

TECHNICAL REPORT

High-voltage direct current (HVDC) systems – Application of active filters





THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2011 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 la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

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.

- Catalogue of IEC publications: www.iec.ch/searchpub

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 It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

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

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00



IEC/TR 62544

Edition 1.0 2011-08

TECHNICAL REPORT

High-voltage direct current (HVDC) systems – Application of active filters

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE

ICS 29.240.99

ISBN 978-2-88912-627-9

CONTENTS

FOREWORD.....	5
1 Scope.....	7
2 Normative references.....	7
3 Terms and definitions	7
3.1 Active and passive filters	8
3.2 Active filter topologies.....	8
shunt active filter	8
3.3 Power semiconductor terms.....	9
3.4 Converter topologies.....	9
4 Active filters in HVDC applications	9
4.1 General	9
4.2 Semiconductor devices available for active filters.....	11
5 Active d.c. filters	11
5.1 Harmonic disturbances on the d.c. side.....	11
5.2 Description of active d.c. filters	12
5.2.1 General	12
5.2.2 Types of converters available.....	12
5.2.3 Connections of the active d.c. filter	13
5.2.4 Characteristics of installed active d.c. filters	15
5.3 Main components in an d.c. active filter.....	16
5.3.1 General	16
5.3.2 Passive part.....	16
5.3.3 Current transducer.....	18
5.3.4 Control system.....	18
5.3.5 Amplifier	19
5.3.6 Transformer.....	19
5.3.7 Protection circuit and arrester	19
5.3.8 Bypass switch and disconnectors	19
5.4 Active d.c. filter control	19
5.4.1 General	19
5.4.2 Active d.c. filter control methods	20
5.5 Example – Performance of the Skagerrak 3 HVDC Intertie active d.c. filter.....	23
5.6 Conclusions on active d.c. filters.....	24
6 Active a.c. filters in HVDC applications.....	25
6.1 General	25
6.2 Harmonic disturbances on the a.c. side of a HVDC system.....	25
6.3 Passive filters	26
6.3.1 Conventional passive filters.....	26
6.3.2 Continuously tuned passive filters	26
6.4 Reasons for using active filters in HVDC systems	27
6.5 Operation principles of active filters	28
6.5.1 Shunt connected active filter	28
6.5.2 Series connected active filter	29
6.6 Parallel and series configuration	29
6.6.1 General	29
6.6.2 Hybrid filter schemes	29
6.7 Converter configurations.....	30

6.7.1	Converters.....	30
6.8	Active a.c. filter configurations	32
6.8.1	Active a.c. filters for low voltage application	32
6.8.2	Active a.c. filters for medium voltage application	33
6.8.3	Active a.c. filters for HVDC applications	33
6.9	Series connected active filters	34
6.10	Control system	34
6.10.1	General	34
6.10.2	Description of a generic active power filter controller	35
6.10.3	Calculation of reference current	36
6.10.4	Synchronous reference frame (SRF)	37
6.10.5	Other control approaches.....	37
6.10.6	HVDC a.c. active filter control approach	38
6.11	Existing active a.c. filter applications.....	38
6.11.1	Low and medium voltage.....	38
6.11.2	High voltage applications	38
6.12	Overview on filter solutions for HVDC systems.....	39
6.12.1	Solution with conventional passive filters.....	39
6.12.2	Solution with continuously tuned passive filters	40
6.12.3	Solution with active filters.....	40
6.12.4	Solution with continuously tuned passive filters and active filters	41
6.12.5	Study cases with the CIGRÉ HVDC model.....	41
6.13	ACfilters for HVDC installations using VSC	43
6.14	Conclusions on active a.c. filters.....	43
	Bibliography	45
	Figure 1 – Shunt connection.....	8
	Figure 2 – Series connection	8
	Figure 3 – Conceptual diagram of allowable interference level and d.c. filter cost	10
	Figure 4 – Simple current source converter	13
	Figure 5 – Simple voltage sourced converter	13
	Figure 6 – Possible connections of active d.c. filters	14
	Figure 7 – Filter components in the active filter.....	17
	Figure 8 – Impedance characteristics of different passive filters.....	17
	Figure 9 – Basic control loop of an active d.c. filter	21
	Figure 10 – Measured transfer function of external system, Baltic Cable HVDC link	22
	Figure 11 – Feedforward control for the active d.c. filter.....	22
	Figure 12 – Measured line current spectra, pole 3 operated as monopole	24
	Figure 13 – Continuously tuned filter	26
	Figure 14 – Example of current waves	28
	Figure 15 – Series and parallel connection	29
	Figure 16 – Hybrid configuration.....	30
	Figure 17 – Three phase current-source converter.....	31
	Figure 18 – Three phase 2 level voltage-sourced converter (three-wire type)	31
	Figure 19 – Three phase 3 level voltage-sourced converter (three-wire type)	32
	Figure 20 – Single-phase voltage sourced converter	32

Figure 21 – Active filter connected to the HV system through a single-tuned passive filter	33
Figure 22 – Active filter connected to the HV system through a double-tuned passive filter	34
Figure 23 – Using an LC circuit to divert the fundamental current component.....	34
Figure 24 – Per-phase schematic diagram of active filter and controller	35
Figure 25 – Block diagram of IRPT	36
Figure 26 – Block diagram of SRF	38
Figure 27 – Plots from site measurements.....	39
Figure 28 – Filter configuration and a.c. system harmonic impedance data	42
Table 1 – The psophometric weighting factor at selected frequencies	12
Table 2 – Voltage to be supplied by the active part with different selections of passive parts	18
Table 3 – Major harmonic line currents, pole 3 operated as monopole	24
Table 4 – Preferred topologies for common LV and MV applications	30
Table 5 – Performance Requirements	41
Table 6 – Parameters of filters at a.c. substation A (375 kV).....	42
Table 7 – Parameters of filters at a.c. substation B (230 kV).....	43
Table 8 – Performance results of filters	43

Document preview generated by EVS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE DIRECT CURRENT (HVDC) SYSTEMS – APPLICATION OF ACTIVE FILTERS

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. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

This Technical Report cancels and replaces IEC/PAS 62544 published in 2011. This first edition constitutes a technical revision.

IEC/TR 62544, which is a technical report, has been prepared by subcommittee 22F: Power electronics for electrical transmission and distribution systems, of IEC technical committee 22: Power electronics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
22F/242/DTR	22F/250/RVC

Full information on the voting for the approval of this technical report 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.

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.

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

This document is a preview generated by EVS

HIGH-VOLTAGE DIRECT CURRENT (HVDC) SYSTEMS – APPLICATION OF ACTIVE FILTERS

1 Scope

This technical report gives general guidance on the subject of active filters for use in high-voltage direct current (HVDC) power transmission. It describes systems where active devices are used primarily to achieve a reduction in harmonics in the d.c. or a.c. systems. This excludes the use of automatically retuned components.

The various types of circuit that can be used for active filters are described in the report, along with their principal operational characteristics and typical applications. The overall aim is to provide guidance for purchasers to assist with the task of specifying active filters as part of HVDC converters.

Passive filters are specifically excluded from this report.

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

IEC 60633, *Terminology for high-voltage direct-current (HVDC) transmission*

IEC 61000 (all parts), *Electromagnetic compatibility (EMC)*

IEC 61975, *High-voltage direct current (HVDC) installations – System tests*

IEC/TR 62001:2009, *High-voltage direct current (HVDC) systems – Guidebook to the specification and design evaluation of A.C. filters*

IEC/TR 62543, *High-voltage direct current (HVDC) power transmission using voltage sourced converters (VSC)*

IEEE 519, *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*

3 Terms and definitions

For the purposes of this technical report, the terms and definitions given in IEC 60633 and IEC 62001:2009 for passive a.c. filters, as well as the following apply.

NOTE Only terms which are specific to active filters for HVDC are defined in this clause. Those terms that are either identical to or obvious extensions of IEC 60633 or IEC 62001:2009 terminology have not been defined.