

TECHNICAL SPECIFICATION



**Power transformers –
Part 20: Energy efficiency**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2017 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 Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
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 corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

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 It also gives information on projects, replaced and withdrawn publications.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 also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions 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

65 000 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.

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: csc@iec.ch.

TECHNICAL SPECIFICATION



**Power transformers –
Part 20: Energy efficiency**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.180

ISBN 978-2-8322-3870-7

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

CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Normative references	8
3 Terms and definitions	8
4 Efficiency and efficiency index calculation	9
4.1 General.....	9
4.2 Methods of evaluating energy performance	10
4.3 Method A	11
4.3.1 Efficiency index general formula	11
4.3.2 Peak efficiency index.....	11
4.4 Method B	12
4.4.1 Efficiency index general formula (El_B)	12
4.4.2 Efficiency index at 50 % loading (El_{B50})	12
5 Specification of energy performance.....	13
6 Energy performance levels	13
6.1 General.....	13
6.2 Liquid immersed transformers	14
6.2.1 Minimum PEI method A	14
6.2.2 Maximum load losses and maximum no load losses for transformers with rated frequency equal to 50 Hz.....	16
6.2.3 Efficiency index method B.....	17
6.3 Dry type transformers	19
6.3.1 Minimum PEI value method A	19
6.3.2 Maximum load loss and maximum no load loss for transformers with rated frequency equal to 50 Hz	21
6.3.3 Efficiency index method B at 50 % load factor	22
7 Tolerance	25
7.1 General.....	25
7.2 Losses	25
7.3 PEI	25
Annex A (informative) Capitalisation of losses	26
A.1 General theory, concept of capitalisation	26
A.2 Impact of capitalisation values	27
A.3 Capitalisation formula	27
A.3.1 General	27
A.3.2 Calculation of factor A	28
A.3.3 Calculation of factor B	28
A.3.4 Use of A and B for tender evaluation.....	30
A.3.5 Determination of factors A and B	31
Annex B (informative) Efficiency based on a survey of world practices.....	32
B.1 General.....	32
B.2 50 Hz efficiency	32
B.3 60 Hz efficiency	32
Annex C (informative) Japanese practices	34
C.1 General.....	34

C.2	Scope	34
C.3	Maximum losses calculation methods	34
C.4	Maximum losses	34
Bibliography.....		36
Figure A.1 – Load profile.....		29
Table 1 – PEI values for single-phase transformers with $U_m \leq 12$ kV and $S_r \leq 100$ kVA		14
Table 2 – PEI values for transformers with $U_m \leq 36$ kV and $S_r \leq 3\,150$ kVA.....		15
Table 3 – PEI values for transformers with $U_m > 36$ kV or $S_r > 3\,150$ kVA		16
Table 4 – Maximum load losses and maximum no load losses for transformers with rated frequency equal to 50 Hz		17
Table 5 – El_{B50} value for liquid-immersed 60 Hz transformers		18
Table 6 – El_{B50} value for liquid-immersed 50 Hz transformers		19
Table 7 – PEI values for dry type transformers with $U_m \leq 36$ kV and $S_r \leq 3\,150$ kVA		20
Table 8 – PEI values for transformers with $U_m \leq 36$ kV and $S_r > 3\,150$ kVA		20
Table 9 – PEI values for transformers with $U_m > 36$ kV.....		21
Table 10 – Maximum load loss and maximum no load loss for transformers with rated frequency equal to 50 Hz		22
Table 11 – El_{B50} values for single-phase dry type 60 Hz transformers		23
Table 12 – El_{B50} values for three-phase dry type 60 Hz transformers		24
Table 13 – El_{B50} values for dry type 50 Hz transformers.....		25
Table B.1 – Efficiency equations for transformers with a primary voltage of 36 kV and below, from 5 kVA to 1 000 kVA single-phase and 15 kVA to 3 150 kVA three-phase, 50 Hz and 50 % load method A		32
Table B.2 – Efficiency equations for transformers with a primary voltage of 36 kV and below, from 5 kVA to 1 000 kVA single-phase and 15 kVA to 3 150 kVA three-phase, 60 Hz and 50 % load method B		33
Table C.1 – Maximum losses		35

INTERNATIONAL ELECTROTECHNICAL COMMISSION

POWER TRANSFORMERS –**Part 20: Energy efficiency****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.
- 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.
- 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. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 60076-20, which is a technical specification, has been prepared by IEC technical committee 14: Power transformers.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
14/852/DTS	14/884/RVDTs

Full information on the voting for the approval of this technical specification 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 reader's attention is drawn to the fact that Annex C lists all of the "in-some-country" clauses on differing practices of a less permanent nature relating to the subject of this standard.

A list of all the parts in the IEC 60076 series, under the general title *Power transformers*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The reason prompting the preparation of this document is the need to save energy and to reduce the emission of greenhouse gases. The objective of this document is to promote a higher average level of energy performance for transformers.

It provides a basic model for national standards and, alternatively, a supplement to national standards that do not cover the whole range of transformers.

This part of IEC 60076 gives methods of specifying a transformer with an appropriate level of energy efficiency according to the loading and operating conditions applicable. It also gives minimum efficiency and maximum losses which lead to a generally acceptable balance between losses and use of other resources.

This document proposes two methods (A and B) of defining an energy efficiency index and introduces three methods of evaluating the energy performance of a transformer.

These are based on existing regional practices:

- a) the Peak Efficiency Index (PEI) which should be used in conjunction with either a total cost of ownership (TCO) approach or any other mean of specifying the load factor.
- b) the no-load and load losses at rated power for rationalization of transformer cores and coils for transformers generally produced in large volumes;
- c) the efficiency at a defined power factor and particular load factor (typically at 50 %).

The appropriate method is chosen by agreement between purchasers and manufacturers or according to local regulations.

A transformer that does not comply with this document can still comply with the requirements of other standards in the IEC 60076 series.

Formulae for the calculation of efficiency are given to reflect different regional practices and purposes. The definition of rated power is given in IEC 60076-1.

Energy efficiency is not the sole basis for choosing a transformer. The total capital and estimated lifetime operating and maintenance costs (TCO) are also significant considerations in determining the most suitable transformer for the intended application, and may lead to the selection of more economical solutions when taking into account the lifetime of the transformers.

This document provides a standard method for evaluating the energy performance of power transformers through the use of the PEI, gives benchmark figures and the reasons why certain transformers may have efficiencies which are higher or lower than the benchmark.

Setting a reasonable value of minimum PEI will be effective in improving the overall energy performance of the installed transformer population by eliminating transformers with low efficiency, with the exception for some specific network limitations.

The use of a minimum value of PEI sets a floor for transformer energy performance, but the use of TCO evaluation for purchasing transformers is essential to select a transformer with the optimal economically justified level of efficiency.

POWER TRANSFORMERS –

Part 20: Energy efficiency

1 Scope

This part of IEC 60076 is applicable to transformers in the scope of IEC 60076-1.

The energy performance levels given in Clause 6 are not applicable to the following transformers:

- transformers for high current rectifiers as described in the IEC 61378 (all parts) and in the IEC 60146 (all parts);
- transformers for furnace applications;
- transformers for offshore applications;

NOTE 1 Transformer to be installed on fixed or floating offshore platforms, offshore wind turbines or on board of ships and all kind of vessels).

- transformers for emergency or temporary mobile installations;

NOTE 2 Transformers designed only to provide cover for a specific time limited situation when the normal power supply is interrupted either due to an unplanned occurrence such as failure or a station refurbishment, but not to permanently upgrade an existing substation.

- traction transformers;
- earthing transformers as described in 3.1.10 of IEC 60076-6:2007.
- phase shifting transformers;
- instrument transformers (IEC 61869-1);
- transformers and auto-transformers specifically designed for railway feeding systems, as defined in EN 50329;
- traction catenary supply transformer for 16,67 Hz;
- transformer for high current rectifiers (IEC 61869-1);

NOTE 3 These are transformers specifically designed and intended to supply power electronic or rectifier loads specified according to IEC 61378-1.

NOTE 4 This exclusion does not apply to transformers intended to provide AC power from DC sources such as transformers for wind turbine and photo voltaic applications as well as transformers designed for DC transmission and distribution applications."

- transformers for railway feeding systems (EN 50329);
- subsea transformers;
- starting-, testing- and welding transformers;
- starting transformers, specifically designed for starting three-phase induction motors so as to eliminate supply voltage dips;

NOTE 5 Examples are transformers that are de-energised during normal operation, used for the purpose of starting a rotating machine).

- transformers specifically designed for explosion-proof and underground mining applications;
- transformers which cannot fulfil the energy performance requirements due to unavoidable size and weight limitations.

NOTE 6 Due to the unavoidable weight and size limitation for a rolling stock application, this definition includes all traction transformers for rolling stock, irrespective of the frequency (e.g. 16,7 Hz, 25 Hz, 50 Hz, 60 Hz).

In this document, "transformers" includes both separate winding transformers and autotransformers.

NOTE 7 Transformers intended to provide AC power from DC sources such as transformers for wind turbine and photo voltaic applications as well as transformers designed for DC transmission and distribution applications are included in the Scope of this document.

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.

IEC 60076-1, *Power transformers – Part 1: General*

IEC 60076-2, *Power transformers – Part 2: Temperature rise for liquid-immersed transformers*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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>

3.1

efficiency

ratio of output active power to input active power

Note 1 to entry: This is an apparent power

3.2

electrical losses

electrical power consumed by the transformer at a particular value of transmitted apparent power excluding the power consumed by the cooling system

3.3

efficiency index method A

EI_A

ratio of the transmitted apparent power of a transformer minus electrical losses including the power consumed by the cooling to the transmitted apparent power of the transformer for a given load factor

3.4

efficiency index method B

EI_B

ratio of the transmitted apparent power of a transformer to the transmitted apparent power of the transformer plus electrical losses for a given load factor

Note 1 to entry: This method is only applicable for naturally cooled transformers.