

IEEE Guide for Loss Evaluation of Distribution and Power Transformers and Reactors

IEEE Power and Energy Society

Sponsored by the
Transformers Committee

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

IEEE Std C57.120™-2017
(Revision of IEEE Std C57.120-1991)

IEEE Guide for Loss Evaluation of Distribution and Power Transformers and Reactors

Sponsor

Transformers Committee
of the
IEEE Power and Energy Society

Approved 14 February 2017

IEEE-SA Standards Board

Abstract: The economic loss evaluation of liquid-filled distribution and power transformers, dry-type distribution and power transformers, and reactors is covered in this guide.

Keywords: economic evaluation, IEEE C57.120™, losses, reactor, transformer

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

Copyright © 2017 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 18 October 2017. 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 978-1-5044-4224-4 STD22715
Print: ISBN 978-1-5044-4225-1 STDPD22715

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.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading “Important Notices and Disclaimers Concerning IEEE Standards Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (“IEEE-SA”) Standards Board. IEEE (“the Institute”) develops its standards through a consensus development process, approved by the American National Standards Institute (“ANSI”), which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups are not necessarily members of the Institute and participate without compensation from IEEE. 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 or the soundness of any judgments contained in its standards.

IEEE Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

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.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own 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.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of 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 of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive 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 comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

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

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document 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.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under U.S. and international copyright laws. They are made available by IEEE and are adopted 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 these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, 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.

Updating of IEEE Standards documents

Users of IEEE Standards documents 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.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, 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 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 Xplore at <http://ieeexplore.ieee.org/> or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at <http://standards.ieee.org>.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

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 by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. 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 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 guide was submitted to the IEEE-SA Standards Board for approval, the Performance Characteristics – Loss Evaluation Guide Working Group had the following membership:

Rogério Verdolin, *Chair*
Roderick Sauls, *Vice Chair*

Jerry Allen	Eduardo Garcia	Pugazhenth Selvaraj
Tauhid Ansari	Krzysztof Kulasek	Hamid Sharifnia
Wallace Binder	Kerry Livingston	Samuel Sharpless
Elizabeth Bray	Terence Martin	Stephen Shull
James Fairris	David Murray	Mike Spurlock
Marcos Ferreira	Ulf Radbrandt	Jason Varnell
Anthony Franchitti	Rakesh Rathi	Sukhdev Walia
	Steven Schappell	Kris Zibert

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

Roy Ayers	Laszlo Kadar	Dhiru Patel
Thomas Barnes	Gael Kennedy	Shawn Patterson
Christopher Baumgartner	Sheldon Kennedy	Paulette Payne Powell
Robert Beavers	Yuri Khersonsky	Brian Penny
Wallace Binder	James Kinney	Alvaro Portillo
Thomas Blackburn	Jim Kulchisky	Iulian Profir
Daniel Blydon	John Lackey	Reynaldo Ramos
William Bloethe	Mikhail Lagoda	Oleg Roizman
W. Boettger	Chung-Yiu Lam	Thomas Rozek
Derek Brown	Benjamin Lanz	Ryandi Ryandi
Paul Cardinal	Thomas La Rose	Daniel Sauer
Stephen Conrad	William Larzelere	Roderick Sauls
John Crouse	Aleksandr Levin	Bartien Sayogo
Willaim Darovny	Hua Liu	Stephen Schroeder
Dieter Dohnal	Thomas Lundquist	Nikunj Shah
Gary Donner	Bruce Mackie	Devki Sharma
Don Duckett	Ryan MacMullin	Yukiyasu Shirasaka
Michael Faulkenberry	Tim-Felix Mai	Stephen Shull
Jorge Fernandez Daher	J. Dennis Marlow	Hyeong Sim
Marcel Fortin	Lee Matthews	Jeremy Smith
Michael Franchek	William McBride	Jerry Smith
Fredric Friend	Mark McNally	Gary Smullin
Shawn Galbraith	Joseph Melanson	Ronald Stahara
Carlos Gaytan	C. Michael Miller	Wayne Stec
Edwin Goodwin	Michael Miller	Troy Alan Tanaka
Randall Groves	Daleep Mohla	Ed TeNyenhuis
Ajit Gwal	Charles Morgan	David Tepen
Said Hachichi	Daniel Mulkey	Malcolm Thaden
John Harley	Jerry Murphy	James Thompson
Timothy Hayden	Ryan Musgrove	Michael Thompson
Jeffrey Helzer	K. R. M. Nair	Rogério Verdolin
Werner Hoelzl	Dennis Neitzel	John Vergis
Gary Hoffman	Arthur Neubauer	Jane Verner
Thomas Holifield	Michael Newman	David Wallach
Mohammad Iman	Raymond Nicholas	Reigh Walling
Paul Jarman	Joe Nims	Kenneth White
John John	Gearold O. H. Eidhin	Alan Wilks
	Bansi Patel	Waldemar Ziomek

When the IEEE-SA Standards Board approved this guide on 14 February 2017, it had the following membership:

Jean-Philippe Faure, *Chair*
Vacant Position, *Vice Chair*
John D. Kulick, *Past Chair*
Konstantinos Karachalios, *Secretary*

Chuck Adams
Masayuki Ariyoshi
Ted Burse
Stephen Dukes
Doug Edwards
J. Travis Griffith
Gary Hoffman

Michael Janezic
Thomas Koshy
Joseph L. Koepfinger*
Kevin Lu
Daleep Mohla
Damir Novosel
Ronald C. Petersen
Annette D. Reilly

Robby Robson
Dorothy Stanley
Adrian Stephens
Mehmet Ulema
Phil Wennblom
Howard Wolfman
Yu Yuan

*Member Emeritus

Introduction

This introduction is not part of IEEE Std C57.120-2017, IEEE Guide for Loss Evaluation of Distribution and Power Transformers and Reactors.

This guide provides details and explanations for determining the constituent components and the methodology for determining the economic value of losses of distribution and power transformers and reactors for both utility and non-utility segments. This guide focuses on the cost of losses from the energy consumption of equipment perspective and does not provide methods to quantify other social or environmental benefits that could be related to equipment efficiencies.

Losses are quantified typically for the purposes of purchasing evaluation or replacement cost analysis. It is important to quantify losses because manufacturers of equipment have a large number of design options available to them and, by providing loss values from the user, it will help the manufacturer to propose the most economic design to fit the user's circumstances.

Loss evaluation is a means to quantify operating cost and is an economic decision. Quantifying losses for comparison is a straightforward process, however, the information required for such evaluation involves forecasting and prediction of costs over a future timeframe. There are many sources of this information available and it is up to the evaluator to identify and select the most appropriate source of data applicable to their circumstances. Economic circumstances are constantly changing and specific to each user's situation, making it impossible for any single number to be used everywhere for loss evaluation.

Prediction of future costs and forecasting requires frequent updating and it is up to the evaluator to use the best information available to determine their own values of losses.

In addition to the identification of value, the evaluator is identified as a reasonable evaluation timeframe. For example, the time period of evaluation may be the useful life of the equipment or be limited to the useful life of the facility or limited by internal corporate investment criteria. The determination of an evaluation time period is entirely dependent on the user and their circumstances.

This guide identifies parameters to consider when performing a loss evaluation, but it is up to the user to identify the parameters most applicable to their circumstances. To provide an example, a primary service transformer in an industrial plant may only have losses evaluated on the basis of energy cost charged to the facility, but an industrial user may include a loss-on-loss factor for secondary step-down transformers in the same facility and include some of the evaluation parameters for distribution transformers.

Merchant generating plants may not need to calculate the parameters associated with transmission assets or the loss-on-loss multipliers for the generator's transformer because their plant is metered at the transmission connection point and the losses in the generation plant transformers only take away from the plant's revenue capability.

This guide will assist the user to decide how to value the efficiency of equipment. Ultimately, the efficiency depends heavily on how the equipment is used, where on the power system it is used, and what decisions are made regarding operating conditions such as loading beyond nameplate and timing of asset additions/replacement. One shall make the selection of parameters for the evaluation based on the best available knowledge.

This guide uses publicly available information on wholesale electricity prices, transformer costs, and other dollar values. These numbers are provided for illustrative purposes only. Actual price (or cost) will vary by time and location. Each user of this guide should determine the price or cost values that he or she believes appropriate for making loss evaluations.

Contents

1. Overview.....	10
1.1 Scope.....	10
1.2 Purpose.....	10
2. Definitions, acronyms, and abbreviations	11
2.1 Definitions.....	11
2.2 Acronyms and abbreviations	12
3. Loss evaluation parameters	13
3.1 General.....	13
3.2 Total owning cost (TOC).....	13
3.3 Cost of no-load losses (A).....	14
3.4 Cost of load losses (B).....	14
3.5 Cost of auxiliary losses (B1, B2)	14
3.6 Equipment parameters.....	15
3.7 Cost parameters	17
3.8 Load parameters	23
3.9 Example.....	28
4. Transformer loss evaluation for industrial and commercial entities and transmission only electric utilities.....	30
4.1 Introduction	30
4.2 Example.....	31
4.3 Alternate methods for determining system investment (SC) for non-vertically integrated utilities and industrial users	33
Annex A (informative) Formulas, tables, and figures	35
Annex B (informative) Description of transformer power losses	50
Annex C (informative) Bibliography	51

IEEE Guide for Loss Evaluation of Distribution and Power Transformers and Reactors

1. Overview

1.1 Scope

This guide covers the economic loss evaluation of liquid-filled distribution and power transformers, dry-type distribution and power transformers, and reactors.

1.2 Purpose

The purpose of this guide is to provide a method of establishing the dollar value of the electric power needed to supply the losses of a transformer (includes distribution and power transformers as well as reactors in this guide). Users can use this loss evaluation to determine the relative economic benefit of a high-first-cost, low-loss unit versus one with a lower first cost and higher losses. Manufacturers can use the evaluation to optimize the design and provide the most economical unit to bid and manufacture. The evaluated cost of losses also enables a user to compare the offerings of two or more manufacturers to aid in making the best purchase choice among competing transformers. Loss evaluation also provides information to a user for establishing the optimum time to retire or replace existing units with modern low-loss transformers. The user should determine, on a dollars-per-kilowatt basis, the sum of the present worth of each kilowatt of losses of a transformer throughout its life, or some other selected period of time. A portion of this evaluated cost can be paid to the manufacturer to reduce losses. However, this evaluated cost includes other costs associated with owning a more expensive piece of equipment, such as financing costs, taxes, etc. This guide provides formulas by which the costs of energy, power, money, and the loading pattern of a transformer can be converted to dollars-per-kilowatt values of the transformer losses.

These dollars-per-kilowatt figures should be furnished to the manufacturer when bids are requested. If the final tested values of losses vary from the manufacturer's guaranteed values, economic adjustments may be made. Nothing in this guide is mandatory. It should not be inferred that the methodology described in this guide is the only valid methodology for computing the cost of transformer losses. Many users have developed their own transformer loss evaluation techniques that are suitable for the intended purpose.

This guide uses publicly available information on wholesale electricity prices, transformer costs, and other dollar values. These numbers are provided for illustrative purposes only. Actual price (or cost) will vary by time and location. Each user of this guide should determine the price or cost values that it believes appropriate for making loss evaluations.

This guide offers a methodology to determine, and thereby specify, the economic value of no-load, load, and auxiliary losses. The use of this guide allows manufacturers to tailor the design to the unique economic situation of each user, and allows the user to evaluate multiple designs.