
6.1.4 Tests	23
6.1.5 Special test on current commutation capability	30
6.2 DC disconnectors and earthing switches.....	32
6.2.1 General	32
6.2.2 Ratings.....	32
7 DC GIS.....	35
7.1 General.....	35
7.2 DC GIS configuration (components of DC GIS)	35
8 DC filter components	35
8.1 General.....	35
8.2 Main DC filter capacitor.....	36
8.2.1 General	36
8.2.2 Design requirements for DC capacitors.....	36
8.2.3 Rated voltage	37
8.2.4 Base voltage for creepage calculation	37
8.2.5 Tests for DC capacitors	38
8.3 Filter resistors.....	41
8.3.1 General	41
8.3.2 Technical data.....	41
8.3.3 Design aspects	43
8.3.4 Maintenance	47
8.3.5 Tests	47
8.4 Filter reactors	51
8.5 Auxiliary capacitors.....	52
8.5.1 General	52

8.5.2	Rated voltage of the auxiliary capacitor banks	52
8.5.3	Base voltage for creepage calculation for auxiliary DC filter capacitors.....	52
8.6	Series blocking filters.....	52
8.7	DC neutral bus capacitor.....	53
9	Coupling capacitors and line traps for power line carrier (PLC).....	53
10	DC surge arresters	53
10.1	General.....	53
10.2	Surge arrester specification	53
10.2.1	General	53
10.2.2	Continuous operating voltage (COV).....	54
10.2.3	Protective characteristics.....	54
10.2.4	Insulation withstand levels of arrester housing.....	55
10.2.5	Energy dissipation capability	55
10.3	Test requirements.....	55
11	Instrument transformers.....	55
11.1	DC current transformer	55
11.2	DC voltage transformer	55
11.3	Current transformers in DC filter circuits	55
12	DC insulators and bushings	55
12.1	Bushings.....	55
12.2	Post insulators	56
12.2.1	General	56
12.2.2	Type tests.....	56
12.2.3	Routine tests	58
12.2.4	Special tests (subject to agreement between the manufacturer and the purchaser)	58
12.3	Suspension insulators	58
13	Monitoring equipment for electrode line or dedicated metallic return.....	58
Annex A (informative)	Overview of DC-side equipment	59
A.1	General.....	59
A.2	DC smoothing reactor	60
A.3	Filter equipment.....	61
A.3.1	DC harmonic filters	61
A.3.2	Series DC blocking filters	63
A.4	DC bushings	64
A.5	Instrument transformers	65
A.5.1	General	65
A.5.2	Direct voltage measurement	65
A.5.3	DC current measurement.....	66
A.6	Surge arresters	69
A.7	Electrode line monitoring and protection equipment	72
Annex B (informative)	DC switching devices for HVDC converter stations.....	74
B.1	General.....	74
B.2	Typical DC switching device applications	76
B.2.1	Metallic return transfer switch (MRTS) and earth return transfer switch (ERTS)	76
B.2.2	Neutral bus switch (NBS).....	78
B.2.3	Neutral bus earthing switch (NBES).....	79

B.2.4	Bypass switch (BPS)	80
B.2.5	Converter paralleling switch.....	81
B.2.6	Line paralleling switch	82
B.3	Design	83
	Bibliography.....	87
Figure 1	– Scope of DC-side equipment for a back-to-back HVDC converter station with one 12-pulse bridge per end	14
Figure 2	– Scope of DC-side equipment for a transmission HVDC converter station with one 12-pulse bridge per pole	15
Figure 3	– Key for application of test voltages.....	24
Figure 4	– Test circuit for commutation test	31
Figure 5	– Typical arrangement of shunt DC filter	36
Figure 6	– Typical scheme of a resistor composed of one module.....	43
Figure 7	– Transient current performance of resistor.....	51
Figure 8	– Operating voltage of a converter bus arrester (CB), rectifier operation	54
Figure A.1	– Main items of DC yard equipment for a typical HVDC transmission scheme.....	59
Figure A.2	– Some commonly used DC filter configurations	62
Figure A.3	– Series blocking filter	64
Figure A.4	– Resistive voltage divider for measurement of direct voltage	65
Figure A.5	– Operating principle of zero-flux CT (simplified)	67
Figure A.6	– Current measurement by resistive shunt using optical powering.....	68
Figure A.7	– Optical current measurement.....	68
Figure A.8	– Typical arrangement of surge arresters in a converter station with one 12-pulse bridge per pole (only one pole shown)	71
Figure A.9	– Electrode line monitoring by AC current injection	73
Figure B.1	– Typical arrangement of DC switching devices for a bipolar transmission scheme with one 12-pulse bridge per pole	75
Figure B.2	– Typical arrangement of bypass switches and disconnectors for a bipolar transmission scheme with two 12-pulse bridges per pole	76
Figure B.3	– Example arrangement of line paralleling switches for a bipolar HVDC transmission scheme	76
Figure B.4	– Example arrangement of converter paralleling switches for a bipolar HVDC transmission scheme.....	82
Figure B.5	– Commutation switch based on the divergent current oscillation method, without (left) and with (right) making switch	84
Figure B.6	– Oscillogram of a commutation event	85
Figure B.7	– Commutation switch with pre-charged capacitor.....	86
Figure B.8	– Parallel arrangement of switches used at very high current.....	86
Table 1	– Summary of main parameters affecting specification of high-speed DC switches.....	19
Table 2	– Table of standard ratings in accordance with IEC 62271-100 and their applicability to high-speed DC switches	20
Table 3	– Test conditions for direct voltage test	25
Table 4	– Test conditions for partial discharge test	25

Table 5 – Test conditions for polarity reversal test 26

Table 6 – Test conditions for RIV test 27

Table 7 – Test conditions for lightning-impulse withstand test 28

Table 8 – Test conditions for switching impulse withstand test 29

Table 9 – Test conditions for power frequency withstand test..... 29

Table 10 – Table of standard ratings in accordance with IEC 62271-102 and their applicability to HVDC disconnectors and earthing switches 32

Table 11 – Ratings for resistors 42

Table 12 – Recommended temperature and temperature rise limits for bolted and welded connections 46

Table B.1 – Summary of main parameters affecting specification of MRTS and ERTS 78

Table B.2 – Summary of main parameters affecting specification of NBS 79

Table B.3 – Summary of main parameters affecting specification of NBES..... 80

Table B.4 –Summary of main parameters affecting specification of BPS 81

Table B.5 – Summary of main parameters affecting specification of CPS 82

Table B.6 – Summary of main parameters affecting specification of LPS 83

INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH VOLTAGE DIRECT CURRENT (HVDC) POWER TRANSMISSION – SYSTEM REQUIREMENTS FOR DC-SIDE EQUIPMENT

Part 1: Using line-commutated 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.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 63014, which is a Technical Specification, has been prepared by IEC technical committee 115: High Voltage Direct Current (HVDC) transmission for DC voltages above 100 kV.

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

Enquiry draft	Report on voting
115/167/DTS	115/178/RVDTS

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

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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.

HIGH VOLTAGE DIRECT CURRENT (HVDC) POWER TRANSMISSION – SYSTEM REQUIREMENTS FOR DC-SIDE EQUIPMENT

Part 1: Using line-commutated converters

1 Scope

This Technical Specification is intended to provide an overall and consistent set of guidelines to facilitate the specification of equipment for the DC-side of a high-voltage direct current (HVDC) system using line-commutated converters. For point-to-point HVDC transmission systems, this document covers all DC-side equipment located between the converter valves and the DC overhead line or cable termination, excluding the converter valves themselves. For back-to-back HVDC systems, this document covers all DC-side equipment excluding the converter valves themselves. Throughout this publication, the terms 'direct voltage' and 'DC voltage' are used interchangeably, as are 'direct current' and 'DC current'.

Traditionally, the largest items of such equipment, such as the DC smoothing reactor and DC harmonic filters, have generally been located outdoors but increasingly the trend is to locate such equipment indoors (although not in the valve hall itself) to provide protection from pollution. Although product standards exist for some DC-side equipment types, many such items of equipment have only standards written for AC applications and, in such cases, the purpose of this document is to provide guidance as to how to specify the additional requirements (particularly with regard to testing) for such equipment to cover their use in DC conditions.

The converter itself is excluded from this scope, being covered by IEC 60700-1 [1]¹ and IEC 60700-2 [2].

Although this document includes requirements for DC disconnectors and certain types of specialised DC switching devices (such as the Metallic Return Transfer Switch (MRTS)), it excludes any type of DC circuit-breaker designed to interrupt fault currents.

DC-side equipment for HVDC systems based on voltage-sourced converter (VSC) technology is excluded from this document and will be covered in a future Part 2 of IEC 63014.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

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

IEC 60071-5, *Insulation co-ordination – Part 5: Procedures for high-voltage direct current (HVDC) converter stations*

¹ Numbers in square brackets refer to the Bibliography.