

**Wind turbines - Part 11: Acoustic noise measurement techniques (IEC 61400-11:2012)**

This document is a preview generated by EVS

## EESTI STANDARDI EESSÕNA

## NATIONAL FOREWORD

See Eesti standard EVS-EN 61400-11:2013 sisaldab Euroopa standardi EN 61400-11:2013 ingliskeelset teksti.	This Estonian standard EVS-EN 61400-11:2013 consists of the English text of the European standard EN 61400-11:2013.
Standard on jõustunud sellekohase teate avaldamisega EVS Teatajas.	This standard has been endorsed with a notification published in the official bulletin of the Estonian Centre for Standardisation.
Euroopa standardimisorganisatsioonid on teinud Euroopa standardi rahvuslikele liikmetele kättesaadavaks 01.03.2013.	Date of Availability of the European standard is 01.03.2013.
Standard on kättesaadav Eesti Standardikeskusest.	The standard is available from the Estonian Centre for Standardisation.

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile [standardiosakond@evs.ee](mailto:standardiosakond@evs.ee).

ICS 27.180

### Standardite reprodutseerimise ja levitamise õigus kuulub Eesti Standardikeskusele

Andmete paljundamine, taastekitamine, kopeerimine, salvestamine elektroonsesse süsteemi või edastamine ükskõik millises vormis või millisel teel ilma Eesti Standardikeskuse kirjaliku loata on keelatud.

Kui Teil on küsimusi standardite autorikaitse kohta, võtke palun ühendust Eesti Standardikeskusega:  
Aru 10, 10317 Tallinn, Eesti; [www.evs.ee](http://www.evs.ee); telefon 605 5050; e-post [info@evs.ee](mailto:info@evs.ee)

### The right to reproduce and distribute standards belongs to the Estonian Centre for Standardisation

No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, without a written permission from the Estonian Centre for Standardisation.

If you have any questions about copyright, please contact Estonian Centre for Standardisation:  
Aru 10, 10317 Tallinn, Estonia; [www.evs.ee](http://www.evs.ee); phone 605 5050; e-mail [info@evs.ee](mailto:info@evs.ee)

English version

**Wind turbines -  
Part 11: Acoustic noise measurement techniques  
(IEC 61400-11:2012)**

Eoliennes -  
Partie 11: Techniques de mesure  
du bruit acoustique  
(CEI 61400-11:2012)

Windenergieanlagen -  
Teil 11: Schallmessverfahren  
(IEC 61400-11:2012)

This European Standard was approved by CENELEC on 2012-12-12. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

**CENELEC**

European Committee for Electrotechnical Standardization  
Comité Européen de Normalisation Electrotechnique  
Europäisches Komitee für Elektrotechnische Normung

**Management Centre: Avenue Marnix 17, B - 1000 Brussels**

## Foreword

The text of document 88/436/FDIS, future edition 3 of IEC 61400-11, prepared by IEC/TC 88 "Wind Turbines" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61400-11:2013.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2013-09-12
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2015-12-12

This document supersedes EN 61400-11:2003 + A1:2006.

EN 61400-11:2013 includes the following significant technical changes with respect to EN 61400-11:2003 + A1:2006:

The technical change is introducing new principles for data reduction procedures.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

## Endorsement notice

The text of the International Standard IEC 61400-11:2012 was approved by CENELEC as a European Standard without any modification.

## Annex ZA (normative)

### Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60688	-	Electrical measuring transducers for converting A.C. and D.C. electrical quantities to analogue or digital signals	EN 60688	-
IEC 60942	2003	Electroacoustics - Sound calibrators	EN 60942	2003
IEC 61260	1995	Electroacoustics - Octave-band and fractional-octave-band filters	EN 61260	1995
IEC 61400-12-1	2005	Wind turbines - Part 12-1: Power performance measurements of electricity producing wind turbines	EN 61400-12-1	2006
IEC 61400-12-2	- <sup>1)</sup>	Wind turbines - Part 12-2: Power performance of electricity producing wind turbines based on nacelle anemometry	EN 61400-12-2	-
IEC 61672	Series	Electroacoustics - Sound level meters	EN 61672	Series
ISO/IEC Guide 98-3-		Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)	-	-

---

<sup>1)</sup> To be published.

## CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references .....	8
3 Terms and definitions .....	9
4 Symbols and units .....	12
5 Outline of method .....	13
6 Instrumentation .....	14
6.1 Acoustic instruments .....	14
6.1.1 General .....	14
6.1.2 Equipment for the determination of the equivalent continuous A-weighted sound pressure level.....	14
6.1.3 Equipment for the determination of A-weighted 1/3-octave band spectra .....	14
6.1.4 Equipment for the determination of narrow band spectra .....	14
6.1.5 Microphone with measurement board and windscreen .....	14
6.1.6 Acoustical calibrator .....	16
6.1.7 Data recording/playback systems .....	16
6.2 Non-acoustic Instruments .....	16
6.2.1 General .....	16
6.2.2 Anemometers .....	16
6.2.3 Electric power transducer .....	17
6.2.4 Other instrumentation .....	17
6.3 Traceable calibration .....	17
7 Acoustic measurements and measurement procedures .....	17
7.1 Acoustic measurement positions .....	17
7.2 Acoustic measurements .....	20
7.2.1 General .....	20
7.2.2 Acoustic measurement requirements .....	20
7.2.3 A-weighted sound pressure level .....	21
7.2.4 A-weighted 1/3-octave band measurements.....	21
7.2.5 A-weighted narrow band measurements .....	21
7.2.6 Optional acoustic measurements at positions 2, 3 and 4.....	21
7.2.7 Other optional measurements .....	21
8 Non-acoustic measurements .....	21
8.1 General .....	21
8.2 Wind speed measurements .....	22
8.2.1 Determination of the wind speed during wind turbine operation.....	22
8.2.2 Wind speed measurements during background noise measurements.....	23
8.3 Downwind direction .....	24
8.4 Other atmospheric conditions .....	24
8.5 Rotor speed and pitch angle measurement.....	24
9 Data reduction procedures.....	24
9.1 General methodology for sound power levels and 1/3-octave band levels.....	24
9.2 Calculation of sound pressure levels .....	27

9.2.1	General .....	27
9.2.2	Calculation of average sound spectra and uncertainty per bin .....	27
9.2.3	Calculation of average wind speed and uncertainty per bin .....	29
9.2.4	Calculation of noise levels at bin centres including uncertainty .....	30
9.3	Apparent sound power levels.....	31
9.4	Apparent sound power levels with reference to wind speed in 10 m height .....	32
9.5	Tonal audibility .....	33
9.5.1	General methodology for tonality .....	33
9.5.2	Identifying possible tones .....	34
9.5.3	Classification of spectral lines within the critical band.....	34
9.5.4	Identified tone .....	37
9.5.5	Determination of the tone level .....	37
9.5.6	Determination of the masking noise level.....	37
9.5.7	Determination of tonality.....	37
9.5.8	Determination of audibility .....	38
9.5.9	Background noise .....	38
10	Information to be reported .....	39
10.1	General .....	39
10.2	Characterisation of the wind turbine .....	39
10.3	Physical environment .....	39
10.4	Instrumentation .....	40
10.5	Acoustic data .....	40
10.6	Non-acoustic data .....	41
10.7	Uncertainty.....	41
Annex A (informative)	Other possible characteristics of wind turbine noise emission and their quantification .....	42
Annex B (informative)	Assessment of turbulence intensity .....	44
Annex C (informative)	Assessment of measurement uncertainty .....	45
Annex D (informative)	Apparent roughness length .....	47
Annex E (informative)	Characterization of a secondary wind screen.....	49
Annex F (normative)	Small wind turbines .....	53
Annex G (informative)	Air absorption .....	57
Bibliography.....		58
Figure 1	– Mounting of the microphone .....	15
Figure 2	– Picture of microphone and measurement board.....	16
Figure 3	– Standard pattern for microphone measurement positions (plan view) .....	18
Figure 4	– Illustration of the definitions of $R_0$ and slant distance $R_1$ .....	19
Figure 5	– Acceptable meteorological mast position (hatched area) .....	22
Figure 6	– Flowchart showing the data reduction procedure.....	26
Figure 7	– Flowchart for determining tonal audibility for each wind speed bin .....	33
Figure 8	– Illustration of $L_{70} \%$ level in the critical band.....	35
Figure 9	– Illustration of lines below the $L_{70} \% + 6$ dB criterion .....	36
Figure 10	– Illustration of $L_{pn,avg}$ level and lines classified as masking.....	36
Figure 11	– Illustration of classifying all spectral lines.....	37
Figure E.1	– Example 1 of a secondary wind screen .....	50

Figure E.2 – Example 2 of secondary wind screen .....	51
Figure E.3 – Example on insertion loss from Table E.1 .....	52
Figure F.1 – Allowable region for meteorological mast position as a function of $\beta$ – Plan view .....	54
Figure F.2 – Example immission noise map .....	56
Figure G.1 – Example of 1/3-octave spectrum.....	57
Table C.1 – Examples of possible values of type B uncertainty components relevant for apparent sound power spectra .....	46
Table C.2 – Examples of possible values of type B uncertainty components for wind speed determination relevant for apparent sound power spectra .....	46
Table D.1 – Roughness length .....	47
Table E.1 – Example on reporting of insertion loss.....	51

This document is a preview generated by EVS

## 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*<sup>1</sup>

---

<sup>1</sup> 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  $\mu$ Pa.

#### 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  $\mu$ Pa.

##### 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  $\mu$ Pa.

#### 3.5

##### bin centre

centre value of a wind speed bin