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TECHNICAL REPORT

RAPPORT TECHNIQUE

Performance of high-voltage direct current (HVDC) systems with line-commutated converters –
Part 3: Dynamic conditions

Fonctionnement des systèmes à courant continu haute tension (CCHT) munis de convertisseurs commutés par le réseau –
Partie 3: Conditions dynamiques

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 3: Dynamic conditions

FOREWORD

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IEC 60919-3, 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 second edition cancels and replaces the first edition, which was issued as a technical specification in 1999. It constitutes a technical revision.

This edition includes the following significant technical 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.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
22F/183/DTR	22F/192/RVC

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 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 this publication will remain unchanged until the maintenance result 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- withdrawn,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.

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

Part 3: Dynamic conditions

1 Scope

This Technical Report provides general guidance on the dynamic performance of high-voltage direct current (HVDC) systems. Dynamic performance, as used in this specification, is meant to include those events and phenomena whose characteristic frequencies or time domain cover the range between transient conditions and steady state. It is concerned with the dynamic performance due to interactions between two-terminal HVDC systems and related a.c. systems or their elements such as power plants, a.c. lines and buses, reactive power sources, etc. at steady-state or transient conditions. The two-terminal HVDC systems are assumed to utilize 12-pulse converter units comprised of three-phase bridge (double way) connections. The converters are assumed to use thyristor valves as bridge arms, with gapless metal oxide arresters for insulation coordination and to have power flow capability in both directions. Diode valves are not considered in this specification. While multi-terminal HVDC transmission systems are not expressly considered, much of the information in this specification is equally applicable to such systems.

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.

This report (IEC 60919-3) which covers dynamic performance, is accompanied by publications for steady-state (IEC 60919-1) and transient (IEC 60919-2) performance. All three aspects should be considered when preparing two-terminal HVDC system specifications.

A difference exists 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 would affect performance specifications for a system. There are many possible variations between different HVDC systems, therefore these are not considered in detail. 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 between the responsibility of users and manufacturers for the work specified.

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: Specification of basic requirements*

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

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

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

IEC/TR 60919-2:2008, *Performance of high-voltage direct current (HVDC) systems with line-commutated converters – Part 2: Faults and switching*

3 Outline of HVDC dynamic performance specifications

3.1 Dynamic performance specification

A complete dynamic performance specification for an HVDC system should consider the following clauses:

– a.c. system power flow and frequency control (see Clause 4);
– a.c. dynamic voltage control and interaction with reactive power sources (see Clause 5);
– a.c. system transient and steady-state stability (see Clause 6);
– dynamics of the HVDC system at higher frequencies (see Clause 7);
– subsynchronous oscillations (see Clause 8);
– power plant interaction (see Clause 9).

Clause 4 deals with using active power control of the HVDC system to affect power flow and/or frequency of related a.c. systems in order to improve the performance of such a.c. systems. The following aspects should be considered at the design of HVDC active power control modes:

a) to minimize the a.c. power system losses under steady-state operation;
b) to prevent a.c. line overload under steady-state operation and under a disturbance;
c) to coordinate with the a.c. generator governor control;
d) to suppress a.c. system frequency deviations under steady-state operation and under a disturbance.

In Clause 5, the voltage and reactive power characteristics of the HVDC substation and other reactive power sources (a.c. filters, capacitor banks, shunt reactors, SVC (static var compensator), synchronous compensators) as well as interaction between them during control of the a.c. bus voltage are considered.

In Clause 6, a discussion is provided concerning methods of controlling active and reactive power of an HVDC link to improve the steady-state and/or transient stability of the interconnected a.c. system by counteracting electromechanical oscillations.

Clause 7 deals with dynamic performance of an HVDC system in the range of half fundamental frequency and above due to both characteristic and non-characteristic harmonics generated by converters. Means for preventing instabilities are also discussed.

In Clause 8, the phenomenon of amplification of torsional, mechanical oscillations in turbine-generators of a thermal power plant at their natural frequencies, due to interaction with an HVDC control system (constant power and current regulation modes), is considered. Specifications for subsynchronous damping control are defined.

The interaction between a power plant and an HVDC system located electrically near to it is considered in Clause 9, taking into account some special features of the nuclear power plant and requirements for the reliability of the HVDC system.