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CONSOLIDATED VERSION

TECHNICAL REPORT

colour inside

Performance of high-voltage direct current (HVDC) systems with line-commutated converters –
Part 2: Faults and switching

IEC TR 60919-2:2008-11+AMD1:2015-06+AMD2:2020-04 CSV(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 2: Faults and switching

FOREWORD

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This consolidated version of the official IEC Standard and its amendments has been prepared for user convenience.

IEC TR 60919-2 edition 2.2 contains the second edition (2008-11) [documents 22F/160/DTR and 22F/165/RVC], its amendment 1 (2015-06) [documents 22F/344/DTR and 22F/345A/RVC] and its amendment 2 (2020-04) [documents 22F/561/DTR and 22F/575/RVDTR].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendments 1 and 2. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

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 60919-2, 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 main changes with respect to the previous edition:

a) this report concerns only line-commutated converters;
b) significant changes have been made to the control system technology;
c) some environmental constraints, for example audible noise limits, have been added;
d) the capacitor coupled converters (CCC) and controlled series capacitor converters (CSCC) have been included.

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

A list of all parts of the IEC 60919 series, 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 the base publication and its amendments 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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PERFORMANCE OF HIGH-VOLTAGE DIRECT CURRENT (HVDC) SYSTEMS WITH LINE-COMMUTATED CONVERTERS –

Part 2: Faults and switching

1 Scope

This part of IEC 60919 which is a technical report provides guidance on the transient performance and fault protection requirements of high voltage direct current (HVDC) systems. It concerns the transient performance related to faults and switching for two-terminal HVDC systems utilizing 12-pulse converter units comprised of three-phase bridge (double way) connections but it does not cover multi-terminal HVDC transmission systems. However, certain aspects of parallel converters and parallel lines, if part of a two-terminal system， are discussed. The converters are assumed to use thyristor valves as the bridge arms, with gapless metal oxide arresters for insulation co-ordination and to have power flow capability in both directions. Diode valves are not considered in this report.

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

The report is comprised of three parts. IEC 60919-2, which covers transient performance, will be accompanied by companion documents, IEC 60919-1 for steady-state performance and IEC 60919-3 for dynamic performance. An effort has been made to avoid duplication in the three parts. Consequently users of this report are urged to consider all three parts when preparing a specification for purchase of a two-terminal HVDC system.

Readers are cautioned to be aware of the difference between system performance specifications and equipment design specifications for individual components of a system. While equipment specifications and testing requirements are not defined herein, attention is drawn to those which could affect performance specifications for a system. Note that detailed seismic performance requirements are excluded from this technical report. In addition, because of the many possible variations between different HVDC systems, these are not considered in detail. Consequently this report should not be used directly as a specification for a specific project, but rather to provide the basis for an appropriate specification tailored to fit actual system requirements for a particular electric power transmission scheme. This report does not intend to discriminate the responsibility of users and manufacturers for the work specified.

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 are included only because of their influence on the HVDC system performance.

For the purpose of this report, 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 a.c. switching substations in this report, a.c. filters and reactive power sources are included, although they may be connected to an a.c. bus separate from the HVDC substation.

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 60146-1-1, *Semiconductor converters – General requirements and line commutated converters – Part 1-1: Specifications of basic requirements*
Amendment 1 (1996)

IEC 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*

IEC 60071-1, *Insulation co-ordination – Part 1: Terms, definitions, principles and rules*

IEC 60700-1, *Thyristor valves for high-voltage direct current (HVDC) power transmission – Part 1: Electrical testing*

IEC TR 60919-1:~~2005~~2010, *Performance of high-voltage direct current (HVDC) systems with line-commutated converters – Part 1: Steady-state conditions*
Amendment 1:2013

IEC TR 60919-3:2009, *Performance of high-voltage direct current (HVDC) systems with line-commutated converters – Part 3: Dynamic conditions*

3 Outline of HVDC transient performance specifications

3.1 Transient performance specifications

A complete performance specification related to transient performance of an HVDC system during faults and switching should also include fault protection requirements.

These concepts are introduced at the appropriate locations in the following transient performance and related clauses:

- Clause 4 – Switching transients without faults
- Clause 5 – AC system faults
- Clause 6 – AC filter, reactive power equipment and a.c. bus faults
- Clause 7 – Converter unit faults
- Clause 8 – DC reactor, d.c. filter and other d.c. equipment faults
- Clause 9 – DC line faults
- Clause 10 – Earth electrode line faults
- Clause 11 – Metallic return conductor faults
- Clause 12 – Insulation co-ordination - HVDC systems
- Clause 13 – Telecommunication requirements
- Clause 14 – Auxiliary systems

Discussion in the following clauses on the d.c. line, earth electrode line and earth electrode is limited to the relationships between these and either the transient performance or protection of HVDC converter stations.

3.2 General comment

In general, control strategies can be used to minimize the effect of disturbances, but when the safety of equipment depends on their correct performance, this should be identified.

4 Switching transients without faults

4.1 General

This clause deals with the transient behaviour of the HVDC system during and after switching operations both on the a.c. and the d.c. sides of converter substations, and is not related to equipment or line faults which are treated in the following clauses of this report.

Switching operations without faults can be classified as follows:

a) energization and de-energization of a.c. side equipment such as converter transformers, a.c. filters, shunt reactors, capacitor banks, a.c. lines, static var compensators (SVC), and synchronous compensators;

b) load rejection;

c) starting and removal from service of converter units;

d) operation of d.c. breakers and d.c. switches for paralleling of poles and lines; connection or disconnection of d.c. lines (poles), earth electrode lines, metallic return paths, d.c. filters, etc.

4.2 Energization and de-energization of a.c. side equipment

During the operating life of an HVDC transmission system, energization and de-energization of converter transformers, a.c. filters, shunt reactors, capacitor banks, SVCs, and other equipment may occur many times. Depending on the characteristics of the a.c. system and the equipment being switched, resulting current and voltage stresses will be imposed on equipment being switched and generally impinge as well on part of the overall a.c. system.

The overvoltages and overcurrents which are critical for plant design are usually due to faults (Clauses 5 to 9), and not to normal switching operations. Nevertheless, they are discussed here for completeness. They are relevant in consideration of disturbances to a.c. system voltages.

Filter switching will also result in transient distortion of the bus voltage. This could disturb the commutation process and in a weak system could lead to commutation failure.

Thus equipment switching should be investigated to:

– determine critical a.c. network and equipment conditions which may contribute to such abnormal stresses and actions which may be taken to mitigate them;

– design the equipment;

– verify arrester duties.

Transients occur routinely when filters and capacitor banks are switched as necessary to control harmonic interference and steady-state terminal voltages.

Because of the frequency of occurrence of switching overvoltages it is generally desirable that the overvoltage protective devices do not absorb appreciable energy during such operations. For example the amplitudes of overvoltages arising from routine switching operations can be