IEC TR 63127

Edition 1.0 2019-06

TECHNICAL REPORT

Guideline for the system design of HVDC converter stations with line-commutated converters

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9407e33ae432/iec-tr-63127-2019

IEC TR 63127:2019-06(en)

THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2019 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 Central Office
3, rue de Varembé
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 It also gives information on projects, replaced and withdrawn publications.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.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9407e33ae432/iec-tr-63127-2019

IEC TR 63127

Edition 1.0 2019-06

TECHNICAL REPORT

Guideline for the system design of HVDC converter stations with line-commutated converters

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9407e33ae432/iec-tr-63127-2019

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.240.01; 29.240.10

ISBN 978-2-8322-7068-4

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

® Registered trademark of the International Electrotechnical Commission

CONTENTS

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9407e33ae432/iec-tr-63127-2019

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1e-4547-9df9-9407e33ae432/iec-tr-63127-2019

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9407e33ae432/iec-tr-63127-2019

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9407e33ae432/iec-tr-63127-2019

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

GUIDELINE FOR THE SYSTEM DESIGN OF HVDC CONVERTER STATIONS WITH LINE-COMMUTATED CONVERTERS

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.
iTeh STANDARD PREVIEW
(standards.iteh.ai)
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.
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9407e33ae432/iec-tr-63127-2019
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.

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 63127, 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.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
115/195/DTR	115/203/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.

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.

A bilingual version of this publication may be issued at a later date.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9407e33ae432/iec-tr-63127-2019

INTRODUCTION

HVDC is an established technology that has been in commercial use for more than 60 years. With the changes in demands due to evolving environmental needs, installation of HVDC systems has increased dramatically in the last 30 years and almost half of HVDC projects were commissioned after the year 2000. HVDC has become a common tool in the design of future global transmission systems.

HVDC systems transmit more electrical power over longer distances than a similar alternating current (AC) transmission system, which means fewer transmission lines are needed, saving both money and land and simplifying permissions. In addition to significantly lowering electrical losses over long distances, HVDC transmission is also very stable and easily controlled, and can stabilize and interconnect AC power networks that are otherwise incompatible. Typically HVDC systems provide unique or superior capabilities in the following aspects:

- long distance bulk power transmission;
- asynchronous interconnections;
- long distance cable;
- controllability;
- lower losses;
- environmental concerns;
- limitation of short-circuit currents.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

Simply due to these technical merits, the market demand for HVDC transmission technology is spreading widely over the world. There are many HVDC power transmission systems with a DC voltage from 50 kV up to 660 kV in different countries. In addition, there are several ±800 kV HVDC power transmission systems which have been built or operated or which are under construction in China, India and Brazil. In 2016, one ±1 100 kV HVDC power transmission system project was started in China.

IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285d19-6c1c-4547-9df0-9467e33ae432/iec-tr-63127-2019

The fast development of the HVDC power transmission and distribution industry has been accompanied by IEC standardization work. More than 40 IEC documents, from DC equipment to DC systems, have been published. Among these, the IEC TR 60919 series, IEC 60633, IEC 60071-5, the IEC TR 62001 series and the IEC 60700 series provide essential information for the design and operation of HVDC power transmission systems.

However, this document provides only a basic guide and refers to typical numbers and examples. Other points and values may also be valid in particular cases and should also be considered accordingly.

GUIDELINE FOR THE SYSTEM DESIGN OF HVDC CONVERTER STATIONS WITH LINE-COMMUTATED CONVERTERS

1 Scope

System design is the basis of construction and operation of HVDC systems. It defines the overall philosophy for the HVDC transmission system and enables the ratings and specifications for the equipment integrated in the project.

This document focuses on the system design of converter stations. It is applicable to point-to-point and back-to-back HVDC systems based on line-commutated converter (LCC) technology.

This document provides guidance and supporting information on the procedure for system design and the technical issues involved in the system design of HVDC transmission projects for both purchaser and potential suppliers. It can be used as the basis for drafting a procurement specification and as a guide during project implementation.

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.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

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

IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/25285df9-6c1e-4547-9df9-9407e33ae432/iec-tr-63127-2019

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 Symbols

4.1 Letter symbols for variables

U_{d} DC voltage between the pole and the neutral bus at the line side of the smoothing reactor

U_{dL} DC voltage of pole line to ground at the measuring point

I_{d} DC current

U_{dmeas} measured DC voltage

P_{ref} power setting at the line side of the smoothing reactor in the rectifier station

X_{t} commutation reactance, including converter transformer reactance and other reactance in the commutation circuit that will affect the commutation process

P_{u} on-load losses of converter transformer and smoothing reactor when a six-pulse converter is operating at rated capacity

R_{th} equivalent resistance of the voltage drop of the thyristor valve (current dependent resistance of the thyristors)

U_{dio} ideal no-load DC voltage of six-pulse converter

U_{k} relative converter transformer inductive voltage drop (short-circuit reactance)

U_{plc} relative voltage drop of AC PLC filter reactors

d_{x} relative inductive DC voltage drop of converter

d_{r} relative resistance DC voltage drop of converter

U_{T} forward voltage drop of converter valve under conducting state

d_{xtotR} total relative inductive DC voltage drop of converter – contains both commutation circuit reactance and the system impedance converted onto valve side

P_{dc} active power of converters

Q_{conv} reactive power consumption of individual converter

Q_{f} reactive power supplied by filters

S_{SC} short-circuit capacity of AC bus

R_{d} total resistance of DC transmission line at each pole

R_{e} resistance of electrode

R_{g} resistance of electrode line

S_{n} rated capacity of a three-phase converter transformer connected to a six-pulse valve group

S_{n3w} rated capacity of a single-phase three-winding converter transformer connected to a 12-pulse valve group

S_{n2w} rated capacity of a single-phase two-winding converter transformer connected to a 12-pulse valve group

U_{v} valve side line voltage of converter transformer

I_{v} valve side line current of converter transformer

U_{l} line voltage of line side of converter transformer

n_{nom} rated ratio of converter transformer at normal tap position

η needed OLTC range of converter transformer

$\Delta\eta$ step size of converter transformer OLTC

L_{d} total inductance from DC side

L_{dr} smoothing reactor inductance

L_{tr} converter transformer inductance per phase

μ overlap angle

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9d07e3fae4d3/iec-tr-63127-2019

α	delay angle
γ	extinction angle
Q_{total}	total reactive power supplied by AC filters and shunt capacitors at normal voltage
Q_{sb}	reactive power supplied by the largest AC filter or shunt capacitor sub-bank at normal voltage
Q_{ac}	reactive power supplied by AC system (negative value means the capability to supply reactive power by AC system)
Q_{dc}	reactive power consumption of converters
K_{v}	voltage correction factor, normally 0,95 to 1,05
Q_{r}	total reactive power absorbed by the shunt reactors of converter station at normal AC voltage
Q_{fmin}	capacity of the minimum filter combination which shall be switched in to meet the harmonic performance requirement at normal AC voltage
ΔU_{AC}	dynamic voltage change because of sub-bank switching
Q_{filter}	reactive power capacity of the filter or shunt capacitor sub-bank to be switched
$\sum Q_{\mathrm{filter}}$	reactive power capacity of the filter or shunt capacitor sub-banks in operation after switching
ΔQ_{dc}	change of reactive power consumption of converters due to sub-bank switching, which sometimes can be ignored

4.2 Subscripts

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9407e33ae432/iec-tr-63127-2019

N	normal value of the variables
R	value of rectifier side
I	value of inverter side
max	maximum value of the variable
min	minimum value of the variable

5 Overview of HVDC system design

5.1 General

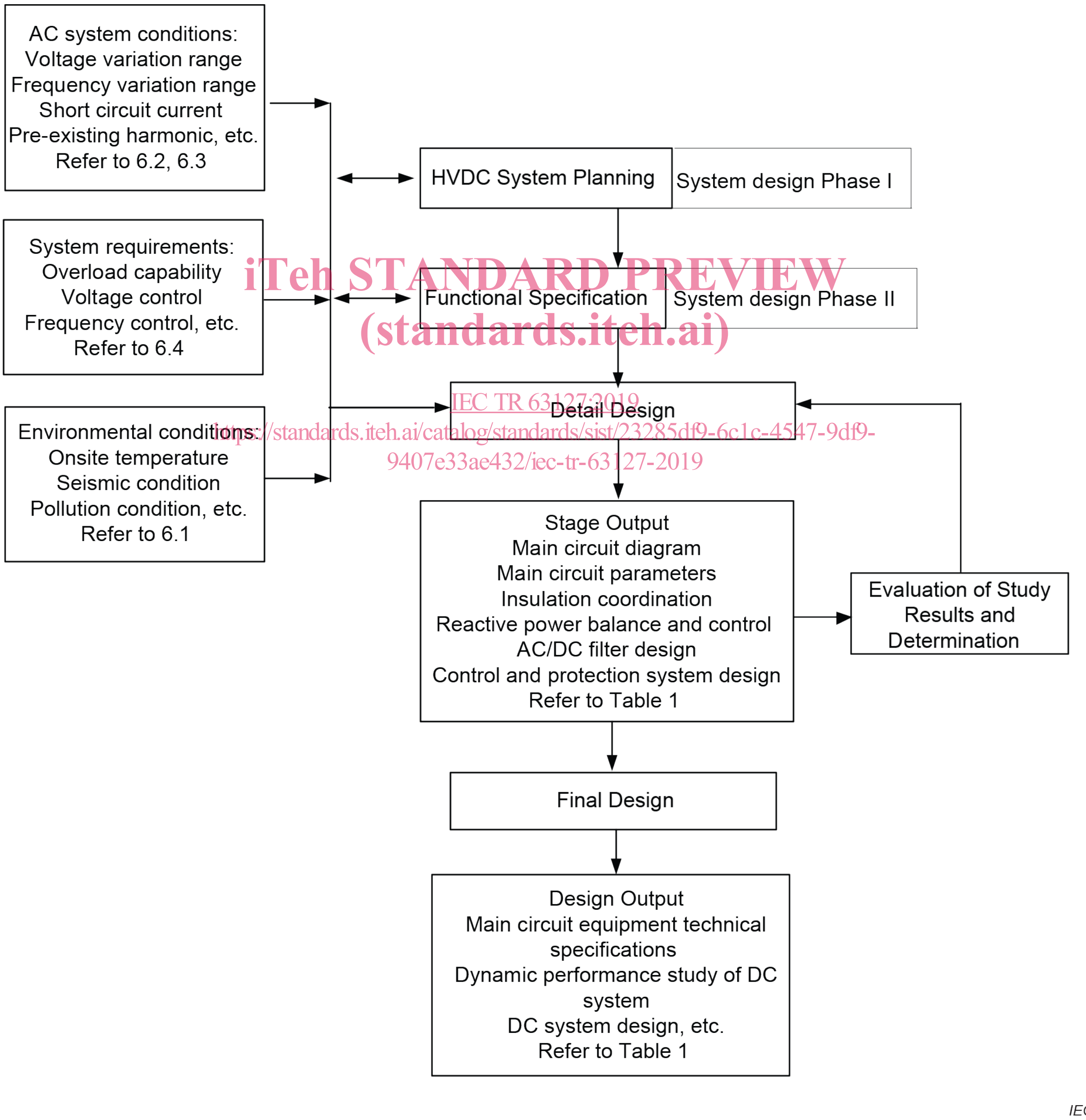
In implementing HVDC projects, the purchaser or the supplier will do preliminary system design work to prepare the various required documents needed by the project. Specific studies and simulations are conducted during the system design to find the optimal project schemes and to demonstrate performance. As a minimum, the following main system features should be determined:

- HVDC system ratings;
- HVDC system operation configurations and control modes;
- reactive power compensation and control;
- harmonic filtering;
- AC/DC interaction and control;
- insulation coordination;
- environmental impacts, such as audible noise, electromagnetic fields, etc.

The system design may be conducted in several phases by different parties, such as purchaser or supplier, during planning, bidding, detailed design stages, for example, as shown in Figure 1. Different tools and models may be introduced in the system design because of different targets or designs at each stage. One should be very careful to adopt the tools and models in a coordinated manner.

A functional specification for the project is usually prepared by the purchaser before the detailed design. It may consist of project objectives and conditions, grid codes, targeted system performance requirements and operation regulations, etc. This functional specification should be treated as both providing inputs and the guide for the system design of an HVDC project. Because the final technology solution is undefined before the detail design stage, it is always necessary to reserve adequate space in the functional specification for further optimization. The owner will issue the specification as a document for bidding if this is a turn-key project. After evaluation of bidding for the specific technology solution, especially for HVDC control, the owner may choose the appropriate solution. Thus, the system features listed above will be studied in more detail based on the chosen technology solution and some additional studies and surveys usually need to be performed to finalize the system design. Finally, all the equipment ratings and specifications will be prepared.

The flowchart of an HVDC system design is summarized in Figure 1.



iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9407e33ae432/iec-tr-63127-2019

Figure 1 – System design in an HVDC project

5.2 Formulation of system design

5.2.1 HVDC system ratings

HVDC system ratings are defined by transmission capacity, DC voltage and DC current. These ratings are evaluated and selected according to considerations such as the exploitation and the market of energy, the conditions and requirements of power grids, the grid code, the transmission distance, the transportation of bulk equipment, the amount and payback of investment together with the environmental conditions, etc.

The capacity is the first item which the purchaser decides on in the planning stage as well as the DC voltage for a long-distance transmission project. Other ratings can be optimized and finalized in the following design stages.

5.2.2 HVDC system configuration

The HVDC system configuration is normally chosen according to the function and rating of the HVDC system, the environmental requirements, the reliability and availability requirements and other similar high-level functional requirements. A preliminary configuration will be suggested prior to other system design work and the final single line diagram of the converter station will be finalized by the detail design.

5.2.3 Reactive power compensation and control

iTeh STANDARD PREVIEW
(standards.iteh.ai)

The converter consumes reactive power in operation. It is necessary to design the reactive power compensation scheme along with the HVDC equipment and control strategy to align with the AC system conditions and requirements. This compensation scheme will be estimated and proposed during planning and then formulated and verified during the detail design together with the related control strategy.

IEC TR 63127:2019
https://standards.iteh.ai/catalog/standards/sist/23285df9-6c1c-4547-9df9-9407e35ae432/iec-tr-63127-2019

Although most of the reactive power to be compensated is inside the converter station, there will still be some reactive power exchange with the AC system. The capability of the AC system to exchange reactive power needs to be specified in the planning.

5.2.4 AC/DC interaction and control

The AC/DC interaction study should be conducted in different phases to demonstrate stable operation and performance of the power grid after integrating the HVDC link. The power flow and stability study should include at least

- starting and stopping of HVDC system,
- steady-state operation,
- AC system faults, and
- DC system faults.

Especially when the short-circuit ratio (SCR) is low, the commutation failure and recovery procedure of the HVDC system after faults should also be carefully studied. The use of capacitor commutated converters (CCC) or controlled series compensated capacitors (CSCC) may be considered as an option for improvement of HVDC operational performance under low SCR condition. For multi-infeed systems, those converters which will impact the study result should be represented in the studies.

AC/DC interaction is normally studied by digital simulation. In the planning stage a simplified HVDC model may be used when the detailed model is unavailable. This simplified model should have enough precision and the study result should cover all the possible situations in practice. The stable operation and performance of the power grid will be demonstrated and proved by detailed modelling with the actual control in the detailed design. The IEC TR 60919 series provides guidance on specifying the requirements.