Prediction and Assessment of Wind Turbine Noise

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1 Introduction

1.1 There are continuing disputes about the factors to be taken into account when assessing noise from wind turbines, and the weight to be given to these factors. These differences are regularly introduced when planning applications are made to local authorities and at public inquiries. We (those listed at the end of this document) have agreed on the following statement, based on our current knowledge and experience to-date. It concerns some aspects of the assessment of noise from wind turbines, explains a number of preferred procedures, and sets out the form in which some information should be presented to support an environmental noise assessment for a proposed wind farm development. The recommendations are not exhaustive but we believe that they may enhance the quality of wind farm noise assessments and usefully limit areas of disagreement between parties acting for developers and those acting for objectors.

1.2 We address the following issues:

- The acquisition of baseline noise data at 'receptor' locations, and the analysis of this data, to take account of site-specific wind shear.
- The prediction of wind turbine noise at receptor locations ('noise immission levels')
- The significance of low-frequency noise, infrasound and ground-borne vibration from wind farms

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2 Acquisition and analysis of background noise data

2.1 The procedures set out in ETSU-R-97 are universally adopted. A data set of $L_{A90,10m}$ background noise levels is acquired at each survey location, correlated with simultaneous measurements of '10 metres height' mean wind speeds on the wind turbine site (existing or proposed). A subsequent stage of the noise assessment involves comparing the predicted wind turbine noise immission levels with the background noise levels at local receptors (most commonly dwellings). The wind turbine noise immission levels at the receptors are predicted based on standardised data provided for wind turbine source Sound Power Levels for a range of '10 metres height wind speeds'. This 10 metres is the reference wind speed measurement height when wind turbine sound power levels are measured in accordance with the current 2nd Edition of IEC 61400-11. Thus both the background noise levels and the wind turbine noise immission levels are referenced to the '10 metres height wind speed'.

2.2 However, there is a potential mismatch between the reference wind speeds used for baseline noise measurements and wind turbine 'source' noise levels, unless site-specific wind shear is taken into account. This is because the relationship between wind speed at different heights above the ground (the wind shear), and in particular between the actual hub-height wind speed (which generally determines the wind turbine Sound Power Level) and the actual wind speed that would be measured at 10 metres height, varies from site-to-site and in different weather conditions. This mismatch can result in significant errors when the comparisons are made between background noise levels and wind turbine noise immission levels.

2.3 To overcome this problem, we recommend that background noise levels are correlated with **derived (**not **measured)** 10 metres height wind speeds, arrived at using the following procedure. Effectively, the result of adopting this procedure is to reference all noise levels (both background levels and immission levels) to the wind speed at turbine hub-height, although the results are stated in terms of the derived 10 metres height wind speed for consistency with IEC 61400-11 and ETSU-R-97. The preferred procedure is as follows:

- For the duration of baseline surveys wind speeds should be measured on the wind farm site at two heights H1 and H2, H1 being not less than 60% of the proposed turbine hub height and H2 being between 40% and 50% of proposed hub height. Generally, this would require the installation of a met. mast approximately 50 metres in height based on current typical hub heights.

- For each ten minute period the mean wind speed measured at height H1 should be corrected to hub height using the wind shear exponent 'm' derived from the mean wind speeds U1 and U2 at heights H1 and H2, using the following standard equation:

$$m = \frac{Log\left(U_1/U_2\right)}{Log\left(H_1/H_2\right)}$$

Where:-
m The shear exponent to be calculated
U1 The wind speed measured at the lower height
U2 The wind speed measured at the upper height
H1 The height of the lower wind speed measurement
H2 The height of the upper wind speed measurement

- The mean hub height wind speed (Uhh) calculated as above should then be corrected to 10 metres height using the standard reference ground roughness length of 0.05 metres.

- Background noise levels should be correlated against this 'derived' 10 metres height wind speed. Use of the derived 10 metres wind speed provides consistency between wind turbine manufacturers' Sound Power Level test data and the baseline noise measurements at receptors and takes account of site-specific wind shear.

- On some sites and in some wind conditions the situation may arise that the wind speed U2 (at the greater height H2) is equal to or lower than the wind speed U1 at the lower height H1. In this situation, the wind shear calculation specified above should not be performed and our suggestion at this time is that the hub height wind speed should be assumed to be the same as the wind speed at the upper height H2.

2.4 If the noise assessment for a specific site follows the above procedure, the same principle should be adopted when measuring wind turbine noise levels at receptors close to that site (e.g. for determining compliance with noise limits in Planning Conditions). Measured noise immission levels should be referenced to derived 10 metres height wind speeds - hub height wind speeds corrected to 10 metres height using the reference roughness length of 0.05 metres. The hub height wind speed may be measured directly (either directly with an anemometer or derived from the turbine power output using the wind turbine wind speed/power curve) or calculated from a measurement at another height using the actual measured wind shear during the ten minute measurement period. Planning Conditions should clearly define the procedure to be followed and provide consistency of approach between assessment of compliance and the environmental impact assessment.

2.5 Where background noise surveys are carried out for sites where wind speeds can only be measured at 10 metres height, then the noise assessment (the comparisons between background noise levels and predicted immission levels at receptors) should take account of the wind shear variations using a method which should be clearly explained. This correction could be applied either to the background noise levels or to the noise immission levels at receptors. However, reliance on 10 metres measured wind speeds should be avoided where possible: the procedure in 2.3 above is preferred. Where noise assessments are based solely on measured 10 metres height wind speeds, then noise limits in Planning Conditions must also refer to measured 10 metres height wind speeds, measured at the same (or equivalent) location as that adopted for the background noise surveys.

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3 Prediction of Wind Turbine Noise Immission Levels

3.1 The preferred method of calculating wind turbine noise immission levels (i.e. noise levels to be experienced at receptor locations in the surrounding area) is the octave band prediction method of International Standard ISO9613-2. The output from an ISO9613-2 prediction model depends on the model input parameters. Specialists working in this field adopt different combinations of input parameters, many of which lead to effectively identical results. In the interests of clarity we recommend that the results of wind turbine noise predictions should be qualified by a statement of the all model inputs used. In particular, the following should be specified:

- *The turbine Sound Power Levels used as input.* These should be supported by documentation from the vendor where appropriate. The status of the input Sound Power Levels should be stated e.g. are they test levels, test levels with an addition for test uncertainty, warranted levels, or ‘generic’ levels derived from data for a number of potential candidate turbines.

- *The atmospheric conditions (temperature and RH) assumed.* 10 ºC and 70% RH are the preferred conditions.

- *The ground factors Gs, Gm, Gr assumed*. On the evidence available, we consider that ISO 9613-2 calculations using either G=0 or G=0.5 (Gs = Gm = Gr) will lead to appropriate prediction of noise immission levels at typical receptor locations, depending on the input values of other parameters. The use of either (a) G=0 together with measured (IEC 61400-11 test) Sound Power Levels or (b) G=0.5 (with a 4 metres receptor height) together with vendor's warranted sound power levels (or measured turbine sound power levels plus an allowance for measurement uncertainty), will generally result in realistic estimates of noise immission levels at receptor locations downwind of wind turbines. Noise immission levels calculated using these combinations of parameters can generally be relied on for the purposes of noise assessment. The assumption of 'soft' ground (G=1) should not be made.

- *The effects of barriers.* Barrier attenuation calculated using the method within ISO9613-2 should not be included within predictions Generally, no account should be taken of barrier attenuation by the landform unless there is no line-of-sight between the receptor and the highest point on the rotor, when a barrier attenuation of 2 dB(A) should generally be assumed. A higher barrier attenuation may be appropriate in cases where a landform 'barrier' is very close to the receptor but the assumption of a barrier attenuation greater than 2 dB(A) requires to be fully justified in the noise assessment.

3.2 Calculations based on IEC 61400-11 test data result in noise immission levels in dB $L_{Aeq,T}$. The ETSU-R-97 procedures adopt the $L_{A90,10m}$ noise index. From the information currently available our view is that the relationship between L_{A90} and L_{Aeq} for wind turbines stated in ETSU-R-97 ($L_{A90,10m} = L_{Aeq,10m} – 2$ dB) remains valid.

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4 Vibration and Low Frequency Noise

4.1 Infrasound is the term generally used to describe sound at frequencies below 20 Hz. At separation distances from wind turbines which are typical of residential locations the levels of infrasound from wind turbines are well below the human perception level. Infrasound from wind turbines is often at levels below that of the noise generated by wind around buildings and other obstacles. Sounds at frequencies from about 20 Hz to 200 Hz are conventionally referred to as low-frequency sounds. A report for the DTI in 2006 by Hayes McKenzie[1] concluded that neither infrasound nor low frequency noise was a significant factor at the separation distances at which people lived. This was confirmed by a peer review by a number of consultants working in this field. We concur with this view.

4.2 A Portuguese group has been researching 'Vibro-acoustic Disease' (VAD) for about 25 years. Their research initially focussed on aircraft technicians who were exposed to very high overall noise levels, typically over 120 dB. A range of health problems has been described for the technicians, which the researchers linked to high levels of low frequency noise exposure. However other research has not confirmed this. Wind

[1] http://www.berr.gov.uk/whatwedo/energy/sources/renewables/explained/wind/onshore-offshore/page31267.html

farms expose people to sound pressure levels orders of magnitude less than the noise levels to which the aircraft technicians were exposed. The Portuguese VAD group has not produced evidence to support their new hypothesis that infrasound and low frequency noise from wind turbines causes similar health effects to those experienced by the aircraft technicians.

4.3 Keele University undertook an assessment of the likely impact of ground-borne vibrations from wind turbines on the seismic array at Eskdalemuir[2]. Whilst the testing shows that vibration can be detected several kilometres from wind turbines Keele University clarified the context of their results: "The levels of vibration from wind turbines are so small that only the most sophisticated instrumentation and data processing can reveal their presence, and they are almost impossible to detect. The Dunlaw study was designed to measure effects of extremely low level vibration on one of the quietest sites (Eskdalemuir) in the world, and one which houses one of the most sensitive seismic installations in the world. Vibrations at this level and in this frequency range will be available from all kinds of sources such as traffic and background"[3]. Scientific instruments are far more sensitive detectors than the human body, which is subject to internally generated noise and vibration.

4.4 From examination of reports of the studies referred to above, and other reports widely available on internet sites, we conclude that there is no robust evidence that low frequency noise (including 'infrasound') or ground-borne vibration from wind farms, generally has adverse effects on wind farm neighbours.

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[2] http://www.esci.keele.ac.uk/geophysics/dunlaw/Final_Report.pdf
[3] http://www.bwea.com/ref/lfn_keele.html