

# INTERNATIONAL STANDARD

# IEC 61400-11

Second edition  
2002-12

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## Wind turbine generator systems –

### Part 11: Acoustic noise measurement techniques

*Aérogénérateurs –*

*Partie 11:  
Techniques de mesure du bruit acoustique*

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**WIND TURBINE GENERATOR SYSTEMS –**

**Part 11: Acoustic noise measurement techniques**

FOREWORD

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The 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 61400-11 has been prepared by IEC technical committee 88: Wind turbine systems.

This second edition of IEC 61400-11 cancels and replaces the first edition published in 1998 and constitutes a technical revision.

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

FDIS	Report on voting
88/166/FDIS	88/171/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.

The committee has decided that the contents of this publication will remain unchanged until 2004. At this date, the publication will be

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- withdrawn;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

## 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. The standard has been prepared with the anticipation that it would be applied by:

- the wind turbine manufacturer striving to meet well defined acoustic emission performance requirements and/or a possible declaration system;
- the wind turbine purchaser in specifying such performance requirements;
- the wind turbine operator who may be required to verify that stated, or required, acoustic performance specifications are met for new or refurbished units;
- the wind turbine planner or regulator 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 insure 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.

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## WIND TURBINE GENERATOR SYSTEMS –

### 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 enough away 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.

The 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. If, in some cases, less comprehensive measurements are needed, such measurements are made according to the relevant parts of this standard.

#### 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 60386:1972, *Method of measurement of speed fluctuations in sound recording and reproducing equipment*

IEC 60651:1979, *Sound level meters*

IEC 60688:1992, *Electrical measuring transducers for converting a.c. electrical quantities to analogue or digital signals*

IEC 60804:2000, *Integrating-averaging sound level meters*

IEC 60942:1997, *Electroacoustics – Sound calibrators*

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

IEC 61400-12:1998, *Wind turbine generator systems – Part 12: Wind turbine power performance testing*



### 3 Definitions

For the purposes of this standard, the following definitions apply:

#### 3.1

##### apparent sound power level

##### $L_{WA}$ (in dB re. 1 pW)

the 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 each wind speed integer from 6 to 10 m/s

#### 3.2

##### audibility criterion

##### $L_a$ (in dB re. 20 $\mu$ Pa)

a frequency dependent criterion curve determined from listening tests, and reflecting the subjective response of a 'typical' listener to tones of different frequencies

#### 3.3

##### A-weighted or C-weighted sound pressure levels

##### $L_A$ or $L_C$ , respectively (in dB re. 20 $\mu$ Pa)

sound pressure levels measured with the A or C frequency weighting networks specified in IEC 60651

#### 3.4

##### directivity

##### $\Delta_j$ (in dB)

the difference between the A-weighted sound pressure levels measured at measurement positions 2, 3, and 4 and those measured at the reference position 1 from the turbine corrected to the same distance from the wind turbine rotor centre

#### 3.5

##### inclination angle

##### $\phi$ (in $^\circ$ )

the angle between the plane of the microphone board and a line from the microphone to the rotor centre

#### 3.6

##### reference distance

##### $R_0$ (in m)

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

#### 3.7

##### reference height

##### $z_{ref}$ (in m)

a height of 10 m used for converting wind speed to reference conditions

#### 3.8

##### reference roughness length

##### $z_{0ref}$ (in m)

a roughness length of 0,05 m used for converting wind speed to reference conditions

#### 3.9

##### sound pressure level

##### $L_p$ (in dB re. 20 $\mu$ Pa)

10 times the  $\log_{10}$  of the ratio of the mean-square sound pressure to the square of the reference sound pressure of 20  $\mu$ Pa

### 3.10

#### standardized wind speed

$V_s$  (in  $\text{ms}^{-1}$ )

wind speed converted to reference conditions (height 10 m and roughness length 0,05 m) using a logarithmic profile

### 3.11

#### tonal audibility $\Delta L_{a,k}$ (in dB)

The difference between the tonality and the audibility criterion at integer wind speeds  $k = 6, 7, 8, 9, 10$

### 3.12

#### tonality $\Delta L_k$ (in dB)

the difference between the tone level and the level of the masking noise in the critical band around the tone at integer wind speeds  $k = 6, 7, 8, 9, 10$

## 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)
$L_{Aeq,k}$	equivalent continuous A-weighted sound pressure level at each integer wind speed, where $k = 6, 7, 8, 9, 10$	(dB)
$L_{Aeq,c,k}$	equivalent continuous A-weighted sound pressure level corrected for background noise at each integer wind speed and corrected to reference conditions, where $k = 6, 7, 8, 9, 10$	(dB)
$L_{Aeq,i}$	equivalent continuous A-weighted sound pressure level in position 'i' corrected for background noise where $i = 1, 2, 3, \text{ or } 4$	(dB)
$L_n$	equivalent continuous sound pressure level of the background noise	(dB)
$L_{pn,j,k}$	sound pressure level of masking noise within a critical band in the 'j <sup>th</sup> ' spectra at the 'k <sup>th</sup> ' wind speed, where $j = 1$ to 12 and $k = 6, 7, 8, 9, 10$	(dB)
$L_{pn,avg,j,k}$	average of analysis bandwidth sound pressure levels of masking in the 'j <sup>th</sup> ' spectra at the 'k <sup>th</sup> ' wind speed, where $j = 1$ to 12 and $k = 6, 7, 8, 9, 10$	(dB)
$L_{pt,j,k}$	sound pressure level of the tone or tones in the 'j <sup>th</sup> ' spectra at the 'k <sup>th</sup> ' wind speed, where $j = 1$ to 12 and $k = 6, 7, 8, 9, 10$	(dB)
$L_s$	equivalent continuous sound pressure level of only wind turbine noise	(dB)
$L_{s+n}$	equivalent continuous sound pressure level of combined wind turbine and background noise	(dB)
$L_{WA,k}$	apparent sound power level, where $k = 6, 7, 8, 9, 10$	(dB)
$P_m$	measured electric power	(W)
$P_n$	normalised electric power	(W)

$R_i$	slant distance, from rotor centre to actual measurement position 'i', where $i = 1, 2, 3,$ or $4$	(m)
$R_0$	reference distance	(m)
$S_0$	reference area, $S_0 = 1 \text{ m}^2$	(m <sup>2</sup> )
$T_c$	air temperature	(C)
$T_k$	air temperature	(K)
$U_A, U_B$	uncertainty components	(dB)
$V_H$	wind speed at hub height, $H$	(m/s)
$V_D$	derived wind speed from power curve	(m/s)
$V_z$	wind speed at height, $z$	(m/s)
$V_s$	standardized wind speed	(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)
$z_{0\text{ref}}$	reference roughness length, $0,05 \text{ m}$	(m)
$z$	anemometer height	(m)
$z_{\text{ref}}$	reference height for wind speed, $10 \text{ m}$	(m)
$\beta$	angle used to define allowable area for anemometer mast location	(°)
$\kappa$	the ratio of standardised wind speed and measured wind speed	
$\Delta_i$	directivity at ' $j^{\text{th}}$ ' position, where $i = 2, 3,$ or $4$	(dB)
$\Delta_{\text{Ltn},j,k}$	tonality of the ' $j^{\text{th}}$ ' spectra at ' $k^{\text{th}}$ ' wind speed, where $j = 1$ to $12$ and $k = 6, 7, 8, 9, 10$	(dB)
$\phi$	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 tonality at integer wind speeds from 6 to 10 m/s of an individual wind turbine. Optionally, directivity may also be determined.

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 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 and wind speeds are made simultaneously over short periods of time and over a wide range of wind speeds. The measured wind speeds are converted to corresponding wind speeds at a reference height of 10 m and a reference roughness length of 0,05 m. The sound levels at standardized wind speeds of 6, 7, 8, 9, and 10 m/s are determined and used for calculating the apparent A-weighted sound power levels.

The directivity is determined by comparing the A-weighted sound pressure levels at three additional positions around the turbine with those measured at the reference position.

Informative annexes are included that cover

- other possible characteristics of wind turbine noise emission and their quantification (Annex A);
- criteria for recording/playback equipment (Annex B);
- assessment of turbulence intensity (Annex C);
- assessment of measurement uncertainty (Annex D).

## 6 Instrumentation

### 6.1 Acoustic instruments

The following equipment is necessary to perform the acoustic measurements as set forth in this standard.

#### 6.1.1 Equipment for the determination of the equivalent continuous A-weighted sound pressure level

The equipment shall meet the requirements of a type 1 sound level meter according to IEC 60804. The diameter of the microphone shall be no greater than 13 mm.

#### 6.1.2 Equipment for the determination of one-third octave band spectra

In addition to the requirements given for type 1 sound level meters, the equipment shall have a constant frequency response over at least the 45 Hz to 11 200 Hz frequency range. The filters shall meet the requirements of IEC 61260 for Class 1 filters.

The equivalent continuous sound pressure levels in one-third octave bands shall be determined simultaneously with centre frequencies from 50 Hz to 10 kHz. It may be relevant to measure the low-frequency noise emission of a wind turbine. In such cases, a wider frequency range is necessary as discussed in Annex A.

#### 6.1.3 Equipment for the determination of narrow band spectra

The equipment shall fulfil the relevant requirements for IEC 60651 type 1 instrumentation in the 20 Hz to 11 200 Hz frequency range.