IEC 62032

Edition 2.0 2012-06

INTERNATIONAL STANDARD

IEEE Std C57.135™

Guide for the Application, Specification, and Testing of Phase-Shifting Transformers

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE X

ICS 29.180

ISBN 978-2-83220-101-5

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

Contents

1. Overview 1
1.1 Scope 1
1.2 Purpose 1

2. Normative references 2

3. Definitions 2

4. Application and theory of PSTs 4
4.1 Introduction 4
4.2 Basic principle of application—advanced and retard phase angle 4
4.3 PST under load 6
4.4 Power transfer 8
4.5 Types of PSTs 10
4.6 Special on load tap changer (OLTC) features 16
4.7 Arrangement of more than one PST 20
4.8 Design criteria 20

5. Service conditions 21
5.1 Usual service conditions 21
5.2 Loading at other than rated conditions 22
5.3 Unusual service conditions 22
5.4 Protection 23

6. Rating data 26
6.1 Polarity, angular displacement, and terminal markings 26
6.2 Impedance 26
6.3 Name plates 27

7. Construction 27
7.1 Enclosed throat connections 27
7.2 Liquid insulation and preservation system 27

8. Short-circuit characteristics 28
8.1 Short-circuit requirements 28

9. Control system 29
9.1 Control equipment and accessories 29
9.2 Requirements 29
9.3 Test code for control systems 31

10. Testing of PSTs 32
10.1 General 32
10.2 Special tests for PSTs 33

11. Tolerances 34
11.1 General 34
11.2 Tolerances for ratio of series and exciting units 34
11.3 Tolerance for phase angle and impedance 34

Published by IEC under license from IEEE. © 2011 IEEE. All rights reserved.

12. Bid document checklist 35
12.1 Nontechnical information 35
12.2 Technical information 35
12.3 Special requirements or conditions 36
12.4 Additional information 36

Annex A (informative) Bibliography 38
Annex B (informative) IEEE List of Participants 40

Published by IEC under license from IEEE. © 2011 IEEE. All rights reserved.

Guide for the Application, Specification, and Testing of Phase-Shifting Transformers

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.

   IEEE Standards documents are developed within IEEE Societies and Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. IEEE develops its standards through a consensus development process, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of IEEE and serve without compensation. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards. Use of IEEE Standards documents is wholly voluntary. IEEE documents are made available for use subject to important notices and legal disclaimers (see http://standards.ieee.org/IPR/disclaimers.html for more information).

   IEC collaborates closely with IEEE in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions 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. The formal decisions of IEEE on technical matters, once consensus within IEEE Societies and Standards Coordinating Committees has been reached, is determined by a balanced ballot of materially interested parties who indicate interest in reviewing the proposed standard. Final approval of the IEEE standards document is given by the IEEE Standards Association (IEEE-SA) Standards Board.

3) IEC/IEEE Publications have the form of recommendations for international use and are accepted by IEC National Committees/IEEE Societies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC/IEEE Publications is accurate, IEC or IEEE 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 (including IEC/IEEE Publications) transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC/IEEE Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC and IEEE do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC and IEEE are 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 IEEE or their directors, employees, servants or agents including individual experts and members of technical committees and IEC National Committees, or volunteers of IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board, 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/IEEE Publication or any other IEC or IEEE 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 implementation of this IEC/IEEE Publication may require use of material 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. IEC or IEEE shall not be held 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

Published by IEC under license from IEEE. © 2011 IEEE. All rights reserved.

determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

International Standard IEC 62032/ IEEE Std C57.135-2011 has been processed through IEC technical committee 14: Power transformers, under the IEC/IEEE Dual Logo Agreement.

This second edition cancels and replaces the first edition, published in 2005, and constitutes a technical revision.

The text of this standard is based on the following documents:

IEEE Std	FDIS	Report on voting
IEEE Std C57.135-2011	14/710/FDIS	14/714/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://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.

Published by IEC under license from IEEE. © 2011 IEEE. All rights reserved.

IEEE Std C57.135™-2011
(Revision of
IEEE Std C57.135-2001)

IEEE Guide for the Application, Specification, and Testing of Phase-Shifting Transformers

Sponsor

Transformers Committee
of the
IEEE Power & Energy Society

Approved 16 June 2011

IEEE-SA Standards Board

Abstract: Theory, application of phase-shifting transformers, and the difference of specification and testing to standard system transformers are described in this guide. Various types of phase-shifting transformers and how to select the optimal design to achieve required control of power flow are covered. An understanding of the terminology, types, construction, and testing specific to phase-shifting transformers is provided.

Keywords: advance phase angle, dual-core design, IEEE C57.135, main transformer, phase-shifting transformer, power transfer, retard phase angle, series transformer, single-core design, special tests

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

Published by IEC under license from IEEE. © 2011 IEEE. All rights reserved.

IEEE Introduction

This introduction is not part of IEEE Std C57.135-2011, IEEE Guide for the Application, Specification, and Testing of Phase-Shifting Transformers.

This guide describes the application, specification, and testing of phase-shifting transformers. It is intended for the following:

— Organizations responsible for the application and specification of phase-shifting transformers for electric transmission systems to control power flow.

— Organizations responsible for testing phase-shifting transformers.

This guide is designed to help organizations:

— Understand the various types of phase-shifting transformers and how to apply them to obtain required control of power flow.

— Prepare specifications for the purchase of phase-shifting transformers.

— Standardize tests and test methods for phase-shifting transformers.

This guide is intended to satisfy the following objectives:

— Promote consistency within organizations for the application and specification of phase-shifting transformers.

— Provide an understanding of the terminology, types, construction, and testing relating specifically to phase-shifting transformers.

— Promote the standardization of testing procedures for phase-shifting transformers.

Since this guide was first published in 2001, several recommendations from users and manufacturers were made to revise it to improve accuracy and applicability. Some of the revisions are as follows:

— Figure 1, Figure 3, Figure 4, Figure 7, and Figure 11 were improved.

— Equation (1) was divided into two parts to show the difference between advance and retard operations.

— A new section on minimum information requirements for specifying a PST was inserted.

— Various editorial changes were made to clarify the contents of the guide.

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.

Published by IEC under license from IEEE. © 2011 IEEE. All rights reserved.

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 guide may require use of subject matter covered by patent rights. By publication of this guide, 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 Patents 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 guide 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.

Published by IEC under license from IEEE. © 2011 IEEE. All rights reserved.

Guide for the Application, Specification, and Testing of Phase-Shifting Transformers

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. Overview

1.1 Scope

This guide covers the application, specification, theory of operation, and factory and field testing of single-phase and three-phase oil-immersed, phase-shifting transformers (PSTs).

This guide is limited to matters particular to PSTs and does not include matters relating to general requirements for power transformers covered in existing standards, recommended practices, or guides.

1.2 Purpose

The terminology, function, application, theory of operation and protection, and design of PSTs are not covered by existing transformer standards and guides. The purpose of this document is to provide guidance to those specifying, designing, and using PSTs.

Published by IEC under license from IEEE. © 2011 IEEE. All rights reserved.

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.

IEC 60076-1, Power Transformers—Part 1: General.[1]

IEC 60076-3, Power Transformers—Part 3: Insulation Levels, Dielectric Tests and External Clearances in Air.

IEC 60076-5, Power Transformers—Part 5: Ability to Withstand Short Circuit.

IEC 60076-7, Power Transformers—Part 7: Loading Guide for Oil-Immersed Power Transformers.

IEEE Std 693™, IEEE Recommended Practice for Seismic Design for Substations.[2,3]

IEEE Std C37.90.1™-1989, IEEE Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus.

IEEE Std C57.12.00™, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.

IEEE Std C57.12.80™, IEEE Standard Terminology for Power and Distribution Transformers.

IEEE Std C57.12.90™, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers, and IEEE Guide for Short-Circuit Testing of Distribution and Power Transformers.

[1] IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.
[2] IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854-4141, USA (http://standards.ieee.org/).
[3] The IEEE standards or products referred to in this clause are trademarks owned by the Institute of Electrical and Electronics Engineers, Incorporated.

Published by IEC under license from IEEE. © 2011 IEEE. All rights reserved.