IEC 61400-11

Edition 3.0 2012-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Wind turbines –
Part 11: Acoustic noise measurement techniques

Éoliennes –
Partie 11: Techniques de mesure du bruit acoustique

IEC 61400-11:2012-11(en-fr)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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FOREWORD

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International Standard IEC 61400-11 has been prepared by IEC technical committee 88: Wind turbines.

This third edition of IEC 61400-11 cancels and replaces the second edition published in 2002 and its Amendment 1 (2006). It constitutes a technical revision, introducing new principles for data reduction procedures.

This bilingual version (2019-01) corresponds to the monolingual English version, published in 2012-11.

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

FDIS	Report on voting
88/436/FDIS	88/440/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.

The French version of this standard has not been voted upon.

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

A list of all parts of the IEC 61400 series, under the general title *Wind turbines,* 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- withdrawn,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

The purpose of this part of IEC 61400 is to provide a uniform methodology that will ensure consistency and accuracy in the measurement and analysis of acoustical emissions by wind turbine generator systems. This International Standard has been prepared with the anticipation that it would be applied by:

- wind turbine manufacturers striving to meet well defined acoustic emission performance requirements and/or a possible declaration system (e.g. IEC/TS 61400-14);
- wind turbine purchasers for specifying performance requirements;
- wind turbine operators who may be required to verify that stated, or required, acoustic performance specifications are met for new or refurbished units;
- wind turbine planners or regulators who must be able to accurately and fairly define acoustical emission characteristics of a wind turbine in response to environmental regulations or permit requirements for new or modified installations.

This standard provides guidance in the measurement, analysis and reporting of complex acoustic emissions from wind turbine generator systems. The standard will benefit those parties involved in the manufacture, installation, planning and permitting, operation, utilization, and regulation of wind turbines. The measurement and analysis techniques recommended in this document should be applied by all parties to ensure that continuing development and operation of wind turbines is carried out in an atmosphere of consistent and accurate communication relative to environmental concerns. This standard presents measurement and reporting procedures expected to provide accurate results that can be replicated by others.

WIND TURBINES –

Part 11: Acoustic noise measurement techniques

1 Scope

This part of IEC 61400 presents measurement procedures that enable noise emissions of a wind turbine to be characterised. This involves using measurement methods appropriate to noise emission assessment at locations close to the machine, in order to avoid errors due to sound propagation, but far away enough to allow for the finite source size. The procedures described are different in some respects from those that would be adopted for noise assessment in community noise studies. They are intended to facilitate characterisation of wind turbine noise with respect to a range of wind speeds and directions. Standardisation of measurement procedures will also facilitate comparisons between different wind turbines.

The procedures present methodologies that will enable the noise emissions of a single wind turbine to be characterised in a consistent and accurate manner. These procedures include the following:

- location of acoustic measurement positions;
- requirements for the acquisition of acoustic, meteorological, and associated wind turbine operational data;
- analysis of the data obtained and the content for the data report; and
- definition of specific acoustic emission parameters, and associated descriptors which are used for making environmental assessments.

This International Standard is not restricted to wind turbines of a particular size or type. The procedures described in this standard allow for the thorough description of the noise emission from a wind turbine. A method for small wind turbines is described in Annex F.

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 60688, *Electrical measuring transducers for converting a.c. electrical quantities to analogue or digital signals*

IEC 60942:2003, *Electroacoustics – Sound calibrators*

IEC 61260:1995, *Electroacoustics – Octave-band and fractional-octave-band filters*

IEC 61400-12-1:2005, *Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines*

IEC 61400-12-2, *Wind turbines – Part 12-2: Power performance verification of electricity producing wind turbines*[1]

1 To be published.

IEC 61672 (all parts), *Electroacoustics – Sound level meters*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

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

3.1
apparent sound power level
L_{WA}
A-weighted sound power level re. 1 pW of a point source at the rotor centre with the same emission in the downwind direction as the wind turbine being measured, L_{WA} is determined at bin centre wind speeds at hub height

Note 1 to entry: Apparent sound power level is expressed in dB re. 1 pW.

3.2
apparent sound power level with reference to wind speed at 10 m height
$L_{WA,10m}$
A-weighted sound power level re. 1 pW of a point source at the rotor centre with the same emission in the downwind direction as the wind turbine being measured, $L_{WA,10m}$ are determined at bin centre wind speeds at 10 m height within the measured wind speed range

Note 1 to entry: Apparent sound power level with reference to wind speed at 10 m height is expressed in dB re. 1 pW.

3.3
audibility criterion
L_a
frequency dependent criterion curve determined from listening tests, and reflecting the subjective response of a “typical” listener to tones of different frequencies

Note 1 to entry: Audibility criterion is expressed in dB re. 20 μPa.

3.4 sound pressure levels

3.4.1 A-weighted sound pressure levels

L_A
sound pressure levels measured with the A frequency weighting networks specified in IEC 61672

Note 1 to entry: A-weighted sound pressure levels are expressed in dB re. 20 μPa.

3.4.2 C-weighted sound pressure levels

L_C
sound pressure levels measured with the C frequency weighting networks specified in IEC 61672

Note 1 to entry: C-weighted sound pressure levels are expressed in dB re. 20 μPa.

3.5
bin centre
centre value of a wind speed bin

3.6
inclination angle
ϕ
angle between the plane of the measurement board and a line from the microphone to the rotor centre

Note 1 to entry: Inclination angle is expressed in °.

3.7
maximum power
maximum value of the binned power curve for the power optimised mode of operation

Note 1 to entry: Maximum power is expressed in kW.

3.8
measured wind speed at height *Z*
$V_{Z,\mathrm{m}}$
wind speed measured at height Z with a mast mounted anemometer

Note 1 to entry: Measured wind speed at height Z is expressed in m/s.

3.9
measured nacelle wind speed at hub height
$V_{\mathrm{nac,m}}$
wind speed measured at hub height with a nacelle anemometer

Note 1 to entry: Measured nacelle wind speed at hub height is expressed in m/s.

3.10
normalised nacelle wind speed at hub height
$V_{\mathrm{nac,n}}$
normalised wind speed measured at hub height with a nacelle anemometer corrected to standard meteorological conditions

Note 1 to entry: Normalised nacelle wind speed at hub height is expressed in m/s.

3.11
normalised wind speed derived from power curve
$V_{\mathrm{P,n}}$
normalised wind speed derived from power curve under standard meteorological conditions

Note 1 to entry: Normalised wind speed derived from power curve is expressed in m/s.

3.12
normalised wind speed at hub height during background noise measurements
$V_{\mathrm{B,n}}$
normalised wind speed at hub height from anemometer

Note 1 to entry: Normalised wind speed at hub height during background noise measurements is expressed in m/s.

3.13
normalised wind speed at hub height
$V_{\mathrm{H,n}}$
normalised wind speed at hub height

Note 1 to entry: Normalised wind speed at hub height is expressed in m/s.

3.14
normalised wind speed at height *Z*
$V_{Z,\mathrm{n}}$
normalised wind speed at height Z from mast mounted anemometer

Note 1 to entry: Normalised wind speed at height Z is expressed in m/s.

3.15
reference distance
R_0
nominal horizontal distance from the centre of the base of the wind turbine to each of the prescribed microphone positions

Note 1 to entry: Reference distance is expressed in m.

3.16
reference roughness length
z_{0ref}
roughness length of 0,05 m used for converting wind speed to meteorological reference conditions

Note 1 to entry: Reference roughness length is expressed in m.

3.17
sound pressure level
L_p
10 times the $\log_{10}$ of the ratio of the square mean sound pressure to the square of the reference sound pressure of 20 μPa

Note 1 to entry: Sound pressure level is expressed in dB re. 20 μPa.

3.18
tonal audibility
$\Delta L_{a,k}$
difference between the tonality and the audibility criterion in each wind speed bin, where k is the centre value of the wind speed bin

Note 1 to entry: Tonal audibility is expressed in dB.

3.19
tonality
ΔL_k
difference between the tone level and the level of the masking noise in the critical band around the tone in each wind speed bin where k is the centre value of the wind speed bin

Note 1 to entry: Tonality is expressed in dB.

3.20
wind speed bin
wind speed interval, 0,5 m/s wide, centred around integer and half-integer wind speeds open at the low end, and closed at the high end

3.21
wind speed at 10 m height
V_{10}
wind speed at 10 m height for reporting apparent sound power levels and spectra with reference to 10 m height

Note 1 to entry: Wind speed at 10 m height is expressed in m/s.

4 Symbols and units

D	rotor diameter (horizontal axis turbine) or equatorial diameter (vertical axis turbine)	(m)
H	height of rotor centre (horizontal axis turbine) or height of rotor equatorial plane (vertical axis turbine) above local ground near the wind turbine	(m)
L_{A} or L_{C}	A or C-weighted sound pressure level	(dB)
L_{Aeq}	equivalent continuous A-weighted sound pressure level	(dB)
$L_{\mathrm{pn},j,k}$	sound pressure level of masking noise within a critical band in the "j^{th}" spectra at the "k^{th}" wind speed bin	(dB)
$L_{\mathrm{pn,avg},j,k}$	average of analysis bandwidth sound pressure levels of masking noise in the "j^{th}" spectra at the "k^{th}" wind speed bin	(dB)
$L_{\mathrm{pt},j,k}$	sound pressure level of the tone or tones in the "j^{th}" spectra at the "k^{th}" wind speed bin	(dB)
$L_{\mathrm{WA},k}$	apparent sound power level, where k is a wind speed bin centre value	(dB)
log	logarithm to base 10	
P_{m}	measured electric power	(kW)
P_{n}	normalised electric power	(kW)
R_1	slant distance, from rotor centre to actual measurement position	(m)
R_0	reference distance	(m)
S_0	reference area, S_0 = 1 m^2	(m^2)
T_{C}	air temperature	(°C)
T_{K}	absolute air temperature	(K)
U_A	type A uncertainty	(-)
U_B	type B uncertainty	(-)
V_H	wind speed at hub height, H	(m/s)
V_{P}	derived wind speed from power curve	(m/s)
V_z	wind speed at height, z	(m/s)
V_{nac}	wind speed from nacelle anemometer	(m/s)
f	frequency of the tone	(Hz)
f_{c}	centre frequency of critical band	(Hz)
p	atmospheric pressure	(kPa)
z_0	roughness length	(m)
$z_{0\mathrm{ref}}$	reference roughness length, 0,05 m	(m)

z	anemometer height	(m)
κ	ratio of normalised wind speed and measured wind speed	(-)
$\Delta L_{\mathrm{tn},j,k}$	tonality of the "j^{th}" spectra at "k^{th}" wind speed	(dB)
ϕ	inclination angle	(°)

5 Outline of method

This part of IEC 61400 defines the procedures to be used in the measurement, analysis and reporting of acoustic emissions of a wind turbine. Instrumentation and calibration requirements are specified to ensure accuracy and consistency of acoustic and non-acoustic measurements. Non-acoustic measurements required defining the atmospheric conditions relevant to determining the acoustic emissions are also specified. All parameters to be measured and reported are identified, as are the data reduction methods required for obtaining these parameters.

Application of the method described in this International Standard provides the apparent A-weighted sound power levels, spectra, and tonal audibility at bin centre wind speeds at hub height and 10 m height of an individual wind turbine. The tonal audibility is included to give information on the presence of tones in the noise. The tonality determined is not giving information on the tonality at other distances. Optionally, measurements can be made in supplementary positions to give information on the directional characteristics.

The method applies to all wind speeds. The wind speed range for documentation is related to the specific wind turbine. As a minimum it is defined as the hub height wind speed from 0,8 to 1,3 times the wind speed at 85 % of maximum power rounded to bin centres. Indicatively, this is a wind speed range of approximately 6 to 10 m/s at 10 m height, depending on the turbine type. The wind speed range may be expanded for instance to comply with national requirements.

The measurements are made at locations close to the turbine in order to minimise the influence of terrain effects, atmospheric conditions or wind-induced noise. To account for the size of the wind turbine under test, a reference distance R_0 based on the wind turbine dimensions is used.

Measurements are taken with a microphone positioned on a measurement board placed on the ground to reduce the wind noise generated at the microphone and to minimise the influence of different ground types.

Measurements of sound pressure levels, sound pressure spectra, wind speeds, electrical power, rotor rotational speed and, if measured, pitch angle are made simultaneously over short periods of time and over a wide range of hub height wind speeds. The sound pressure levels and spectra at bin centre wind speeds are determined and used for calculating the apparent A-weighted sound power spectra and levels.

Annexes are included that cover:

– other possible characteristics of wind turbine noise emission and their quantification (Annex A informative);
– assessment of turbulence intensity (Annex B informative);
– assessment of measurement uncertainty (Annex C informative);
– apparent roughness length (Annex D informative);
– classification of a secondary wind screen (Annex E informative);
– small wind turbines (Annex F normative);