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Comparison of Wind Turbine Manufacturers' Noise Data for Use in Wind Farm Assessments

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Abstract

Input data for wind farm noise assessments are provided by the turbine manufacturers in the form of sound power level values for 'standardised' 10 m height wind speeds. The format, in which sound power levels are provided, together with possible uncertainties, differs from manufacturer to manufacturer. Some specifications recommend the use of an additional safety margin to allow for measurement uncertainties. Others state measurement uncertainties from test reports, standard deviation from averaging several test reports, K-values depending on the extent of the confidence level (according to IEC/TS 61400-14:2005) or no information about uncertainties at all. An overview of different methods of publishing wind turbine sound power levels and the result of comparing different wind turbine types for the same development site is given.

Introduction

Wind farm noise assessments are carried out according to country-specific requirements; for example ETSU-R-97 in the United Kingdom, Planning Guidelines from the Department of the Environment, Heritage and Local Government in the Republic of Ireland and TA Lärm plus further specifications in Germany. In general, the international standard ISO 9613 *Acoustics - Attenuation of sound during propagation outdoors* is used to calculate sound pressure levels which result from wind farm developments at noise sensitive properties. Sound power level data is the fundamental input parameter for such calculations. The values, that manufacturers specify, can be based on a variety of sources; theoretical calculations, noise measurements of a single turbine representing a certain make and model, or mean values over a certain number of noise measurements, with or without adding a measurement uncertainty. Depending on the input data, the result can vary widely.

Documents from several of the larger wind turbine manufacturers have been reviewed and the difference in the way the noise data is provided is discussed.

Manufacturers’ Methods of Presenting Noise Data

The way in which wind turbine sound power level data is presented by the manufacturers varies significantly. There is no standardised approach.

Some manufacturers issue warranted noise levels for use in noise assessments; others state noise levels for information only but attach a noise warranty to their contract with the buyer, others in turn warrant sound power levels at hub height and give calculated sound power levels referenced to 10 m height for information only. It can also happen that no official document from a manufacturer is available and that noise assessments are based only on a single turbine sound power level test report. If the sound levels from the measurement report are used without adding a measurement uncertainty, there will be no safety margin to allow for measurement uncertainties, uncertainties of the calculation model or slight variation within a batch of turbines.

Every manufacturer has their own method of providing published noise data. In the absence of measurement reports on which noise warranties/statements could be based, calculations are often used to derive noise levels. Calculations can be based on wind turbines of a similar size from the same manufacturer, up- or down-scaled to the new turbine size, or on the same blade model, with amendments to account for a different rotational speed. Only follow-up noise measurements can show how accurate such methods are. In this case, the manufacturer should provide an appropriate safety margin to allow for uncertainties with such a methodology.

A more common method is to conduct a turbine test according to IEC 61400-11 *Wind turbines – Part 11: Acoustic noise measurement techniques* on the prototype or the first erected turbines and, based on that measurement, issue a warranty/statement. The margin between measured and warranted/stated value may vary between only a few tenths of a dB up to 3 or 4 dB depending on the manufacturer.

Noise data is normally given for standardised wind conditions i.e. wind speed at 10 m height based on a ground roughness of 0.05 as specified in IEC 61400-11, but guaranteed noise levels may also be supplied with reference to hub height wind speeds, or specified for 10 m height with alternative roughness factors or values of shear exponent.

Declaration of Tonality Values

In most countries a “penalty” is added for prominent tones in broadband noise when carrying out noise assessments. Information about tones, or warranties for the absence of tones, in the turbine noise, however, is not always given in the manufacturers’ documentations.

Some manufacturers claim that their wind turbines don’t emit any noise with tonal components and therefore don’t make any official statement at all.

Other manufacturers give warranties applicable to the near vicinity of a turbine. A minor tonality of 0-2 dB at the turbine should not be relevant at the receptor and therefore should not lead to a penalty.

Others give a warranty that the tonal audibility ΔL_a is smaller than or equal to 4 dB, measured at the turbine in a test according to IEC 61400-11. But how does this tonal component appear at a receptor? Will it be masked by broadband noise at the receptor location or will it still be audible? In the UK, ETSU-R-97, which refers to measurements at receptors, specifies that a measured tone level of 4 dB above the audibility threshold results in the application of a penalty of 3 dB.

Another method is to warrant the absence of tones at receptors. In this case, tonal noise would not have to be considered in the noise assessment but it would be the responsibility of the manufacturer, to ensure that no tonal noise is present at the neighbouring properties.

Uncertainty of Noise Data

Very often, no information about the accuracy of the provided noise data is given and local authorities have to trust that an adequate safety margin has been added to allow for uncertainties of the measurements and propagation model.

In some turbine warranty documents it is stated that warranties are only valid for sound power levels measured according to IEC 61400-11. In these documents it is often not stated whether a measurement uncertainty has been taken into account in the derivation of the stated sound power levels. It is not always clear whether the warranty level is deemed to be met if the apparent sound power level, plus or minus the measurement uncertainty, is equal to or below the warranted noise levels.

There are manufacturers that recommend a certain safety margin added to the warranted sound power level. One manufacturer, for example, recommends adding 1 dB to allow for such uncertainties. In this case, the warranty is valid for noise levels as described in a table, plus/minus 1 dB. For a worst case calculation, this 1 dB would have to be added to the given sound power levels.

In another document, it is stated that the noise levels in the document are the ‘average expected values L_W’. To gain the declared apparent sound power level L_{Wd}, according to IEC TS 61400-14, it is stated that L_W should be increased by 2 dB. This is one of the few manufacturers’ documents in which the technical specification IEC TS 61400 *Part 14: Declaration of apparent sound power level and tonality values* is mentioned at all.

One very comprehensive document has been found so far, which includes all the required information such as standard deviation for test reproducibility, mean values of measurement test reports including uncertainty, standard deviation for product unit-to-unit variability and the K-value for 95% confidence level according to IEC 61400-14.

Conditions for Sound Power Level Measurements/Validity

Not all the considered documents mention particular conditions for which the sound power levels are valid. Others are more specific in that respect. Examples of such conditions are:

- measurement standard for the verification of the turbine noise sound power level: IEC 61400-11:2002
- roughness length z_0 = 0.05 for calculating the standardised wind speed at 10 m height
- clean blades, no dirt, no ice, no rain on the blades, no damage to the leading edge
- a certain turbulence intensity
- a certain (vertical) wind shear
- a certain (vertical) inflow angle

The question that arises here is, what happens to the noise levels when those stated conditions are not present at a site? What allowance has to be given for “non-ideal” conditions, which one would expect in practice for most of the time? How do wind turbines within a wind farm interact?

1/3 Octave/Octave Band Data

In general, octave or 1/3 octave band data is not warranted at all. If included in official manufacturers’ data, it is given ‘for information only’. Some manufacturers publish a sample measurement report together with the noise document from which the relevant octave data can be taken.

Some measurement reports contain octave or third octave band data, or both, for the whole measurement range. Others only state the ones at either the highest wind speed or the wind speed at 10 m height, where 95% of the rated power is reached.

When calculation of receptor noise levels for each wind speed is required, for example according to ETSU-R-97 in the UK, and if the relevant information is available, octave band data for each wind speed could be used. The method commonly used in practice is to take the octave band data for the highest noise level, at reference or other wind speed, and adjust it to the other noise levels at the relevant wind speeds.

If the manufacturers don’t supply a specific set of octave band levels for use in the noise assessment, or if there are several measurements reports for one turbine type, consultancies have to take the decision which octave band data to use for noise predictions. This may lead to variation in the assessment.

If, on the other hand, several measurement reports are available, one approach could be to calculate the mean value for each frequency band across the various reports.

In one manufacturer’s document, the octave data of all the noise measurements have been plotted in a graph and three different sets of octave data have been derived: an optimistic model with higher noise levels at higher frequencies, a pessimistic model with higher levels at lower frequencies and the average with 50%

of each of the previous models. It is up to the consultant who carries out the noise assessment, which model is preferred.

Other Issues

There are other issues currently not addressed by wind turbine manufacturers' warranted/stated noise data, such as

- the minimum separation distance needed between wind turbines so that turbulence intensity does not increase to such an extent that the sound power levels increase significantly
- amplitude modulation
- a clear declaration of two speed machines and the relevant noise data for each generator stage
- noise data when the turbine is braking for changing generator stages (two speed).

This information is important when examining the effects of wind turbine noise on surrounding properties.

Technical Specification IEC TS 61400-14

As there are individual variations between different turbines of the same batch, turbine noise specification based on measurement results from a single turbine of a particular make and model can hardly be seen as representative of these turbines as a whole. The technical specification IEC TS 61400-14 *Wind Turbines - Part 14: Declaration of apparent sound power level and tonality values* provides a method to determine declared noise emission values from a sample of turbines of the same type. Its aim is, to facilitate the comparison of apparent sound power levels and tonality values of different wind turbine types and to increase the reliability of wind farm noise assessments.

IEC TS 61400-14 allows the calculation of the mean apparent sound power level $\overline{L}_W$ and the standard deviation 'σ' from a minimum of three noise measurements at individual turbines of the same type.

The declared apparent sound power level L_{Wd} is then calculated from

$$L_{Wd} = \overline{L}_W + K$$

where L_{Wd} is the declared apparent sound power level of wind turbines of the same make and model

$\overline{L}_W$ is the mean apparent sound power level of at least three measurements

K represents a certain confidence level.

K is equal to 1.645·σ for a probability of 95 %, that the apparent sound power level, derived from a turbine test in accordance with IEC 61400-11 at wind turbine of a certain batch, does not exceed the declared value for this batch. For a lower confidence level, a smaller multiplier than 1.645 may be used.

The standard deviation used for the declaration is calculated from three standard deviations: the standard deviation 's', which is determined when averaging the apparent sound power levels, the standard deviation of reproducibility 'σ_R' and the standard deviation of production 'σ_P'.

The more measurement results are available for the determination of $\overline{L}_W$, the more reliable L_{Wd} will be. Increasing the number of measurements will usually result in decreasing 's' and 'K', unless the individual measurement results differ significantly.

The declaration of tonality according to IEC 61400-14 should not be performed in the same way as for the apparent sound power level. The results of all measurements should be stated individually.

Comparison of Noise Data

In the following figures, apparent sound power levels with examples of differently derived uncertainty margins are displayed for comparison.

Figure 1 shows the apparent sound power level L_W from one measurement in black, the same L_W with the measurement uncertainty of this measurement report added in a dashed black line, the mean apparent sound power level $L_{W,mean}$ (=$\overline{L}_W$ in the previous chapter) derived from three measurement results in green, and the declared apparent sound power level according to IEC TS 61400-14 with an added confidence level K in orange.

It can be seen, that in this case, the average apparent sound power level of three measurements is higher than the apparent sound power level of the first test result for wind speeds below 9 m/s.

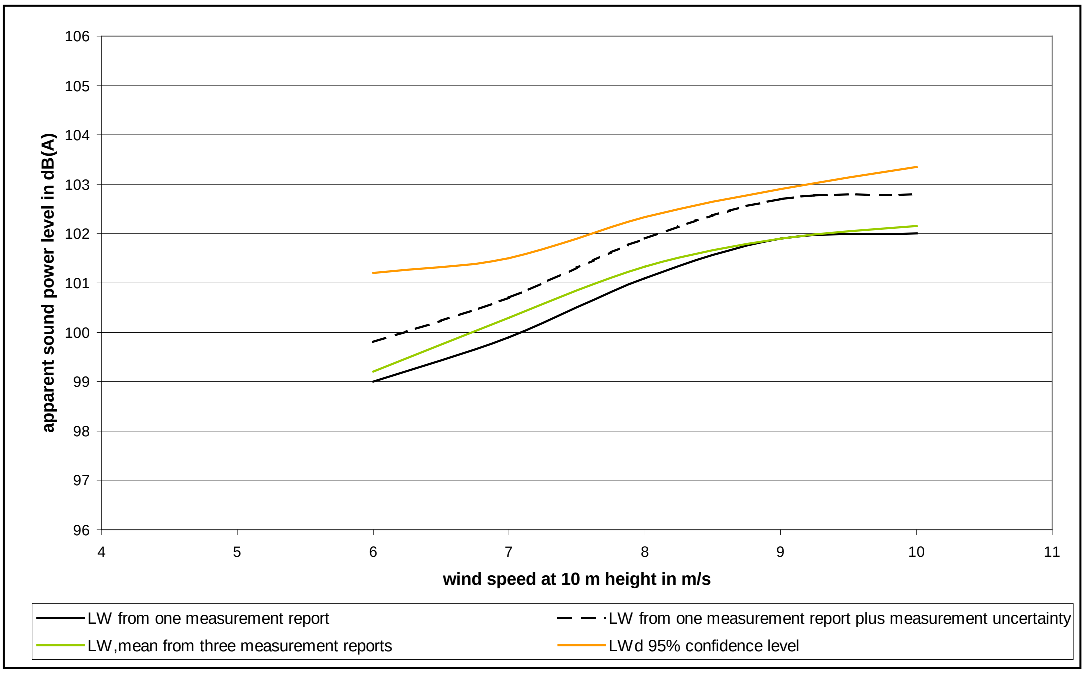

Figure 1: Comparison of measurement results from one measurement L_W, L_W plus measurement uncertainty, mean apparent sound power level derived from three measurement results $L_{W,mean}$ and declared apparent sound power level L_{Wd} with 95% confidence level.

Figure 2 shows the same mean apparent sound power level as in Figure 1 in green, warranted noise data in red and the sound power level which could be recommended for the use in a noise assessment, assuming the safety margin in this recommendation would be + 1 dB.

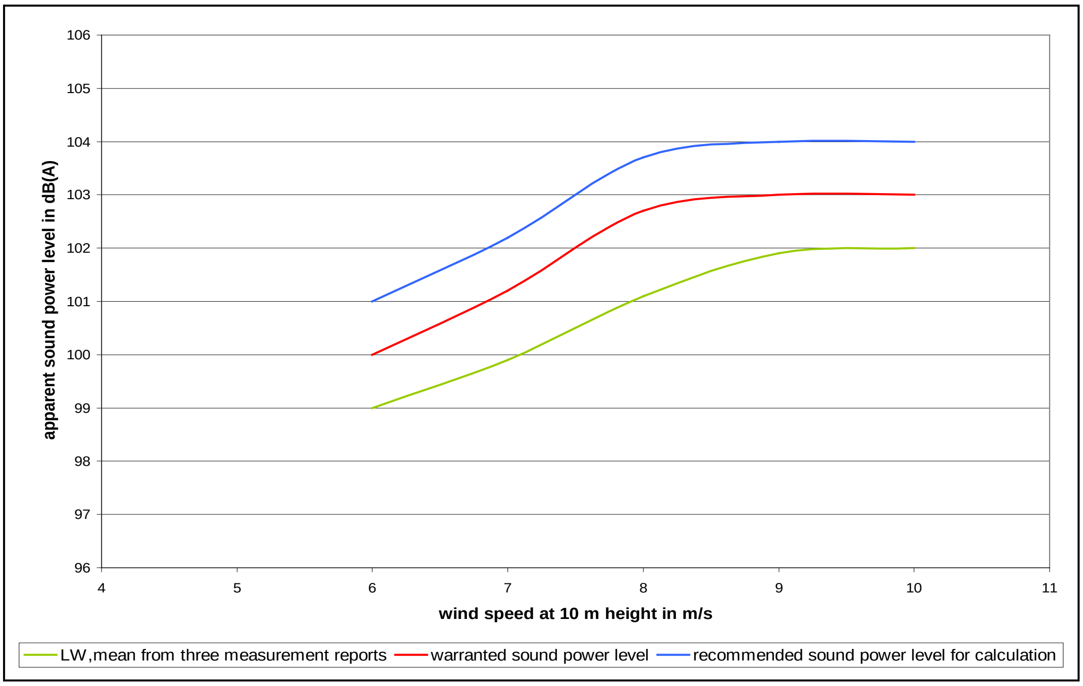

Figure 2: Comparison of mean apparent sound power level derived from three measurement results with warranted apparent sound power level and with recommended sound power level for noise assessments.

In Figure 3 all of the above mentioned noise data are combined.

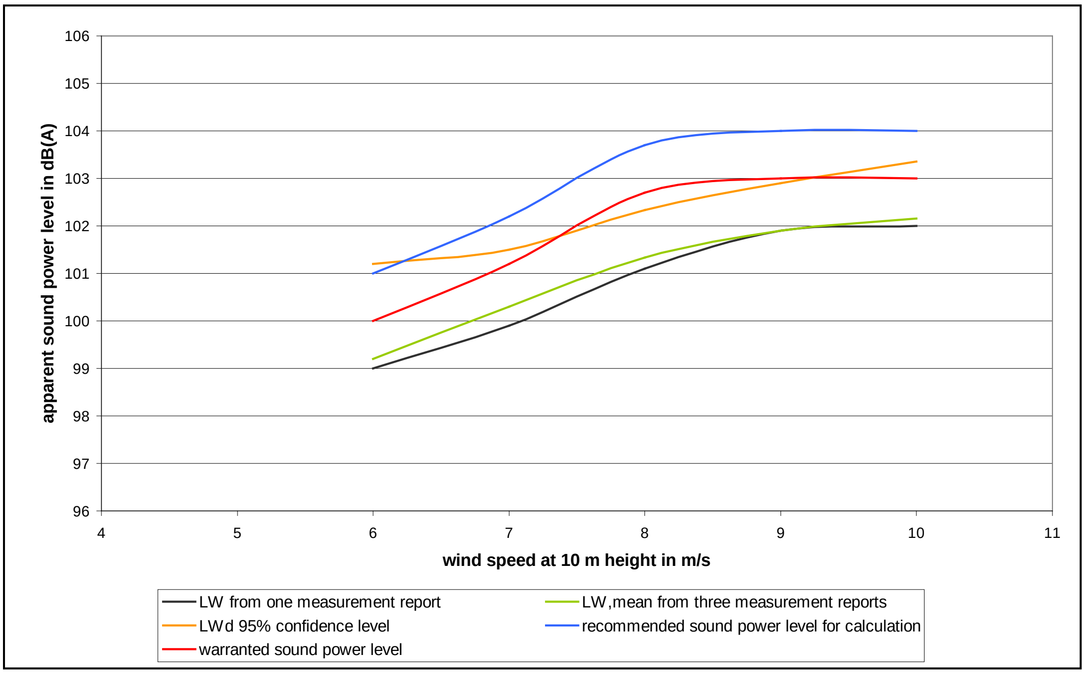

Figure 3: Combination of Figure 1 and 2.

Figure 3 reveals how different the results of a noise assessment may be depending on which set of noise data is used for the prediction.

The orange line symbolises the declared apparent sound power level. When using these noise levels it can be assumed that with a probability of 95% the actual apparent sound power level of a turbine of the same batch, is below this stated declared apparent sound power level. In the presented case, the warranted noise levels are lower than the declared apparent sound power level for wind speeds below 7.5 m/s and above 9 m/s. For these wind speeds the probability that the actual sound power level is above the warranted sound power level increases compared to wind speeds between 7.5 and 9 m/s.

In this case, using the manufacturer’s recommended sound power level gives sufficient planning reliability. But it may also be overcautious and result in a layout with fewer wind turbines than might actually be possible.

Figure 3 also indicates graphically the implications of manufacturers using different methods for deriving warranted/stated noise data. It is difficult to interpret the results of an assessment for several candidate wind turbine types unless the input data from all manufacturers is presented in a standardised format.

The quality of the declared sound power level, however, depends on the available measurement reports. The more measurement reports available for a batch, the more representative the mean apparent sound power level will be.

Conclusions

At the moment it is difficult to compare turbine noise data as specified in manufacturers’ documents on a like for like basis because the methods for deriving the input data are not comparable.

To gain confidence in manufacturers’ noise data, it is important to know how they are derived. Full measurement reports, including measurement uncertainty to verify the stated noise data, are desirable if not essential. If no measurement reports of a turbine model are available, the noise data should be handled with care.

Consultants can calculate the declared apparent sound power level for a turbine model themselves when at least three measurement reports of the same turbine make are provided. In doing this for all the candidate wind turbines at one site, a useful comparison could be achieved regardless of the different methods used by turbine manufacturers for providing a warranty or statement of wind turbine sound power levels.

It would be preferable for all manufacturers to state their noise levels in accordance with IEC TS 61400-14 with the relevant uncertainties, standard deviation and so on, so that it is clear, how noise levels are derived and thus allow noise assessments to be compared on a like for like basis. The noise documents should also include the full measurement reports used to calculate the declared apparent sound power level.

In terms of tonality, octave data and other factors referred to, more information in official noise documents from the manufacturers would be beneficial for noise assessments.

References

The turbine manufacturers’ wind turbine noise data documents are examples of the vast amount of documentations, which are available for all sorts of different wind turbine types. This list is not exhaustive.

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