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Appendix 10.2

Noise Predictions Methodology

Contents

List of Abbreviations

Abbreviation	Description
Lw	Source Sound Power Level
D	Directivity Factor
A_{geo}	Geometrical Divergence
A_{atm}	Atmospheric Absorption
A_{gr}	Ground Effect
A_{bar}	Barrier Attenuation
A_{misc}	Miscellaneous Other Effects

10.2. NOISE PREDICTIONS METHODOLOGY

A10.2.1. The ISO 9613-2 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 according to the following:

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

A10.2.2. These factors are discussed in detail below together with additional terms for taking concave valleys and 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.

L_W - Source Sound Power Level

A10.2.3. The sound power level of a noise source is normally expressed in dB re: 1pW. Noise predictions are based on sound power levels detailed in the noise chapter.

A10.2.4. 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.

D – Directivity Factor

A10.2.5. 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.

A_{geo} – Geometrical Divergence

A10.2.6. 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

A10.2.7. The wind turbine may be considered as a point source beyond distances corresponding to one rotor diameter.

A_{atm} - Atmospheric Absorption

A10.2.8. 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:

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

where d = distance from the turbine

α = atmospheric absorption coefficient in dB/m

A10.2.9. Values of 'α' from ISO 9613 Part 1 corresponding to a temperature of 10ºC and a relative humidity of 70%, the values specified in the UK Institute of Acoustics, *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbines Noise* (IOA GPG), which give relatively low levels of atmospheric attenuation and correspondingly worst case noise predictions, as given below.

Table 10.1: Frequency dependent atmospheric absorption coefficients

Octave Band Centre Frequency (Hz)	63	125	250	500	1k	2k	4k	8k
Atmospheric Absorption Coefficient (dB/m)	1.22×10^{-4}	4.11×10^{-4}	1.04×10^{-3}	1.93×10^{-3}	3.70×10^{-3}	9.66×10^{-3}	3.28×10^{-2}	0.117

A_{gr} - Ground Effect

A10.2.10. 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 4 m should be used.

A_{bar} - Barrier Attenuation

A10.2.11. 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 concludes that an attenuation of just 2 dB(A) should be allowed where the direct line of site 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 site.

A_{misc} – Miscellaneous Other Effects

A10.2.12. 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.

Concave Valley

A10.2.13. 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.

A10.2.14. A condition is recommended in the IOA GPG for indicating where this correction should be applied:

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

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.

A10.2.15. Whilst this condition is useful at highlighting where the ground profile beneath a source – 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.

A10.2.16. A computer programme is used to generate the ground profiles beneath each source – receptor path. From these plots it is possible to determine where a correction is appropriate.

References

- ISO 9613-1, Acoustics - Attenuation of sound during propagation outdoors, Part 1: Method of calculation of the attenuation of sound by atmospheric absorption, International Organization for Standardization, 1992
- UK Institute of Acoustics, A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbines Noise, May 2013
- ETSU W/13/00385/REP, A Critical Appraisal of Wind Farm Noise Propagation, DTI 2000
- Wyle Research Report WR 88-19, Measurement and Evaluation of Environmental Noise from Wind Energy Conversion Systems in Alameda and Riverside Counties, October 1988