

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Power transformers –
Part 12: Loading guide for dry-type power transformers**

**Transformateurs de puissance –
Partie 12: Guide de charge pour transformateurs de puissance de type sec**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2008 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.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: 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.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,...). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: www.iec.ch/online_news/justpub

Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.

- Electropedia: www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:

Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Power transformers –
Part 12: Loading guide for dry-type power transformers**

**Transformateurs de puissance –
Partie 12: Guide de charge pour transformateurs de puissance de type sec**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX

V

ICS 29.180

ISBN 2-8318-1015-2

CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Normative references	7
3 Terms and definitions	7
4 Effect of loading beyond nameplate rating	8
4.1 General.....	8
4.2 General consequences.....	8
4.3 Effects and hazards of short-time emergency loading.....	8
4.4 Effects of long-time emergency loading	9
5 Ageing and transformer insulation lifetime	9
5.1 General.....	9
5.2 Lifetime	9
5.3 Relation between constant continuous load and temperature	10
5.4 Ageing rate.....	11
5.5 Lifetime consumption	11
5.6 Hot-spot temperature in steady state.....	11
5.7 Assumed hot-spot factor.....	12
5.8 Hot-spot temperature rises at varying ambient temperature and load conditions.....	12
5.9 Loading equations	12
5.9.1 Continuous loading.....	12
5.9.2 Transient loading.....	13
5.10 Determination of winding time constant	14
5.10.1 General	14
5.10.2 Time constant calculation method.....	14
5.10.3 Time constant test method.....	15
5.11 Determination of winding time constant according to empirical constant.....	15
5.12 Calculation of loading capability	15
6 Limitations.....	17
6.1 Current and temperature limitations.....	17
6.2 Other limitations	17
6.2.1 Magnetic leakage field in structural metallic parts.....	17
6.2.2 Accessories and other considerations.....	17
6.2.3 Transformers in an enclosure	18
6.2.4 Outdoor ambient conditions	18
Annex A (informative) Ageing rate	19
Annex B (informative) Examples of lifetime consumptions for 3 load regimes.....	24
Annex C (informative) List of symbols	33
Bibliography.....	35
Figure A.1 – Molecule structure of an epoxy	19
Figure A.2 – Thermal endurance graph	22
Figure B.1 – Step change loading curve.....	25
Figure B.2 – Hot-spot temperature rise and life consumption	27

Figure B.3 – Load current and winding hot-spot temperature rise.....	30
Figure B.4 – Ageing rate versus time	30
Table 1 – Constants for lifetime equation	10
Table 2 – Maximum hot-spot winding temperature	16
Table 3 – Current and temperature limits applicable to loading beyond nameplate rating	17
Table B.1 – Lifetime consumption calculations	26
Table B.2 – Life consumption calculations for varying load	29
Table B.3 – Life consumption calculation	31

INTERNATIONAL ELECTROTECHNICAL COMMISSION

POWER TRANSFORMERS –**Part 12: Loading guide for dry-type power 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. 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 provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 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.

International Standard IEC 60076-12 has been prepared by IEC technical committee 14: Power transformers.

This standard cancels and replaces IEC 60905 (1987). This first edition constitutes a technical revision.

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

FDIS	Report on voting
14/584/FDIS	14/590/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.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of 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 maintenance result 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.

INTRODUCTION

This part of IEC 60076 provides guidance for the specification and loading of dry type power transformers from the point of view of operating temperatures and thermal ageing. It provides the consequence of loading above the nameplate rating and guidance for the planner to choose appropriate rated quantities and loading conditions for new installations.

IEC 60076-11 is the basis for contractual agreements and it contains the requirements and tests relating to temperature-rise figures for dry type power transformers during continuous rated loading. It should be noted that IEC 60076-11 refers to the average winding temperature rise while this part of IEC 60076 refers mainly to the hot-spot temperature and the latter stated values are provided only for guidance.

This part of IEC 60076 gives mathematical models for judging the consequence of different loading, with different temperatures of the cooling medium, and with transient or cyclical variation with time. The models provide for the calculation of operating temperatures in the transformer, particularly the temperature of the hottest part of the winding. This hot-spot temperature is used for estimation of the number of hours of life time consumed during a particular time period.

This part of IEC 60076 further presents recommendations for limitations of permissible loading according to the results of temperature calculations or measurements. These recommendations refer to different types of loading duty – continuous loading, short-time and long time emergency loading. An explanation of ageing fundamentals is given in Annex A.

POWER TRANSFORMERS –

Part 12: Loading guide for dry-type power transformers

1 Scope

This part of IEC 60076 is applicable to dry-type transformers according to the scope of IEC 60076-11. It provides the means to estimate ageing rate and consumption of lifetime of the transformer insulation as a function of the operating temperature, time and the loading of the transformer.

NOTE For special applications such as wind turbine application transformers, furnace transformers, welding machine transformers, and others, the manufacturer should be consulted regarding the particular loading profile.

2 Normative references

The following referenced documents are indispensable for the application 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 60076-11, *Power transformers – Part 11: Dry-type transformers*

IEC 60216-1, *Electrical insulating materials – Properties of thermal endurance – Part 1: Ageing procedures and evaluation of test results*

IEC 61378-1:1997, *Convertor transformers – Part 1: Transformers for industrial applications*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

long-time emergency loading

loading resulting from the prolonged outage of some system elements that will not be reconnected before the transformer reaches a new and higher steady state temperature

3.2

short-time emergency loading

unusually heavy loading of a transient nature (less than one time constant of the coil) due to the occurrence of one or more unlikely events which seriously disturb normal system loading

3.3

hot-spot

if not specifically defined, “hot-spot” means the hottest-spot of the winding

3.4

relative thermal ageing rate

for a given hot-spot temperature, the rate at which transformer insulation ageing is reduced or accelerated compared with the ageing rate at a reference hot-spot temperature