Technical Appendix

Drummarnock Wind Farm

Technical Appendix 11-1: Noise Prediction Methodology

Drummarnock Wind Farm Limited

July 2024

Contents

Tables

1 Overview

The noise prediction methodology is based on guidance in ESTU-R-97 *The Assessment and Rating of Noise from Wind Farms* and the UK Institute of Acoustics (IOA) document *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbines Noise* (GPG). These documents detail the assessment and calculation approach for wind farm noise, and advocate for the use of ISO 9613 *Acoustics – Attenuation of sound during propagation outdoors* as the basis for the noise predictions, with some specific assumptions and adjustments.

2 ISO 9613

The ISO 9613 standard is used for predicting sound pressure level for downwind propagation by taking the source sound power level for each turbine in separate octave bands and subtracting a number of attenuation factors. These are set out in ISO 9613-2 *General method of calculation* according to the following:

Predicted Octave Band Noise Level = $L_W + D - A_{geo} - A_{atm} - A_{gr} - A_{bar} - A_{misc}$

These factors are discussed in detail below together with an additional term for taking wind direction into account where required. The predicted octave band levels from each turbine are summed together to give the overall 'A' weighted predicted sound level.

2.1 L_W – Source Sound Power Level

The sound power level of a noise source is normally expressed in dB re: 1 pW. Noise predictions are based on sound power levels detailed in the noise chapter.

The octave band noise spectra used for the predictions have been taken from the technical specifications of the turbine with the results shown in the noise chapter.

2.2 D – Directivity Factor

The directivity factor allows for an adjustment to be made where the sound radiated in the direction of interest is higher than that for which the sound power level is specified. In this case the sound power level is measured in a down wind direction, corresponding to the worst-case propagation conditions considered here and needs no further adjustment.

2.3 A_{geo} – Geometrical Divergence

The geometrical divergence accounts for spherical spreading in the free-field from a point sound source resulting in an attenuation depending on distance according to:

$$A_{geo} = 20 \times \log(d) + 11$$

where d = distance from the turbine.

The wind turbine may be considered as a point source beyond distances corresponding to one rotor diameter.

2.4 A_{atm} – Atmospheric Absorption

Sound propagation through the atmosphere is attenuated by the conversion of the sound energy into heat. This attenuation is dependent on the temperature and relative humidity of the air through which the sound is travelling and is frequency dependent with increasing attenuation towards higher frequencies. The attenuation depends on distance according to:

$$A_{atm} = d \times a$$

Where d = distance from the turbine

a = atmospheric absorption coefficient in dB/m

Values of 'a' from ISO 9613 Part 1 *Calculation of the absorption of sound by the atmosphere* correspond to a temperature of 10 °C and a relative humidity of 70 %, the values specified in the IOA GPG. These values give relatively low levels of atmospheric attenuation and correspondingly worst-case noise predictions, as given below.

Table A1-1: Frequency-dependent atmospheric absorption coefficients

Octave band centre frequency (Hz) Atmospheric Absorption	Octave band centre frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
Coefficient (dB/m)	0.000122	0.000411	0.00104	0.00193	0.0037	0.00966	0.0328	0.117

2.5 A_{gr} – Ground Effect

Ground effect is the interference of sound reflected by the ground with the sound propagating directly from source to receiver. The prediction of ground effects are inherently complex and depend on the source height, receiver height, propagation height between the source and receiver and the ground conditions. The ground conditions are described according to a variable G which varies between 0 for 'hard' ground (includes paving, water, ice, concrete & any sites with low porosity) and 1 for 'soft' ground (includes ground covered by grass, trees or other vegetation). The IOA GPG states that where wind turbine source noise data includes a suitable allowance for uncertainty, a ground factor of G = 0.5 and a receptor height of 4m should be used.

2.6 A_{bar} – Barrier Attenuation

The effect of any barrier between the noise source and the receiver position is that noise will be reduced according to the relative heights of the source, receiver and barrier and the frequency spectrum of the noise. The barrier attenuations predicted by the ISO 9613 model have, however, been shown to be significantly greater than that measured in practice under down wind conditions. The results of a study of propagation of noise from wind farm sites carried out for ETSU-R-97 concludes that an attenuation of just 2 dB(A) should be allowed where the direct line of sight between the source and receiver is just interrupted and that 10 dB(A) should be allowed where a barrier lies within 5 m of a receiver and provides a significant interruption to the line of sight. In this case a correction of 2 dB has been applied where there is no line of sight between the source and the receiver.

2.7 A_{misc} – Miscellaneous Other Effects

ISO 9613 includes effects of propagation through foliage, industrial plants and housing as additional attenuation effects. These have not been included here and any such effects are unlikely to significantly reduce noise levels below those predicted.

2.8 Concave Ground Profile

Sound propagation across a concave ground profile, for example valleys or where the ground falls away significantly between the turbine and the receptor, incurs an additional correction of +3 dB(A) to the overall A-weighted noise levels. This correction is implemented in order to take account of the reduced ground effects and, under some rare circumstances, the potential for multiple reflection paths caused by the concave profile.

A condition is recommended in the IOA GPG for indicating where this correction should be applied:

$$h_m \geq 1.5 \times \left(\frac{abs(h_s - h_r)}{2} \right)$$

where h_m is the mean height above ground along the direct path between the source and the receptor,

h_s is the absolute source height above ground level, and

h_r is the absolute receptor height above ground level.

Whilst this condition is useful at highlighting where the ground profile beneath a source-to-receptor path may be concave, it is inherently non-robust and can produce false positives. It should therefore be used in conjunction with a visual assessment of the ground profile when determining whether a correction should be applied.

A computer programme is used to generate the ground profiles beneath each source-to-receptor path. From these plots it is possible to determine where a correction is appropriate. For all wind turbines included in the cumulative assessment the corrections have been applied as calculated which results in a conservative predicted noise level as the propagation conditions may not occur in practice when indicated by the formula.

The resultant topographical corrections for the Proposed Development, which include barrier and concave ground profile corrections, are given in Appendix 9-2: Corrections for Ground Profile & Barriers.

3 References

Institute of Acoustics (May 2013). A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise. IOA.

International Organization for Standardization (1993). ISO 9613-1, Acoustics - Attenuation of sound during propagation outdoors, Part 1: Calculation of the absorption of sound by the atmosphere. ISO.

International Organization for Standardization (2024). ISO 9613-2, Acoustics - Attenuation of Sound During Propagation Outdoors, Part 2: Engineering method for the prediction of sound pressure levels outdoors. ISO.

ETSU-R-97 (1996). The Assessment and Rating of Noise from Wind Farms. MM for the DTI.