Wind turbine noise emission.
Wind speed measurents below hub hight give poor accuracy

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Abstract

When determining the noise emission from a wind turbine the sound pressure level is measured at a certain distance simultaneously with the wind. The sound pressure level is plotted versus the wind speed and the reference sound power level is determined from the value at 8 m/s. According to current measurement standards the wind speed can be measured in front of the turbine at a height of 10 m.

This paper shows a case were wind speed measurements below hub height would have caused large errors. The correlation between the wind speed at 10 m and the sound level was very poor and a deviating wind profile caused large systematic errors. It is strongly recommended that wind speed measurements are carried out at hub height or determined from the wind-power curve of the turbine.

1 Measurement methods

A method for determining the sound power level from a wind turbine has been schematically described by the Danish Ministry of Environment [1]. It states that the sound pressure level should be measured on the ground at a distance of 1 - 2 times the hub height in the downwind direction, see figure a. The wind speed should be measured simultaneously at a height of 10 m. The sound pressure level at 8 m/s is determined from the data pairs by means of linear regression. The reference sound power level is calculated from the sound level and the distance between the microphone and the turbine hub.

In 1996 the International Energy Agency published a more elaborate method [2]. The principles are the same but the sound pressure level should be measured in four positions around the wind turbine. The measurements of wind speed can be carried out in three ways:

- from the electric output. If the wind-power curve has been determined it can be used to measure the wind speed. This is the preferred method.
- with an anemometer at hub height.
- with an anemometer at a height of 10 m

The measured wind speed is corrected to reference conditions at 10 m assuming a logarithmic wind profile and a roughness length of the ground of 0,05 m.

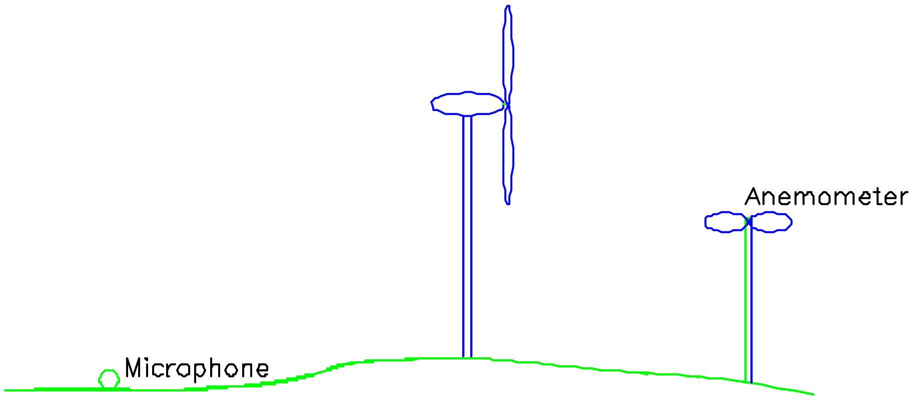

Figure A The sound pressure level is measured on the ground in the downwind direction and the wind speed is measured in the upwind direction at 10 m height.

2 Measurements at Näsudden

In spring 1997 we made noise emission measurements on the new wind turbine prototype NWP 1000 at Näsudden, Gotland [3]. Our measurements followed the IEA recommendations. No wind-power curve was available and the turbine was 58 m high so it was decided to measure the wind speed at 10 m. However, it turned out that a meteorological mast had been raised in front of the turbine. A main purpose was to determine the wind-power curve.

Thus we had access to the wind speed at 10 m from our own measurements and at 32 and 58 m (hub height) from the meteorological mast.

The measurements were made at daytime 11.15 - 12.40 and at night 21.20 - 22.20 when the wind had increased.

The measurement results are shown in Figure 2 and Figure 3. Measurements made at daytime and night-time are separated. The wind speed has been corrected to reference conditions.

The results from wind measurements at 10 m (Figure 2) show poor correlation between sound level and wind speed. Also, there are systematic differences between day and night.

The results from wind measurements at 58 m (Figure 3) show very good correlation and good agreement between day and night.

The determined sound levels at 8 m/s is given in Table 1 for the different sets of data. It is shown that the wind measurements at 10 m give a difference of 5 dB(A) between day and night.

This spread can be explained by the wind profile in Figure 4. The wind profile has changed drastically during the evening. When the wind speed at hub height has increased from 8 to 13 m/s it has stayed almost constant at 10 m. An even larger spread could be expected if we had made measurements at 17.00 when the wind profile was extremely even.

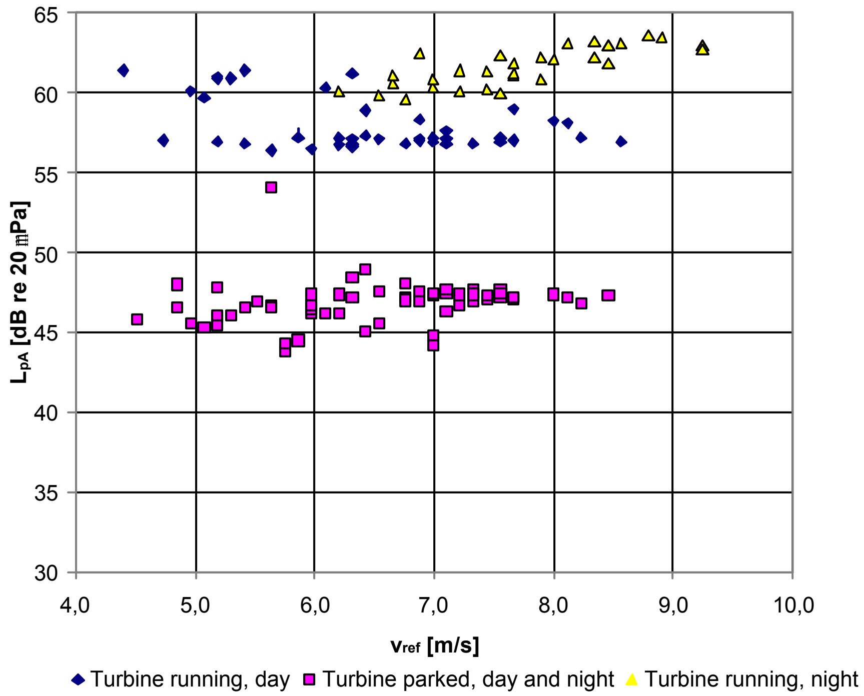

Figure B Sound level versus wind speed at reference conditions, measured at a height of 10 m

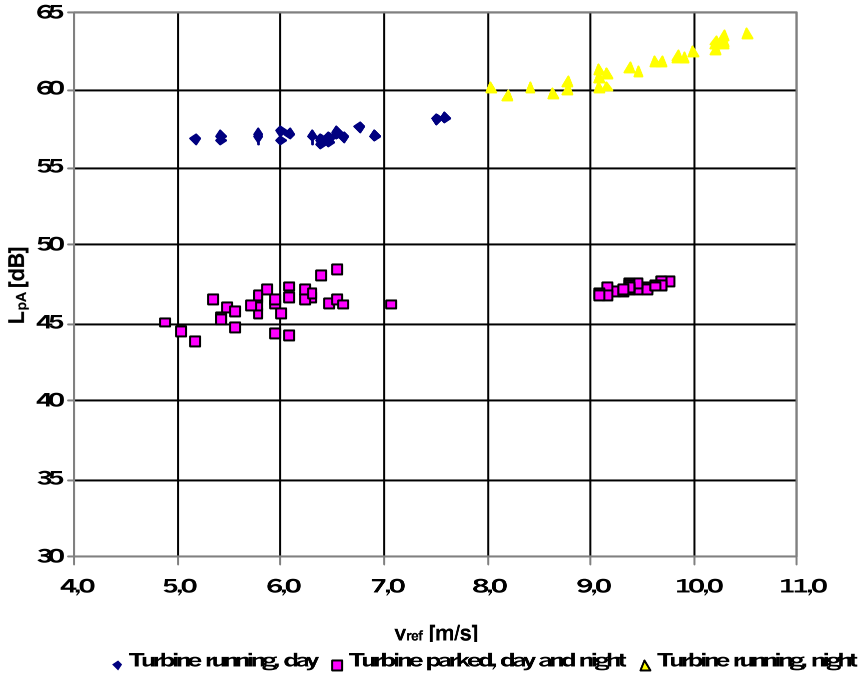

Figure C Sound level versus wind speed at reference conditions, measured at hub height, 58 m.

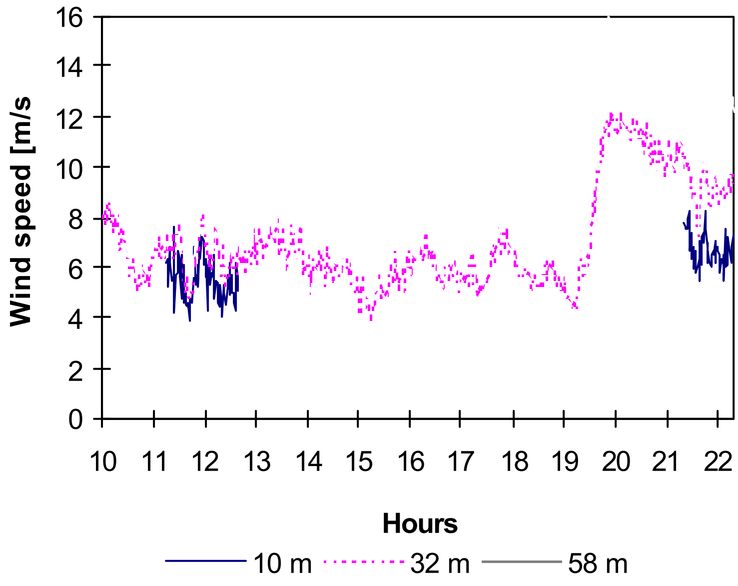

Figure D Measured wind speed at three different heights during the day.

Table A Determined sound level at 8 m/s using different sets of measurement data.

Wind measurement	L_{pA} at 8 m/s	Correlation coefficient
10 m, day	57 dB(A)	0,33
10 m, night	62 dB(A)	0,47
58 m	59 dB(A)	0,96

3 Conclusions

Our measurements show that wind speed measurements at 10 m, which is demanded in the Danish method and allowed in the IEA method, give poor correlation between wind speed and sound level. Also a the wind profile can cause large systematic errors, probably ± 3 dB or more. The systematic errors are not possible to detect. It is strongly recommended that the wind speed should always be measured at hub height or obtained from the produced power.

4 References

1. Danish Ministry of Environment (1991) *“Bekjentgørelse nr 304. om støy fra vindmøller”*
2. International Energy Agency, (1994) *“Recommended Practices for wind Turbine Testing. 4. Acoustics. Measurements of Noise Emission from Wind Turbines” 3. Edition*.
3. Vattenfall Utveckling AB (1998) *”Nordic 1000. Utvecklingen av ett vindkraftverk enligt den svenska linjen.”*