

TECHNICAL REPORT



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



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Part 1: Steady-state conditions**

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CONTENTS

FOREWORD.....	8
INTRODUCTION.....	10
1 Scope.....	11
2 Normative references	12
3 Terms and definitions	12
4 Types of HVDC systems	12
4.1 General.....	12
4.2 HVDC back-to-back system	12
4.3 Monopolar HVDC system with earth return.....	13
4.4 Monopolar HVDC system with metallic return.....	16
4.5 Bipolar earth return HVDC system	17
4.6 Bipolar HVDC system with metallic return	20
4.7 Two 12-pulse groups per pole.....	21
4.8 Converter transformer arrangements.....	24
4.9 DC switching considerations	25
4.10 Series-capacitor-compensated HVDC systems.....	28
4.11 LCC/VSC hybrid bipolar system	32
5 Environment information.....	33
6 Rated power, current and voltage	36
6.1 Rated power	36
6.1.1 General	36
6.1.2 Rated power of an HVDC system with transmission line	36
6.1.3 Rated power of an HVDC back-to-back system.....	36
6.1.4 Direction of power flow	37
6.2 Rated current.....	37
6.3 Rated voltage	37
7 Overload and equipment capability	37
7.1 Overload	37
7.2 Equipment capability.....	38
7.2.1 General	38
7.2.2 Converter valve capability.....	38
7.2.3 Capability of oil-cooled transformers and reactors	39
7.2.4 AC harmonic filter and reactive power compensation equipment capability	39
7.2.5 Switchgear and buswork capability	39
8 Minimum power transfer and no-load stand-by state	39
8.1 General.....	39
8.2 Minimum current	39
8.3 Reduced direct voltage operation.....	40
8.4 No-load stand-by state.....	40
8.4.1 General	40
8.4.2 Converter transformers – No-load stand-by	40
8.4.3 Converter valves – No-load stand-by	40
8.4.4 AC filters and reactive compensation – No-load stand-by	41
8.4.5 DC reactors and DC filters – No-load stand-by	41

8.4.6	Auxiliary power system – No-load stand-by	41
8.4.7	Control and protection – No-load stand-by	41
9	AC system	41
9.1	General	41
9.2	AC voltage	41
9.2.1	Rated AC voltage	41
9.2.2	Steady-state voltage range	41
9.2.3	Negative sequence voltage	42
9.3	Frequency	42
9.3.1	Rated frequency	42
9.3.2	Steady-state frequency range	43
9.3.3	Short-term frequency variation	43
9.3.4	Frequency variation during emergency	43
9.4	System impedance at fundamental frequency	43
9.5	System impedance at harmonic frequencies	43
9.6	Positive and zero-sequence surge impedance	43
9.7	Other sources of harmonics	44
9.8	Subsynchronous torsional interaction (SSTI)	44
10	Reactive power	44
10.1	General	44
10.2	Conventional HVDC systems	44
10.3	Series capacitor compensated HVDC schemes	46
10.4	Converter reactive power consumption	46
10.5	Reactive power balance with the AC system	46
10.6	Reactive power supply	46
10.7	Maximum size of switchable VAR banks	47
11	HVDC transmission line, earth electrode line and earth electrode	47
11.1	General	47
11.2	Overhead line(s)	47
11.2.1	General	47
11.2.2	Electrical parameters	47
11.3	Cable line(s)	48
11.3.1	General	48
11.3.2	Electrical parameters	48
11.4	Earth electrode line	49
11.5	Earth electrode	49
12	Reliability	49
12.1	General	49
12.2	Outage	49
12.2.1	General	49
12.2.2	Scheduled outage	49
12.2.3	Forced outage	49
12.3	Capacity	50
12.3.1	General	50
12.3.2	Maximum continuous capacity P_m	50
12.3.3	Outage capacity P_o	50
12.3.4	Outage derating factor (ODF)	50
12.4	Outage duration terms	50

12.4.1	Actual outage duration (AOD)	50
12.4.2	Equivalent outage duration (EOD)	50
12.4.3	Period hours (PH)	50
12.4.4	Actual outage hours (AOH)	51
12.4.5	Equivalent outage hours (EOH)	51
12.5	Energy unavailability (EU)	51
12.5.1	General	51
12.5.2	Forced energy unavailability (FEU)	51
12.5.3	Scheduled energy unavailability (SEU)	52
12.6	Energy availability (EA)	52
12.7	Maximum permitted number of forced outages	52
12.8	Statistical probability of outages	52
12.8.1	Component faults	52
12.8.2	External faults	52
13	HVDC control	52
13.1	Control objectives	52
13.2	Control structure	53
13.2.1	General	53
13.2.2	Converter unit firing control	53
13.2.3	Pole control	54
13.2.4	HVDC substation control	56
13.2.5	Master control	58
13.3	Control order settings	58
13.4	Current limits	58
13.5	Control circuit redundancy	59
13.6	Protection system	59
13.7	Measurements	59
14	Telecommunication	60
14.1	Types of telecommunication links	60
14.2	Telephone	60
14.3	Power line carrier (PLC)	60
14.4	Microwave	61
14.5	Radio link	61
14.6	Optical fibre telecommunication	61
14.7	Classification of data to be transmitted	61
14.8	Fast response telecommunication	62
14.9	Reliability	62
15	Auxiliary power supplies	63
15.1	General	63
15.2	Reliability and load classification	63
15.3	AC auxiliary supplies	64
15.4	Batteries and uninterruptible power supplies (UPS)	64
15.5	Emergency supply	65
16	Audible noise	65
16.1	General	65
16.2	Public nuisance	65
16.2.1	General	65
16.2.2	Valves and valve coolers	66

16.2.3	Converter transformers	66
16.2.4	DC reactors	66
16.2.5	AC filter reactors	66
16.3	Noise in working areas	66
17	Harmonic interference – AC	67
17.1	AC side harmonic generation	67
17.2	Filters	67
17.3	Interference disturbance criteria	70
17.4	Levels for interference	71
17.5	Filter performance	72
18	Harmonic interference – DC	72
18.1	DC side interference	72
18.1.1	Harmonic currents in HVDC transmission line	72
18.1.2	Characteristic and non-characteristic harmonics	72
18.1.3	Groups of harmonics	73
18.1.4	Calculation of harmonic currents	73
18.1.5	Calculation of induced voltages	73
18.1.6	Personnel safety	73
18.1.7	DC filters	73
18.2	DC filter performance	74
18.2.1	Requirements for voice communication circuits	74
18.2.2	Levels of interference	74
18.2.3	Safety	74
18.3	Specification requirements	75
18.3.1	Economic level of filtering	75
18.3.2	General criteria	76
18.3.3	Factors to be taken into account for calculations	76
18.3.4	Calculation of currents	77
19	Power line carrier interference (PLC)	77
19.1	General	77
19.2	Performance specification	78
20	Radio frequency interference	79
20.1	General	79
20.2	RFI from HVDC systems	80
20.2.1	RFI sources	80
20.2.2	RFI propagation	80
20.2.3	RFI characteristics	80
20.3	RFI performance specification	81
20.3.1	RFI risk assessment	81
20.3.2	Specification RFI limit and its verification	81
20.3.3	Design aspects	82
21	Power losses	82
21.1	General	82
21.2	Main contributing sources	83
21.2.1	General	83
21.2.2	AC filters and reactive power compensation	83
21.2.3	Converter bridges	83
21.2.4	Converter transformer	83

21.2.5	DC reactor	83
21.2.6	DC filter	84
21.2.7	Auxiliary equipment	84
21.2.8	Other components	84
22	Provision for extensions to the HVDC systems	84
22.1	General.....	84
22.2	Specification for extensions	84
Annex A	(informative) Factors affecting reliability and availability of converter stations	87
A.1	Design and documentation.....	87
A.1.1	General	87
A.1.2	General design principles	87
A.1.3	More detailed design principles	88
A.1.4	Software design principles.....	88
A.1.5	RAM records.....	89
A.2	Operation.....	89
A.2.1	Training	89
A.2.2	Maintenance programs affecting reliability	90
A.2.3	Spare parts.....	91
Bibliography		94
Figure 1	– Twelve-pulse converter unit	11
Figure 2	– Examples of back-to-back HVDC systems	13
Figure 3	– Monopolar HVDC system with earth return	14
Figure 4	– Two 12-pulse units in series.....	15
Figure 5	– Two 12-pulse units in parallel.....	16
Figure 6	– Monopolar HVDC system with metallic return	17
Figure 7	– Bipolar system	18
Figure 8	– Metallic return operation of the unfaulted pole in a bipolar system.....	19
Figure 9	– Bipolar HVDC system with metallic return	21
Figure 10	– Bipolar system with two 12-pulse units in series per pole	23
Figure 11	– Bipolar system with two 12-pulse units in parallel per pole	24
Figure 12	– DC switching of line conductors	26
Figure 13	– DC switching of converter poles	27
Figure 14	– DC switching – Overhead line to cable	28
Figure 15	– DC switching – Two bipolar converters and lines	29
Figure 16	– DC switching – Intermediate.....	30
Figure 17	– Capacitor commutated converter configurations	31
Figure 18	– LCC/VSC hybrid bipolar system	33
Figure 19	– Variations of reactive power Q with active power P of an HVDC converter	45
Figure 20	– Control hierarchy for HVDC/UHVDC system	55
Figure 21	– Converter voltage-current characteristic	57
Figure 22	– Examples of AC filter connections for a bipole HVDC system	68
Figure 23	– Circuit diagrams for different filter types	69
Figure 24	– RY COM interference meter results averaged – Typical plot of converter interference levels on the DC line	79

Figure 25 – Recommended measurement procedure with definition of measuring point	82
Figure 26 – Extension methods for HVDC systems	86
Table 1 – Information supplied for HVDC substation	34
Table 2 – Performance parameters for voice communication circuits: Subscribers and trunk circuits	75

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**PERFORMANCE OF HIGH-VOLTAGE DIRECT CURRENT
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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 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.

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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.

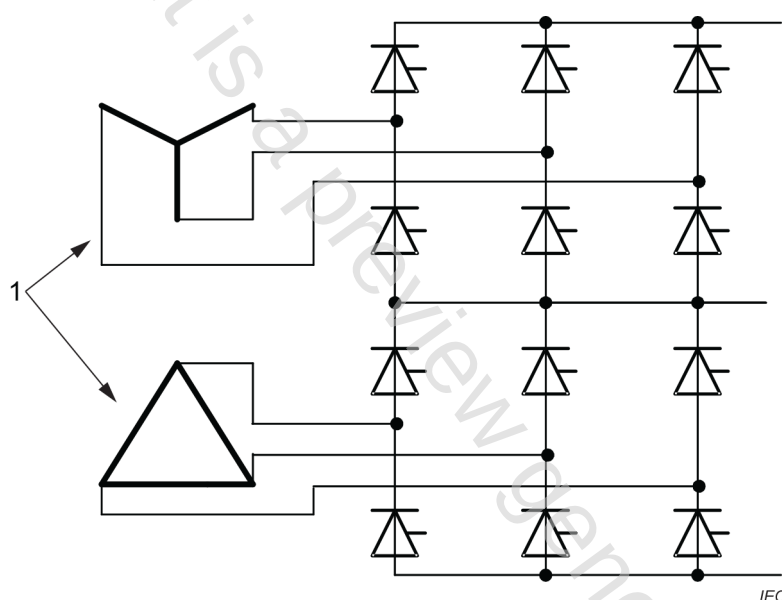
For the purpose of this document, an HVDC substation is assumed to consist of one or more converter units installed in a single location together with buildings, reactors, filters, reactive power supply, control, monitoring, protective, measuring and auxiliary equipment. While there is no discussion 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.