

IEEE Guide for Commissioning High-Voltage Direct-Current (HVDC) Converter Stations and Associated Transmission Systems

Sponsor
**Substations Committee
of the
IEEE Power Engineering Society**

Reaffirmed 10 December 2002

Approved 10 July 1997

IEEE Standards Board

Abstract: General guidelines for commissioning high-voltage direct-current (HVDC) converter stations and associated transmission systems are provided. These guidelines apply to HVDC systems utilizing 6-pulse or 12-pulse thyristor-valve converter units operated as a two-terminal HVDC transmission system or an HVDC back-to-back system.

Keywords: high-voltage direct-current (HVDC) commissioning, HVDC transmission systems, off-site tests, on-site tests, precommissioning

The Institute of Electrical Engineers, Inc.

345 East 47th Street, New York, NY 10017-2394, USA

Copyright © 1997 by the Institute of Electrical and Electronics Engineers, Inc.

All rights reserved. Published 1997. Printed in the United States of America.

ISBN 1-55937-953-7

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher

IEEE Standards documents are developed within the Technical Committees of the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE which have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least once every five years for revision or reaffirmation. When a document is more than five years old, and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason IEEE and the members of its technical committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE Standards Board
345 East 47th Street
New York, NY 10017
USA

Note: Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents for which a license may be required by an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; (508) 750-8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Introduction

[This introduction is not a part of IEEE Std 1378-1997, IEEE Guide for Commissioning High-Voltage Direct-Current (HVDC) Converter Stations and Associated Transmission Systems.]

This guide provides general guidelines for commissioning high-voltage direct-current (HVDC) converter stations and associated transmission systems. This guide provides assistance and guidance for developing an appropriate commissioning test plan that will need to be tailored to fit the requirements and application of the specific project.

At the time this guide was completed, the Joint Working Group I5 of the High-Voltage Power Electronics Stations Subcommittee (I0) and 15.05.12 of the DC and Flexible AC Transmission Subcommittee (15.05) had the following membership:

Duane Torgerson, *Chair*
Dennis Edwardson, *Vice Chair*

Jacque Allaire
Michael Bahrman
Michael H. Baker
Hans Bjorklund
Richard Bunch

Donald M. Christie
Ben L. Damsky
Jeffrey Donahue
Erich Klenk

Pat McDowell
Al J. Molnar
Bradley D. Railing
Georg Wild
Tim Wu

The following persons were on the balloting committee:

Hanna E. Abdallah
William J. Ackerman
S. J. Arnot
Michael H. Baker
Lars A. Bergstrom
Wayne R. Block
William Brenner
James F. Christenson
Donald M. Christie
Ben L. Damsky
Frank A. Denbrock
W. Bruce Dietzman
Richard Dube

Dennis Edwardson
Gary R. Engmann
George G. Karady
Erich Klenk
Hermann Koch
Lawrence M. Laskowski
Alfred A. Leibold
H. Peter Lips
A. P. Sakis Meliopoulos
John E. Merando, Jr.
Al J. Molnar
Abdul M. Mousa

Philip R. Nannery
Gary A. Petersen
Trevor Pfaff
R. J. Piwko
Bradley D. Railing
Paulo F. Ribeiro
Hazairin Samaulah
Bodo Sojka
Rao Thallam
Duane R. Torgerson
J. G. Tzimirangas
John Vithayathil
Tim Wu

When the IEEE Standards Board approved this guide on 10 July 1997, it had the following membership:

Donald C. Loughry, *Chair*
Richard J. Holleman, *Vice Chair*
Andrew G. Salem, *Secretary*

Clyde R. Camp
Stephen L. Diamond
Harold E. Epstein
Donald C. Fleckenstein
Jay Forster*
Thomas F. Garrity
Donald N. Heirman
Jim Isaak
Ben C. Johnson

Lowell Johnson
Robert Kennelly
E. G. “Al” Kiener
Joseph L. Koepfinger*
Stephen R. Lambert
Lawrence V. McCall
L. Bruce McClung
Marco W. Migliaro
Louis-François Pau

Gerald H. Peterson
John W. Pope
Jose R. Ramos
Ronald H. Reimer
Ingo Rüsçh
John S. Ryan
Chee Kiow Tan
Howard L. Wolfman

*Member Emeritus

Also included are the following nonvoting IEEE Standards Board liaisons:

Satish K. Aggarwal

Alan H. Cookson

Kim Breitfelder, *IEEE Standards Project Editor*

CLAUSE	PAGE
1. Overview	1
1.1 Scope	1
1.2 Purpose	1
1.3 Applications	1
2. References	2
3. Definitions and acronyms	3
3.1 Definitions.....	3
3.2 Acronyms	3
4. General	4
4.1 Commissioning planning	5
4.2 Ambient conditions	5
5. Off-site tests	6
5.1 Routine and type tests	7
5.2 Steady-state performance tests.....	7
5.3 Dynamic performance tests.....	8
5.4 Functional performance tests	8
6. On-site precommissioning	8
6.1 Preconditions.....	9
6.2 Verification of equipment installation	9
6.3 Verification of connections.....	9
6.4 Insulation tests.....	9
6.5 Control, protection, and monitoring.....	10
6.6 Capacitance, reactance, and resistance measurements	10
6.7 Turns ratio and polarity tests	10
6.8 Switching devices	10
7. On-site subsystem testing.....	10
7.1 Preconditions.....	11
7.2 AC and DC station service power	11
7.3 Building and valve halls	11
7.4 AC yard, AC filters, reactive power compensation, and converter transformers	11
7.5 Thyristor valves.....	11
7.6 DC yard and DC filters	12
7.7 Control and protection	12
7.8 DC transmission system.....	12
7.9 Earth electrode	12
8. On-site converter station tests	13
9. On-site transmission testing	14

CLAUSE	PAGE
9.1 Dry-run tests.....	14
9.2 Extended back-to-back tests.....	14
9.3 Round power/circulating-power tests	15
10. On-site trial operation	15
10.1 Preconditions.....	15
10.2 Power scheduling operation	15
11. On-site acceptance tests	16
11.1 Preconditions.....	16
11.2 Steady-state ratings	16
11.3 Disturbance tests	18
12. Documentation	19
12.1 Commissioning plan	20
12.2 Design documentation.....	22
12.3 Safety considerations	23
12.4 Performance documentation	23
12.5 As-built documentation	23
12.6 Nonconformity report	24
Annex A (informative) Bibliography	25

IEEE Guide for Commissioning High-Voltage Direct-Current (HVDC) Converter Stations and Associated Transmission Systems

1. Overview

1.1 Scope

This guide provides general guidelines for commissioning high-voltage direct-current (HVDC) converter stations and associated transmission systems. These guidelines apply to HVDC systems utilizing 6-pulse or 12-pulse thyristor-valve converter units (see Figure 1) operated as a two-terminal HVDC transmission system or an HVDC back-to-back system (see IEEE Std 1030-1987).¹ Excluded from this guide are guidelines for commissioning multi-terminal HVDC systems, synchronous compensators, static synchronous compensators, and static var compensators.

1.2 Purpose

The purpose of this guide is to provide guidance and assistance for developing an appropriate commissioning test plan for HVDC converter stations and associated transmission systems. Users of this guide will find that an HVDC commissioning plan will need to be tailored to fit the requirements and applications of the specific project.

1.3 Applications

Personnel qualifications, training, and the division of commissioning responsibility between the various users of the guide (utilities, manufacturers, consultants, and others) are not discussed, since each project will have contract-defined areas of responsibility. The HVDC commissioning guidelines included in this guide consider the following:

- a) Commissioning planning
- b) Off-site tests
 - 1) Routine and type tests
 - 2) Dynamic performance tests
 - 3) Functional performance tests

¹Information on references can be found in Clause 2.

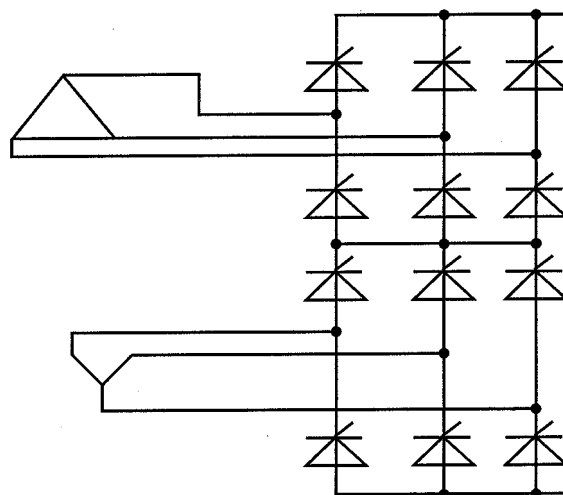


Figure 1— 12-Pulse thyristor-valve converter units

- c) On-site tests
 - 1) Precommissioning
 - 2) Subsystem tests
 - 3) Converter station tests
 - 4) Transmission tests
 - 5) Trial operation
- d) Acceptance tests
- e) Documentation

2. References

This guide shall be used in conjunction with the following standards.

ANSI C63.2-1996, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 kHz to 40 GHz—Specifications.²

IEEE Std 1030-1987, IEEE Guide for Specification of High-Voltage Direct-Current Systems, Part I—Steady-state Performance (ANSI).³

IEEE Std 1158-1991 (Reaff 1996), IEEE Recommended Practice for Determination of Power Losses in HVDC Converter Stations (ANSI).⁴

IEEE P1126, December 1995, Draft Guide to Control and Protection of HVDC Systems.⁵

IEEE PC57.129/D10, October 1996, Draft Trial-Use General Requirements and Test Code for Oil-Immersed HVDC Converter Transformers.

²ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

³IEEE Std 1030-1987 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181.

⁴IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁵Numbers preceded by P are IEEE authorized standards projects that were not approved by the IEEE Standards Board at the time this publication went to press. For information about obtaining drafts, contact the IEEE.

3. Definitions and acronyms

3.1 Definitions

3.1.1 back-to-back test: A test of a bipolar station in which the transmission terminals of two converters are temporarily jumpered in the station. One converter is run as rectifier while the other converter is run as inverter.

3.1.2 circulating-power test: Operation of a bipolar HVDC transmission system so that power flows in the opposite direction in each pole. High power levels up to system rating can be used for test purposes with losses and net reactive only being supplied from the ac network. *Synonym:* **round-power test**.

3.1.3 dc converter load rejection: Tripping, blocking, or ramping HVDC converters to cause a significant reduction in transmitted power.

3.1.4 dc-side short circuit test: A test in which the dc terminals of a converter are temporarily jumpered. *Synonym:* **zero dc voltage test**.

3.1.5 disturbance testing: Tests performed to verify the dc system response to ac faults, dc line faults, loss of one pole (if applicable), and other dynamic response criteria.

3.1.6 dry-run test: A test of switching or tripping sequences with equipment not energized or “dry.”

3.1.7 dynamic performance test: Testing of the transient performance of a dc system either on the actual system or on a system simulator. Such testing includes fault recovery performance, step responses, and ac system interaction.

3.1.8 end-to-end test: A test series of all performance requirements with the dc system under normal operating conditions and, as conditions permit, under contingency operating conditions. *Synonym:* **transmission test**.

3.1.9 extended back-to-back test: A test of a bipolar station in which the transmission terminals of two converters are temporarily jumpered at the remote end of the transmission line. One converter is run as rectifier while the other converter is run as inverter.

3.1.10 functional performance test: Tests of the steady-state performance of control functions and sequences.

3.1.11 heat-run test: A test that verifies equipment to be within thermal design when operated for an extended period at maximum current. *Synonym:* **loading test**.

3.1.12 integration test: The testing of several subsystems that perform in combination.

3.1.13 loading test: *See:* **heat-run test**.

3.1.14 open-line test: A test that energizes a converter dc yard up to full voltage without energizing the remote station. The test can be configured to also test energize the transmission line.

3.1.15 round-power test: *See:* **circulating-power test**.

3.1.16 runback: The control of a dc system to reduce power to match loss of generation on the ac network.

3.1.17 transmission test: *See:* **end-to-end test**.

3.1.18 trial operation: A period of normal operation of the dc system near the end of commissioning.

3.1.19 zero dc voltage test: *See:* **dc-side short circuit test**.

3.2 Acronyms

CTS	cable terminal station
DFR	digital fault recorder
HVAC	heating, ventilating, and air conditioning
HVDC	high-voltage direct-current
MRTB	metallic return transfer breaker

MRTS	metallic return transfer switch
OHTL	overhead transmission line
OLT	open-line test
PLC	power-line carrier
RTU	remote terminal unit
SCADA	supervisory control and data acquisition
SER	sequence of events recorder
TFR	transient fault recorder
TNA	transient network analyzer
VBE	valve base electronics

4. General

HVDC systems (see Figure 2) have been developed for transfer of electric energy where ac transmission may not be the preferred choice or the most economic solution. Long overhead lines, relatively long undersea cable installations, or connections between asynchronous systems have been the conventional applications of HVDC transmission technologies.

HVDC commissioning tests are the continuation of a systematic test program that begins with off-site tests on each of the equipment items to be installed in the HVDC converter stations (see Figure 3). These tests involve routine and type tests (where applicable) as well as functional and dynamic performance tests of the HVDC control and protection system hardware and software. The test program continues with on-site precommissioning tests of equipment, subsystem tests, and converter station tests. The test program culminates in testing of the entire HVDC transmission system during end-to-end tests.

Precommissioning tests involve localized testing and checkout of individual equipment items. These tests are performed after equipment items are installed at the site.

Subsystems consist of pieces of equipment items that are grouped together according to common functions. The purpose of subsystem tests is to independently check the necessary functional performance of all HVDC subsystems before starting converter station tests.

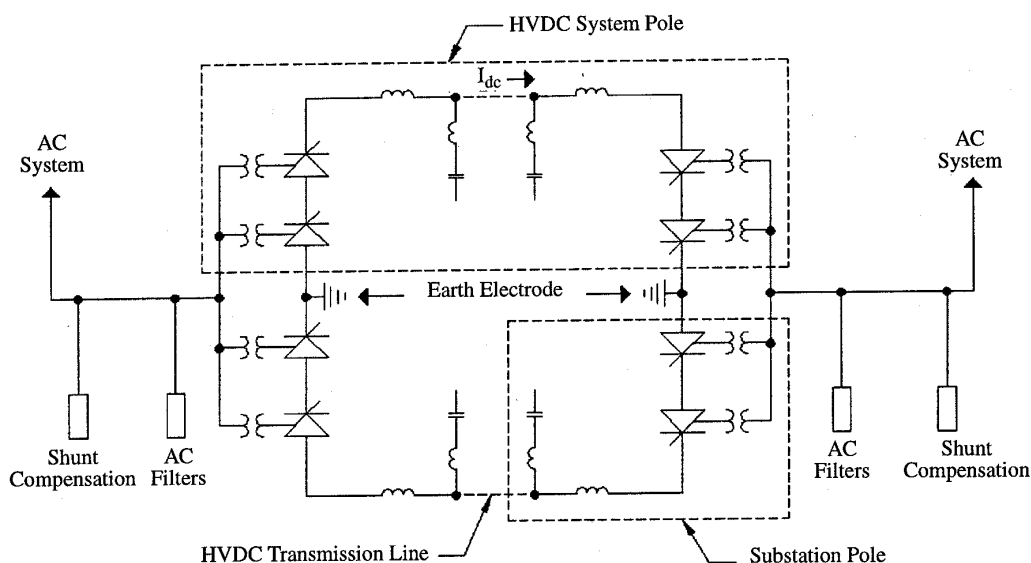


Figure 2— Example of bipolar HVDC transmission system