Environmental Impact Assessment Report

Swarclett Wind Farm

Technical Appendix 6-2: Noise Prediction Methodology

Swarclett Wind Energy Limited

June 2024

Contents

1 Methodology 1
1.1 Predicted Octave Band Noise Level 1
1.1.1 L_w – Source Sound Power Level 1
1.1.2 D – Directivity Factor 1
1.1.3 A_{geo} – Geometrical Divergence 1
1.1.4 A_{atm} – Atmospheric Absorption 2
1.1.5 A_{gr} – Ground Effect 2
1.1.6 A_{bar} – Barrier Attenuation 3
1.1.7 A_{misc} – Miscellaneous Other Effects 3
2 Concave Ground Profile 3
3 BESS Facility Noise Predictions 4
3.1 Battery Energy Storage Unit 4
3.2 4 MW PCS Inverter Unit 4
3.3 5 MW Solar Transformer 4
3.4 Sound Power levels 5
4 Construction Noise Predictions 5
5 References 6

Tables

Table 9-2-1: Frequency dependent atmospheric absorption coefficients 2
Table 9-2-2: Normalised noise spectra, dB L_{WA} 5
Table 9-2-3: Assumed Plant and Number 5
Table 9-2-4: Assumed Plant Noise Levels 5

1 Methodology

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 (or other noise source) in separate octave bands and subtracting a number of attenuation factors according to the following methodology. The formula for predicting the octave band noise level is set out at the beginning of section 1.1 and each of the attenuation factors are described at subsections 1.1.1 through to 1.1.7:

1.1 Predicted Octave Band Noise Level

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

The predicted octave band levels from each turbine (or other noise source) are summed together to give the overall 'A' weighted predicted sound level.

1.1.1 L_W – Source Sound Power Level

The sound power level of a noise source is normally expressed in dB re: 1pW. Noise predictions are based on the overall broadband sound power levels detailed in the noise chapter at table 9-2.

The octave band noise spectra used for the wind turbine noise predictions have been taken from the technical specifications of the candidate turbine with the details also shown in the noise chapter at table 9-2.

Octave band noise spectra used for the Battery Energy Storage System BESS facility noise predictions have been taken from technical reports/datasheets for the candidate electrical plant and are shown at Table 9-2-2 below.

Octave band noise spectra used for the construction noise predictions have been taken from BS5228-1:2009 +A1:2019and are shown at Table 9-2-4 below.

1.1.2 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 the case of wind turbines, 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.

Sound power levels for other noise sources used in predictions for the BS 4142 and BS5228 assessments are considered to be representative of worst-case directions and no directivity patterns have been used for these noise sources.

1.1.3 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 source.

Wind turbines may be considered as a point source beyond distances corresponding to one rotor diameter.

All noise sources considered in the predictions for the BS 4142 and BS5228 assessments have also been modelled as point sources.

1.1.4 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 corresponding to a temperature of 10°C 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 conservative noise predictions, as given below.

Table 9-2-1: Frequency dependent atmospheric absorption coefficients

Temperature/Humidity	Octave band centre frequency (Hz) Atmospheric Absorption Coefficient (dB/m)							
	63	125	250	500	1000	2000	4000	8000
10°/70%	0.000122	0.000411	0.00104	0.00193	0.0037	0.00966	0.0328	0.117

The same assumptions about temperature, humidity and the corresponding atmospheric absorption coefficients have also been used for the predictions used in the BS 4142 and BS5228 assessments.

1.1.5 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.

Receiver heights of 4m and a ground factor of G = 0.5 have also been used for the predictions used in the BS 4142 and BS5228 assessments.

1.1.6 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 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.

For the purposes of the BS 4142 and BS 5228 assessments, no topography has been included and no barriers have been included in the design. This effect has therefore not been considered here and this represents a conservative approach.

1.1.7 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 Concave Ground Profile

Although not necessarily specific to wind turbines, research has indicated that concave ground profiles can reduce ground effects and provide additional reflection paths for sound between wind turbines and receptors. This effect is not specifically accounted for as part of the ISO 9613 methodology and is only considered in relation to predictions of wind turbine noise.

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:

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

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.

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.

No significant concave ground profiles exist between the swarclett turbines and any of the nearest receptors and, accordingly, no corrections have been added.

3 BESS Facility Noise Predictions

The sound sources throughout these predictions are modelled as point sources which is an appropriate assumption when separation distances between sources and receivers are large. The final models of electrical plant may vary, but the following has been assumed for the noise model:

- Three Trina Elementa liquid cooled battery energy storage containers;
- Three Power Electronics Freemaq PCSK GEN3 power control system (PCS) units
- Three 5.0 MW Transformers.

No other equipment or buildings on the site are expected to make any noise or provide any significant attenuation to the propagation of environmental noise and so have not been modelled.

3.1 Battery Energy Storage Unit

A measurement report provided by the manufacturers of the Battery Energy Storage units (Trina Energy Storage Co. Ltd.), states measured sound pressure levels at various locations and distances from the unit, and these have been used to derive sound power levels for the units.

The data is assumed to be A-weighted although it is not specifically stated and therefore this is a conservative assumption. The highest sound pressure level measurement at a distance of 1 m corresponds to a sound power level of 85.2 dBA. A noise spectrum was not provided so a suitable spectrum has been taken from Hayes McKenzie's database for a Siemens Fluence Liquid Cooler and normalised to 85.2 dBA. The noise spectrum is considered suitable since the Trina units are liquid cooled and likely to have similar acoustic profile to the Siemens unit. Sound is assumed to propagate from these units as a point source at a height of 2 m.

3.2 4 MW PCS Inverter Unit

The candidate Power Control System (PCS) unit is a Power Electronics Freemaq PCSK GEN3 inverter. The manufacturer has provided test sound level measurements for the inverter unit fitted with a noise reduction kit and operating at 70% fan speed, which is expected to be worst-case.

The measurement report provides measured levels and calculated sound power levels in third octave bands resulting in a total sound power level of 91.2 dB L_{WA}. Sound is assumed to propagate from these units as a point source at a height of 0.8 m (in line with the top of the noise attenuator exhaust grill).

3.3 5 MW Solar Transformer

Data from Siemens, for their GEAFOL cast-resin transformers (that are known to be suitable for installation at solar farms) indicates a sound power level of 76 dB L_{WA} for a 5 MW transformer. A noise spectrum was not provided so a suitable spectrum has been taken from Hayes McKenzie's database and normalised to 76.0 dBA. These plant items are assumed to propagate sound as a point source from a height of 2 m.

3.4 Sound Power levels

Table 9-2-2 shows the octave band spectra used in the BESS facility noise predictions.

Table 9-2-2: Normalised noise spectra, dB L_{WA}

Unit	Octave band centre frequency (Hz)								Total
	63	125	250	500	1000	2000	4000	8000	
Battery Energy Storage Unit	64.0	81.1	78.6	78.0	76.2	72.4	63.2	49.1	85.2
PCS Inverter Unit	53.8	73.9	78.4	86.8	82.0	92.5	64.0	58.1	94.0
5 MW Transformer	37.8	58.4	60.1	75.8	55.3	40.6	39.6	-	76.0

4 Construction Noise Predictions

In carrying out the predictions it has been assumed that all plant involved with track construction is located at the nearest possible point to the closest property (Durran Mains). It should be noted that this is unlikely to occur in practice, for any length of time but gives very much worst case noise levels which cannot be expected to be exceeded. The plant assumed for each activity is shown in Table 9-2-3.

Table 9-2-3: Assumed Plant and Number

Location/Activity	Plant List	No. of Items
Quasi Static Track Construction	Dozer	1
	Wheeled Backhoe Loader	1
	Dump Truck	1
	Tracked Excavator 27kW	1
	Road Roller	1

Predictions have been carried out following the ISO 9613-2 methodology described above which is in line with methodology set out in BS 5228-1:2009 +A1:2019. Octave band sound power data for each of these items of plant has been taken from BS 5228-1:2009 +A1:2019 and these details are supplied at Table 9-2-4 below.

Table 9-2-4: Assumed Plant Noise Levels

Plant List	Table Ref (from BS 5228:2009)	Ref. no	Octave Band Sound Pressure Levels (Hz)								A-weighted sound power level, dB LWA
			63	125	250	500	1k	2k	4k	8k	
Dozer	C.5	12	108	106	99	98	102	96	93	89	104.7
Dump Truck	C.9	16	114	117	116	116	114	111	104	98	118.5
Road Roller	C5	19	115	113	103	101	103	101	97	91	107.7
Tracked Excavator 27kW	C.5	35	110	100	99	97	97	98	89	82	102.7
Wheeled Backhoe Loader	C.2	8	102	94	92	92	91	88	87	78	95.9

5 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 (1992). 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 (1996). ISO 9613-2, Acoustics - Attenuation of Sound During Propagation Outdoors, Part 2: General Method of Calculation.

British Standards Institute (BSI) (2009 + 2014), BS 5228 + A1, Code of Practice for Noise and Vibration Control on Construction and Open Sites.