



IEEE Standard General Requirements and Test Code for Dry-Type and Oil-Immersed Smoothing Reactors for DC Power Transmission

IEEE Power & Energy Society

Sponsored by the
Transformers Committee

IEEE
3 Park Avenue
New York, NY 10016-5997, USA

29 June 2010

IEEE Std 1277™-2010
(Revision of
IEEE Std 1277-2000)

Currently in preview, click buy full version

IEEE Standard General Requirements and Test Code for Dry-Type and Oil-Immersed Smoothing Reactors for DC Power Transmission

Sponsor

Transformers Committee
of the
IEEE Power & Energy Society

Approved 25 March 2010

IEEE-SA Standards Board

Abstract: The electrical, mechanical, and physical requirements of oil-immersed and dry-type air-core smoothing reactors for high-voltage direct current (HVDC) applications are specified. Test code is defined and appropriate technical background information is presented or identified.
Keywords: construction, dry-type air-core, HVDC, oil-immersed, rating, smoothing reactors, test code application

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2010 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 29 June 2010. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by the Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-0-7381-6241-6 STD96056
Print: ISBN 978-0-7381-6242-3 STDPD96056

IEEE prohibits discrimination, harassment and bullying. For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.
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 IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied "AS IS."

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 every five years for revision or reaffirmation, or every ten years for stabilization. When a document is more than five years old and has not been reaffirmed, or more than ten years old and has not been stabilized, 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.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon his or her independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretation is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of 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 societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered the official position of IEEE or any of its committees and shall not be considered to be, nor be relied upon as, a formal interpretation of the IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

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. Recommendations to change the status of a stabilized standard should include a rationale as to why revision or withdrawal is required. Comments and recommendations on standards, and requests for interpretation, should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854
USA

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; +1 978 750 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 part of IEEE Std 1277-2010, IEEE Standard General Requirements and Test Code for Dry-Type and Oil-Immersed Smoothing Reactors for DC Power Transmission.

In 1986 the Transformers Committee of the Institute of Electrical and Electronic Engineers created the HVDC Converter Transformers and Smoothing Reactors Subcommittee. This committee developed from the working group that prepared paper 85 SM 375-1, “Recommended Dielectric Tests and Test Procedures for Converter Transformers and Smoothing Reactors.” Although smoothing reactors for HVDC application have been built and operated for over 30 years, prior to IEEE Std 1277 there were only a limited number of papers, guides, and standards available that presented suggested dielectric tests for the HVDC equipment (see Annex G of this standard for a list of some of the most relevant documents). The IEC reactor standard IEC 60076-6:2007 [B9] also covers smoothing reactors in a specific clause; focus is not, however, application-specific.^a With the increased activity in HVDC transmission, there was a significant need for a standard specifically covering the requirements and testing of smoothing reactors for HVDC applications, and the first responsibility of the new subcommittee was to create proposed standards for converter transformers and smoothing reactors for HVDC application. Two separate standards were developed—one for oil-filled converter transformers and one for both dry-type and oil-filled smoothing reactors. IEEE Std 1277 was originally released in 2000 as “trial use” and, approximately two years later in 2002, was granted “full use” status.

Significant accomplishments of IEEE Std 1277-2000 included:

- a) Establishment of dielectric tests on HVDC equipment. In addition to the polarity reversal and 1 h dc tests recommended by previous papers, a special 1 h ac-applied voltage test was included for oil-filled smoothing reactors to demonstrate insulation integrity for service conditions.
- b) A consistent test methodology was developed for both oil-immersed and dry-type air-core smoothing reactors that reflects both in-service operating stresses as well as current test equipment capability.

The purpose of this current revision is the same as the original document, which is to define requirements and test code for dry-type and oil-immersed smoothing reactors for HVDC application. Although requirements are usually construction independent, test code is not, and the revision of the standard will continue to reflect this characteristic. This revision is required to upgrade test code, design considerations and application information based on feedback from manufacturers and “end users”—dry-type or oil-immersed specific when required. Test code methodology has been modified to reflect current technology.

Notice to users

Laws and regulations

Users of these documents should consult all applicable laws and regulations. Compliance with the provisions of this standard does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

^a The numbers in brackets correspond to those of the bibliography in Annex G.

Copyrights

This document is copyrighted by the IEEE. It is made available for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making this document available for use and adoption by public authorities and private users, the IEEE does not waive any rights in copyright to this document.

Updating of IEEE documents

Users of IEEE standards should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect. In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE Standards Association web site at <http://ieeexplore.ieee.org/xpl/standards.jsp>, or contact the IEEE at the address listed previously.

For more information about the IEEE Standards Association or the IEEE standards development process, visit the IEEE-SA web site at <http://standards.ieee.org>.

Errata

Errata, if any, for this and all other standards can be accessed at the following URL: <http://standards.ieee.org/reading/ieee/updates/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Interpretations

Current interpretations can be accessed at the following URL: <http://standards.ieee.org/reading/ieee/interp/index.html>.

Patents

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 is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patent Claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this standard was submitted to the IEEE-SA Standards Board for approval, the HVDC Converter Transformers and Smoothing Reactors Working Group had the following membership:

Richard F. Dudley, *Chair*

Sten Andersson
Jack Aromin
Gene Blackburn
Fred E. Elliot
Joseph Foldi
Alan C. Forrest
Jan Hajek
Peter Heinzig

Lars-Erik Juhlin
Robyn L. Page
Klaus Papp
Carlos Piexoto
Ugo Piovan
Christoph Ploetner
Klaus Pointner

Ulf Radbrandt
Les Recksiedler
Pierre Riffon
Michael Sharp
Joe D. Watson
Tony Weekes
Gene Wolf
Waldemar Ziomek

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

Wallace Binder
Gene Blackburn
William Bloethe
Carl Bush
Suresh Channarasappa
Dieter Dohnal
Richard F. Dudley
Gary Engmann
Joseph Foldi
Jalal Gohari
Randall Groves
David Harris
Peter Heinzig
Gary Heuston

Lars-Erik Juhlin
Joseph L. Koepfinger
Jim Kulchisky
Saumen Kundu
Chung-Yiu Lam
G. Luri
J. Dennis Marlow
Joseph Melanson
Gary Michel
Michael S. Newman
Klaus Papp
Bansi Patil
J. Patton
Alvaro Portillo

Iuliana Profir
Jean-Christophe Riboud
Pierre Riffon
Michael Roberts
Charles Rogers
Marnie Roussel
Bartien Sayogo
Devki Sharma
Gil Shultz
James E. Smith
Jerry Smith
Gary Stoedter
John Vergis
Jane Verner

When the IEEE-SA Standards Board approved this standard on 25 March 2010, it had the following membership:

Robert M. Grow, *Chair*
Richard H. Hulett, *Vice Chair*
Steve M. Mills, *Past Chair*
Judith Gorman, *Secretary*

Karen Bartleson
Victor Berman
Ted Burse
Clint Chaplin
Andy Drozd
Alexander Gelman
Jim Hughes

Young Kyun Kim
Joseph L. Koepfinger*
John Kulick
David J. Law
Hung Ling
Oleg Logvinov
Ted Olsen

Ronald C. Petersen
Thomas Prevost
Jon Walter Rosdahl
Sam Sciacca
Mike Seavey
Curtis Siller
Don Wright

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Satish K. Aggarwal, *NRC Representative*
Richard DeBlasio, *DOE Representative*
Michael Janezic, *NIST Representative*

Lisa Perry
IEEE Standards Program Manager, Document Development

Matthew J. Coyle
IEEE Standards Program Manager, Technical Program Development

Contents

1. Scope	1
2. Normative references	1
3. Definitions	3
4. Letter symbols	4
5. General requirements—Systems and environmental data	
5.1 Usual service conditions	5
5.2 Unusual service conditions	6
5.3 Environmental Impact—Oil-immersed smoothing reactors	9
5.4 Synthetic materials—Oil-immersed smoothing reactors	9
5.5 Transformer oil—Oil-immersed smoothing reactors	9
6. Rating data	9
6.1 Basis for rating	9
6.2 Rated dc voltage	10
6.3 Rated currents	10
6.4 Inductance	10
6.5 Basic impulse insulation level	11
6.6 Cooling classes	12
6.7 Other requirements	12
7. Construction of oil-immersed smoothing reactors	14
7.1 Tank and tank components for oil-immersed smoothing reactors	14
7.2 Oil preservation for oil-immersed smoothing reactors	16
7.3 Auxiliary equipment for oil-immersed smoothing reactors	18
8. Tests	20
8.1 General	20
8.2 Routine, design, and other tests for smoothing reactors	21
9. Losses and inductance	25
9.1 Losses	25
9.2 Inductance	26
10. Temperature rise and loading conditions	26
10.1 Temperature-rise limits and loading conditions	26
10.2 Temperature of metallic parts in contact with insulation	27
10.3 Temperature of other metallic parts	27
10.4 Temperature rise of insulating liquid	28
10.5 Temperature rise of terminals	28
11. Dielectric tests and insulation levels	28
11.1 Impulse tests	28
11.2 DC voltage tests	29
11.3 DC polarity-reversal test with partial discharge measurements for oil-immersed smoothing reactors	29
11.4 Low-frequency voltage tests on line terminals	30

12. Test code.....	31
12.1 General	31
12.2 Resistance measurements	31
12.3 Losses and impedance	34
12.4 Temperature-rise test	38
12.5 Dielectric tests for oil-immersed smoothing reactors	45
12.6 Dielectric tests for dry-type smoothing reactors	55
12.7 Audible sound level test.....	61
12.8 Short-circuit withstand capability verification.....	64
12.9 Capacitor discharge test.....	65
12.10 DC power test for oil-immersed and dry-type SMRs	65
12.11 Seismic verification	66
12.12 Nameplates for oil-immersed and dry-type smoothing reactors	67
 Annex A (informative) Application of HVDC smoothing reactors.....	 70
 Annex B (informative) Construction and installation of dry-type air-core smoothing reactors for HVDC application	 76
 Annex C (informative) Short-circuit capability.....	 79
 Annex D (informative) In-service overloading of HVDC smoothing reactors.....	 82
 Annex E (informative) Smoothing reactors used in voltage source converters (VSC) HVDC schemes.....	 89
 Annex F (informative) Smoothing reactors for 800 kV ultra high voltage direct current	 93
 Annex G (informative) Bibliography	 95

IEEE Standard General Requirements and Test Code for Dry-Type and Oil-Immersed Smoothing Reactors for DC Power Transmission

IMPORTANT NOTICE: This standard is not intended to ensure safety, security, health, or environmental protection. Implementers of the standard are responsible for determining appropriate safety, security, environmental, and health practices or regulatory requirements.

This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

1. Scope

The scope of this standard is the definition and specification of the requirements and test code for dry-type and oil-immersed smoothing reactors for high-voltage direct current (HVDC) power transmission. This standard only applies to smoothing reactors for dc transmission. It does not apply to other smoothing reactors such as reactors for power converters for variable speed drives, etc.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI C68.3-1976, American National Standard Recommended Practice for the Detection and Measurement of Partial Discharges (Corona) During Dielectric Tests.¹

ANSI S1.4-1983, American National Standard Specification for Sound Level Meters.

¹ ANSI publications are available from the Customer Service Department, American National Standards Institute, 25 W. 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).