Project 318848 Zephyr Haramsoya

Wind Turbine noise emission measurement

Client information

Zephyr AS
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1. Summary

Acoustic noise measurements have been performed, in accordance with standard IEC 61400-11, Edition 3.0, for one wind turbine in island Haramsoya (Ålesund Municipality) Norway, located by west coast Norway.

The measurements and evaluations were made according to the international standard IEC 61400-11, Edition 3.0, “Wind turbines – Part 11: Acoustic noise measurement techniques”. Wind speed during all sound measurements was measured with a weather station @ 10 m height.

The measured wind turbine is type Vestas V136-4.2. The nacelle height is 82 meters, and the rotor diameter is 136 meters. Wind turbine locations of Haram are shown in Figure 1.

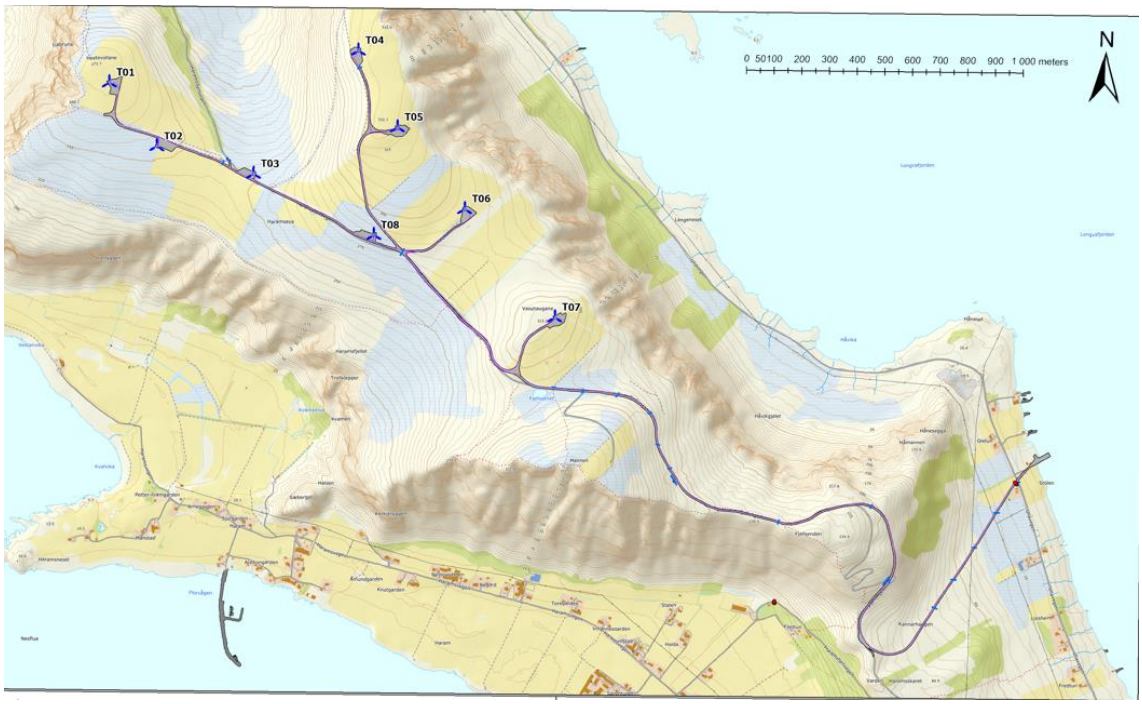

Figure 1. Location and numbering of Haramsoya wind turbines. Measurements was carried out for the wind turbine T07.

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Based on the conducted emission measurements, sound power levels at average integer wind speed from 8 to 13 m/s at hub height were determined for the wind turbine.

Table 1. Resulting sound power levels for wind turbine T07. Please also review the comments below the table.

Wind speed bin center @hub height [m/s]	Measured L_{WA} [dB]	Uncertainty u_{LWA} [dB]
8	97,3	0,9
8,5	98,0	0,6
9	100,7	0,9
9,5	100,5	0,7
10	100,6	0,9
10,5	100,4	0,9
11	100,5	0,9
11,5	100,2	1,1
12	99,5	1,4
12,5	98,8	1,0
13	99,2	0,9

2. Results

Results and detailed information regarding the measurements of wind turbine T07 are presented in appendix 1.

2.1. Deviations from the measurement standard

The microphone location and measurements plate had to be changed due the changes in wind direction during the measurement period. The distance between individual measurement locations were about 5–50 meters. The distance to the wind turbine nacelle was measured in all measurement locations. Background noise was measured for all measurement locations.

The weather conditions changed quickly during the measurement period at about 14:31–14:32. The wind speed at the hub height raised from the under 8 m/s to over 13 m/s during 2-minute period. Even though this sudden change we managed to get sufficient measurement data for all wind speed bins except wind speed bin 12,5 m/s (9 measurement data points). Amount of background noise data doesn't fulfill the demands of the standard. At least 10 data points are needed for total noise and background noise.

During the measurement, background noise levels were low and background noise was weakly correlated with the wind speed (there's no trees or other significant background noise sources on the island). When background noise levels are clearly lower than total noise levels, total noise is almost totally caused by the wind turbine and the background noise correction doesn't change the result. Thus, we can state that measured background noise data is enough for reliable results and conclusions.

Table 2. Amount of 10 second measurement data points in total and background noise.

Wind speed bin [m/s]										
8	**8,5**	**9**	**9,5**	**10**	**10,5**	**11**	**11,5**	**12**	**12,5**	**13**
Amount of 10 second measurement data points in total noise										
22	22	52	27	10	10	13	11	10	9(1	13
Amount of 10 second measurement data points in background noise										
9(1	5(1	6(1	6(1	4(1	1(1	3(1	2(1	3(1	3(1	5(1

(1Not enough measurement data according to standard

2.2. Comparison of sound power levels

The measured sound power levels on wind speeds 8–13 m/s were 2,3–4,7 dB lower than the values stated in the performance specification of the wind turbine (table 3). The calculated uncertainty of measured total sound power level varies between ± 0,6…1,4 dB. When calculated uncertainty is considered, measured values are still less than stated in the performance specifications.

Table 3. Measured sound power levels for wind speed bins (@ 10 m) and comparison to performance specification of V136-4.0/4.2, Power Optimized Mode PO1/PO1-0S (HWO) data sheet.

Hub height wind speed	8 m/s	9 m/s	10 m/s	11 m/s	12 m/s	13 m/s
Measured L_{WA} [dB]	97,3	98,0	100,5	100,5	98,5	99,2
Uncertainty u_{LWA} [dB]	0,9	0,9	0,9	0,9	1,4	0,9
Performance specification L_{WA} [dB]	102,8	103,9	103,9	103,9	103,9	103,9

2.3. Tonality

Tonality analysis was made for whole measurement time when the wind turbine was operating. Tonality analysis is made with using A-weighting. All the tones with tonal audibility more than -3 dB are reported (table 4). FFT-spectra are analyzed with a resolution of 1–2 Hz.

Table 4. Results of the tonality analysis

Time period	Tonal audibility [dB]	Frequency [Hz]
12:18–12:53	0,87 dB	110 Hz
12:53–13:29	4,5 dB	112 Hz
13:44–14:28	1,9 dB	118 Hz
14:34–14:44	-	-
15:07–15:50	-	-

16:44–17:34	-	-
17:55–18:14	-	-

Noise from the wind turbine 7 was found to be tonal. The measurements are made relatively close (< 200 m) to the wind turbine and the tonality is not directly applicable at longer distances (> 1000 m).

2.4. Uncertainty

The uncertainties in table 3 (u_{LWA}) are given as combined standard uncertainties (u_B) in the table 5 and uncertainties calculated on the distribution of the measurement data (u_A).

Table 5. Evaluated type B uncertainties.

Component	Standard uncertainty [dB]
Calibration, u_{B1}	0,2
Board, u_{B3}	0,3
Wind screen insertion loss, u_{B4}	0,1
Distance and direction, u_{B5}	0,5
Weather conditions, u_{B7}	0,2
Wind speed measured [a], u_{B8}	0,2
Wind speed derived [b], u_{B8}	0,7
Wind speed, power curve, u_{B9}	0,2
[a] Through nacelle anemometer or met mast [b] Through power curve	

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Appendix

1) Additional information
2) Secondary windscreen specification

Wind turbine information

Table 1-1: Wind turbine data.

Manufacturer	Type	Power [kW]	Hub height [m]	Rotor diameter [m]
Vestas	V136-4.2	4200	82	136

Environment

Table 1-2:Measurement environment.

Roughness class	Nearby reflecting areas	Background noise
0,05 (Farmland with some vegetation)	None	Low levels from vegetation

Instruments

Table 1-3: Instruments used during measurements.

Type	Brand	Model	Serial number
Sound level meter	Norsonic	140	1403922
Weather station	Kestrel	5500	2587518

Note. The equipment used at the measurements was calibrated according to standard. The sound level meter meets the requirements for measurement devices “Class 1” according to IEC 61672.

Background noise measurement

According to the measurement standard, the wind mast shall be placed in the location that represents best the wind situation at the turbine position. The figure below shows approved positions (shaded) for wind mast placement.

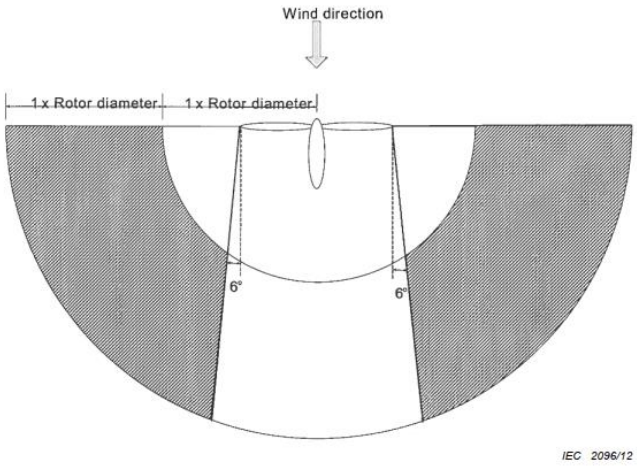


Table 1-4: Wind mast position.

Position	Standard	Height [m]
200 m Southwest	Yes	10

Table 1-5: Weather data.

Relative humidity [%]	Pressure [hPa]	Temperature [°C]
83–95	1001–1004	9–14

Emission measurement

Emission measurements were performed in “Reference position 1” at horizontal distance R_0 (tower height + rotor radius) with tolerance of ± 30 m.

The measurement position meets the conditions for a “+6 dB-position”, which means that the measured values were reduces with 6 dB to correct for the sound reflection from the board. Measurement values were also fixed for the insertion loss of the used secondary windscreen (appendix 2).

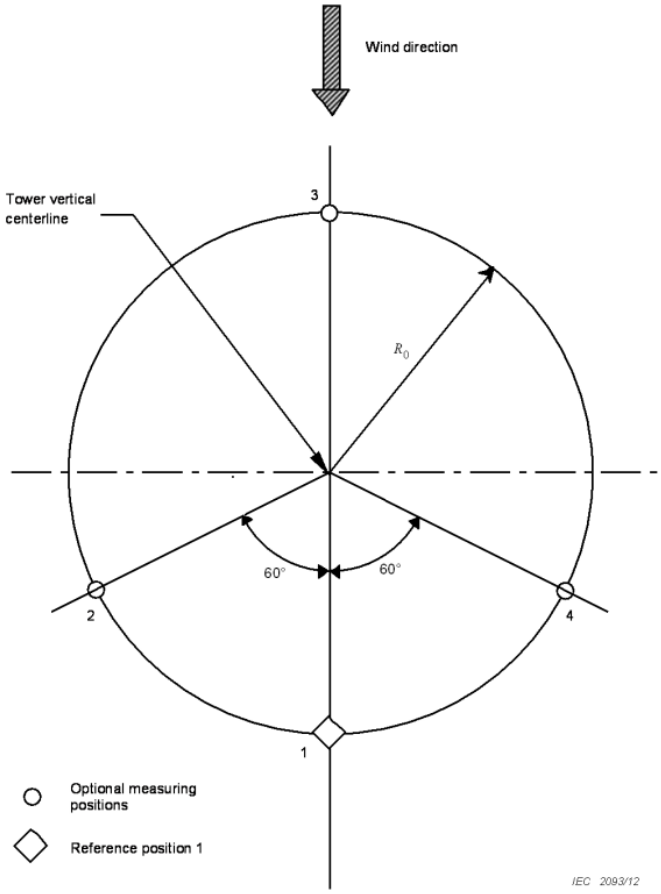


Figure 1-1: Measurement position R_0

Measurement photos

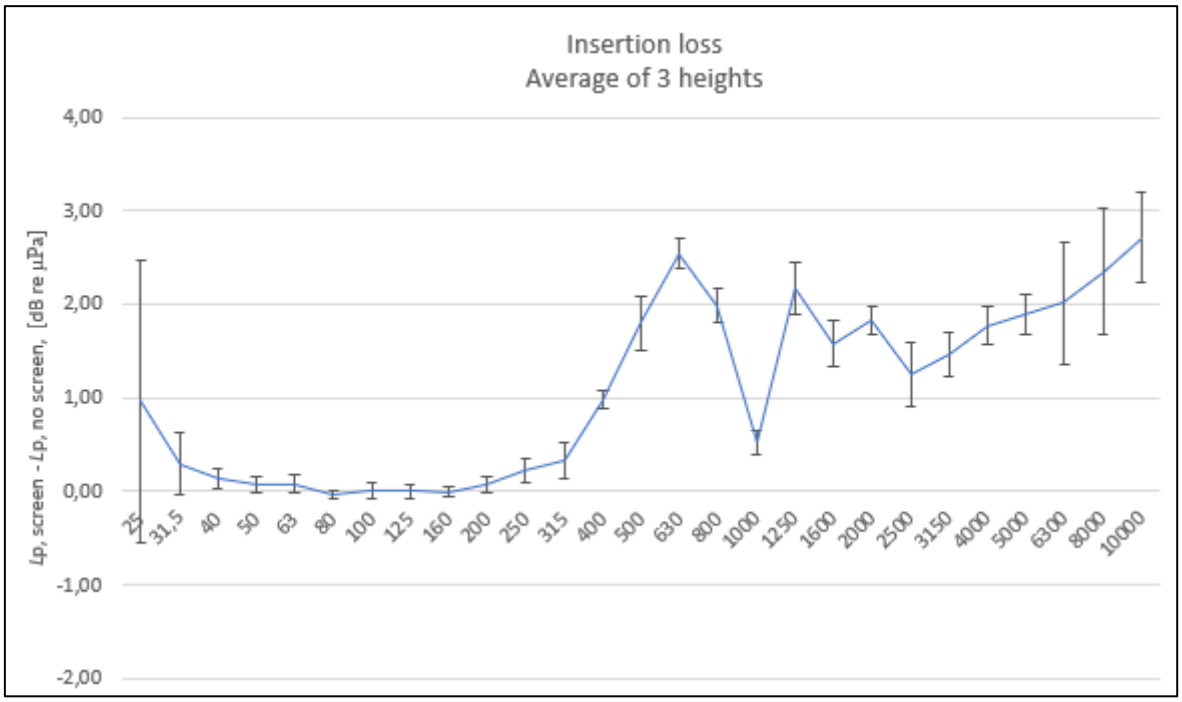
Figure 1-2: Wind turbine T07 and sound lever meter with measurement board and secondary windscreen.

Figure 1-3: Wind turbine T07 and the 10 m tall weather mast

Insertion loss of the secondary windscreen in 1/3-octave bands

(Insertion loss of the frequency 125 Hz is used to the octave bands 20 Hz, 25 Hz and 31,5 Hz)

1/3-octave band [Hz]	Insertion loss [dB]	Standard deviation [dB]
20	0	0,1
25	0	0,1
31,5	0	0,1
40	0,1	0,1
50	0,1	0,1
63	0,1	0,1
80	0	0,1
100	0	0,1
125	0	0,1
160	0	0,1
200	0,1	0,1
250	0,2	0,1
315	0,3	0,2
400	1,0	0,1
500	1,8	0,3
630	2,5	0,2
800	2,0	0,2
1000	0,5	0,1
1250	2,2	0,3
1600	1,6	0,3
2000	1,8	0,2
2500	1,3	0,3
3150	1,5	0,2
4000	1,8	0,2
5000	1,9	0,2
6300	2,0	0,6
8000	2,4	0,7
10 000	2,7	0,5


Insertion loss
Average of 3 heights
4,00
3,00
2,00
1,00
0,00
-1,00
-2,00
Lp, screen - Lp, no screen, [dB re µPa]
25
31,5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000