INTERNATIONAL STANDARD

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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 –

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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.

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

FDIS	Report on voting
88/96/FDIS	88/97/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.

Annexes A, B, C, D and E are for information only.

A bilingual version of this standard may be issued at a later date.

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 (WTGS). This standard has been prepared with the anticipation that it would be applied by:

– the WTGS manufacturer striving to meet well defined acoustic emission performance requirements and/or a possible declaration system;

– the WTGS purchaser in specifying such performance requirements;

– the WTGS operator who may be required to verify that stated, or required, acoustic performance specifications are met for new or refurbished units;

– the WTGS planner or regulator who must be able to accurately and fairly define acoustical emission characteristics of WTGS 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 (WTGS). The standard will benefit those parties involved in the manufacture, installation planning and permitting, operation, utilization, and regulation of WTGS. The technically accurate measurement and analysis techniques recommended in this document should be applied by all parties to ensure that continuing development and operation of WTGS 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.

The consistency of results using the method for measurement of tonality will be assessed, and future revisions will address any identified shortcomings.

WIND TURBINE GENERATOR SYSTEMS –

Part 11: Acoustic noise measurement techniques

1 General

1.1 Scope and object

This part of IEC 61400 presents sound measurement procedures that enable noise emissions of a wind turbine to be characterized. 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 characterization of wind turbine noise with respect to a range of wind speeds and directions. Standardization of measurement procedures will also facilitate comparisons between different wind turbines.

The procedures present methodologies that will enable the noise emissions of a single WTGS to be characterized 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 WTGS 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 WTGS of a particular size or type. The procedures described in this standard allow for the thorough description of the noise emission from a WTGS. If, in some cases, less comprehensive measurements are needed, such measurements are made according to the relevant parts of this standard.

1.2 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this part of IEC 61400. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 61400 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

IEC 60651:1979, *Sound level meters*

IEC 60688:1997, *Electrical measuring transducers for converting a.c. electrical quantities to analogue or digital signals*

IEC 60804:1985, *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*

1.3 Definitions

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

1.3.1
acoustic reference wind speed V_{aref} (in metres per second)
a wind speed of 8 m/s at reference conditions (10 m height, roughness length equal to 0,05 m) used in the calculation of the apparent sound power level to provide a uniform basis for the comparison of apparent sound power levels from different WTGS

1.3.2
apparent sound power level L_{WA} (in decibels)
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 as determined at the acoustic reference wind speed

1.3.3
A-weighted or C-weighted sound pressure levels (in decibels)
sound pressure levels measured with the A or C frequency weighting networks specified in IEC 60651, designated by L_A or L_C, respectively

1.3.4
directivity Δ_i (in decibels)
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 downstream from the turbine corrected to the same distance from the WTGS rotor centre

1.3.5
grazing angle ϕ (in degrees)
the angle between the plane of the microphone board and a line from the microphone to the rotor centre

1.3.6
reference distance R_0 (in metres)
the nominal horizontal distance from the centre of the base of the WTGS to each of the prescribed microphone positions

1.3.7
reference height z_{ref} (in metres)
a height of 10 m used for converting wind speed to reference conditions

1.3.8
reference roughness length z_{0ref} (in metres)
a roughness length of 0,05 m used for converting wind speed to reference conditions

1.3.9
sound pressure level L_p (in decibels)
10 times the logarithm to the base 10 of the ratio of the mean-square sound pressure to the square of the reference sound pressure of 20 μPa

1.3.10
standardized wind speed V_s (in metres per second)
wind speed converted to reference conditions (height 10 m and roughness length 0,05 m) using a logarithmic profile

1.3.11
tonality ΔL_{tn} (in decibels)
the difference between the tone level and the level of the masking noise in the critical band around the tone

1.4 Symbols and units

β	angle used to define allowable area for anemometer mast location	(°)
ϕ	grazing angle	(°)
D	rotor diameter (horizontal axis turbine) or equatorial diameter (vertical axis turbine)	(m)
Δ_i	directivity at "i th" position	(dB)
ΔL_{tn}	tonality	(dB)
f	frequency of tone	(Hz)
f_c	centre frequency of critical band	(Hz)
z	anemometer height	(m)
z_{ref}	reference height for wind speed, 10 m	(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)
$L_{Aeq,c}$	equivalent continuous A-weighted sound pressure level corrected for background noise at acoustic reference wind speed and corrected to reference conditions	(dB)
$L_{Aeq,i}$	equivalent continuous A-weighted sound pressure level in position "i" corrected for background noise	(dB)
L_n	equivalent continuous sound pressure level of the background noise	(dB)
L_p	sound pressure level	(dB)
L_{pn}	sound pressure level of masking noise within a critical band	(dB)
$L_{pn,avg}$	average of analysis bandwidth sound pressure levels of masking noise	(dB)
L_{pt}	sound pressure level of the tone or tones	(dB)
L_s	equivalent continuous sound pressure level of wind turbine noise alone	(dB)
L_{s+n}	equivalent continuous sound pressure level of combined wind turbine and background noise	(dB)
L_{WA}	apparent sound power level	(dB)
p	atmospheric pressure	(kPa)
P_m	measured electric power	(W)
P_n	normalised electric power	(W)
R_1	slant distance to reference position 1	(m)
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)
t	air temperature	(°C)
U_A, U_B, U_C	uncertainty components	(dB)
V_z	wind speed at height, z	(m/s)
V_{aref}	acoustic reference wind speed, 8 m/s	(m/s)
V_s	standardized wind speed	(m/s)
z_0	roughness length	(m)
z_{0ref}	reference roughness length, 0,05 m	(m)

1.5 Abbreviations

1.5.1 FFT Fast Fourier transform

1.5.2 WTGS Wind turbine generator system(s)

2 Outline of method

This part of IEC 61400 defines the procedures to be used in the measurement, analysis and reporting of acoustic emissions of WTGS. Instrumentation and calibration requirements are specified to ensure accuracy and consistency of acoustic and non-acoustic measurements. Non-acoustic measurements required to define 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 to obtain these parameters.

Application of the method described in this International Standard provides the value of the apparent A-weighted sound power level, its variation with wind speed and the directivity of an individual WTGS. Measurements include octave or third-octave band sound pressure levels, and narrow band spectra.

The measurements are made at locations close to the turbine in order to minimize the influence of terrain effects, atmospheric conditions or wind-induced noise. To account for the size of the WTGS under test, a reference distance R_0 based on the WTGS 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 minimize 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 adjusted to corresponding wind speeds at a reference height of 10 m and a reference roughness length of 0,05 m. The sound level at the acoustic reference wind speed of 8 m/s is determined based on a derived regression line correlating the sound levels and wind speeds. The apparent A-weighted sound power level is calculated from that sound level.

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 acoustic characteristics of WTGS noise that may be present (annex A);
– criteria for data recording and playback equipment (annex B);
– assessment of turbulence intensity (annex C);
– measurement uncertainty (annex D).

3 Instrumentation

3.1 Acoustic instruments

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

3.1.1 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.

3.1.2 Equipment for the determination of octave or 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 frequency range 45 Hz to 5 600 Hz. The filters shall meet the requirements of IEC 61260 for Class 1 filters.

The equivalent continuous sound pressure levels in octave or third-octave band shall be determined simultaneously with centre frequencies from 63 Hz to 4 kHz (third-octaves from 50 Hz to 5 kHz). It may be relevant to measure the low-frequency noise emission of a WTGS. In such cases, a wider frequency range is necessary, as discussed in annex A.

3.1.3 Equipment for the determination of narrow band spectra

The equipment shall fulfill the relevant requirements for IEC 60651 type 1 instrumentation in the frequency range 20 Hz to 5 600 Hz.

3.1.4 Microphone with reflecting surface and windscreen

The microphone shall be mounted on a flat hard board with the diaphragm of the microphone in a plane normal to the board and with the axis of the microphone pointing towards the wind turbine, as in figures 1 and 2. The board shall have a minimum width or diameter of 1,0 m and be made from a material that is acoustically hard, such as a piece of plywood or hard chip-board with a thickness of at least 12,0 mm, or a piece of metal with a thickness of at least 2,5 mm. If a rectangular board is used, the microphone shall be placed 100 mm to 150 mm from any line of symmetry.

The windscreen to be used with the ground-mounted microphone shall consist of a primary and, where necessary, a secondary windscreen. The primary windscreen shall consist of one half of an open cell foam sphere with a diameter of approximately 90 mm, which is centred around the diaphragm of the microphone, as in figure 2.

The secondary windscreen shall be used when it is necessary to obtain an adequate signal-to-noise ratio at low frequencies in high winds.

For example, it could consist of a wire frame of approximate hemispherical shape, at least 450 mm in diameter, which is covered with a 13 mm to 25 mm layer of open cell foam with a porosity of 4 to 8 pores per 10 mm. This secondary hemispherical windscreen shall be placed symmetrically over the smaller primary windscreen.

If the secondary wind screen is used, the frequency response of the secondary wind screen mounted on a hard board must be documented.

3.1.5 Acoustical calibrator

The complete sound measurement system, including any recording, data logging or computing systems, shall be calibrated immediately before and after the measurement session at one or more frequencies, using an acoustical calibrator on the microphone. The calibrator shall fulfill the requirements of IEC 60942 class 1, and shall be used within its specified environmental conditions.

3.1.6 Data recording/playback systems

If a data recording/playback system is an integral part of the measurement instrumentation, the entire chain of measurement instruments shall fulfil the relevant requirements of IEC 60651, for type 1 instrumentation. Examples are given in annex B.

3.2 Non-acoustic instruments

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