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2005-03

Wind turbines –

Part 14: Declaration of apparent sound power level and tonality values

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WIND TURBINES –

Part 14: Declaration of apparent sound power level and tonality values

FOREWORD

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

IEC 61400-14, which is a technical specification, has been prepared by IEC technical committee 88: Wind turbines.

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

Enquiry draft	Report on voting
88/193/DTS	88/222/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.

IEC 61400 consists of the following parts, under the general title *Wind turbines:*

Part 1: Design requirements

Part 2: Safety of small wind turbines

Part 11: Acoustic noise measurement techniques

Part 12: Wind turbine power performance testing

Part 13: Measurement of mechanical loads

Part 14: Declaration of apparent sound power level and tonality values

Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines

Part 23: Full-scale structural testing of rotor blades

Part 24: Lightning protection

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

- 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- withdrawn,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.

INTRODUCTION

Information on the apparent sound power level and tonality of wind turbines is needed by planners, manufacturers and authorities. At present, wind turbine noise specifications tend to be based on measurement results from a single turbine of a particular make and model, and these are then taken to be representative of these turbines as a whole. Clearly, this is unlikely to be the case, as there will be individual variation between different turbines. The intention of this technical specification is to determine declared noise emission values from a sample of turbines of the same type. The declaration will increase the reliability of wind farm planning and facilitate the comparison of apparent sound power levels and tonality values of different types of wind turbines.

WIND TURBINES –

Part 14: Declaration of apparent sound power level and tonality values

1 Scope

This part of IEC 61400 gives guidelines for declaring the apparent sound power level and tonality of a batch of wind turbines. The measurement procedures for apparent sound power level and tonality are defined in IEC 61400-11.

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 61400-11:2002, *Wind turbines – Part 11: Acoustic noise measurement techniques*

ISO 4871:1996, *Acoustics – Declaration and verification of noise emission values of machinery and equipment*

ISO 7574 (all parts), *Acoustics – Statistical methods for determining and verifying stated noise emission values of machinery and equipment*

3 Terms and definitions

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

3.1
standard deviation of reproducibility σ_R
standard deviation of noise emission values obtained under reproducibility conditions, i.e. the repeated application of the same noise emission measurement method on the same wind turbine at different times and under different conditions (different wind directions, different personnel, different apparatus)

3.2
standard deviation of production σ_P
standard deviation of measured noise emission values obtained at different turbines from a batch, using the same noise emission measurement method under repeatability conditions (same operators, same apparatus)

3.3
total standard deviation σ_t
σ_t is defined as

$$\sigma_t = \sqrt{\sigma_P^2 + \sigma_R^2} \qquad (1)$$

3.4
batch
wind turbines of the same make and model with identical specifications constitute a batch. A batch is characterized by the same declared apparent sound power level and tonality. The range of components included in a declaration is specified in the related manufacturer's statement.

NOTE Since slight changes in the turbine design affect the apparent sound power level and the tonality, Annex B contains information on the influence of turbine parameters on measured acoustic characteristics.

4 General

In ISO 4871 and ISO 7574 general procedures for declaration and verification of acoustic noise emitted by machinery and equipment are described. For batches, the declaration and verification procedure is based on the assumption that the standard deviation of production of the type is known from measurements.

The declaration procedure specified here differs from the ISO procedure and allows a declaration based on a minimum of three measurements.

The declaration procedures may be used to declare values at any wind speed for which measurement results are available.

5 Declaration

5.1 Declaration of apparent sound power level for a wind turbine

The apparent sound power level according to IEC 61400-11 shall be declared.

The declared apparent sound power level for a wind turbine can be determined from n measurement results $\{L_i\}$ i = 1,....n obtained by performing one measurement at each of n individual turbines of the same type. For wind turbines of the same type and tower but of different hub heights, the sound power level may be converted to another hub height according to Annex A.

The n measurements result in a mean value $\overline{L}_{\mathrm{W}}$ and a standard deviation s defined as follows:

$$\overline{L}_{\mathrm{W}} = \frac{1}{n}\sum_{i=1}^{n} L_i \tag{2}$$

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(L_i - \overline{L}_{\mathrm{W}}\right)^2} \tag{3}$$

The standard deviation of production σ_{P} can be estimated from

$$\sqrt{s^2 - \sigma_{\mathrm{R}}^{\ 2}} \le \sigma_{\mathrm{P}} \le s \tag{4}$$

An estimate of the standard deviation of reproducibility σ_{R} is 0,9 dB (see typical uncertainties given in Annex D of IEC 61400-11). As long as only limited data on the real standard deviation of reproducibility is available, and, as for some cases, very small values of σ_{R} were found, the relation σ_{P} = s shall be used.

The standard deviation σ used for the declaration (including the standard deviation σ_{R} and σ_{P} from the n existing measurements and the standard deviation σ_{R} and σ_{P} of a verification measurement) is then determined by

$$\sigma = \sqrt{\frac{1}{n}(\sigma_{\mathrm{R}}^2 + \sigma_{\mathrm{P}}^2) + (\sigma_{\mathrm{R}}^2 + \sigma_{\mathrm{P}}^2)} = \sqrt{\frac{1+n}{n}(\sigma_{\mathrm{R}}^2 + \sigma_{\mathrm{P}}^2)} \tag{5}$$

with σ_{R} = 0,9 dB and σ_{P} = s.

The declared apparent sound power level is calculated from

$$L_{\mathrm{Wd}} = \overline{L}_{\mathrm{W}} + K = \overline{L}_{\mathrm{W}} + 1{,}645\,\sigma \qquad (6)$$

The apparent sound power level shall be declared by dual-number noise emission values reporting both $\overline{L}_{\mathrm{W}}$ and K. K represents a certain confidence level and K =1,645 σ reflects a probability of 5 % that an apparent sound power level measurement result made according to IEC 61400-11 performed at a turbine of the batch exceeds the declared value.

5.2 Declaration of tonality

Declaration of tonality reports the tonality and frequency(ies) of each turbine from the batch. Declaration of tonality shall not be performed in the same way as for the apparent sound power level. At present, very limited data for statistical treatment is available.

6 Information to be reported

All the individual measurement reports shall be annexed to the declaration report.

Further information to be reported is as follows.

a) Wind turbine details

- turbine manufacturer;
- model number/name;
- rated power;
- hub height;
- rotor diameter;
- manufacturer certificates detailing component differences, provided by manufacturer.

b) Declaration results

Apparent sound power level results

- the individually measured apparent sound power levels $\{L_{\mathrm{i}}\}$ i = 1,....n;
- the mean of the measured apparent sound power levels $\overline{L}_{\mathrm{W}}$;
- the sample standard deviation of the apparent sound power levels, s;
- σ_{P}, σ_{R}, σ;
- K;
- declared value, L_{Wd}.

c) Tonality results

For all measurements the tonality and the tonal frequency(ies).

Annex A
(informative)

Method of calculating apparent sound power level to another hub height

For wind turbines of the same type and tower but of different hub heights, the sound power level may be converted to another hub height under the assumption of a logarithmic wind profile.

If the sound pressure level is measured and the sound power level $L_{\mathrm{WA,P,\ meas}}$ is calculated for a wind turbine, the sound power level $L_{\mathrm{WA,P,\ new}}$ for the same wind turbine at another hub height may be determined using the regression values of the measured turbines.

The wind speed value ($v_{10,i}$) at 10 m above ground causes the same power output at the measured wind turbine as on the same wind turbine at a new hub height for chosen wind speed ($v_{10,\mathrm{ref}}$) at 10 m above ground.

$$v_{10,i} = v_{10,\mathrm{ref}} \left[\frac{\ln \frac{h_{\mathrm{new}}}{z_0}}{\ln \frac{h_{\mathrm{meas}}}{z_0}} \right] \tag{A.1}$$

where

$v_{10,i}$	is the determined wind speed at 10 m above ground;
$v_{10,\mathrm{ref}}$	is the reference wind speed at 10 m above ground;
h_{new}	is the new hub height of wind turbine;
h_{meas}	is the hub height of measured wind turbine;
z_0	is the roughness length.

The sound pressure is then determined using the regression coefficients of the measured wind turbine for total and background noise using the calculated wind speed ($v_{10,i}$) from equation A.1. The background corrected sound pressure value is determined using equation A.2.

$$L_{\mathrm{Aeq,c,meas(v\,10,}i)} = 10\ \lg(10^{L_{\mathrm{Aeq,meas(v\,10,}i)} \times 0{,}1} - 10^{L_{\mathrm{back,meas(v10,}i)} \times 0{,}1}) \tag{A.2}$$

where

$L_{\mathrm{Aeq,c,meas\ (v10,}i)}$	is the background corrected sound pressure level of wind turbine related to wind speed at 10 m above ground (measured wind turbine);
$L_{\mathrm{Aeq,meas\ (v10,}i)}$	is the sound pressure level of total noise related to wind speed at 10 m above ground;
$L_{\mathrm{back,meas\ (v10,}i)}$	is the sound pressure level of background noise related to wind speed at 10 m above ground.

Using this sound pressure value ($L_{\mathrm{Aeq,c,meas(v10,}i)}$) the sound power level ($L_{\mathrm{WA,P,meas(v10,}i)}$) will be determined considering the geometric data of the measured wind turbine.

$$L_{\mathrm{WA,P,meas(v10,}i)} = L_{\mathrm{Aeq,meas(v10,}i)} - 6 + 10\ \lg\left[\frac{4\pi R_1^2}{s_0}\right] \tag{A.3}$$

where

$L_{\mathrm{WA,P,meas\ (v10,}i)}$ is the sound power level related to the wind speed at 10 m above ground (measured wind turbine);

$L_{\mathrm{Aeq,meas\ (v10,}i)}$ is the sound pressure level of total noise related to wind speed at 10 m above ground;

R_1 is the distance between rotor centre and microphone;

S_0 is the reference area S_0 = 1 m^2.

The calculated sound power level ($L_{\mathrm{WA,P,meas(v10,}i)}$) from equation A.3 corresponds to the sound power level ($L_{\mathrm{WA,P,new(v10,ref)}}$) for chosen hub-height ($h_{\mathrm{N,new}}$) and wind speed ($v_{10,\mathrm{ref}}$).

$$L_{\mathrm{WA,P,new(v10,ref)}} = L_{\mathrm{WA,P,meas(v10,}i)} \tag{A.4}$$

where

$L_{\mathrm{WA,P,new\ (v10,ref)}}$ is the converted sound power level at $v_{10,\mathrm{ref}}$ and new hub height;

$L_{\mathrm{WA,P,meas\ (v10,}i)}$ is the sound power level related to the wind speed at 10 m above ground (measured wind turbine).

Annex B
(informative)

Influence of turbine and site characteristics on the acoustical performance

a) Hub height

The apparent sound power level is correlated to the acoustic reference wind speed and not to the wind speed at hub height. An increase in hub height will increase the apparent sound power level and might have an unpredictable effect on tonality.

b) Tip speed

The apparent sound power level is very sensitive to the tip speed ($L_{\mathrm{w}} \sim$ (50 to 60) $\log V_{\mathrm{tip}}$). An increase in tip speed will cause an increase in apparent sound power level.

c) Pitch setting

Pitch settings affect the fundamental aero-acoustic processes on the blades, which may significantly change the overall apparent sound power level and the tonality.

d) Gear box

A major potential source of mechanically generated tones is the gear box. Small changes in the design (like gear ratio, tooth shape, casing thickness) can have a significant effect on the frequency and level of the tones.

e) Blades

Changes to the blade geometry, such as trailing edge thickness, tip shape, blade surface finish, internal structure, twist distribution, may all cause significant changes to the acoustical performance.

f) The turbulence intensity of the test site may influence the sound generation.

In addition to the above-mentioned items, there are a number of other items (generator, tower type, yaw motors, cooling fans, hydraulic pumps, etc.) which may influence the acoustical performance.

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