



BSI Standards Publication

## Power transformers

Part 19: Rules for the determination of uncertainties in the measurement of the losses on power transformers and reactors

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

**National foreword**

This Published Document is the UK implementation of IEC/TS 60076-19:2013.

The UK participation in its preparation was entrusted to Technical Committee PEL/14, Power transformers.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2013.

Published by BSI Standards Limited 2013.

ISBN 978 0 580 83075 4

ICS 29.180

**Compliance with a British Standard cannot confer immunity from legal obligations.**

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 30 April 2013.

**Amendments/corrigenda issued since publication**

Date	Text affected
30 April 2013	Cover page title corrected



# TECHNICAL SPECIFICATION

# SPÉCIFICATION TECHNIQUE

---

## Power transformers –

**Part 19: Rules for the determination of uncertainty in the measurement of the losses on power transformers and reactors**

## Transformateurs de puissance –

**Partie 19: Règles pour la détermination des incertitudes de mesure des pertes des transformateurs de puissance et des bobines d'inductance**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

PRICE CODE  
CODE PRIX

**W**

ICS 29.180

ISBN 978-2-83220-693-5

**Warning! Make sure that you obtained this publication from an authorized distributor.  
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

## CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Normative references.....	7
3 Terms and definitions.....	7
4 Symbols.....	8
4.1 General symbols.....	8
4.2 Symbols for uncertainty.....	9
5 Power measurement, systematic deviation and uncertainty.....	10
5.1 General.....	10
5.2 Model function.....	10
5.3 Measuring systems.....	10
6 Procedures for no-load loss measurement.....	11
6.1 General.....	11
6.2 Model function for no-load losses at reference condition.....	11
6.3 Uncertainty budget for no-load loss.....	12
7 Procedures for load loss measurement.....	13
7.1 General.....	13
7.2 Model function for load loss measurement at rated current.....	13
7.3 Reporting to rated current and reference temperature.....	14
7.4 Uncertainty budget for the measured power $P_2$ reported to rated current.....	14
7.4.1 General.....	14
7.4.2 Uncertainties of measured load loss power $P_2$ at ambient temperature $\theta_2$ .....	14
7.5 Uncertainty budget for reported load loss at reference temperature.....	15
8 Three-phase calculations.....	16
8.1 Power measurement.....	16
8.2 Reference voltage.....	17
8.3 Reference current.....	17
9 Reporting.....	17
9.1 Uncertainty declaration.....	17
9.2 Traceability.....	17
10 Estimate of corrections and uncertainty contributions.....	18
10.1 Instrument transformers.....	18
10.2 Uncertainty contributions of ratio error of instrument transformers.....	18
10.3 Uncertainty contribution of phase displacement of instrument transformers.....	19
10.3.1 General.....	19
10.3.2 Complete reference procedure.....	19
10.3.3 Class index procedure.....	20
10.4 Voltage and current measurements.....	21
10.5 Power meter.....	21
10.6 Correction to sinusoidal waveform.....	22
10.7 Winding temperature at load loss measurement.....	23
10.8 Winding resistance measurement.....	23
Annex A (informative) Example of load loss uncertainty evaluation for a large power transformer.....	25

Annex B (Informative) Example of load loss uncertainty evaluation for a distribution transformer .....	33
Bibliography.....	37
Table 1 – Measured no-load loss uncertainties .....	12
Table 2 – Measured load loss uncertainties at ambient temperature .....	15
Table 3 – Absolute uncertainty of the additional losses at temperature $\theta_2$ .....	15
Table 4 – Absolute uncertainty of load losses $P_{LL}$ reported at reference temperature .....	16
Table 5 – Procedures for the determination of phase displacement uncertainties .....	19
Table A.1 – Transformer ratings.....	25
Table A.2 – Loss measurement results (one phase).....	27
Table A.3 – Calibration of voltage and current transformers .....	27
Table A.4 – Uncertainty contributions.....	29
Table B.1 – Transformer ratings.....	33
Table B.2 – Measured quantities.....	34
Table B.3 – Calibration of the current transformers .....	35
Table B.4 – Uncertainty contribution .....	36

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

### POWER TRANSFORMERS –

#### Part 19: Rules for the determination of uncertainties in the measurement of the losses on power transformers and reactors

#### 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, accept 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 60076-19, 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
14/726/DTS	14/736A/RVC

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

A list of all parts in the IEC 60076 series, published 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 web site 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.

## INTRODUCTION

The losses of the transformers (no-load and load losses) are object of guaranty and penalty in the majority of the contracts and play an important role in the evaluation of the total (service) costs and therefore in the investments involved.

According to ISO/IEC 17025 the result of any measurement should be qualified with the evaluation of its uncertainty. A further requirement is that known corrections shall have been applied before evaluation of uncertainty.

Corrections and uncertainties are also considered in IEC 60076-8 where some general indications are given for their determination.

This Technical Specification deals with the measurement of the losses that from a measuring point of view consist of the estimate of a measurand and the evaluation of the uncertainty that affects the measurand itself.

The uncertainty range depends on the quality of the test installation and measuring system, on the skill of the staff and on the intrinsic measurement difficulties presented by the tested objects.

The submitted test results are to be considered the most correct estimate and therefore this value has to be accepted as it stands.

In the annexes to this document, two examples of uncertainty calculations are reported for load loss measurements on large power and distribution transformers.

Standards, technical reports and guides mentioned in the text are listed at the end of the document.

It is stated that guaranty and penalty calculations should refer to the best estimated values of the losses without considering the measurement uncertainties.

## POWER TRANSFORMERS –

### Part 19: Rules for the determination of uncertainties in the measurement of the losses on power transformers and reactors

#### 1 Scope

This part of IEC 60076, which is a Technical Specification, illustrates the procedures that should be applied to evaluate the uncertainty affecting the measurements of no-load and load losses during the routine tests on power transformers.

Even if the attention is especially paid to the transformers, when applicable the specification can be also used for the measurements of reactor losses, except large reactors with very low power factor.

#### 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60076-1:2011, *Power transformers – Part 1: General*

IEC 60076-2:2011, *Power transformers – Part 2: Temperature rise for liquid-immersed transformers*

#### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60076-1 and 60076-2, as well as the following apply.

NOTE The following terms and definitions were taken from ISO/IEC Guide 98-3:2008.

##### 3.1 uncertainty (of measurement)

parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

[SOURCE: ISO/IEC Guide 98-3:2008, 2.2.3]

##### 3.2 standard uncertainty

uncertainty of the result of a measurement expressed as a standard deviation

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.1]

##### 3.3 type A evaluation (of uncertainty)

method of evaluation of uncertainty by the statistical analysis of series of observations

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.2]