

TECHNICAL REPORT



**Guidelines for operation and maintenance of line commutated converter (LCC)
HVDC converter station**

(standards.iteh.ai)

IEC TR 63065:2017

<https://standards.iteh.ai/catalog/standards/sist/7f96961a-e1c8-4d80-8b40-53156683f907/iec-tr-63065-2017>



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2022 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC TR 63065:2017

<https://standards.iteh.ai/catalog/standards/sist/7f96961a-e1c8-4d80-8b40-53156683f907/iec-tr-63065-2017>



TECHNICAL REPORT



**Guidelines for operation and maintenance of line commutated converter (LCC)
HVDC converter station**

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[IEC TR 63065:2017](https://standards.iteh.ai/catalog/standards/sist/7f96961a-e1c8-4d80-8b40-53156683f907/iec-tr-63065-2017)

<https://standards.iteh.ai/catalog/standards/sist/7f96961a-e1c8-4d80-8b40-53156683f907/iec-tr-63065-2017>

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.200; 29.240.01

ISBN 978-2-8322-3828-8

Warning! Make sure that you obtained this publication from an authorized distributor.

REDLINE VERSION



**Guidelines for operation and maintenance of line commutated converter (LCC)
HVDC converter station**

(standards.iteh.ai)

IEC TR 63065:2017

<https://standards.iteh.ai/catalog/standards/sist/7f96961a-e1c8-4d80-8b40-53156683f907/iec-tr-63065-2017>

CONTENTS

FOREWORD	4
1 Scope	6
2 Normative references	6
3 Terms, definitions, and abbreviated terms	6
3.1 Terms and definitions	6
3.2 Abbreviated terms	7
4 Operation	8
4.1 Operation policy	8
4.1.1 Target reliability and availability	8
4.1.2 Operation cost	9
4.1.3 Manned or unmanned	9
4.2 Operation condition and limits	9
4.3 Operations of an HVDC system	10
4.3.1 General	10
4.3.2 Typical operation configuration	10
4.3.3 Set up the control mode	12
4.3.4 Operation procedure	13
4.4 Operations of HVDC equipment	16
4.4.1 Converter valves	16
4.4.2 Converter transformers and oil immersed smoothing reactors	19
4.4.3 AC/DC breakers and switchgear	22
4.4.4 AC/DC filters	24
4.4.5 Control and protections	27
4.4.6 DC measurement instruments	29
4.4.7 Valve cooling system	30
4.4.8 Auxiliary power system	33
4.4.9 Fire protection system	34
5 Maintenance	35
5.1 Maintenance policy	35
5.1.1 General	35
5.1.2 Corrective maintenance	36
5.1.3 Time-based maintenance (TBM)	36
5.1.4 Condition-based maintenance (CBM)	36
5.1.5 Reliability-centred maintenance (RCM)	37
5.1.6 Maintenance programme	37
5.2 Maintenance during operation	37
5.2.1 Routine maintenance for converter transformers	37
5.2.2 Maintenance for control and protections	38
5.2.3 Maintenance for DC measurements	38
5.2.4 Routine maintenance for valve cooling system	38
5.2.5 Routine maintenance for Fire protection system	39
5.3 Maintenance under outage	39
5.3.1 Converter valves	39
5.3.2 Converter transformers	39
5.3.3 AC/DC breakers and switchgear	41
5.3.4 AC/DC filters	41

5.3.5	DC measurements	42
5.3.6	Valve cooling system	42
5.3.7	AC/DC arresters	43
5.3.8	Fire protection system	43
6	Fault analysis and troubleshooting.....	44
6.1	General.....	44
6.2	System disturbances.....	44
6.3	Station faults.....	44
6.4	General information for fault analysis	45
6.4.1	General	45
6.4.2	Interpreting events and the TFR	45
6.4.3	Checking plant circuit diagram and application software logics	45
6.4.4	Analyzing the equipment status	45
6.4.5	Simulation	45
6.4.6	Site test.....	46
6.4.7	Involving the HVDC supplier	46
7	Training.....	46
7.1	General.....	46
7.2	Operator training program	46
7.2.1	General	46
7.2.2	Training courses	46
7.2.3	Participation during installation and commissioning	46
7.3	Maintenance training program.....	47
7.3.1	General	47
7.3.2	Training courses	47
7.3.3	Training during equipment installation and testing	47
7.3.4	Continuous transfer of knowledge.....	48
8	Spare parts.....	48
9	Tools	49
10	Documentation	50
10.1	General.....	50
10.2	Documents to be provided by the supplier.....	50
10.3	Documents to be prepared by the operators.....	50
10.4	Statistics and analysis	50
	Bibliography.....	52
	Table 1 – Basic tools needed for operation and maintenance of an HVDC converter station	49

INTERNATIONAL ELECTROTECHNICAL COMMISSION

GUIDELINES FOR OPERATION AND MAINTENANCE OF LINE COMMUTATED CONVERTER (LCC) HVDC CONVERTER STATION

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) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

IEC TR 63065 edition 1.1 contains the first edition (2017-09) [documents 115/153/DTR and 115/163/RVDTR] and its amendment 1 (2022-06) [documents 115/280/DTR and 115/294/RVDTR].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. 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 TR 63065, which is a technical report, has been prepared by IEC technical committee 115: High Voltage Direct Current (HVDC) transmission for DC voltages above 100 kV.

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

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 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

(standards.iteh.ai)

[IEC TR 63065:2017](https://standards.iteh.ai/catalog/standards/sist/7f96961a-e1c8-4d80-8b40-53156683f907/iec-tr-63065-2017)

<https://standards.iteh.ai/catalog/standards/sist/7f96961a-e1c8-4d80-8b40-53156683f907/iec-tr-63065-2017>

GUIDELINES FOR OPERATION AND MAINTENANCE OF LINE COMMUTATED CONVERTER (LCC) HVDC CONVERTER STATION

1 Scope

This Technical Report provides general guidance on basic principles and general proposals for the safe and economic operation and maintenance of an LCC converter station.

These guidelines are based on the operation and maintenance practices that have been used successfully during the last decades at HVDC converter stations all over the world, and can be referred to by new HVDC users to optimize operation and maintenance policy and assist in performing the operation and maintenance work.

This document focuses only on the operation and maintenance of the equipment inside an LCC converter station, including back-to-back HVDC systems. The operation and maintenance of HVDC overhead transmission lines, HVDC cables and voltage sourced converter (VSC) are not covered by this document.

NOTE Usually the agreement between the purchaser and the suppliers of the HVDC converter station includes specific requirements regarding contractual requirements of particular systems. Such specific requirements will supersede the general/typical description mentioned in this document and all functions mentioned in this document are not necessarily applicable for all systems.

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, *Terminology for high-voltage direct current (HVDC) transmission*

IEC 60919 (all parts), *Performance of high-voltage direct current (HVDC) systems with line-commutated converters*

IEC 61975, *System tests for High-voltage direct current (HVDC) installations*

IEC TS 62672-1, *Reliability and availability evaluation of HVDC systems – Part 1: HVDC systems with line commutated converters*

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60633 and the following 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>

**3.1.1
manned station**

MS

HVDC converter station that is operated locally by several operators, 24 h a day

Note 1 to entry: In some systems the manned station controls and observes not only its own converter station but also the opposite unmanned station.

**3.1.2
unmanned station**

US

HVDC converter station that is operated remotely with no operator on site

**3.1.3
time based maintenance**

TBM

maintenance carried out in accordance with a specified time schedule, in most cases annually

**3.1.4
condition-based maintenance**

CBM

necessary maintenance performed based on the equipment's condition, sometimes combined with TBM

**3.1.5
reliability centred maintenance**

RCM

necessary maintenance performed after analyzing the performance of the equipment

**3.1.6
operator**

person operating the converter station

**3.1.7
asset manager**

person that manages the plant/asset for the overall planning, operation, maintenance and performance in accordance with a set of criteria as assigned by the asset owner

3.2 Abbreviated terms

BOD	break over diode
BPS	by-pass switch
CBM	condition-based maintenance
CT	current transformer
DGA	dissolved gas analysis
GIS	gas insulated switchgear
GRTS	ground return transfer switch
HMI	human-machine interface
LCC	line commuted converter
MCB	micro circuit breaker
MRTB	metallic return transfer breaker
MV	medium voltage
NBS	neutral bus switch
OEM	original equipment manufacturer

OLT	open line test
OLTC	on line tap changer
OTDR	optical time domain reflectometer
RCM	reliability-centred maintenance
RPC	reactive power control
SCADA	supervisory control and data acquisition
SER	sequence of event records
TBM	time-based maintenance
TFR	transient fault record

4 Operation

4.1 Operation policy

4.1.1 Target reliability and availability

Generally, an availability of 97 % is requested as the minimum value in the design specification of a new HVDC project. This is based on a forced unavailability of less than 1 % and a scheduled unavailability of about 2 %. With good quality control applied in the design, manufacture, installation and testing stages, as well as appropriate operating and careful maintenance during operation, this requirement can be met in most modern HVDC systems.

According to the survey conducted by CIGRE B4 AG4 ([2] to [6]¹) for the period 2003 to 2014, typical target performance indicators for an HVDC system can be:

- a) forced unavailability < 1 %;
- b) availability > 97 %.

Scheduled unavailability varies from system to system depending on which operation and maintenance policy is taken. This can be seen from the performance reports of CIGRE B4 AG4. For example, some systems perform maintenance using 24 h shifts, whereas others work only 8 h a day and leave the system out of service for 16 h each day and on weekends. In other systems, maintenance is performed when the generator is not available (thermal unit out for maintenance or low water conditions, etc.). That is why the typical scheduled unavailability and overall unavailability is not given above.

The number of forced outages, including sudden interruption of power transmission both by protections and by manual emergency shutdown, is an important parameter for reliability. Usually, for a bipolar LCC HVDC scheme, the number of monopole trips is designed to be four times or fewer a year and the number of bipolar trips below once every ten years. According to the operation practice of modern HVDC systems, the number of monopole trips can be even limited to once a year. In systems with more than one converter in series per pole, the converters' trips can be limited to two trips per converter per station.

Outage hours, a parameter that indicates not only the health of the equipment but also the ability of maintenance, also affect the reliability and availability considerably. The outage hours would be longer due to severe damage of the equipment, complex fault analyzing and troubleshooting, or long waiting times for tools or spare parts. Every effort should be made to put the HVDC system back into full operation as soon as possible.

Refer to IEC TS 62672-1 for the main performance indicators.

¹ Numbers in square brackets refer to the Bibliography.

4.1.2 Operation cost

The operation cost covers the following aspects:

- a) human resources (salary for the operation and maintenance staff),
- b) consumables,
- c) maintenance and tests,
- d) auxiliary power and cooling waters,
- e) spare parts,
- f) improvements and upgrade, and
- g) other costs.

There are a number of variables that will impact the operational cost of an HVDC station. The human resources cost for an unmanned station is much less than for a manned station. The maintenance cost for an RCM station is much less than for a TBM station. The spare parts cost for an old station is usually higher than for a new station.

Due to the above reasons, it is hard to give an average cost for running an HVDC converter station for one year. The costs can be reduced if optimal operation, maintenance and spare part policies are considered.

4.1.3 Manned or unmanned

Traditionally, an LCC HVDC converter station is a manned station, where several operators monitor the status of the HVDC link and the equipment 24 h a day. Even for a manned station, the power flow on the HVDC system may be dispatched remotely. As development in automation increases, as well as the improvement of HVDC equipment, unmanned stations or less-manned stations (e.g. manned only during office hours) are more common. Many stations in Europe (like FennoSkan, SwePol) are unmanned. An unmanned converter station is operated remotely from an operation centre or even a dispatch centre, and manned only when something has failed.

Some important HVDC converter stations, such as Itaipu (Brazil), Nelson River (Canada) and Fulong (China), which are responsible for transmitting 70 % of the power generated by nearby hydro plants, are still manned stations. Equipment failure can be fixed faster at a manned station. This in turn contributes to the reliability and availability of the HVDC link.

Whether a station is manned or unmanned can be evaluated technically and economically. If it takes more than two hours to drive from a nearby city to the station, if the equipment failure rate of the station is still high, or if the converter station is critical to the grid, it may be better to man the station.

NOTE Some parts of the text in this document are applicable for manned stations only and are not applicable for unmanned stations, as there is no operator in the station.

4.2 Operation condition and limits

Before entering commercial operation of an HVDC converter station, the following conditions are normally required to be fulfilled:

- a) the system test (IEC 61975) and the trial operation have been completed successfully;
- b) the operating and maintenance staff is available and has been trained;
- c) the communication between the dispatch centre and the converter station has been set up;
- d) the standard operating procedure for operation and maintenance of the HVDC station has been established; and
- e) spare parts are available.

Keeping and preserving the life of an HVDC converter station/link is the most important aspect to manage. Generally, HVDC systems are planned, designed and expected to have a lifetime of 30 years or more. To meet this requirement, operation limits should be clearly defined and faithfully followed by the operating and maintenance staff. They at least include:

- 1) the current, voltage and temperature of the main equipment are within the limits defined by HVDC suppliers;
- 2) the temperature, humidity and cleanliness of the valve hall, valve cooling system, relay buildings and control rooms can meet the requirements of normal operation of related equipment or devices;
- 3) the maximum acceptable current for electrodes and station grounds is such that it will not affect nearby industry pipes or the environment;
- 4) environment (oil, water, PCB, etc.) management systems and procedures are in place and the staff regularly reviews these procedures.

4.3 Operations of an HVDC system

4.3.1 General

Subclause 4.3 gives a generic guidance as to how to operate an HVDC system. Note that the suppliers' documentation for the given HVDC system shall always be consulted for the particular HVDC system.

4.3.2 Typical operation configuration

4.3.2.1 General

Availability, reliability, and flexibility for operation and maintenance are closely related to the operational configuration of HVDC systems. The general configuration and performance of high voltage direct current (HVDC) system are given in IEC 60919.

4.3.2.2 Point-to-point HVDC system

A point-to-point HVDC system is mainly for bulk transmission. It usually consists of two separate poles, which can be operated individually or together in a bipolar arrangement. This kind of system can be operated in three operating configurations.

a) Bipolar ground return with bipolar power control

This is the normal operation mode for a bipolar HVDC system. Active power order is shared between each pole and the current of both poles is balanced so that the earth current is kept to a low value, typically less than 10 A. Furthermore, if one pole is tripped, part of its power can be taken up by the healthy pole so that less power will be lost. The above benefits make this the most commonly used operation modes in a bipolar HVDC system.

During bipolar operation, the bipole neutral bus can be connected to either the electrode or the station ground. This allows the electrode or electrode lines maintenance job to be done without interruption of normal power transmission. However, it may be noted that when the station ground is used, in the event of a trip of a pole, another pole will also be tripped as a consequence of increased station ground current. Attention should also be paid to a possible station ground potential change at pole ground fault.

Under contaminated conditions, which are often a combination of rain or fog in an HVDC station or along the corridor of its DC lines, the affected pole can continue the power transmission by running at reduced voltage, for instance 70 % or 80 % of rated DC voltage. The current of each pole is balanced by the control system and the earth current is still limited to a low value. The HVDC system can resume the rated voltage when the weather conditions improve.

In the case where the DC equipment of one pole develops a fault such that the power or current needs to be limited to a certain level, the defective pole can be set to pole power control or pole current control.

b) Monopole metallic return

This is an optional operation mode for a bipolar system. If one pole for a bipolar HVDC system is not available, and if long-term flow of high earth current is not allowable and the DC line of the other pole is still available, the remaining pole can be connected to both DC lines and earthed at one predefined station. The equipment belonging to the outage pole can be checked or repaired and put into operation again. Compared to monopole ground return, the power loss on the DC line will be doubled, so once the faulty pole is available again, the operating pole can be transferred back first from metallic return to ground return and then to bipolar ground return.

c) Monopole ground return

This is also an optional operation mode for a bipolar HVDC system. If one pole is not available, for example when it is under construction, maintenance, or it is tripped by protections, and if long-term flow of earth current is acceptable, the remaining pole is connected to the electrode via the MRTB and can go on operating. The equipment belonging to the faulty pole, as well as its DC line, can be checked or repaired and put into operation again.

4.3.2.3 Back-to-back HVDC system

A back-to-back HVDC system is mainly used for asynchronous connections. In this arrangement, there are no DC transmission lines or DC filters, and both converters are located at one station. The valves for both the rectifier and the inverter are typically located in one valve hall.

There is only one operating configuration for a back-to-back system. The 12-pulse converters of both the rectifier and the inverter are connected directly through busbars. Some back-to-back systems are comprised of several units so that the loss of a converter will not lead to a total loss of power transmission or network islanding.

4.3.2.4 Two 12-pulse converters per pole

If the DC voltage or DC current of the converter reach their limits, two 12-pulse converters are connected in series or in parallel for higher voltage or higher current. This configuration is applied to Nelson River, Itaipu, and the UHVDC systems in China and India.

The operational configuration of 12-pulse converters per pole is the same as for bipolar systems except that the system can still be operated in bipole mode when one converter is out of service (forced or scheduled). In this case, the pole will operate at half the normal voltage or half the DC current capability.

4.3.2.5 Set up the operation configuration

Operators should evaluate the state of main circuit equipment including:

- a) AC configuration and minimum availability of AC filter;
- b) availability of HVDC equipment of each pole;
- c) allowed ground return current;
- d) connectivity of DC lines;
- e) ensuring all major or critical alarms have already been acknowledged and reset.

The operational configuration can then be set up by connecting both poles or a single pole, in ground return or metallic return, and the DC lines of each pole or of both poles.