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

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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 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:

<table>
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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- withdrawn,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 should be given to coordination of each part with the overall HVDC system performance objectives and to ensuring that the interface of each with the system should be 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 may be inadvisable.

Clause 4 to Clause 22 of this document set out a complete steady-state performance specification for an HVDC system should consider Clauses 3 to 21 of this report.

Terms and definitions for high-voltage direct current (HVDC) transmission used in this report are given in IEC 60633.

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 may be connected to an AC bus separate from the HVDC substation, as discussed in Clause 17.
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 requirements for 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.

This technical report, which covers steady-state performance, is followed by additional documents on dynamic performance and transient performance. All three aspects should be considered when preparing two-terminal HVDC system specifications.

The difference 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 should is not be 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 60146-1-1, Semiconductor converters – General requirements and line commutated converters – Part 1-1: Specifications of basic requirements

IEC/TR 60146-1-2, Semiconductor converters – General requirements and line commutated converters – Part 1-2: Application guide

IEC 60146-1-3, Semiconductor converters – General requirements and line commutated converters – Part 1-3: Transformers and reactors

IEC 60633, Terminology for High-voltage direct current (HVDC) transmission – Vocabulary

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

Part 1: Steady-state conditions

FOREWORD

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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 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:

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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;

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.
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