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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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Determination of power losses in high-voltage direct current (HVDC) converter stations ~~with line-commutated converters~~ 1

FOREWORD

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This commented version (CMV) of the official standard IEC 61803:2026 edition 3.0 allows the user to identify the changes made to the previous IEC 61803:2020 edition 2.0. Furthermore, comments from IEC SC 22F experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

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 ~~line-commutated~~ 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. **2**

In some applications, synchronous compensators, static var compensators (SVC), or static synchronous compensator (STATCOM) ~~may be~~ 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 **3**. 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 ~~could~~ 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

List of comments

1 This new edition of IEC 61803 extends the application scope to both LCC and VSC HVDC schemes.

2 Most recent VSC schemes are of the MMC type; therefore, the focus of this standard remains on MMC-type VSC schemes.

3 For VSC valves, the specific IEC 62751 standard exists; for other components in the VSC schemes, the current edition of IEC 61803 can be used.

4 Notes are introduced to differentiate the definition of the load level for LCC and VSC schemes.

5 A sentence is introduced to clarify that the measured losses still need to be corrected for nominal parameters and ambient/operating conditions. This correction is important for verification against the guaranteed loss values.

6 Figure 2 is introduced to include VSC schemes in this standard.

7 The text is introduced to explain the differences in harmonic generation behaviour between LCC and VSC schemes.

8 The note aligns the definition of no-load operation for VSC schemes for the purpose of loss comparison, although in real operation VSC schemes do have additional no-load loss contributions from the converter valves, which can be neglected.

9 The text and the note are introduced to highlight the harmonic behaviour of VSC schemes compared to LCC schemes and how this could be handled for the purpose of loss calculation.

10 Guidelines on how to handle harmonic losses of transformers in VSC schemes are provided in this text.

11 The text is introduced for VSC schemes and accordingly applies loss calculation for any type of filters in the scheme, as appropriate.

12 Specific text is introduced for VSC schemes.

13 The text clarifies that, irrespective of some contribution of harmonic losses beyond the 49^{th} harmonic in VSC schemes, the upper limit for loss comparison remains the 49^{th} harmonic.

14 The text is introduced for the specific application of DC-side reactors in VSC schemes.

15 The text is added to clarify the need for series filters.

16 Subclause 5.10 is introduced to clarify the possible locations of reactors used in VSC schemes, and the following paragraph explains how reactor losses are to be calculated in VSC schemes.

17 Subclause 5.11 is introduced because VSC valves have specific valve reactors, which shall be included in the loss calculations.

18 Typical loss values for VSC MMC stations are added for informational purposes as a corresponding comparison with Table B.1 for LCC schemes.

19 The note is added with a specific explanation for VSC schemes, with a cross-reference to other IEC standards, so that for the purpose of loss calculation only the converter blocked condition is considered. This also aligns with the existing definition in this IEC document for the “no-load operating state”.