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Small Wind Turbines – Comparison of Acoustic Noise Measurements in Accordance with IEC 61400-11 Ed. 3 and BWEA Small Wind Turbine Guideline

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Summary

In order to be approved under the Microgeneration Certification Scheme (MCS), it is required to carry out acoustic noise measurements on small wind turbines amongst other things. An MCS certificate is an eligibility requirement to qualify for the UK Government's FIT[1] scheme for renewable energy generation. Until recently, such measurements were carried out in accordance with a standard published by the BWEA (British Wind Energy Association – now RenewableUK). RenewableUK has revoked this standard, and now in both, RenewableUK and MCS documentation, BS EN 61400-11:2013 (equivalent to the international standard IEC 61400-11:2012 Edition 3.0) is referenced as measurement standard for such acoustic noise testing. The main document of the standard is written for 'large' wind turbines, turbines of a size commonly used today, i.e. from several hundred kW to multiple MW rated power. Due to their different behaviour and possibly reduced wind turbine data availability, Annex F of this standard provides instructions on how to deal with the specifics of small wind turbines, i.e. turbines with a rated power below 100 kW. This presentation looks at the differences between the BWEA standard and BS EN 61400-11:2013, Annex F when measuring and assessing small wind turbines.

1. Introduction

The withdrawn standard P-IEC 61400-11 ed 2.0/2.1[2] *Wind Turbine generator systems - Part 11: Acoustic noise measurement techniques* was the relevant international standard for acoustic noise measurements for 10 years from 2002 to 2012 when it was replaced by the technically revised Edition 3.0 (Ed.3), which also introduced new principles for data reduction, and, relevant for this paper, included a normative annex, Annex F *Small Wind Turbines*. Ed.3 has been implemented into a national standard in the UK as BS EN 61400-11:2013. The superseded Edition 2/2.1

[1] Feed-in tariff scheme designed by the Government to promote the update of a range of small-scale renewable and low-carbon electricity generation technologies. (source: www.ofgem.gov.uk)
[2] Ed. 2.1 is the consolidated version of Ed.2 (2002) and the amendment 1 published in 2006

did not describe any deviation to take into account the specific acoustic behaviour or the lower cost solutions of small wind turbines (turbine data output may not be available etc). Instead, this had been dealt with by national standards, e.g. the British Wind Energy Association's (BWEA) *Small Wind Turbine Performance and Safety Standard* (2008) in the UK or the American Wind Energy Association's standard of the same title issued in 2009.

Since many acoustic measurements for small wind turbines sold on the UK market were carried out as part of the MCS[3] certificate for approved sustainable energy technologies, they were carried out in accordance to the BWEA standard. The certificates issued before January 2014, when the new version of MCS 006 came into effect, are valid until January 2019. Certification after January 2014 may either use the old standard until January 2017 or IEC 61400-11 Ed.3. From January 2017 onwards, it is mandatory to use IEC 61400-11 Ed.3 for acoustic noise measurements (see MCS 006 Revision 2.1 and RenewableUK Small Wind Turbine Standard (2014)). Therefore, for a period of five years, measurement reports in accordance with the BWEA small wind turbine standard and IEC 61400-11 Ed.3 will be available for small wind turbines at the same time. This paper will look into the differences of the two analysis methods and whether results are directly comparable.

2. Acoustic Measurements and Assessment of Small Wind Turbines

2.1 Measurement Set-up for Horizontal Axis Wind Turbines

The following table gives an overview of the differences and similarities of the measurement set-up of the BWEA measurement standard and IEC 61400-11 Ed.3 Annex F. Vertical Axis Wind Turbines are not considered here.

Table 1: Differences and Similarities of the Measurement Set-up in accordance with BWEA standard and IEC 61400-11 Ed.3 Annex F

	BWEA standard (generally follows BS EN 61400-11 (2003)/IEC 61400-11 Ed.2 with the exceptions listed below)	**IEC 61400-11 Ed.3 Annex F** (generally follows IEC 61400-11 (Ed.3) general method with the exceptions listed below)
Turbine Size	rotor swept area up to 200 m^2	rated power up to 100 kW
Wind speed determination	measured, not derived from power curve	measured directly, not derived from power curve
Wind speed reference height	hub height (if measured at height other than hub height, use power law to correct - no correction for temperature and air pressure)	rotor centre (if measured at a height other than rotor centre height, first normalise to standard meteorological conditions and then use power law to adjust to rotor centre height)
Wind speed measurement height	minimum of 5 m agl	minimum of 10 m agl, preferably at rotor centre height but not

[3] Microgeneration Certification Scheme initiated by the Department of Energy and Climate Change (DECC, London/UK

	BWEA standard (generally follows BS EN 61400-11 (2003)/IEC 61400-11 Ed.2 with the exceptions listed below)	**IEC 61400-11 Ed.3 Annex F** (generally follows IEC 61400-11 (Ed.3) general method with the exceptions listed below)
		more than 25 m difference between rotor centre and anemometer height
Met mast position	2 - 4 * D directly upwind of turbine rotor	2 - 4 * D directly upwind of turbine rotor
Allowed wind measurement sector	anemometer within ± 90° from directly upwind, resulting in a 180° arc	anemometer within ± 90° from directly upwind, resulting in a 180° arc
Ground Board	diameter 1 m	diameter at least 1 m, material and dimensions specified (information in general method)
Microphone measurement distance	R_0 = rotor tip height (H + D/2)	R_0 = rotor tip height (H + D/2)
Allowed acoustic measurement sector	± 60° of directly downwind position, resulting in a 120° arc	± 45° of directly downwind position, resulting in a 90° arc
Averaging period	at least T = 4 * D in [s] minimum T = 10 s	T = 10 s
What is measured	broad band sound pressure levels (A-weighted)	sound pressure levels in 1/3 octave bands (A-weighted) and broad band sound pressure level (A-weighted)

with D: rotor diameter in m
H: hub height in m
agl: above ground level

2.2 Assessment

Table 2 below summarises the differences and similarities of the data processing in accordance with both considered measurement standards.

Table 2: Differences and Similarities of the Assessment in accordance with BWEA standard and IEC 61400-11 Ed.3 Annex F

	BWEA standard (generally follows BS EN 61400-11 (2003)/IEC 61400-11 Ed.2 with the exceptions listed below)	**IEC 61400-11 Ed.3 Annex F** (generally follows IEC 61400-11 (Ed.3) general method with the exceptions listed below)
Minimum amount of data	100 valid noise and wind speed data pairs	not specified in Annex F; *general method* requires at least 180 data points for both, total and background noise, of which at least 10 measurements shall be made in each half integer wind speed bin[4]
Required wind speed range	cut-in to 11 m/s (minimum), up to cut-out if possible, in particular for turbines with speed control mechanism	cut-in to 11 m/s (minimum), up to cut-out if possible, in particular for turbines with speed control mechanism
Reference wind speed (at rotor centre height)	8 m/s	not a single reference wind speed specified but a range of wind speeds: cut-in wind speed to 11 m/s at rotor centre height as minimum
Data consolidation	plot of noise versus wind speed, linear regression through data where there is a noise characteristic with several distinguished linear parts, two or more linear regressions shall be fitted; only the one that includes the 8 m/s reference wind speed is used for calculating the Apparent Emission Sound Power Level $L_{W,8m/s}$	data sorted into 1 m/s integer-centred bins; sound pressure levels and wind speed levels are averaged in each bin. if the wind speed average is other than the integer level, both, sound pressure level corresponding to integer wind speed is interpolated
Background noise correction	linear regression through background noise, correct 8 m/s reference value	data sorted into 1 m/s integer-centred bins and averaged (see above); background noise correction in each 1/3 octave band
Calculation of sound power level	spherical propagation from rotor centre to measurement board and 6 dB correction for ground board	spherical propagation from rotor centre to measurement board and 6 dB correction for ground board
Wind Speed Dependence S_{dB}	Slope of the linear regression of noise vs wind speed	n/a – individual values calculated per wind speed bin

[4] in Annex F data is sorted in integer wind speed bins

	BWEA standard (generally follows BS EN 61400-11 (2003)/IEC 61400-11 Ed.2 with the exceptions listed below)	**IEC 61400-11 Ed.3 Annex F** (generally follows IEC 61400-11 (Ed.3) general method with the exceptions listed below)
Sound Power Level	Apparent Emission Sound Power Level at hub height wind speed of 8 m/s $L_{W,8m/s}$	Apparent Sound Power Level calculated for each wind speed bin as energy sum of the average sound power levels in each 1/3 octave band (referenced to rotor centre height and a second table with reference height 10 m agl)
Uncertainty of Measurement	Standard deviation σ, including uncertainty for linear regression	combination of type A[5] and B[6] uncertainties; calculation of covariance[7] between sound and wind speed averages
Declared Sound Power Level	$L_{Wd,8m/s} = L_{W,8m/s} * 1.645 * \sigma$	not specified in Part 11/Annex F; described in IEC/TS 61400-14:2005
Tonality Assessment	1/3 octave band analysis to ISO 1996-2:2007 is acceptable analysis to BS EN 61400-11 can be used	narrow band analysis as specified in general method; tonal audibility based on a minimum of twelve 10 s A-weighted spectra, as close as possible to integer wind speed; overall tonality determined as average of the twelve individual tonality levels
Tonal Penalty	Yes or No: 5 dB or 0 dB	not specified, but tonal audibility greater than -3 dB reported

2.3 Result Presentation

The BWEA standard required further information above and beyond the requirements if IEC 61400-11 (Ed.2 or 3) which are:

- Declared Apparent Sound Power Level (sound power level + 1.645*measurement uncertainty + tonal penalty P if applicable)
- Noise Slope

[5] standard error of the estimated noise spectra

[6] determined by judgement;
examples for sound level determination: calibration of acoustic instruments; tolerances on the chain of acoustic measurement instruments; uncertainty on the acoustic conditions for microphone board, on wind screen insertion loss, on distance from microphone to hub and direction, on acoustic impedance of air; on changing weather conditions
examples for wind speed determination: uncertainty for measured wind speed (uncertainty on anemometer calibration, site effects, power reading); uncertainty on derived wind speed from power curve uncertainty

[7] measure how much two random variables change together

- Prediction of the sound pressure level at a slant distance of 60 m and 25 m (rotor centre to observer). It should be noted that for the sound propagation the following assumptions were made:
    - hemispherical propagation (spherical spreading used for wind turbine noise when predicting with ISO 9613-2)
    - no ground effect considered
    - no air absorption considered
    - use of overall A-weighted declared sound power level (no frequency dependent attenuation terms calculated)
- Immission Noise Map displaying three areas with the colour scheme red for predicted sound pressure levels above 45 dB(), yellow for sound pressure levels between 40 and 45 dB(A) and green for sound pressure levels below 40 dB(A).

Figure 1 shows an example of a presentation of the acoustic data from a small wind turbine, as specified in the BWEA standard (source www.kingspanwind.com), showing the aforementioned immission noise map.

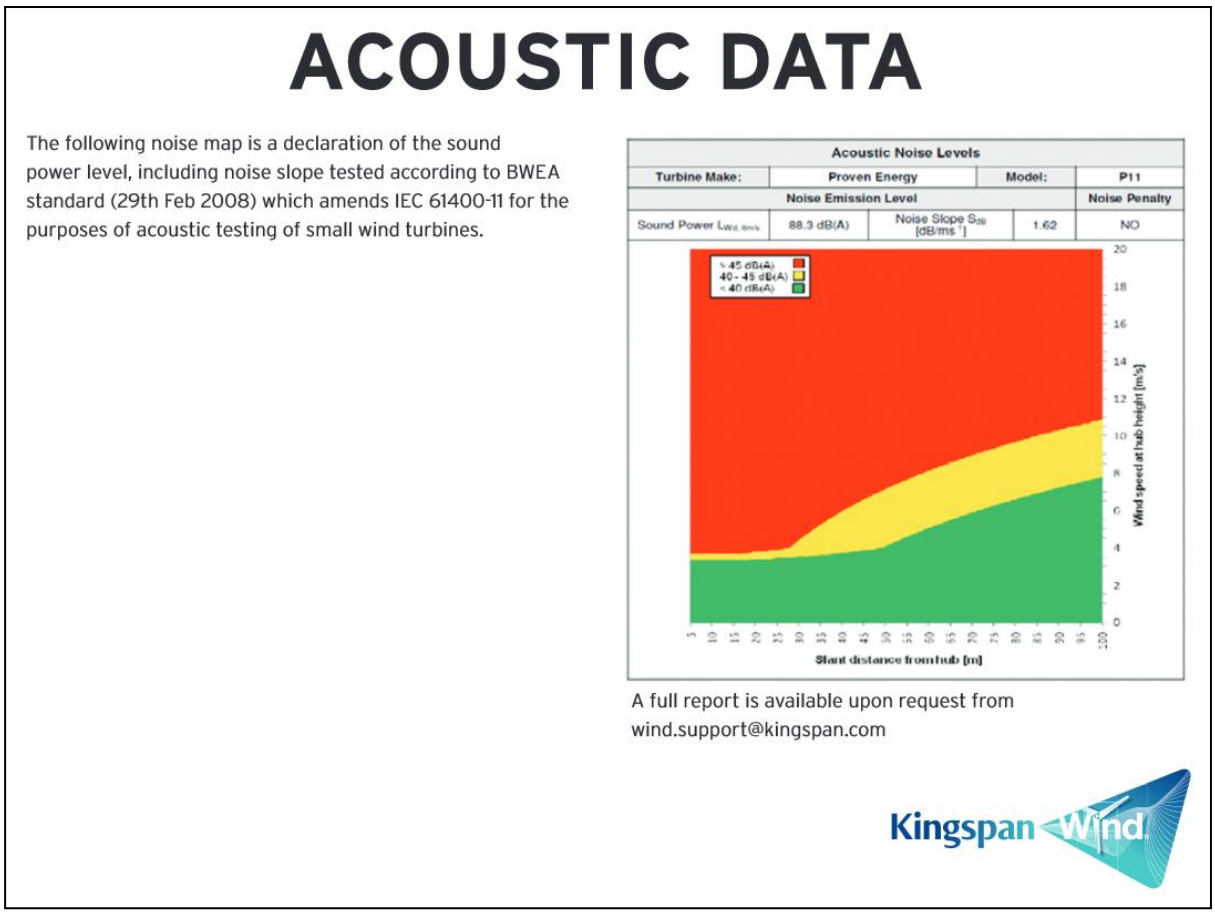

Figure 1: Presentation of Acoustic Data of a Small Wind Turbine by a Manufacturer (www.kingspan.com)

The Immission Noise Map is not provided online by all manufacturers but some manufacturers state the sound power level or as a minimum information, the distance at which the predicted sound pressure level equals 40 and 45 dB(A) which is shown in Figure 2.

Noise Profile

The Ampair 20kW has the following noise profile:

- 45dB(A) at 100m*
- 40dB(A) at 178m*
- Noise Slope: 1.47 dB/m/s (change in sound levels per m/s change in wind speed)*

*Data from MCS Summary Reports, sound power levels at the turbine hub as measured in an 8m/s wind.

Figure 2: Presentation of Acoustic Data of a Small Wind Turbine by a different Manufacturer (www.ampair.com)

The information required by Annex F are the same as in the general method with the exception of measured power, rotor rpm, pitch angle and yaw direction as they may not be available for small wind turbines.

Furthermore Annex F requires an immission noise map, as shown in Figure 3, which is directly taken from Annex F.

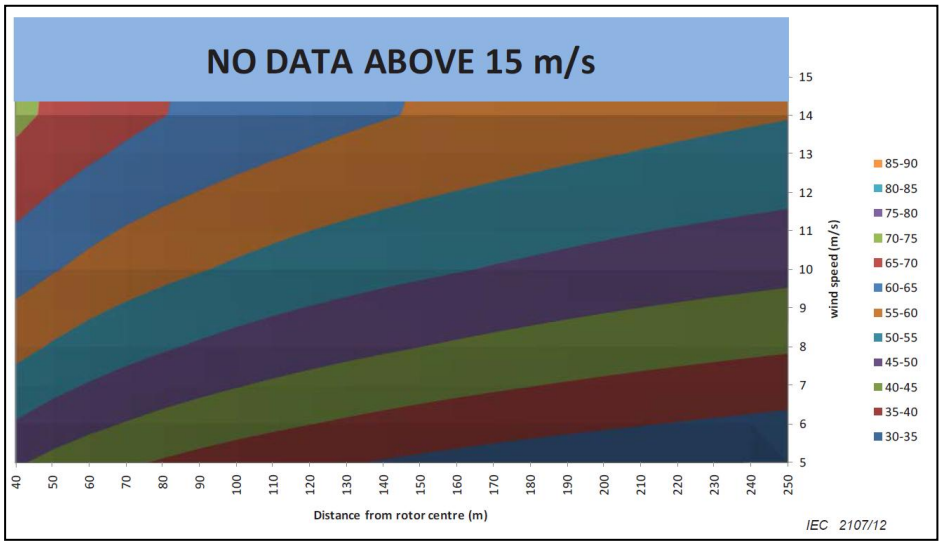

Figure 3: Example of an immission noise map taken from BS EN 61400-11:2013 (Figure F.2)

The differences to the BWEA standard immission noise map are:

- Showing sound pressure levels in 5 dB steps rather than just three different areas
- Sound pressure level calculated using spherical spreading instead of hemispherical spreading in the BWEA standard
- Use of apparent sound power level without included uncertainties (that is an assumption as it is not specified) rather than the Declared Apparent Sound Power Level as defined by the BWEA standard
- No tonal penalty added to the sound power level as tonal penalties are country specific and therefore cannot be included in an international standard; if a tonal penalty is required, this needs to be stated separately

- Not specified whether the calculation of the sound pressure levels for given distance and wind speed are based on broad band sound power levels or on the (1/3) octave band levels nor whether atmospheric attenuation or ground absorption should be considered

3.0 Differences in Results between BWEA standard and IEC 61400-11 Ed.3

The assessment of an acoustic noise data measurement carried out in accordance with the withdrawn BWEA standard and tonal analysis using 1/3 octave band data will be compared with an assessment in accordance to IEC 61400-11 Ed.3 including a narrow band analysis to determine tonality. The results will be presented at the Wind Turbine Noise Conference 2015 in Glasgow.

4.0 Conclusions

Due to a transitional period of five years, where acoustical data of small wind turbines will be available in the UK based on two different measurement standards, this paper looked into the differences between the standards in question, the BWEA Small Wind Turbine Standard and IEC 61400-11 Ed.3/BS EN 61400-11:2013 Annex F.

The differences in measurement set-up, analysis and data presentation were described in chapter 2 above. The differences suggest that the results of assessments carried out in accordance to one standard cannot be directly compared to the other. In particular the immission noise maps are based on different sound power levels and using different propagation assumptions, and therefore cannot be used to compare the results of two different wind turbine models on a like for like basis if different standards have been used.

An assessment of the acoustic noise measurement of a small wind turbine will be carried out in accordance with each of the standards and the results presented at the WTN 2015 conference in Glasgow.

References

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