IEC TR 60919-1

Edition 4.0 2020-04

TECHNICAL REPORT

colour inside

Performance of high-voltage direct current (HVDC) systems with line-commutated converters – Part 1: Steady-state conditions

IEC TR 60919-1:2020-04 (en)

IEC Central Office
3, rue de Varembé
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 corrigendum or an amendment might have been published.

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 It also gives information on projects, replaced and withdrawn publications.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 once a month by email.

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.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries 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 TR 60919-1

Edition 4.0 2020-04

TECHNICAL REPORT

Performance of high-voltage direct current (HVDC) systems with line-commutated converters – Part 1: Steady-state conditions

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 29.200; 29.240.99 ISBN 978-2-8322-8038-6

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

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

PERFORMANCE OF HIGH-VOLTAGE DIRECT CURRENT (HVDC) SYSTEMS WITH LINE-COMMUTATED CONVERTERS –

Part 1: Steady-state conditions

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".

IEC TR 60919-1, 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 fourth edition cancels and replaces the third edition, published in 2010, Amendment 1:2013 and Amendment 2:2017. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Figure 8 and Figure 20 have been updated, a new Figure 18 "LCC/VSC hybrid bipolar system" has been added;

b) the HVDC system control objectives have been supplemented;

c) additional explanations regarding the HVDC system control structure have been given;

d) a new subclause 13.6 on HVDC system protection has been added.

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

Draft TR	Report on voting
22F/535/DTR	22F/549A/RVDTR

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

A list of all parts of the IEC 60919 series, published under the general title *Performance of high-voltage direct current (HVDC) systems with line-commutated converters*, can be found on the IEC website.

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.

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

The difference between system performance specifications and equipment design specifications for individual components of a system is realized. Frequently, performance specifications are prepared as a single package for the two HVDC substations in a particular system. Alternatively, some parts of the HVDC system can be separately specified and purchased. In such cases, due consideration is given to coordination of each part with the overall HVDC system performance objectives and to ensuring that the interface of each with the system is clearly defined. Typical of such parts, listed in the appropriate order of relative ease for separate treatment and interface definition, are:

a) DC line, electrode line and earth electrode;

b) telecommunication system;

c) converter building, foundations and other civil engineering work;

d) reactive power supply including AC shunt capacitor banks, shunt reactors, synchronous and static reactive power (var) compensators;

e) AC switchgear;

f) DC switchgear;

g) auxiliary systems;

h) AC filters;

i) DC filters;

j) DC reactors;

k) converter transformers;

l) surge arresters;

m) series commutation capacitors;

n) valves and their ancillaries;

o) control and protection systems.

NOTE The last four items are the most difficult to separate, and, in fact, separation of these four can be inadvisable.

Clause 4 to Clause 22 of this document set out a complete steady-state performance specification for an HVDC system.

Since the equipment items are usually separately specified and purchased, the HVDC transmission line, earth electrode line and earth electrode (see Clause 11) are included only because of their influence on the HVDC system performance.

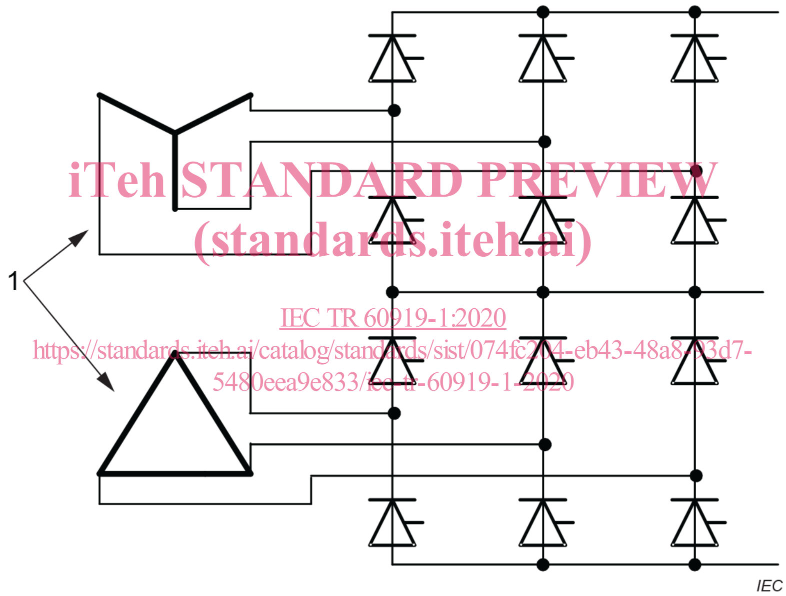
For the purpose of this document, an HVDC substation is assumed to consist of one or more converter units installed in a single location together with buildings, reactors, filters, reactive power supply, control, monitoring, protective, measuring and auxiliary equipment. While there is no discussion of AC switching substations in this document, AC filters and reactive power sources are included, although they can be connected to an AC bus separate from the HVDC substation, as discussed in Clause 17.

PERFORMANCE OF HIGH-VOLTAGE DIRECT CURRENT (HVDC) SYSTEMS WITH LINE-COMMUTATED CONVERTERS –

Part 1: Steady-state conditions

1 Scope

This part of IEC 60919 provides general guidance on the steady-state performance requirements of high-voltage direct current (HVDC) systems. It concerns the steady-state performance of two-terminal HVDC systems utilizing 12-pulse converter units comprised of three-phase bridge (double-way) connections (see Figure 1), but it does not cover multi-terminal HVDC transmission systems. Both terminals are assumed to use thyristor valves as the main semiconductor valves and to have power flow capability in both directions. Diode valves are not considered in this document.



Key

1 Transformer valve windings

Figure 1 – Twelve-pulse converter unit

Only line-commutated converters are covered in this document, which includes capacitor commutated converter circuit configurations. General aspects of semiconductor line-commutated converters are given in IEC 60146-1-1, IEC TR 60146-1-2 and IEC 60146-1-3. Voltage-sourced converters are not considered.

The distinction is made between system performance specifications and equipment design specifications for individual components of a system. Equipment specifications and testing requirements are not defined in this document. Also excluded from this document are detailed seismic performance requirements. In addition, because there are many variations between different possible HVDC systems, this document does not consider these in detail; consequently, it is not used directly as a specification for a particular project, but rather to provide the basis for an appropriate specification tailored to fit actual system requirements.

This document, which covers steady-state performance, is followed by the additional documents of IEC TR 60919-2 on faults and switching as well as IEC TR 60919-3 on dynamic conditions. All three aspects are considered when preparing two-terminal HVDC system specifications.

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 60633, *High-voltage direct current (HVDC) transmission – Vocabulary*

CIGRÉ Technical Brochure (TB) No. 391:2009, *Guide for measurement of radio frequency interference from HV and MV substations. Disturbance propagation, characteristics of disturbance sources, measurement techniques, conversion methodologies and limits*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60633 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 Types of HVDC systems

4.1 General

This part of the specification should include the following basic data:

a) general information on the location of the HVDC substations and the purpose of the project;

b) type of system needed, including a simple one-line diagram;

c) number of 12-pulse converter units;

d) pertinent information derived from the discussion in Clause 4.

Generally, in studies of projects of the types discussed in this document, economic considerations should take into account the capital costs, the cost of losses, cost of outages and other expected annual expenses.

In terms of the type of system, the "capacitor-commutated converter (CCC)" and "controlled series capacitor converter (CSCC)" technology may be suitable alternatives to a conventional HVDC scheme. These are described in 4.10.

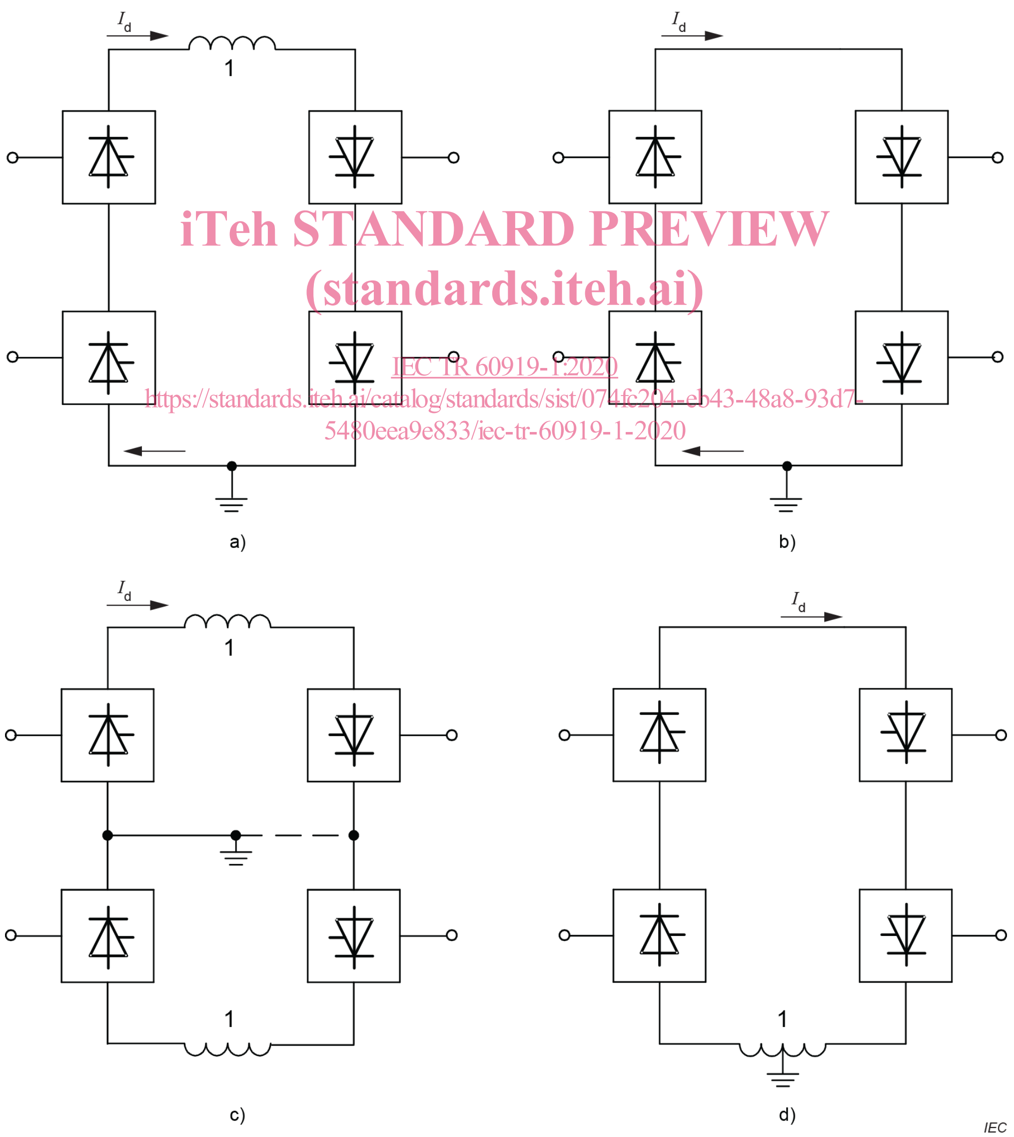
4.2 HVDC back-to-back system

In this arrangement there is no DC transmission line and both converters are located at one site. The valves for both converters may be located in one valve hall, or even in one integrated structure or separately as outdoor valves. Similarly, many other items for the two converters, such as the control system, cooling equipment, auxiliary system, etc., may be located in one area or even integrated in layout into configurations common to the two converters. Circuit configurations may vary. Examples are given in Figure 2. The performance and economics of these configurations differ and should be evaluated. DC filters are not needed.

The voltage and current ratings for a given power rating should be optimized to achieve the lowest system cost, including the evaluated cost of losses. Ordinarily, the user does not need to specify the direct voltage and current ratings, unless there are specific reasons to do so, for example, for compatibility with an already existing station, to provide for a future extension or for some other reason. Economics dictate that each converter will usually be a 12-pulse converter unit, however it is not mandatory. Where operating criteria require that the loss of one converter unit will not cause loss of full power capability, large HVDC substations could be comprised of two or more back-to-back systems. For this, some of the equipment of the back-to-back systems can, for economic reasons, be located in the same area or even physically integrated, but events which could cause a failure of equipment required by all back-to-back systems need to be carefully considered and preventive measures taken where appropriate.

4.3 Monopolar HVDC system with earth return

Cost considerations often lead to the adoption of a monopolar HVDC system with earth return (Figure 3), particularly for cable transmission which may be expensive.



Key

1 DC reactor

Figure 2 – Examples of back-to-back HVDC systems