



SLOVENSKI STANDARD
SIST EN 60076-18:2012

01-december-2012

Močnostni transformatorji - 18. del: Merjenje frekvenčne odzivnosti

Power transformers - Part 18: Measurement of frequency response

Transformateurs de puissance - Partie 18: Mesure de la réponse en fréquence

Ta slovenski standard je istoveten z: EN 60076-18:2012

[SIST EN 60076-18:2012](https://standards.iteh.ai/catalog/standards/sist/5ffc9061-d1dc-4794-8052-945f16cafd86/sist-en-60076-18-2012)

<https://standards.iteh.ai/catalog/standards/sist/5ffc9061-d1dc-4794-8052-945f16cafd86/sist-en-60076-18-2012>

ICS:

29.180 Transformatorji. Dušilke Transformers. Reactors

SIST EN 60076-18:2012

en

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[SIST EN 60076-18:2012](#)

<https://standards.iteh.ai/catalog/standards/sist/5ffc9061-d1dc-4794-8052-945f16cafd86/sist-en-60076-18-2012>

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 60076-18

September 2012

ICS 29.180

English version

**Power transformers -
Part 18: Measurement of frequency response
(IEC 60076-18:2012)**

Transformateurs de puissance -
Partie 18: Mesure de la réponse
en fréquence
(CEI 60076-18:2012)

Leistungstransformatoren -
Teil 18: Messung des
Frequenzübertragungsverhaltens
(IEC 60076-18:2012)

STANDARD PREVIEW
This European Standard was approved by CENELEC on 2012-08-13. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.
(standards.iteh.ai)

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

<https://standards.iteh.ai/catalog/standards/sist/5ffc9061-d1dc-4794-8052-7510ca003a1a/en-60076-18:2012>
This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Foreword

The text of document 14/718/FDIS, future edition 1 of IEC 60076-18, prepared by IEC/TC 14 "Power transformers" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60076-18:2012.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2013-05-13
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2015-08-13

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60076-18:2012 was approved by CENELEC as a European Standard without any modification.

ITeH STANDARD PREVIEW
(standards.iteh.ai)

[SIST EN 60076-18:2012](https://standards.iteh.ai/catalog/standards/sist/5ffc9061-d1dc-4794-8052-945f16cafd86/sist-en-60076-18-2012)

<https://standards.iteh.ai/catalog/standards/sist/5ffc9061-d1dc-4794-8052-945f16cafd86/sist-en-60076-18-2012>



IEC 60076-18

Edition 1.0 2012-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Power transformers –
Part 18: Measurement of frequency response
(standards.iteh.ai)

Transformateurs de puissance –
Partie 18: Mesure de la réponse en fréquence
(standards.iteh.ai)

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX



ICS 29.180

ISBN 978-2-83220-222-7

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.....	5
1 Scope.....	7
2 Terms and definitions	7
3 Purpose of frequency response measurements	8
4 Measurement method	9
4.1 General.....	9
4.2 Condition of the test object during measurement	10
4.3 Measurement connection and checks	11
4.3.1 Measurement connection and earthing	11
4.3.2 Zero-check measurement	11
4.3.3 Repeatability check	11
4.3.4 Instrument performance check.....	11
4.4 Measurement configuration	12
4.4.1 General	12
4.4.2 Principles for choosing the measurement configuration	12
4.4.3 Star- and auto-connected windings with a neutral terminal	13
4.4.4 Delta windings and other windings without an accessible neutral	13
4.4.5 Zig-zag connected windings.....	14
4.4.6 Two-winding three-phase transformers	14
4.4.7 Three-phase auto-transformers.....	14
4.4.8 Phase shifting transformers.....	14
4.4.9 Reactors.....	14
4.4.10 Method for specifying additional measurements.....	14
4.5 Frequency range and measurement points for the measurement	15
5 Measuring equipment	15
5.1 Measuring instrument	15
5.1.1 Dynamic range	15
5.1.2 Amplitude measurement accuracy	16
5.1.3 Phase measurement accuracy	16
5.1.4 Frequency range	16
5.1.5 Frequency accuracy	16
5.1.6 Measurement resolution bandwidth.....	16
5.1.7 Operating temperature range.....	16
5.1.8 Smoothing of recorded data.....	16
5.1.9 Calibration.....	16
5.2 Measurement leads	16
5.3 Impedance	17
6 Measurement records	17
6.1 Data to be recorded for each measurement	17
6.2 Additional information to be recorded for each set of measurements	18
Annex A (normative) Measurement lead connections	20
Annex B (informative) Frequency response and factors that influence the measurement.....	23
Annex C (informative) Applications of frequency response measurements	37

Annex D (informative) Examples of measurement configurations	39
Annex E (informative) XML data format.....	43
Bibliography.....	44
Figure 1 – Example schematic of the frequency response measurement circuit.....	10
Figure A.1 – Method 1 connection.....	21
Figure A.2 – Method 3 connection.....	22
Figure B.1 – Presentation of frequency response measurements	23
Figure B.2 – Comparison with a baseline measurement	24
Figure B.3 – Comparison of the frequency responses of twin transformers	24
Figure B.4 – Comparison of the frequency responses from sister transformers	25
Figure B.5 – Comparison of the frequency responses of three phases of a winding.....	25
Figure B.6 – General relationships between frequency response and transformer structure and measurement set-up for HV windings of large auto-transformer	27
Figure B.7 – Effect of tertiary delta connection on the frequency response of a series winding	28
Figure B.8 – Effect of star neutral connection on the tertiary winding response	29
Figure B.9 – Effect of star neutral termination on series winding response	29
Figure B.10 – Measurement results showing the effect of differences between phases in internal leads connecting the tap winding and OLTC	30
Figure B.11 – Effect of measurement direction on frequency response	30
Figure B.12 – Effect of different types of insulating fluid on frequency response	31
Figure B.13 – Effect of oil filling on frequency response	31
Figure B.14 – Effect of a DC injection test on the frequency response	32
Figure B.15 – Effect of bushings on frequency response.....	32
Figure B.16 – Effect of temperature on frequency response	33
Figure B.17 – Examples of bad measurement practice.....	34
Figure B.18 – Frequency response of a tap winding before and after partial axial collapse and localised inter-turn short-circuit with a photograph of the damage	34
Figure B.19 – Frequency response of an LV winding before and after axial collapse due to clamping failure with a photograph of the damage [8].....	35
Figure B.20 – Frequency response of a tap winding with conductor tilting with a photograph of the damage [1]	36
Figure D.1 – Winding diagram of an auto-transformer with a line-end tap changer	40
Figure D.2 – Connection diagram of an inductive inter-winding measurement on a three-phase YNd1 transformer.....	41
Figure D.3 – Connection diagram for a capacitive inter-winding measurement on a three-phase YNd1 transformer.....	42
Figure D.4 – Connection diagram for an end-to-end short-circuit measurement on a three-phase YNd1 transformer.....	42
Table 1 – Standard measurements for a star connected winding with taps	13
Table 2 – Standard measurements for delta connected winding without tap	14
Table 3 – Format for specifying additional measurements	15
Table D.1 – Standard end-to-end measurements on a three-phase auto-transformer	39
Table D.2 – Tap-changer connections.....	40

Table D.3 – Inductive inter-winding measurements on a three-phase YNd1 transformer.....	41
Table D.4 – Capacitive inter-winding measurements on a three-phase YNd1 transformer	41
Table D.5 – End-to-end short-circuit measurements on a three-phase YNd1 transformer	42

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[SIST EN 60076-18:2012](https://standards.iteh.ai/catalog/standards/sist/5ffc9061-d1dc-4794-8052-945f16cafd86/sist-en-60076-18-2012)

<https://standards.iteh.ai/catalog/standards/sist/5ffc9061-d1dc-4794-8052-945f16cafd86/sist-en-60076-18-2012>

INTERNATIONAL ELECTROTECHNICAL COMMISSION

POWER TRANSFORMERS –

Part 18: Measurement of frequency response

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.

International Standard IEC 60076-18 has been prepared by IEC technical committee 14: Power transformers.

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

FDIS	Report on voting
14/718/FDIS	14/728/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 the IEC 60076 series can be found, under the general title *Power transformers*, 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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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.

iTeh STANDARD PREVIEW (standards.iteh.ai)

[SIST EN 60076-18:2012](#)

<https://standards.iteh.ai/catalog/standards/sist/5ffc9061-d1dc-4794-8052-945f16cafd86/sist-en-60076-18-2012>

POWER TRANSFORMERS –

Part 18: Measurement of frequency response

1 Scope

This part of the IEC 60076 series covers the measurement technique and measuring equipment to be used when a frequency response measurement is required either on-site or in the factory either when the test object is new or at a later stage. Interpretation of the result is not part of the normative text but some guidance is given in Annex B. This standard is applicable to power transformers, reactors, phase shifting transformers and similar equipment.

2 Terms and definitions

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

2.1

frequency response

amplitude ratio and phase difference between the voltages measured at two terminals of the test object over a range of frequencies when one of the terminals is excited by a voltage source

Note 1 to entry: The frequency response measurement result is a series of amplitude ratios and phase differences at specific frequencies over a range of frequency.

Note 2 to entry: The measured voltage is the voltage developed across an impedance and so it is also related to current.

2.2

frequency response analysis

FRA

technique used to detect damage by the use of frequency response measurements

Note 1 to entry: The terms SFRA and IFRA are commonly used and refer to the use of either a swept frequency voltage source or an impulse voltage source. Provided the measuring equipment complies with the requirements of Clause 5, this standard can be applied to both techniques.

2.3

source lead

lead connected to the voltage source of the measuring instrument used to supply an input voltage to the test object

2.4

reference lead

V_{in}

lead connected to the reference channel of the measuring instrument used to measure the input voltage to the test object

2.5

response lead

V_{out}

lead connected to the response channel of the measuring instrument used to measure the output voltage of the test object

2.6**end-to-end measurement**

frequency response measurement made on a single coil (phase winding) with the source and reference (V_{in}) leads connected to one end and the response (V_{out}) lead connected to the other end

2.7**capacitive inter-winding measurement**

frequency response measurement made on two adjacent coils (windings of the same phase) with the source and reference (V_{in}) leads connected to one end of a winding, the response (V_{out}) lead connected to one end of another winding and with the other winding ends floating

Note 1 to entry: This type of measurement is not applicable to windings which have common part or connection between them.

2.8**inductive inter-winding measurement**

frequency response measurement made on two adjacent coils (windings of the same phase) with the source and reference (V_{in}) leads connected to one end of the higher voltage winding, the response (V_{out}) lead connected to one end of the other winding and with the other ends of both windings grounded

2.9**end-to-end short circuit measurement**

frequency response measurement made on a single coil (phase winding) with the source and reference (V_{in}) leads connected to one end, the response (V_{out}) lead connected to the other end, and another winding of the same phase short-circuited

2.10**baseline measurement**

frequency response measurement made on a test object to provide a basis for comparison with a future measurement on the same test object in the same configuration

3 Purpose of frequency response measurements

Frequency response measurements are made so that Frequency Response Analysis (FRA) can be carried out. FRA can be used to detect changes to the active part of the test object (windings, leads and core).

NOTE FRA is generally used to detect geometrical changes and electrical short-circuits in the windings, see Annex B.

Some examples of conditions that FRA can be used to assess are:

- damage following a through fault or other high current event (including short-circuit testing),
- damage following a tap-changer fault,
- damage during transportation, and
- damage following a seismic event.

Further information on the application of frequency response measurements is given in Annex C.

The detection of damage using FRA is most effective when frequency response measurement data is available from the transformer when it is in a known good condition (baseline measurement), so it is preferable to carry out the measurement on all large transformers either in the factory or when the transformer is commissioned at site or both. If a baseline

measurement is not available for a particular transformer, reference results may be obtained from either a similar transformer or another phase of the same transformer (see Annex B).

Frequency response measurements can also be used for power system modelling including transient overvoltage studies.

4 Measurement method

4.1 General

To make a frequency response measurement, a low voltage signal is applied to one terminal of the test object with respect to the tank. The voltage measured at this input terminal is used as the reference signal and a second voltage signal (the response signal) is measured at a second terminal with reference to the tank. The frequency response amplitude is the scalar ratio between the response signal (V_{out}) and the reference voltage (V_{in}) (presented in dB) as a function of the frequency. The phase of the frequency response is the phase difference between V_{in} and V_{out} (presented in degrees).

The response voltage measurement is made across an impedance of 50 Ω . Any coaxial lead connected between the test object terminal and the voltage measuring instrument shall have a matched impedance. To make an accurate ratio measurement, the technical parameters of the reference and response channels of the measuring instrument and any measurement leads shall be identical.

NOTE 1 The characteristic impedance of the coaxial measuring leads is chosen to match the measuring channel input impedance to minimise signal reflections and reduce the influence of the coaxial lead on the measurement to the point where it has little or no practical effect on the measurement within the measurement frequency range. With a matched impedance lead, the measuring impedance is effectively applied at the test object terminal.

NOTE 2 As V_{out}/V_{in} varies over a wide range, it is expressed in decibels (dB). The relative voltage response in dB is calculated as $20 \times \log_{10}(V_{out}/V_{in})$, where (V_{out}/V_{in}) is the scalar ratio.

An example of the general layout of the measurement method using coaxial measuring leads is shown in Figure 1.