



IEC 61803

Edition 3.0 2026-05

INTERNATIONAL STANDARD

Determination of power losses in high-voltage direct current (HVDC) converter stations

CONTENTS

FOREWORD	3
1 Scope	5
2 Normative references	5
3 Terms, definitions and symbols	6
3.1 Terms and definitions.....	6
3.2 Symbols.....	7
3.2.1 Common.....	7
3.2.2 Line-commutated converters.....	8
4 Overview	8
4.1 General.....	8
4.2 Ambient conditions	12
4.2.1 General	12
4.2.2 Outdoor standard reference temperature	12
4.2.3 Coolant standard reference temperature.....	12
4.2.4 Standard reference air pressure	12
4.3 Operating parameters	12
5 Determination of equipment losses	13
5.1 Thyristor valve losses (LCC only).....	13
5.1.1 General	13
5.1.2 Thyristor conduction loss per valve.....	16
5.1.3 Thyristor spreading loss per valve	17
5.1.4 Other conduction losses per valve	19
5.1.5 DC voltage-dependent loss per valve.....	19
5.1.6 Damping loss per valve (resistor-dependent term)	20
5.1.7 Damping loss per valve (change of capacitor energy term)	21
5.1.8 Turn-off losses per valve	22
5.1.9 Reactor loss per valve	22
5.1.10 Total valve losses	23
5.1.11 Temperature effects	23
5.1.12 No-load operation loss per valve.....	24
5.2 Transformer losses	24
5.2.1 General	24
5.2.2 No-load operation losses	24
5.2.3 Operating losses	25
5.2.4 Auxiliary power losses	26
5.3 AC filter losses	26
5.3.1 General	26
5.3.2 AC filter capacitor losses	27
5.3.3 AC filter reactor losses	27
5.3.4 AC filter resistor losses.....	28
5.3.5 Total AC filter losses	28
5.4 Shunt capacitor bank losses	28
5.5 Shunt reactor losses	28
5.6 DC smoothing reactor losses	29
5.7 DC filter losses	30
5.7.1 General	30

5.7.2	DC filter capacitor losses	30
5.7.3	DC filter reactor losses	31
5.7.4	DC filter resistor losses	31
5.7.5	Total DC filter losses	31
5.8	Auxiliaries and station service losses	31
5.9	Series filter losses	32
5.10	Phase reactor losses (VSC only).....	33
5.11	Valve reactor losses (VSC only).....	35
5.12	Other equipment losses	35
Annex A	(informative) Calculation of harmonic currents and voltages (LCC only).....	36
A.1	Harmonic currents in converter transformers.....	36
A.2	Harmonic currents in the AC filters.....	36
A.3	Harmonic voltages on the DC side	37
A.4	DC side harmonic currents in the smoothing reactor	37
Annex B	(informative) Typical station losses	38
Annex C	(informative) HVDC converter station loss evaluation – An illustration	39
C.1	General.....	39
C.2	Loss evaluation under various cases.....	40
Bibliography	43
Figure 1	– Typical high-voltage direct current (HVDC) equipment for one pole of an LCC scheme	10
Figure 2	– Typical high-voltage direct current (HVDC) equipment for one pole of a VSC scheme.....	11
Figure 3	– Simplified three-phase diagram of an HVDC 12-pulse converter (LCC)	14
Figure 4	– Simplified equivalent circuit of a typical thyristor valve	15
Figure 5	– Current and voltage waveforms of a valve operating in a 12-pulse converter.....	16
Figure 6	– Thyristor on-state characteristic	17
Figure 7	– Conduction current and voltage drop of thyristor	18
Figure 8	– Distribution of commutating inductance between L_1 and L_2	20
Figure 9	– Thyristor current during reverse recovery	22
Figure 10	– Typical phase reactor and valve reactor arrangement per arm of a VSC scheme.....	34
Table B.1	– Typical values of losses for a LCC station.....	38
Table B.2	– Typical values of losses for a VSC MMC station.....	38
Table C.1	– Conditions for calculation of losses in case D1	41
Table C.2	– Conditions for calculation of losses in case D2	41

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**Determination of power losses in high-voltage
direct current (HVDC) converter stations**

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) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 61803 has been prepared by subcommittee 22F: Power electronics for electrical transmission and distribution systems, of IEC technical committee 22: Power electronic systems and equipment. It is an International Standard.

This third edition cancels and replaces the second edition published in 2020. This edition constitutes a technical revision.

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

- a) HVDC stations with voltage-sourced converters (VSC) technology have been included;
- b) to facilitate the application of this document and to ensure its quality remains consistent, 5.1.8 and 5.8 have been reviewed, taking into consideration that the present thyristor production technology provides considerably less thyristor parameters dispersion comparing with the situation in 1999 when the first edition of IEC 61803 was developed; therefore, the production records of thyristors can be used for the power losses calculation;

- c) the calculation of the total station load losses (cases D1 and D2 in Annex C) has been corrected.

The text of this International Standard is based on the following documents:

Draft	Report on voting
22F/860/FDIS	22F/868/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

1 Scope

This document applies to all high-voltage direct current (HVDC) converter stations with line-commutated converters (LCC) as well with voltage-sourced converters (VSC) used for power exchange (power transmission or back-to-back installation) in utility systems. For line-commutated converters (LCC), this document presumes the use of 12-pulse thyristor converters but can, with due care, also be used for 6-pulse thyristor converters.

Where VSC is referred to in this document, it is assumed to be of the MMC-type or similar, with very low harmonic generation. It is important to treat other types of VSC as appropriate.

In some applications, synchronous compensators, static var compensators (SVC), or static synchronous compensator (STATCOM) are connected to the AC bus of the HVDC converter station. The loss determination procedures for such equipment are not included in this document.

This document presents a set of standard procedures for determining the total losses of an HVDC converter station, except for VSC valves which are covered by the IEC 62751 series. The procedures cover all parts, except as noted above, and address no-load operation and operating losses together with their methods of calculation which use, wherever possible, measured parameters.

Converter station designs employing novel components or circuit configurations compared to the typical design assumed in this document, or designs equipped with unusual auxiliary circuits that can affect the losses, are assessed on their own merits.

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 60076-1, *Power transformers - Part 1: General*

IEC 60076-6, *Power transformers - Part 6: Reactors*

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

IEC 60700-1:2015, *Thyristor valves for high voltage direct current (HVDC) power transmission - Part 1: Electrical testing*
IEC 60700-1:2015/AMD1:2021

IEC 60871-1, *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V - Part 1: General*

IEC 62747, *Terminology for voltage-sourced converters (VSC) for high-voltage direct current (HVDC) systems*

Bibliography

IEC 60747-6, *Semiconductor devices - Part 6: Discrete devices - Thyristors*

IEC TR 60919-1:2020, *Performance of high-voltage direct current (HVDC) systems with line-commutated converters - Part 1: Steady-state conditions*

IEC 61000-4-7, *Electromagnetic compatibility (EMC) - Part 4-7: Testing and measurement techniques - General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*

IEC 61378-3:2015, *Converter transformers - Part 3: Application guide*

IEC TR 62001-5, *High-voltage direct current (HVDC) systems - Guidance to the specification and design evaluation of AC filters - Part 5: AC side harmonics and appropriate harmonic limits for HVDC systems with voltage sourced converters (VSC)*

IEC 62751 (all parts), *Power losses in voltage sourced converter (VSC) valves for high-voltage direct current (HVDC) systems*

IEC 62751-1, *Power losses in voltage sourced converter (VSC) valves for high-voltage direct current (HVDC) systems - Part 1: General requirements*

IEC 62751-2, *Power losses in voltage sourced converter (VSC) valves for high-voltage direct current (HVDC) systems - Part 2: Modular multilevel converters*

IEC/IEEE 60076-57-129:2017, *Power transformers - Part 57-129: Transformers for HVDC applications*

CEPEK, M. et al., *Loss Measurement in High Voltage Thyristor Valves*, IEEE Transactions on Power Delivery, Vol. 9, 1994

Load Losses in HVDC Converter Transformers, CIGRE JWG 12/14.10 paper, Electra 174, Oct 1997, pp 53-56

KIMBARK, E.W., *Direct Current Transmission*, Vol. I, John & Sons, Inc., New York, 1971

TOBIN, W.H. et al., *Power Loss in Large Area Thyristors Designed for 50/60 Hz Phase Control Rectifier Circuits*, paper presented at the 16th annual meeting of the IEEE – IAS, Oct 5-9, 1981

UHLMANN, E., *Power Transmission by Direct Current*, Springer-Verlag Berlin, Heidelberg, New York, 1995