IEC 60076-10

Edition 2.0 2016-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Power transformers –
Part 10: Determination of sound levels

Transformateurs de puissance –
Partie 10: Détermination des niveaux de bruit

IEC 60076-10:2016-03(en-fr)

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POWER TRANSFORMERS –

Part 10: Determination of sound levels

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.

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International Standard IEC 60076-10 has been prepared by IEC technical committee 14: Power transformers

This second edition cancels and replaces the first edition published in 2001 and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

– additional useful definitions introduced;
– definition of distribution type transformers introduced for the purpose this standard;
– new clause for sound level measurement specification introduced;
– requirement for 1/3 octave band measurements introduced for transformers other than distribution type transformers;

– standard measurement distance changed from 0,3 m to 1 m for transformers other than distribution type transformers;
– height of measurement surface is now clearly defined to count from the reflecting plane;
– measurement surface formula unified;
– correction criteria for intensity method introduced;
– rules for sound measurements on dry-type reactors introduced;
– figures revised;
– new informative test report templates introduced (Annex B);
– IEC 60076-10-1 (application guide) revised in parallel providing worthwhile information for the use of this standard.

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

FDIS	Report on voting
14/846/FDIS	14/849/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 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

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- withdrawn,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

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INTRODUCTION

One of many parameters considered when specifying, designing and placing transformers, reactors and their associated cooling devices is the sound level that the equipment is likely to emit under defined in-service conditions. This part of IEC 60076 provides the basis for the specification and test of sound levels.

This standard describes in a logical sequence the loading conditions, how to specify and to test as well as how to evaluate and report sound levels for the equipment under test. A new section for the specification of sound levels has been introduced as Clause 5.

For the purpose of this standard, the definition "distribution type transformers" was introduced. This reflects industry's need to maintain simpler and faster sound measurements for this category of transformers.

The new requirement for reporting 1/3-octave band spectra for all sound levels (including the background noise) on units for installation in substations reflects the more onerous conditions imposed by planning authorities on the purchaser and also the improved functionality of modern instrumentation.

When the sound intensity method was introduced in this standard limited experience was available. During subsequent years of operating this standard levels of experience have significantly increased and necessary changes have become evident. The equivalence of the pressure and the intensity methods has been demonstrated within certain test limitations.

The introduction of new validation criteria for the intensity method recognises these limitations. The permissible pressure – intensity index ΔL remains 8 dB however the difference between measured sound pressure level and reported sound intensity level is limited to 4 dB.

For the pressure method the correction procedure for reflections has been enhanced by recommending the application of frequency dependent K values derived by measurement of the reverberation time of the test facility. Where K is derived from absorption coefficients the table for the average absorption coefficients has been rationalised to represent surfaces likely to be found in the working environment.

Walk-around procedure and point-by-point procedure are equally applicable. The walk-around procedure reflects the evolution of working practice allowing more time efficient measurements mainly on large units. For distribution type transformers and in special situations (health and safety) the point-by-point procedure is more appropriate.

In order to mitigate near-field effects the preferred measurement distance is set to 1 m with exceptions for distribution type transformers, small test facilities, situations with low signal-to-noise ratio and for health and safety where the distance is maintained at 0,3 m.

One single formula for the calculation of the measurement surface area S has been introduced because the former complexity could only result in differences always smaller than 1 dB.

All figures describing the measurement surface area have been revised to be in accordance with the enveloping method for sound power determination. The height h is always measured from the test facility floor regardless of the height of the supports beneath the test object unless the test object is mounted on a support with a sufficiently large surface acting as reflecting plane.

Additional figures explain the procedure for the determination of the measurement surface area and the prescribed contour for a number of configurations of dry-type reactors.

When using this standard, it is recommended to frequently refer to the corresponding application guide IEC 60076-10-1:2016 as it promotes understanding with important background information and helpful details. IEC 60076-10 and IEC 60076-10-1 were revised in parallel by the same maintenance team resulting in fully aligned documents.

POWER TRANSFORMERS –

Part 10: Determination of sound levels

1 Scope

This Part of IEC 60076 defines sound pressure and sound intensity measurement methods from which sound power levels of transformers, reactors and their associated cooling devices are determined.

NOTE For the purposes of this standard, the term "transformer" frequently means "transformer or reactor".

The methods are applicable to transformers, reactors and their cooling devices – either fitted to or separate from the transformer – as covered by the IEC 60076 and IEC 61378 series.

This standard is primarily intended to apply to measurements made at the factory. Conditions on-site can be very different because of the proximity of objects, including other transformers. Nevertheless, this standard is applied to the extent possible for on-site measurements.

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 60076-8:1997, *Power transformers – Part 8: Application guide*

IEC 61043:1993, *Electroacoustics – Instruments for the measurement of sound intensity – Measurements with pairs of pressure sensing microphones*

IEC 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications*

IEC 61672-2, *Electroacoustics – Sound level meters – Part 2: Pattern evaluation tests*

ISO 3382-2:2008, *Acoustics – Measurement of room acoustic parameters – Part 2: Reverberation time in ordinary rooms*

ISO 3746:2010, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane*

ISO 9614-1:1993, *Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 1: Measurement at discrete points*

ISO 9614-2:1996, *Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 2: Measurement by scanning*

3 Terms and definitions

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

3.1
sound pressure

p

fluctuating pressure superimposed on the static (barometric) pressure by the presence of sound

Note 1 to entry: It is expressed in pascal, Pa.

3.2
sound pressure level

L_p

ten times the logarithm to the base 10 of the ratio of the square of the r.m.s. sound pressure to the square of the reference sound pressure (p_0 = 20 × 10^{-6} Pa)

Note 1 to entry: It is expressed in decibels, dB.

$$L_p = 10 \times \lg \frac{p^2}{p_0^2} \tag{1}$$

3.3
sound intensity

I

vector quantity describing the magnitude and direction of the sound power flow per unit area at a given position

Note 1 to entry: The unit is watts per square metre, W/m^2.

3.4
normal sound intensity

I_n

component of the sound intensity in the direction normal to a measurement surface

Note 1 to entry: By convention, normal sound intensity is counted positive if the energy flow is directed away from the test object and negative if the energy flow is directed towards the test object.

3.5
normal sound intensity level

L_I

ten times the logarithm to the base 10 of the ratio of the r.m.s. normal sound intensity to the reference sound intensity (I_0 = 1 × 10^{-12} Wm^{-2})

Note 1 to entry: It is expressed in decibels, dB.

$$L_I = 10 \times \lg \frac{|I_n|}{I_0} \tag{2}$$

Note 2 to entry: Since I_n can be either positive or negative, a separate direction flag F_{Dir} for L_I to indicate the direction of flow of energy is to be maintained for further analysis such as calculating average and integral quantities.

3.6
direction flag
F_{Dir}
indication for the direction of sound energy flow, required for sound intensity because of its vector nature

Note 1 to entry: +1 for sound energy flow away from the test object, –1 for sound energy flow towards the test object.

3.7
sound power
W
rate at which airborne sound energy is radiated by a source

Note 1 to entry: It is expressed in watts, W.

3.8
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of a given r.m.s. sound power to the reference sound power ($W_0 = 1 \times 10^{-12}$ W)

Note 1 to entry: It is expressed in decibels, dB.

$$L_W = 10 \times \lg \frac{W}{W_0} \tag{3}$$

3.9
total sound level
sound level comprising the whole frequency range under consideration

Note 1 to entry: This level is returned either directly by the measurement device or derived by logarithmic summation of the sound levels of all individual frequency bands.

3.10
principal radiating surface
hypothetical surface surrounding the test object, assumed to be the surface from which sound is radiated

3.11
measurement surface
S
surface enveloping the test object at the measurement distance from the principal radiating surface on which the measurement path(s) or points are located

3.12
surface measure
L_S
ten times the logarithm to the base 10 of the ratio of the measurement surface S to the reference surface S_0 (1 m^2)

Note 1 to entry: It is expressed in decibels, dB.

$$L_S = 10 \times \lg \frac{S}{S_0} \tag{4}$$

3.13
measurement distance
x
horizontal distance between the principal radiating surface and the measurement surface

3.14
prescribed contour
horizontal path(s) on the measuring surface on which measurements shall be made

3.15
walk-around procedure
sound level measurement obtained by continuously moving the microphone(s) along the prescribed contour(s) at constant walking speed as the device is measuring a time averaged and spatially averaged sound level

Note 1 to entry: Test equipment may record a digital audio file during the measuring procedure for post-processing to determine the necessary quantities.

3.16
point-by-point procedure
sound level measurements obtained from a number of discrete microphone positions on the prescribed contour(s), equally spaced and not more than 1 m apart

Note 1 to entry: The spatial average sound level is the average of all the point measurements.

3.17
background noise level
A-weighted sound pressure level measured along the prescribed contour with the test object inoperative

3.18
environmental correction
K
correction that accounts for the influence of undesired sound reflections from room boundaries and/or reflecting objects in the test room when sound pressure measurements are used

3.19
P-I index
ΔL
difference between uncorrected spatially averaged sound pressure level and spatially averaged sound intensity level

Note 1 to entry: A-weighted values shall be used.

3.20
distribution type transformers
transformers for installation other than in substations with rated power typically lower than 5 000 kVA

Note 1 to entry: This definition is made for the purpose of this standard.

Note 2 to entry: This definition applies to both liquid-immersed and dry-type transformers.

4 Sound power for different loading conditions

4.1 General

There are three components of sound potentially contributing to the overall transformer sound power level in service:

- sound power at no-load excitation;
- sound power of the cooling device;
- sound power due to load current.

The representation of the sound power level of a transformer at a certain service condition is given by the logarithmic sum of the three sound power components at this service condition. For details see Clause 13.

4.2 Sound power at no-load excitation

Sound power due to no-load excitation has to be regarded for all types of transformer. The excitation voltage shall be of sinusoidal or practically of sinusoidal waveform and rated frequency. The voltage shall be in accordance with 11.5 of IEC 60076-1:2011. In the case of reactors a no-load condition does not exist since rated current will flow as soon as rated voltage is applied. For more information on reactor sound testing see IEC 60076-6.

The usual condition for sound power level determination of transformers at no-load excitation refers to rated voltage at an untapped winding. Other excitation conditions may occur in service leading to lower or higher sound power levels and might also be the condition for a guarantee and if so shall be specified by the purchaser. For transformers designed to operate with variable flux, the sound power at no-load excitation is strongly impacted by the tapping position. The tapping position for the sound measurement has therefore to be agreed between manufacturer and purchaser during tender stage.

If a transformer is fitted with reactor-type on-load tap-changer equipment where the reactor may on certain tap-changer positions be permanently energized, the measurements shall be made with the transformer on a tapping which involves this condition and which is also as near to the principal tapping as possible.

The selected test conditions shall be clearly indicated in the test report.

NOTE DC bias magnetization of the core can cause a significant increase in the measured sound levels. Its presence is indicated by the existence of odd harmonics of the excitation frequency in the sound spectrum and this can be identified by a narrow band analysis. The DC bias impact on no-load sound level measurements during factory testing can be practically eliminated by an over excitation run for some minutes. When over excitation is not a practical option, as in on-site measurements, DC bias elimination after a transformer inrush event can take several hours or even days.

4.3 Sound power of the cooling device(s)

The usual condition for sound power level determination is to have all cooling devices necessary to operate the transformer at its rated power running.

In case of a water cooling device, the water flow need not be maintained during sound level testing.

In case of variable speed cooling devices (usually fans) the speed during sound level testing has a significant effect on the sound power level. The speed of the cooling device selected for the sound level measurement shall be the speed necessary to operate the transformer at its rated power under the most onerous external cooling medium conditions.

The selected test conditions shall be clearly indicated in the test report.

4.4 Sound power due to load current

The main component of the sound power level due to load current, for most transformers, is of double the power frequency.

The magnitude of the load current sound power level can be roughly estimated by Equations (5) and (6):

$$L_{\mathrm{WA,\,Ir}} \approx 39 + 18 \times \lg \frac{S_{\mathrm{r}}}{S_{\mathrm{p}}} \quad \text{for 50 Hz power frequency} \tag{5}$$

$$L_{\mathrm{WA,\,Ir}} \approx 44 + 18 \times \lg \frac{S_{\mathrm{r}}}{S_{\mathrm{p}}} \quad \text{for 60 Hz power frequency} \tag{6}$$

where

$L_{\mathrm{WA,Ir}}$ is the estimated A-weighted sound power level of the transformer at rated current and rated frequency at short-circuit condition;

S_{r} is the rated power in MVA;

S_{p} is the reference power (1 MVA).

For auto-transformers and three winding transformers, the equivalent two-winding rated power is used instead of S_{r}, in accordance with 3.2 of IEC 60076-8:1997.

NOTE 1 The predictions with Equations (5) and (6) are usually within ±6 dB of the measured sound power level due to rated load current.

A guideline to estimate the significance of the sound power due to load current is given by Equations (5) and (6). When the calculated values are 10 dB or more below the sound power level estimated at no-load excitation, its contribution will be negligible and therefore need not be tested, unless the purchaser has specified the test.

NOTE 2 Distribution type transformers usually do not require consideration of sound power due to load current.

When this measurement is required, one winding shall be short-circuited and the rated current at rated frequency shall be injected into the other winding.

Unless otherwise specified, the tests shall be carried out with the tap-changer (if any) on the principal tapping. However, this tap position may not give the maximum sound level in service due to variations of the magnetic stray field distributions in the windings, the core and the tank shielding elements.

The selected test conditions shall be clearly indicated in the test report.

The sound power level at a current different from the rated current can be calculated by Equation (7):

$$L_{\mathrm{WA,\,IT}} = L_{\mathrm{WA,\,Ir}} + 40 \times \lg \frac{I_{\mathrm{T}}}{I_{\mathrm{r}}} \tag{7}$$

where

$L_{\mathrm{WA,Ir}}$ is the calculated or measured A-weighted sound power level at rated current;

$L_{\mathrm{WA,IT}}$ is the calculated A-weighted sound power level at actual current;

I_{r} is the rated current;

I_{T} is the actual current.

The equation is valid for currents in the range of 60 % to 130 % of rated current. It shall also be applied to calculate the sound power level due to rated load current if, in case of test bay limitations, testing is agreed to be done at a current lower than rated current.