IEC TR 62001-1

Edition 1.0 2016-05

TECHNICAL REPORT

High-voltage direct current (HVDC) systems – Guidance to the specification and design evaluation of AC filters –

Part 1: Overview

colour inside

IEC TR 62001-1:2016-05(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.200

ISBN 978-2-8322-3401-3

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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HIGH-VOLTAGE DIRECT CURRENT (HVDC) SYSTEMS – GUIDANCE TO THE SPECIFICATION AND DESIGN EVALUATION OF AC FILTERS –

Part 1: Overview

FOREWORD

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IEC TR 62001-1, 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 electronic systems and equipment.

This first edition of IEC TR 62001-1, together with IEC TR 62001-2[1], IEC TR 62001-3[1] and IEC TR 62001-4, cancels and replaces IEC TR 62001 published in 2009. This edition constitutes a technical revision.

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1 To be published.

IEC TR 62001-1 includes the following significant technical changes with respect to IEC TR 62001:

a) Clauses 3 to 5, 7 to 9, 17, 20, Annexes A and C to E have been expanded and supplemented;
b) Annexes C and F on the definition of telephone interference parameters and voltage sourced converters have been added.

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

Enquiry draft	Report on voting
22F/378/DTR	22F/384A/RVC

Full information on the voting for the approval of this document 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 TR 62001 series, published under the general title *High-voltage direct current (HVDC) systems – Guidance to the specification and design evaluation of AC filters*, 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 website 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- withdrawn,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.

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.

INTRODUCTION

IEC TR 62001 is structured in four parts:

Part 1 – Overview

This part concerns specifications of AC filters for high-voltage direct current (HVDC) systems with line-commutated converters, permissible distortion limits, harmonic generation, filter arrangements, filter performance calculation, filter switching and reactive power management and customer specified parameters and requirements.

Part 2 – Performance

This part deals with current-based interference criteria, design issues and special applications, field measurements and verification.

Part 3 – Modelling

This part addresses the harmonic interaction across converters, pre-existing harmonics, AC network impedance modelling, simulation of AC filter performance.

Part 4 – Equipment

This part concerns steady-state and transient ratings of AC filters and their components, power losses, audible noise, design issues and special applications, filter protection, seismic requirements, equipment design and test parameters.

HIGH-VOLTAGE DIRECT CURRENT (HVDC) SYSTEMS – GUIDANCE TO THE SPECIFICATION AND DESIGN EVALUATION OF AC FILTERS –

Part 1: Overview

1 Scope

This part of IEC TR 62001, which is a Technical Report, provides guidance on the specifications of AC filters for high-voltage direct current (HVDC) systems with line-commutated converters and filter performance calculation.

This document deals with the specification and design evaluation of AC side harmonic performance and AC side filters for HVDC schemes. It is intended to be primarily for the use of the utilities and consultants who are responsible for issuing the specifications for new HVDC projects and evaluating designs proposed by prospective suppliers.

The scope of this document covers AC side filtering for the frequency range of interest in terms of harmonic distortion and audible frequency disturbances. It excludes filters designed to be effective in the Power Line Carrier (PLC) and radio interference spectra.

The bulk of this document concentrates on the "conventional" AC filter technology and line-commutated HVDC converters. The changes entailed by new technologies are also discussed.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
specification
document which defines the overall system requirements for an AC filter and the AC system environment in which it operates

Note 1 to entry: Such a document is normally issued by utilities to the prospective HVDC manufacturers. It also ensures the uniformity of proposals and sets guidelines for the evaluation of bids.

Note 2 to entry: The term as used here does not refer to the detailed engineering specifications relating to individual items of equipment, which are prepared by the HVDC manufacturer as a result of the filter design process.

Note 3 to entry: The specification defines the technical basis for a contract between two parties: the customer (2.2) and the contractor (2.3).

2.2
customer
organization which is purchasing the HVDC converter station, including the AC filters

Note 1 to entry: The term “customer” is taken to cover similar terms which may be used in specifications, such as owner, client, buyer, utility, user, employer and purchaser, and also covers a consultant representing the customer.

2.3
contractor
organization which has the overall responsibility for delivery of the HVDC converter station, including the AC filters, as a system

Note 1 to entry: The contractor may in turn contract one or more sub-suppliers of individual items of equipment.

Note 2 to entry: The term “contractor” is taken to cover similar terms which may be used in specifications, such as manufacturer, or supplier.

Note 3 to entry: Where the context clearly refers to the pre-contract stage of a project, the word “bidder” has been used instead of “contractor”, to indicate a prospective contractor, or tenderer.

2.4
branch
arm
set of components (capacitor, inductor, resistor), either in singular or interconnected arrangement, which may be isolated off load for maintenance

Note 1 to entry: In interconnected arrangement, it forms a smallest tuned filter unit.

SEE: Figure 22

2.5
sub-bank
one or more branches which can be switched (connected or disconnected) on load for reactive power control

Note 1 to entry: The switch does not necessarily need to have fault clearing capability.

SEE: Figure 22

2.6
bank
one or more sub-banks which can be switched together by a circuit breaker

SEE: Figure 22

3 Outline of specifications of AC filters for HVDC systems

3.1 General

When installing an HVDC converter station in an AC system, the way in which it may affect the quality of power supply in that system is always an important issue. One of the main power quality topics is that of harmonic performance.

The AC side current of an HVDC converter has a highly non-sinusoidal waveform, and, if allowed to flow in the connected AC system, might produce unacceptable levels of distortion. AC side filters are therefore required as part of the total HVDC converter station, in order to reduce the harmonic distortion of the AC side current and voltage to acceptably low levels.

HVDC converters also consume substantial reactive power, a large proportion of which is normally supplied locally within the converter station. Shunt connected AC filters appear as capacitive sources of reactive power at fundamental frequency, and normally in conventional HVDC schemes the AC filters are used to compensate most or all of the reactive consumption of the converter. Additional shunt capacitors and reactors may also be used to ensure that the desired reactive balance is maintained within specified limits under defined operational conditions.

The design of the AC filters therefore normally has to satisfy these two requirements of harmonic filtering and reactive power compensation, for various operational states and load levels. Optimization of this design is the task of the AC filter designer, and the constraints under which the design is made are defined in the specification.

The AC filters form a substantial part of a conventional HVDC converter station. The fundamental reactive power rating of the AC filters (including shunt capacitors where applicable) at each converter station has typically been in the range of 50 % to 60 % of the active power rating of the scheme. Together with the required switchyard equipment, the AC filters can occupy over half of the total land requirements of an HVDC scheme. The cost of manufacture, installation and commissioning of the AC filter equipment is significant, being typically in the approximate range of 10 % of the total station costs. In addition, the filter design studies can be extensive and may have an impact on many other aspects of station design (see [1, 2, 3][2]) and on the total project schedule. Once in operation, the AC filters will continue to have a major importance due to requirements for switching, maintenance, component spares, and reliability.

It is therefore important that the way in which the requirements for the AC filters are specified is such as to allow the design to be optimized in terms of all the above factors, while fulfilling the essential functions of disturbance mitigation and reactive power compensation.

In general, this document assumes that the purchase of an HVDC converter station, including AC filters, will be made on a turnkey or similar basis, such as has been the case for the majority of HVDC schemes to date. The discussions herein of aspects such as provision of technical information, allocation of risks and so on therefore apply principally to such an all-inclusive approach. If the alternative approach of specifying and purchasing equipment item by item were adopted, then these aspects of the document would have to be reconsidered in the context of the particular scheme, although the purely technical content of the document would still be applicable.

Most specifications for HVDC projects are issued in a final format after definition of the details of the project by the customer and possibly consultants. An alternative approach which has recently been used is discussed in Annex A.

3.2 Boundaries of responsibility

Before a specification enters into the detail of AC filter design requirements, it should first clearly define the boundaries of responsibility between customer and contractor.

In this respect there are two extreme approaches.

c) The customer defines an AC system impedance, distortion limits and other performance criteria to be satisfied by calculation, the calculation method, and the parameters to be taken into account. The bidder, and later on the contractor, then makes studies and designs filters based on this information, and has the responsibility to prove, to the satisfaction of the customer, that the proposed filter design complies with all the specification requirements. The risk that the AC filters do not perform adequately under field conditions lies mainly with the customer.
d) At the other extreme, the customer defines only the maximum actual measured distortion and disturbance to be permitted (or even more simply, that there are no problems of distortion or disturbance). The customer may also specify field tests to confirm that the defined limits are not exceeded. The bidder, and later on the contractor, then has full responsibility for determining the AC system impedance, defining all relevant parameters, and designing AC filters which will perform in practice within the limits specified by the customer (or proposed as reasonable by the contractor) and withstand all actual operating conditions. Most risks in this case lie with the contractor.

For a customer with relatively little in-house study capability, approach b) might appear attractive. However, there are several disadvantages to b), as follows.

- It implies that at the tender stage, several prospective contractors will all have to make extensive studies of AC system impedance and local harmonic limit requirements. This will be expensive and difficult to achieve during a short tender period. Therefore, these

[2] Numbers in square brackets refer to the Bibliography.