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TECHNICAL SPECIFICATION

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Wind energy generation systems – Part 11-2: Acoustic noise measurement techniques – Measurement of wind turbine sound characteristics in receptor position



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Wind energy generation systems – Part 11-2: Acoustic noise measurement techniques – Measurement of wind turbine sound characteristics in receptor position

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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WIND ENERGY GENERATION SYSTEMS –

Part 11-2: Acoustic noise measurement techniques – Measurement of wind turbine sound characteristics in receptor position

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The text of this Technical Specification is based on the following documents:

Draft	Report on voting
88/995/DTS	88/1009/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61400 series, published under the general title *Wind energy generation systems*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
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INTRODUCTION

The primary objective of this document is to establish uniform measurement and data analysis techniques to facilitate the evaluation of the A-weighted sound pressure level, or other acoustical properties, attributable to wind turbines at representative far-field locations. While this is a seemingly simple objective, wind turbines require wind to operate and the presence of wind complicates reliable acoustical measurements, either directly through wind induced microphone noise or indirectly through wind induced vegetative rustling sound. The presence of other common environmental sounds (planes, trains, road traffic, industrial, agricultural activities, etc.) can complicate or adversely influence the measured sound level. Owing to the distance of sound propagation, the meteorological conditions have a significant impact on the measurement results and the influence should be considered.

Given that the regulatory requirements and history vary from country to country (and even within the same country), this document does not dictate regulatory metrics, but provides guidance on how best to isolate the sound attributable to wind turbines alone in the presence of other environmental sounds. It also provides guidance for those whose regulatory history for wind or other sources require the evaluation of specific acoustical aspects that have historically been subject to highly varying methodologies. Some countries have substantial experience with wind turbines while other countries are new to the special requirements of wind turbine sound measurements. Both can find guidance on how to standardise their approaches.

In general, the document can be used by regulators and authorities, measurement laboratories, developers, operators and manufacturers for

- comparison with local regulation;
- comparison with guarantee values;
- where no tradition for regulations of wind turbine sound immissions is available it can be used to aid the decision process;
- assessment of the sound characteristics in wind turbine sound as well as the sound level.

WIND ENERGY GENERATION SYSTEMS –

Part 11-2: Acoustic noise measurement techniques – Measurement of wind turbine sound characteristics in receptor position

1 Scope

This part of IEC 61400-11 presents measurement procedures, that enable the sound characteristics of a wind turbine to be determined at receptor (immission) locations. This involves using measurement methods appropriate to sound immission assessment at far-field locations of a wind turbine or wind farm. The procedures described are different in some respects from those that would be used for noise assessment from other industrial sound sources in environmental noise impact assessments. They are intended to facilitate characterization of wind turbine sound with respect to a range of wind speeds and directions.

The procedures present methodologies that will enable the sound immission and sound characteristics of wind turbines to be described in a consistent and accurate manner. These procedures include the following aspects:

- location of acoustic measurement positions (receptor position);
- 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 parameters, and associated descriptors which are used for making environmental assessments.

This document is not restricted to wind turbines of a particular size or type. The procedures described in this document allow for the thorough description of the sound characteristics and sound immissions from wind turbines.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60942, *Electroacoustics – Sound calibrators*

IEC 61400-11:2012, *Wind turbines – Part 11: Acoustic noise measurement techniques*
IEC 61400-11:2012/AMD1:2018

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

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

ISO 1996-2:2017, *Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of sound pressure levels*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

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 as described

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

[SOURCE: IEC 61400-11:2012, 3.1]

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, $L_{WA,10m}$ is determined at integer wind speeds at 10 m height within the wind speed range achieved during measurements

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

[SOURCE: IEC 61400-11:2012, 3.2, modified – “achieved during measurements has been added to the definition.]

3.3
A-weighted sound pressure level
L_A
sound pressure level measured with the A frequency weighting networks as specified in IEC 61672-1

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

3.4
bin centre
centre value of a wind speed bin or wind direction bin

3.5
time-weighted and frequency-weighted sound pressure level
ten times the logarithm to the base 10 of the ratio of the time-mean-square of the sound pressure to the square of a reference value, being obtained with a standard frequency weighting and standard time weighting

Note 1 to entry: Sound pressure is expressed in pascal (Pa).

Note 2 to entry: The reference value is 20 µPa.

Note 3 to entry: Time-weighted and frequency-weighted sound pressure level is expressed in decibels (dB).

Note 4 to entry: The standard frequency weightings are A-weighting and C-weighting as specified in IEC 61672-1, and the standard time weightings are F-weighting and S-weighting as specified in IEC 61672-1

3.6
background sound
contribution from all sources of acoustic sound other than the source of interest (i.e. wind turbine)

3.7
total sound
totally encompassing sound composed of sound from many sources near and far (including background sound and sound source of interest)

3.8
low frequency sound
sound containing frequency components of interest within the range generally covering the 1/3-octave bands 10 Hz to 200 Hz

Note 1 to entry: This definition is specific for this document. Other definitions can apply in different national regulations.

3.9
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

3.10
tone frequency
f_{T}
frequency of the spectral line (or mid band frequency of the narrow band filter), to the level of which the tone contributes most strongly

3.11
tone level
L_{T}
energy summation of the narrow-band level with the tone frequency, f_{T}, and the lateral lines about f_{T}, assignable to this tone

Note 1 to entry: If the critical band for the frequency, f_{T}, under consideration contains a number of tones, then the tone level, L_{T}, is the energy sum of these tones. This level, L_{T}, is then assigned to the frequency of the participating tone that has the maximal value of audibility, ΔL.

3.12
audibility
ΔL
difference between the tonality and the audibility criterion, a_{v} in each wind speed bin

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

3.13
bandwidth
frequency range of a number of neighbouring spectral lines

Note 1 to entry: If the width of a frequency band is calculated, for which its beginning or end does not correspond to the boundary between two spectral lines, then only the spectral lines that lie in their full width within the calculated frequency range are assigned to the frequency band.

3.14
sampling frequency
f_S
number of samples taken per second

3.15
block length
N
block of sampling values that in discrete form represents a time-limited range of the time signal to be analysed

3.16
line spectrum
narrow-band spectrum
frequency spectrum
plot of sound pressure level as a function of the frequency in the frequency bands of constant bandwidth

3.17
line spacing
frequency resolution
distance between neighbouring spectral lines where the line spacing in the fast Fourier transform (FFT) is given by

$$\Delta f = f_S/N$$

where

f_S is the sampling frequency

N is the block length

3.18
critical band
frequency band with a bandwidth, Δf_c, within which the auditory system integrates the sound intensity in the formation of loudness and within which it integrates the sound intensity in the formation of the masking threshold

3.19
mean narrow-band level of the critical band
L_s
energy mean value of all narrow band levels in a critical band that (as a rule) does not exceed this value by more than 6 dB

3.20
audibility criterion
a_v
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.

3.21
critical band level
L_G
level of the noise that is assigned to the critical band that describes the masking characteristic of the noise for one or more tones of the noise in the critical band

3.22
amplitude modulation
regular fluctuation in the level of sound, the period of fluctuations being related to the rotational speed of the wind turbine

Note 1 to entry: This characteristic might be described by a listener as a repetitive ‘swish’, ‘whoomph’ or ‘thump’.

3.23
impulsivity
sudden onset of a sound

Note 1 to entry: The character and prominence of the impulse at the immission point depends on the character of the emitted sound, the distance and propagation path from the sound source and the background sound. Therefore the impulsiveness of a sound is characterised by the onset of the sound independently of the category of the sound source.

Note 2 to entry: The definition includes only the onset of a sound, not the sound as a whole. ”Sudden” is based on an auditive judgement, which is expressed in terms of physical measurements in this method.

3.24
test plan
document that identifies the goals and objectives of an investigation or measurement campaign to make it possible to select the appropriate setup

3.25
long term measurements
series of continuous unattended measurements typically for several days, weeks, or months

3.26
short term measurements
series of attended measurements

3.27
receptor position
position where the sound characteristics are to be determined

3.28
remote sensing device
RSD
light detection and ranging (LiDAR) using light or sonic detection and ranging (SoDAR) using acoustical signals to determine the wind speed or wind speed profile

3.29
binning wind speed
wind speed usually at 10 m height used for binning measurement results

Note 1 to entry: The binning wind speed can be measured or calculated.

3.30
mode of operation
operational mode of a wind turbine characterized by the sound and power curve for a certain power and sound power output

3.31
reference roughness length
z_{0ref}
roughness length of 0,05 m used for converting wind speed between heights by using a logarithmic wind speed profile

3.32
sound relevant wind turbines, pl.
group of wind turbines with most relevant contribution to the sound characteristic at receptor position used for the determination of wind speed

3.33
wind shear
change in wind speed with height

3.34
nacelle anemometer
anemometer mounted on the nacelle of the wind turbine

3.35
averaging time /measurement interval
length of time for a measurement interval of typically 10 s, 60 s or 600 s

Note 1 to entry: Averaging can consist of applying shorter intervals, for example 1 s to 10 s logging data building up to the required interval.

3.36
SCADA data
data achieved from the wind farm data system

Note 1 to entry: Typically included in SCADA data are power, RPM, wind speed, yaw position pitch. Sometimes air temperature, barometric pressure, relative humidity etc. ,are included as well.

3.37
blade passage frequency
number of times a blade passes a given point on the rotor disc in 1 s

3.38
far-field location
location which is at a distance from the wind farm corresponding to the receptor location

4 Symbols and units

D	rotor diameter (horizontal axis wind turbine) or equatorial diameter (vertical axis wind turbine)	(m)
H	height of rotor centre (horizontal axis wind turbine) or height of rotor equatorial plane (vertical axis wind turbine) above local ground near the wind turbine	(m)
L_A or L_C	A-weighted or C-weighted sound pressure level	(dB)
L_{Aeq}	equivalent continuous A-weighted sound pressure level	(dB)
$L_{WA,k}$	apparent sound power level, where k is a wind speed bin centre value	(dB)
log	logarithm to base 10	
P_m	measured electric power	(W)
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_{bin}	binning wind speed at 10 m height	(m/s)