ICSV13 - Vienna
The Thirteenth International Congress on Sound and Vibration
Vienna, Austria, July 2-6, 2006

NOISE FROM WIND TURBINES AND COMPARISON WITH STANDARDS

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Abstract

Australia has recently produced a Draft Standard, "Acoustics – Measurement, prediction and assessment of noise and wind turbine generators" [1]. It has similarities to the various Standards developed mainly in European countries. There is some uncertainty about whether potentially different environmental and topological conditions could affect the predicted and measured noise levels in country areas of Australia. Thus acoustic and meteorological measurements were carried out and recorded on a recently established wind farm in Victoria. The measurements were made over a period of 2 weeks and included statistical parameters, (such as L_{A10}, L_{A90}, and L_{Aeq}), spectral information, as well as wind speed and direction. Class I, II and III methods for noise predictions were investigated. A wide scatter of results was obtained, but the general trends were clear and indicated that the measured levels were slightly below those expected based on the manufacturer's guaranteed values. Tonal components were relatively small. The proposed Standard, which uses the Class 1 method (based on the manufacturer's data), appears to be a reasonable and acceptable approach for predicting the noise levels from these wind turbine generators.

INTRODUCTION

Currently 90% of Victoria's energy demands are met through the use of coal fired plants. The emissions account for up to 50% of the greenhouse gases. It is predicted that by 2010 the demand for energy will increase by 15% and consequently there is an increasing interest in viable renewable energy sources. Victoria has several on-shore wind farms including the recently completed one used for this study, namely that at Challicum Hills near Ararat in country Victoria. It contains 35 wind turbines on private farming land, and each turbine can produce up to 1.5MW. An important environmental issue is that of noise and the nuisance it causes to residential areas in the vicinity. There is a considerable body of data already available regarding wind turbine and wind farm noise, e.g. [2] – [12] but the Australian Draft Standard, noted above, has recently been produced and the present study was used as a basis for evaluating the approaches presented there. (It is interesting to note in passing that another wind farm, proposed for the Gippsland area of Victoria, was recently blocked by the Federal Government although it had been approved by the State Government. This rejection apparently was on the basis that the wind farm proposed a threat to an endangered bird species, the orange-bellied parrot. It was estimated that one bird a year could be killed by the wind farm. Noise seemed to be less of an issue?)

The study found that the prediction methods of the Draft Standard were generally appropriate and that the measured values, although they contained some reasonable scatter, were slightly below those expected on the basis of the Draft Standard.

DATA COLLECTION

Measurements were made at distances of 100 m and 200 m from a turbine which was on the boundary of the wind farm. Measurement positions, in accordance to the Draft Standard, and with the International Standard [6], were chosen as shown in Figure 1. The closest turbines to the one used for the main measurements were at distances of approximately 600 to 700 m from this measurement position and probably had little effect on the measured values. Other noise sources, (apart from environmental ones due e.g. to rustling of leaves and grass etc.), included minimal road traffic noise, and possibly some farming noise. The latter sources were found to be negligible over the 2 week period used to collect the data.

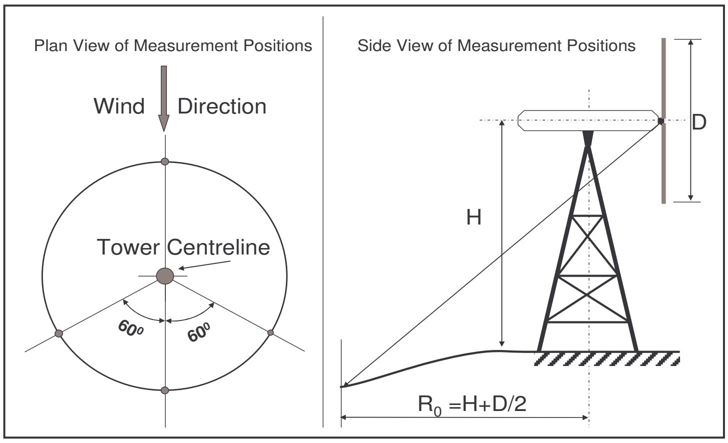

Figure 1. Details of the measurement positions

The acoustic data collected, at the 3 microphone positions, (2 at 100 m and 1 at 200 m) included L_{Amin}, L_{Amax}, L_{A10}, L_{A50}, L_{A90}, L_{Aeq}. One-third octave band measurements were also taken over a shorter period of time. The meteorological measurements included wind speed, wind direction, pressure, temperature and humidity.

EXPERIMENTAL RESULTS

Initially the parameters, L_{Aeq}, L_{A90}, L_{A50}, and L_{A10}, measured over the two week period were plotted at 10 minute intervals at each of the measurement positions. The results for the A weighted energy equivalent noise levels are given in Figure 2.

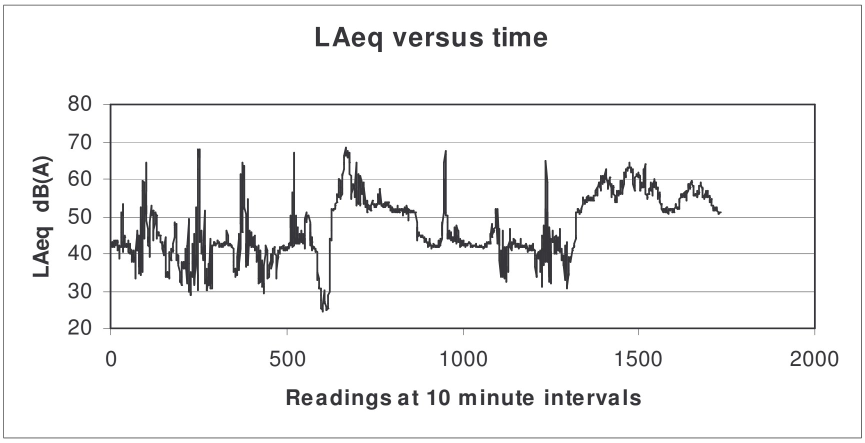

Figure 2. Variation of noise levels (at 100 m) with time

It was immediately obvious that the noise levels varied significantly with time although there was apparently little periodicity associated with it. However detailed checking on a daily basis suggested slightly higher noise levels during some of the days when compared with the corresponding noise levels at night.

To check if the various noise parameters were related to wind speed, the wind speeds were similarly plotted at 10 minute intervals as shown in Figure 3.

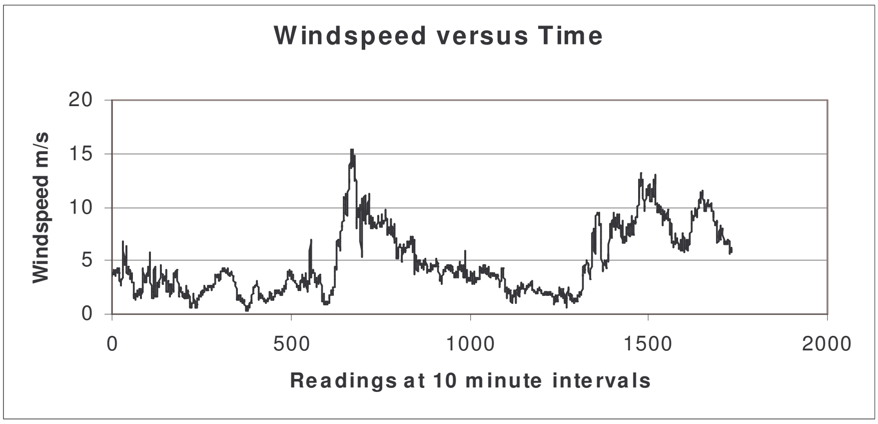

Figure 3 Variation of wind speeds (at 100 m) with time

An inspections of these two graphs indicated that the acoustic parameters seemed to be generally related to the wind speed although there was some significant variation. This variation in noise levels with wind speed was evaluated by plotting the acoustic data as a function of the wind speed. Some typical results, for L_{Aeq} and L_{A90} are given in Figures 4 and 5 below.

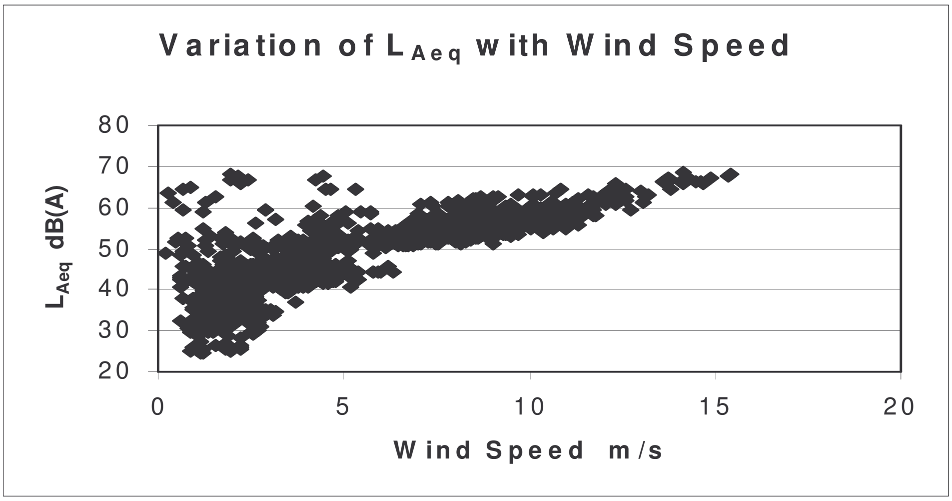

Figure 4. Noise levels (at 100 m) with wind speed.

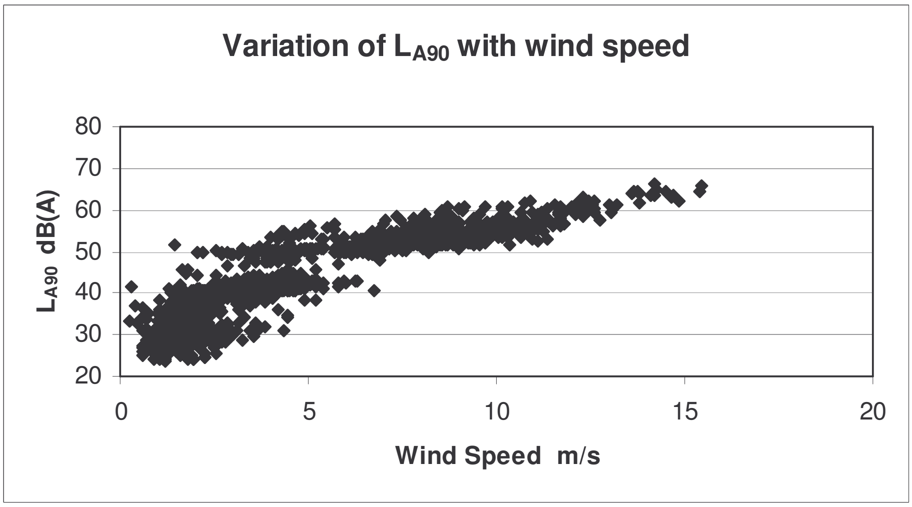

Figure 5. Background noise levels (at 100 m) with wind speed

There is an obvious general trend of increasing noise levels with increasing wind speeds. It is clear also that low noise levels were only associated with low wind speeds, although a low wind speed by itself did not guarantee a low noise level. The background noise levels of Figure 5 showed less scatter than did the Energy Equivalent Noise level, L_{Aeq}, of Figure 4, as might be reasonably expected.

The wind turbines were designed to always face the wind and thus produce maximum power. It was no surprise therefore that the noise levels were effectively independent of wind direction as shown in Figure 6.

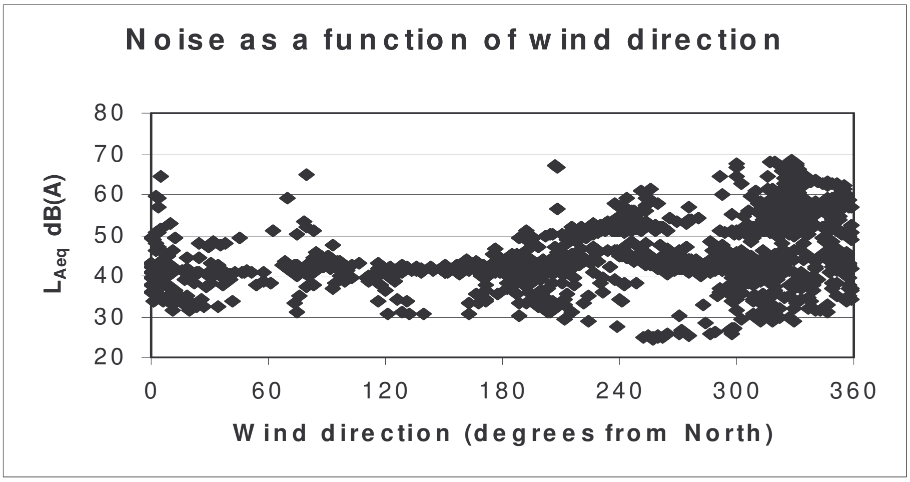

Figure 6. Effect of wind direction on noise levels (at 100 m)

Further detailed analysis of the variation in wind speed indicated that the wind speed was not uniform in all directions. Thus at the lower wind speeds – say less than about 3 m/s - the direction was fairly randomly distributed through 360^o. At the higher wind speeds – say above 8 m/s – there was a trend for the wind to be blowing from the north or north westerly direction. This simply reflected the pattern of air movement in that part of Australia.

Spectral analyses were also carried out to determine if there were any significant tones present in the wind turbine noise, since it has been well established that noise containing tones is considered to be more annoying than board band noise. The various Standards, including the Draft Australian Standard, apply a penalty of 5 dB if such tones are present. Some typical results, based on the 1/3rd octave band spectra are given in Figure 7. The background noise, determined by using L_{90dBA}, was essentially void of any tones. There was some indication of tones present in the plot of L_{Aeq}, (and also in the plot of L_{10} which is not presented here). Careful listening revealed a high pitched tone, from time to time, which was probably associated with one of the blades. The source of this tone could not be positively identified, but the origin of the sound seemed to be aerodynamic rather than mechanical.

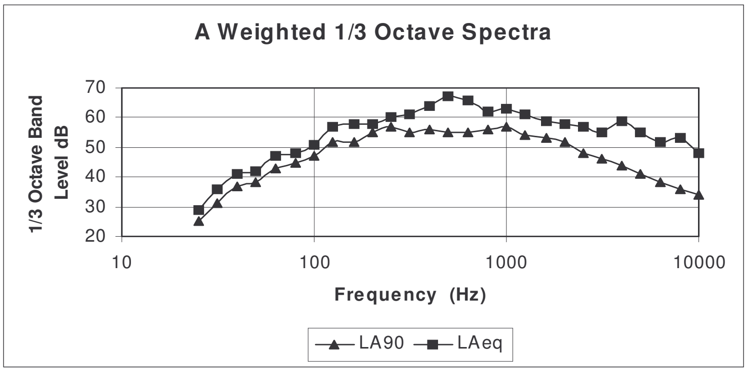

Figure 7. Spectral details of the noise levels

PREDICTION OF NOISE LEVELS

The various Standards have a variety of methods for predicting sound pressure levels from Wind Turbines. They are essentially divided into 3 general approaches, namely Class I, Class II, and Class III, [7]. Within some of these methods a number of different techniques can be used as outlined below.

Class I Methods

The Class I method is the simplest and assumes a hemispherical propagation of sound from the turbine, but includes as well a factor to account for the attenuation of sound within the atmosphere. The equation for sound pressure level, SPL, takes the form:

$$SPL = L_w - 10 \, Log_{10} \, (2 \, \pi \, R^2) - \alpha R, \qquad (1)$$

where L_w = the sound power of the source, dB(A),
R = distance from the observer to the hub,
α = an absorption coefficient, dB/m, (usually taken as 0.005 dB/m).

The sound power level of the source may be provided by the Manufacturer or be determined empirically from parameters such as the electrical power output of the turbine, (method 1), or the rotor diameter, (method 2), or a combination of tip speed and rotor diameter, (method 3). In the latter 2 methods the sound pressure levels will be constant at a given distance since the diameter is fixed, and the tip speed is essentially constant. The Draft Standard proposes the method based on the data provided by the manufacturer.

Class II Methods

These methods are based on the consideration of the various mechanisms causing wind turbine noise, using selected wind turbine parameters. The contributing factors are the inflow turbulence noise, the noise from the interaction of the turbulent boundary layer and the blade trailing edge, and the noise from vortex shedding at the trailing edge. Of these, the first was found to be the most significant for this study. It depended on parameters such as the number of blades, the air density, and the rotor blade chord at 0.7 m, the outer rotor radius, the wind turbulence, the speed of sound, and a frequency dependent scaling factor.

Class III Methods

This method includes all of the above parameters of Class II but includes as well such factors as type of tower, upwind/downwind orientation, turbulence intensity spectra, atmospheric stability conditions, wind direction etc. This method could not be applied in the present case due both to the lack of detail (such as atmospheric turbulence, surface roughness) as well as the need for sophisticated computational fluid dynamics software.

The following Table summarises the results for Class I and II methods and compares the results with the measured data at 100 m for a number of wind speeds.

Table 1. Comparisons of Measured and Predicted Sound Pressure Levels

Wind Speed m/s	Measured Values dB(A)	**Class I**				**Class II**
		Manufacturers Data	Method 1	Method 2	Method 3	
4	42.0	49	45	61	52	44
5	43.5	50	49	61	52	48
6	46.5	50	52	61	52	51
7	48.5	50	54	61	52	53
8	52.0	52	56	61	52	56
9	53.0	54	58	61	52	58
10	54.5	54	59	61	52	60

It was clear from this Table that the Class I method using the Manufacturer's data gave reasonable values although at low wind speeds it overestimated the levels somewhat. Method 1 of Class I was also reasonable although it overestimated the levels at the higher wind speeds. Methods 2 and 3 gave constant values and were doubtful for that reason. The Class II method also gave reasonable estimates although the values were a little high at the higher wind speeds.

SUMMARY

Measurements of noise levels and meteorological properties have been carried out on a recently constructed wind farm located in country Victoria. The noise levels varied significantly during the 2 week period and there was some indication that they did increase a little during the daylight hours. However there was a clear connection between wind speed and noise levels even though there was significant scatter. Low noise levels only occurred at low wind speeds. (Interestingly this could give rise to greater awareness of wind farm noise since the ambient noise due to rustling of trees etc would also decrease thus reducing its masking effect on the wind farm noise. This would be particularly the case if the lower wind speeds occurred at night.) However high noise levels did occur at times at low wind speeds, but they were much more prevalent at the higher wind speeds. The wind farm noise was relatively independent of wind direction, even though the higher wind speeds tended to occur from the north and the north-west.

A comparison of measured and predicted noise levels indicated that the simpler approach of the Class I method was essentially adequate in view of the large scatter of results that occurred in the measured values. The method based on the manufacturer's data was found to be reasonably reliable.

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