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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

FOREWORD

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IEC TR 62544 edition 1.1 contains the first edition (2011-08) [documents 22F/242/DTR and 22F/250/RVC] and its amendment 1 (2016-04) [documents 22F/377/DTR and 22F/381A/RVC].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

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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.

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 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- withdrawn,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.

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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, IEC 62001~~:2009~~ and 62747 terminology have not been defined.

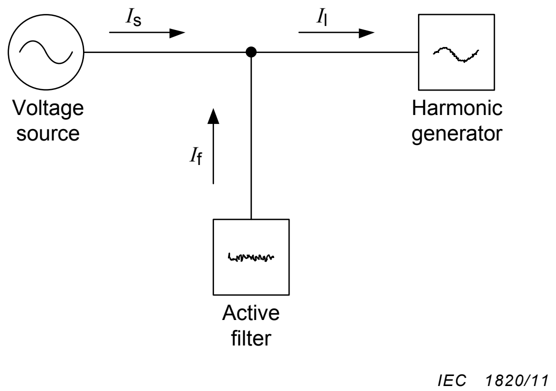

Figure 1 – Shunt connection

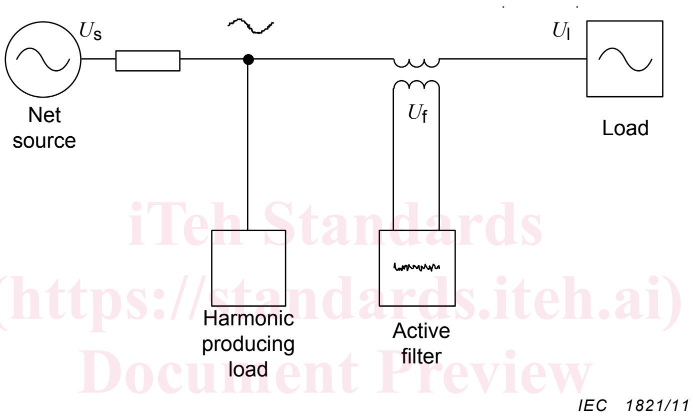

Figure 2 – Series connection

3.1 Active and passive filters

3.1.1
active filter
a filter whose response to harmonics is either wholly or partially governed by a controlled converter

3.1.2
passive filter
a filter whose response to harmonics is governed by the impedance of its components

3.2 Active filter topologies

3.2.1
shunt active filter
an active filter connected high-voltage (HV) to low-voltage (LV) or HV to ground such that it experiences the full a.c. or d.c. voltage of the HVDC system or its a.c. connection (see Figure 1)

3.2.2
series active filter
an active filter connected between the HVDC converter and the a.c. or d.c. supplies such that it must withstand the full HVDC system current, either a.c. or d.c. (see Figure 2)

3.2.3
shunt and series active filter
an active filter containing both series and shunt elements as defined above

3.3 Power semiconductor terms

~~NOTE There are several types of power semiconductor devices which can be used in active filters for HVDC and currently the IGBT is the major device used in such converters. The term IGBT is used throughout this report to refer to the switched valve device. However, the report is equally applicable to other types of devices with turn-off capability in most of the parts.~~

3.3.1
insulated gate bipolar transistor
IGBT
~~a controllable switch with the capability to turn-on and turn-off a load current~~
turn-off semiconductor device with a gate terminal (G) and two load terminals emitter (E) and collector (C)

NOTE 1 An IGBT has three terminals: a gate terminal (G) and two load terminals - emitter (E) and collector (C).

NOTE 2 By applying appropriate gate to emitter voltages, current in one direction can be controlled, i.e. turned on and turned off.

3.3.2
free-wheeling diode
FWD
power semiconductor device with diode characteristic.

NOTE 1 A FWD has two terminals: an anode (A) and a cathode (K). The current through the FWDs is in opposite direction to the IGBT current.

NOTE 2 FWDs are characterized by the capability to cope with high rates of decrease of current caused by the switching behaviour of the IGBT.

3.3.3
IGBT-diode pair
arrangement of IGBT and FWD connected in inverse parallel

3.3.4
turn-off semiconductor device
controllable semiconductor device which may be turned on and off by a control signal

EXAMPLE Insulated gate bipolar transistor (IGBT).

NOTE There are several types of turn-off semiconductor devices which can be used in active filters for HVDC. Currently, the IGBT is the major device used in such converters. The term IGBT is used throughout this Technical Report to refer to the turn-off semiconductor device. However, this Technical Report is equally applicable to other types of devices with turn-off capability in most of the parts.

3.4 Converter topologies

3.4.1
pulse width modulation
PWM
a converter operation technique using high frequency switching with modulation to produce a particular waveform when smoothed

3.4.2
two-level converter
~~a~~ converter in which the voltage ~~at~~ between the a.c. terminals of the voltage sourced converter (VSC) unit and the VSC unit midpoint is switched between two discrete d.c. ~~voltage~~ levels

3.4.3
three-level converter
~~a~~ converter in which the voltage ~~at~~ between the a.c. terminals of the voltage sourced converter (VSC) unit and the VSC unit midpoint is switched between three discrete d.c. ~~voltage~~ levels

3.4.4
multi-level converter
a converter in which the voltage at the a.c. terminals of the VSC unit is switched between more than three discrete d.c. voltage level.

4 Active filters in HVDC applications

4.1 General

The conversion process in an HVDC transmission system introduces harmonic currents into the d.c. transmission lines and the a.c. grid connected to the HVDC converters. These harmonic currents may cause interference in the adjacent systems, like telecommunication equipment. The conventional solution to reduce the harmonics has been to install passive filters in HVDC converter stations [1][1]. When the power line consists of cables, this filtering is normally not necessary. The development of power electronics devices and digital computers has made it possible to achieve a new powerful way for a further reduction of harmonic levels, namely, active filters.

The active filters can be divided into two groups, active a.c. and d.c. filters. Active d.c. filter installations are in operation in several HVDC links and have been economically competitive due to more onerous requirements for telephone interference levels on the d.c. overhead lines (Figure 3). An active a.c. filter is already in operation as well. In addition to the active d.c. filter function of mitigating the harmonic currents on the d.c. overhead lines, the active a.c. filters may be part of several solutions in the HVDC scheme to improve reactive power exchange with the a.c. grid and to improve dynamic stability.

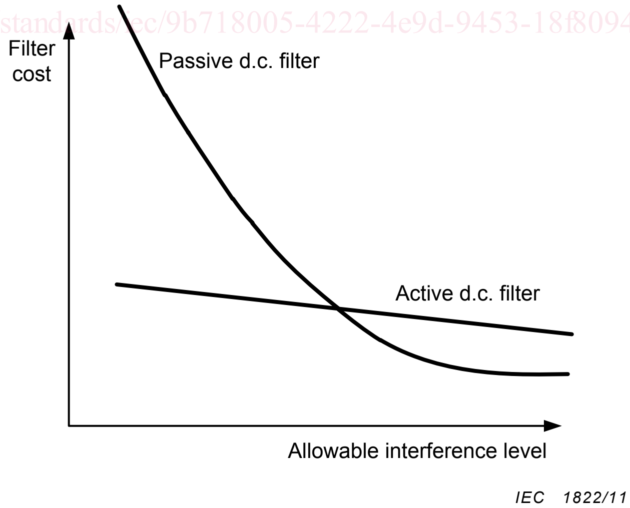

Figure 3 – Conceptual diagram of allowable interference level and d.c. filter cost

The features of active filters are the following:

- Active a.c. and d.c. filters consist of two parts, a passive part and a corresponding active part which are loaded with the same currents. Due to the fact that the passive a.c. filter is used to supply the HVDC converter demand of reactive power and thereby loaded with the

1 Figures in square brackets refer to the Bibliography.