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Wind Turbine Noise Measurements in Chile

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ABSTRACT

Wind turbine noise is one of the most important environmental issues when wind farms are operating. Rural communities can be affected due to the noise impact, particularly during night-time when the background noise levels are lower. On the other hand, the wind industry in Chile is growing fast. Renewable energy today represents 19% of the total electrical capacity in the national systems, and wind energy contributes 6% to this value. According to the energy national policy it is expected that by 2050 renewable energy will represent at least 70% of the total electrical capacity, which will require a significant increase in of wind energy in the country. This implies that more wind farms will be built in Chile and possibly, a greater number of people will be affected by the noise. Within the framework of a management strategy to address wind farms noise control, noise measurements have been made in Chile, identifying the variations presented by noise levels in relation to the measurement technique and acoustic descriptor. This paper presents a comparative analysis of these measurements.

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1 INTRODUCTION

Wind turbines and wind farms are a very complex noise sources to characterize. The variation on the configuration of each wind farm and the distance between the turbines influences the acoustic emission of the turbine. In addition, the radiation pattern of the turbine and its amplitude modulation characteristic produced by the rotational dynamics of the blades when interacting with the wind complicates the measurement of wind turbine noise[1-3].

There are different techniques to measure noise from wind turbines and wind farms. It is possible to measure the apparent sound power level of a particular wind turbine or the emission of an entire wind farm at a certain point of reference.

In order to evaluate the differences between noise measurement techniques, this work considers the characterization of the sound pressure levels of a particular wind farm and the apparent sound power levels of two models of wind turbines (two cases). The acoustic descriptors L(A)eq and L(A)90-10 minutes at a distance of 250 meters from the wind farm are used. In addition, a short comparison between the noise measurement of a wind turbine using the IEC 61400-11[4] (IEC) technique and a microphone phased array is performed.

2 WIND FARM NOISE MEASUREMENT

2.1 Methodology

To measure wind farm noise, a noise monitoring station was installed 250 meters away from the turbines. The microphone was located at 4 meter height over the ground with an ACO-PACIFIC WSX-80T1 windshield. Figure 1 shows the measure point. Figure 2 shows the noise monitoring station installed at the measurement point.

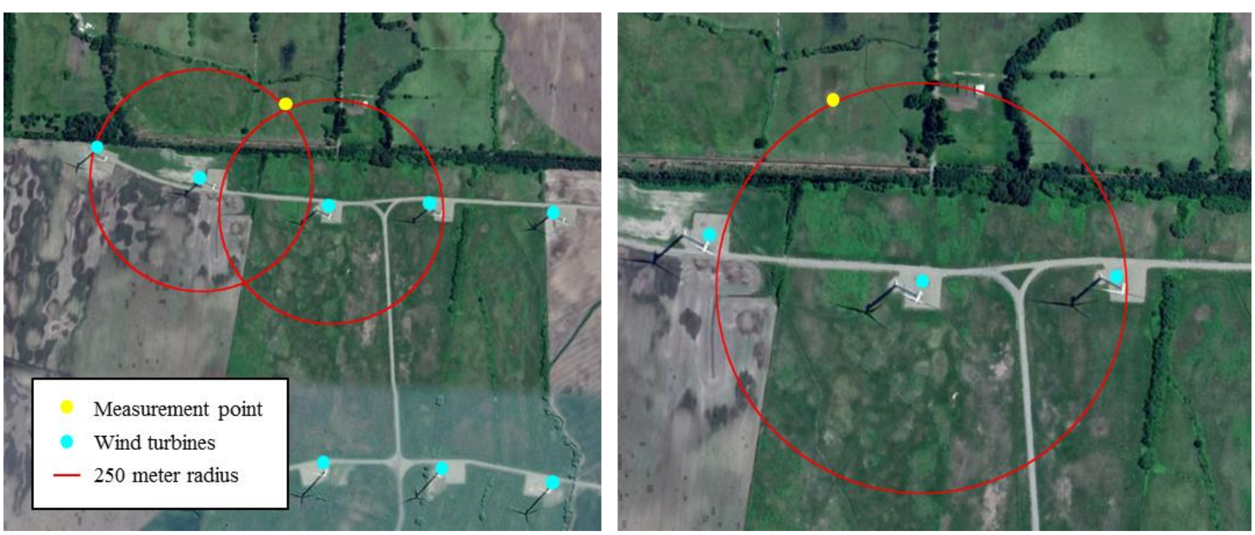

Fig. 1 – Representation of the measurement point

Fig. 2 – Noise monitoring station at the measurement point

The measurements were performed for 2 weeks, recording the L(A)eq-10 minutes and the L(A)90-10 minutes noise descriptors. Wind speed was recorded from the turbine sensor at hub. It was approximately in the same direction for the two weeks (downwind).

2.2 Results

Figures 3 and 4, shows the one-day data for the noise descriptors and the hub height wind speed variation. It is possible to appreciate the variation in the data to be louder during night, especially at low wind speeds (Figure 3) and more scattered during day.

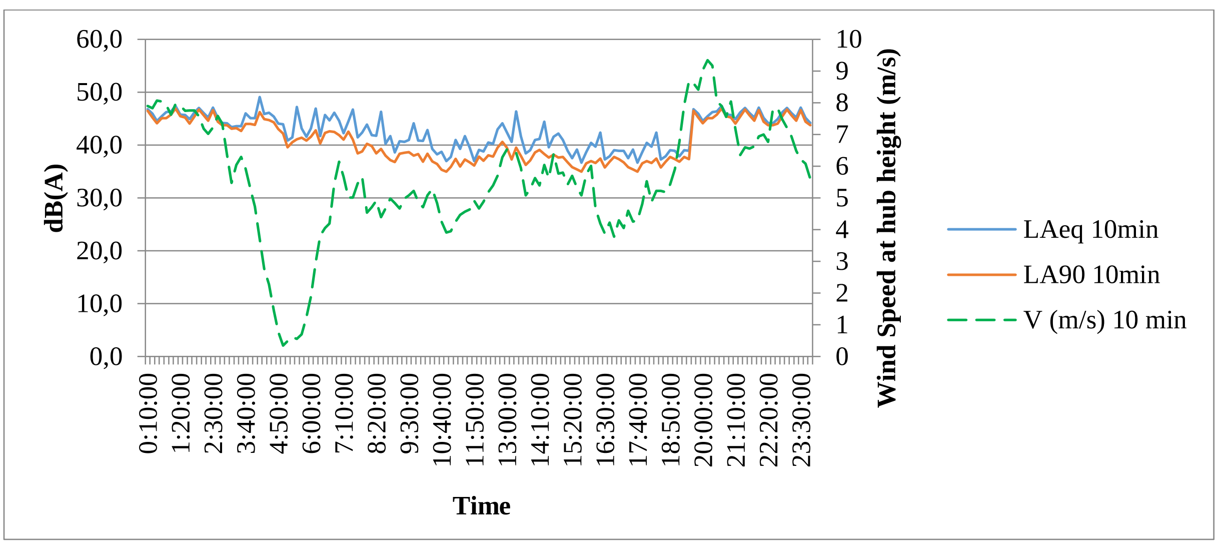

Fig. 3 – Day 11 of measured data for 10 minutes samples.

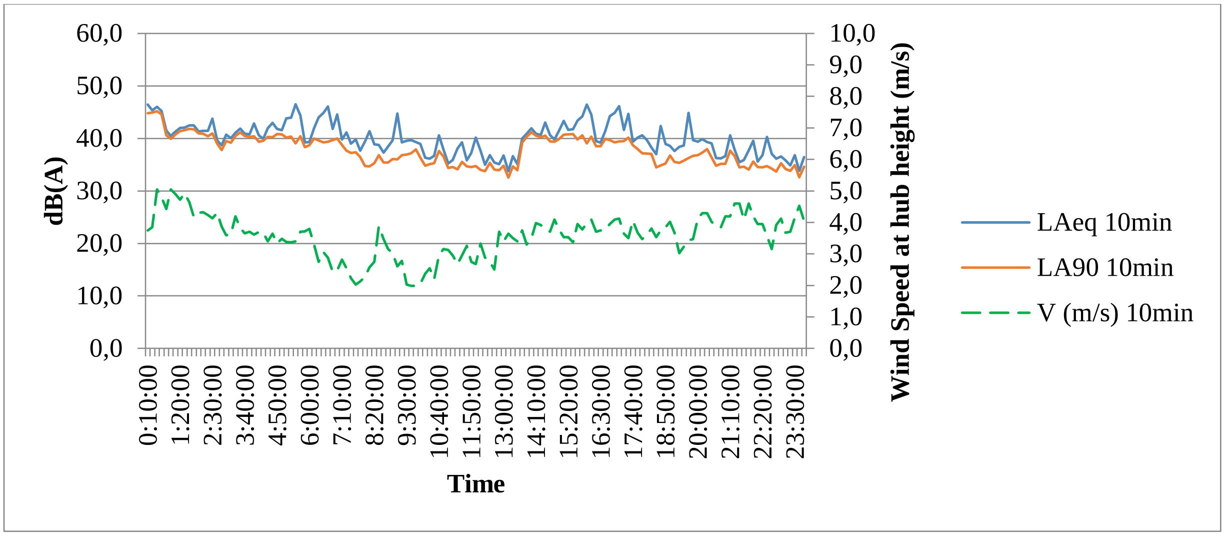

Fig. 4 – Day 14 of measured data for 10 minutes samples.

Figures 5 and 6 shows the noise measurements in day-time period, from 7am to 9pm and Figures 7 and 8 shows the noise measurements during night-time period from 9pm to 7am, for L(A)eq and L(A)90 the two descriptors, respectively. Noise levels are about the same for wind speeds from 8 to 14 m/s, for day and night time.

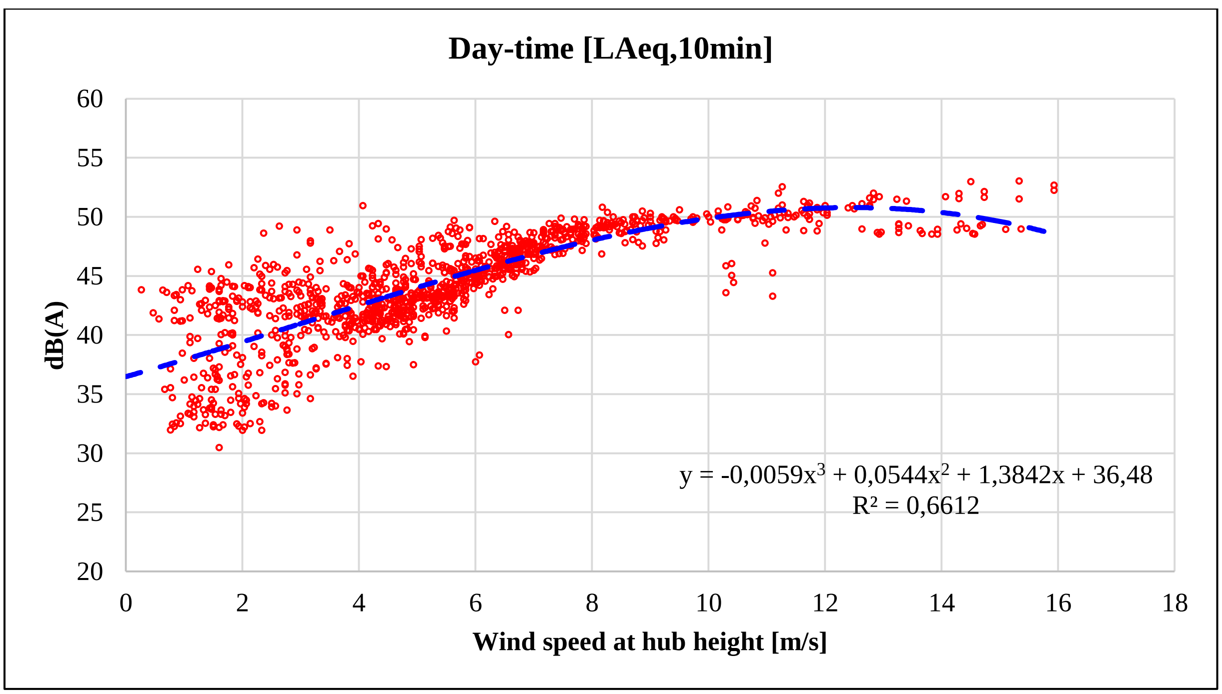

Fig. 5 – Two weeks of measured data LAeq 10 minute, day time period.

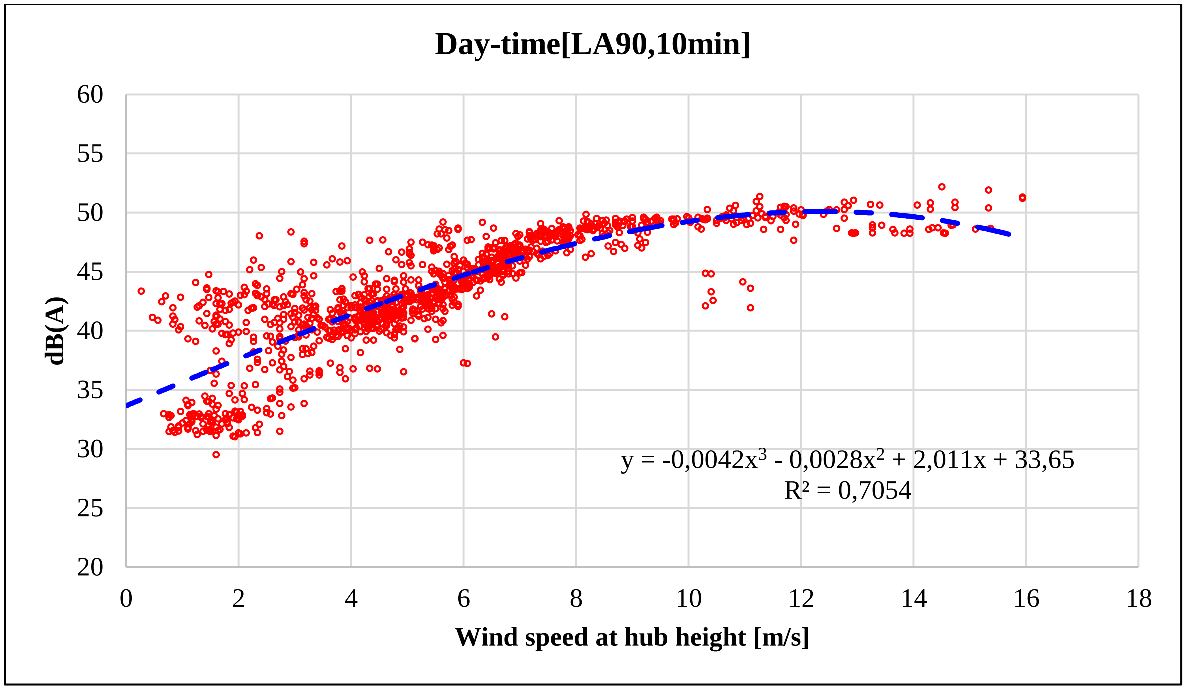

Fig. 6 – Two weeks of measured data LA90 10 minute, day time period.

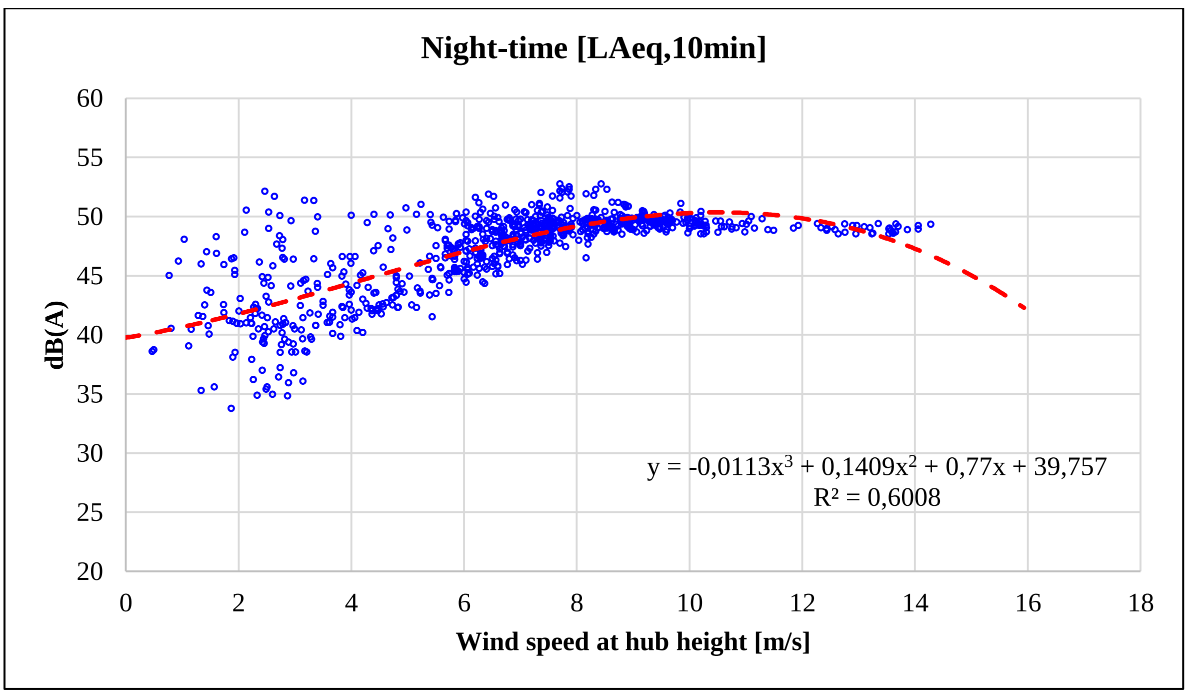

Fig. 7 – Two weeks of measured data LAeq 10 minute, night time period.

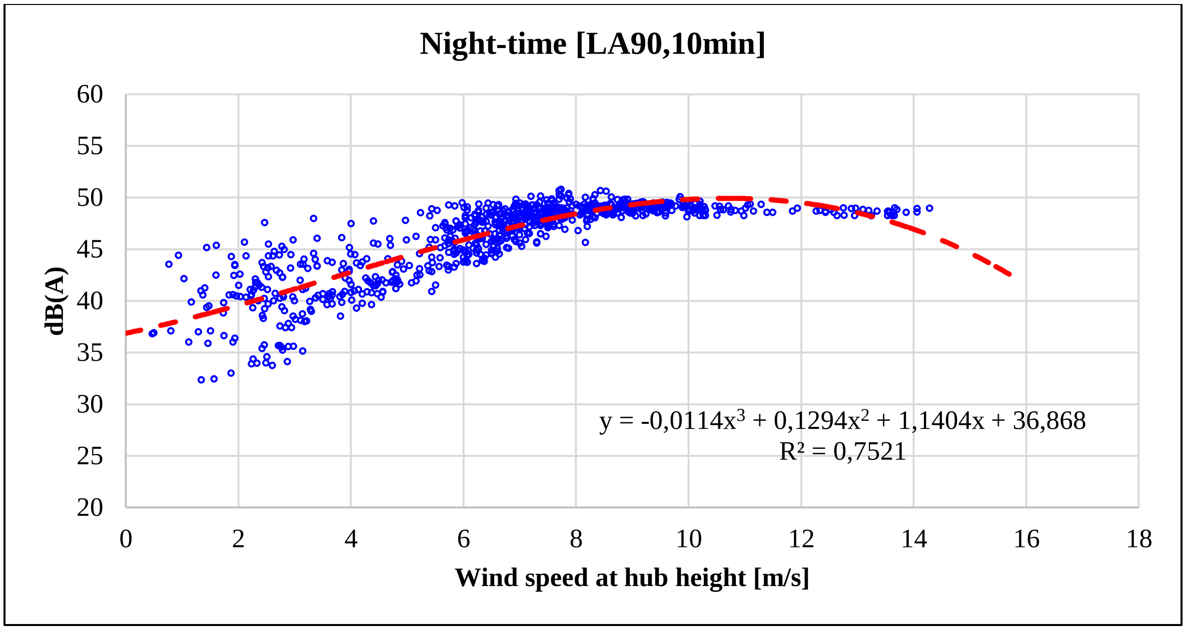

Fig. 8 – Two weeks of measured data LA90 10 minute, night time period.

There is a moderate correlation for all measurements $(0{,}6 < R^2 < 0{,}8)$, which is representative of the emission of the wind farm. It is observed again that maximum samples are corrected by the L(A)90 descriptor, increasing the correlation factor for the graphs, presenting a more representative curve of emission.

For the comparison of L(A)eq-10 minutes and L(A)90-10 minutes, it is possible to notice in the Figures 3 and 4 that peaks of L(A)eq are corrected by the L(A)90 descriptor. It can be noticed a trend between wind speed and noise in late hours more than in the first hours of the day. This is probably product of the thermal inversion, which generates high noise levels product of the wind close to the ground. Usually, higher wind speeds also lead to higher noise levels, but this relationship is clearly affected by other factors, too (e.g. in this case, between 3 and 6 o'clock in the morning the noise is still high while the speed is low).

3 WIND TURBINE NOISE MEASUREMENTS

3.1 Methodology

For the measurement of apparent sound power levels of a wind turbine, the international regulation IEC and the beamforming technique (acoustic camera) were considered. Table 1 shows the wind turbine measured.

Table 1 – Wind turbines measured.

	Model	Power	Hub Height
WT	Vestas	2,0 MW	95 m

For the application of the first technique (IEC), an ACO PACIFIC HEMI18 wind screen was used, meeting the standards required in the IEC regulation. The reflecting plate used to mount the microphone has a 1 meter diameter and a thickness of 15 mm.

Fig. 9 – Sound power level measurement equipment according to IEC 61400-11.

To calculate the apparent sound power level of the source, the following equation was used[5]:

$$L_{WA_{ref}} = L_{A_{ref}} + 10 \log 4\pi(R^2 + h^2) - 6\,dB \quad (1)$$

Where $L_{A_{ref}}$ corresponds to the sound pressure levels recorded in the measurements, R is the measurement distance between the microphone and the base of the wind turbine, h is the hub height of the wind turbine, and 6 dB is the correction due to the reflecting plate.

The acoustic camera integrates a phased array of 30 microphones, a data acquisition interface Bruel & Kjaer LAN-XI 3660-C-100 and a portable computer with B&K Pulse Reflex software. v21. It was located 300 meters away from the turbine and it was used to characterize the noise emission from two wind turbines of the same type. For the first case, just one turbine was operating. Second case considers two wind turbines running. Figure 10 shows the camera installed.

Fig. 10 – Acoustic camera for the beamforming technique measurements

3.2 Results

Figure 11 presents the sound spectrum for the IEC and phased array techniques. The overall apparent sound power level for the turbine with the IEC method corresponds to 107,3 dB(A), while the overall apparent sound power level measured with the camera is 113,1 dB(A) for one wind turbine and 115,8 dB(A) for the two wind turbines operating.

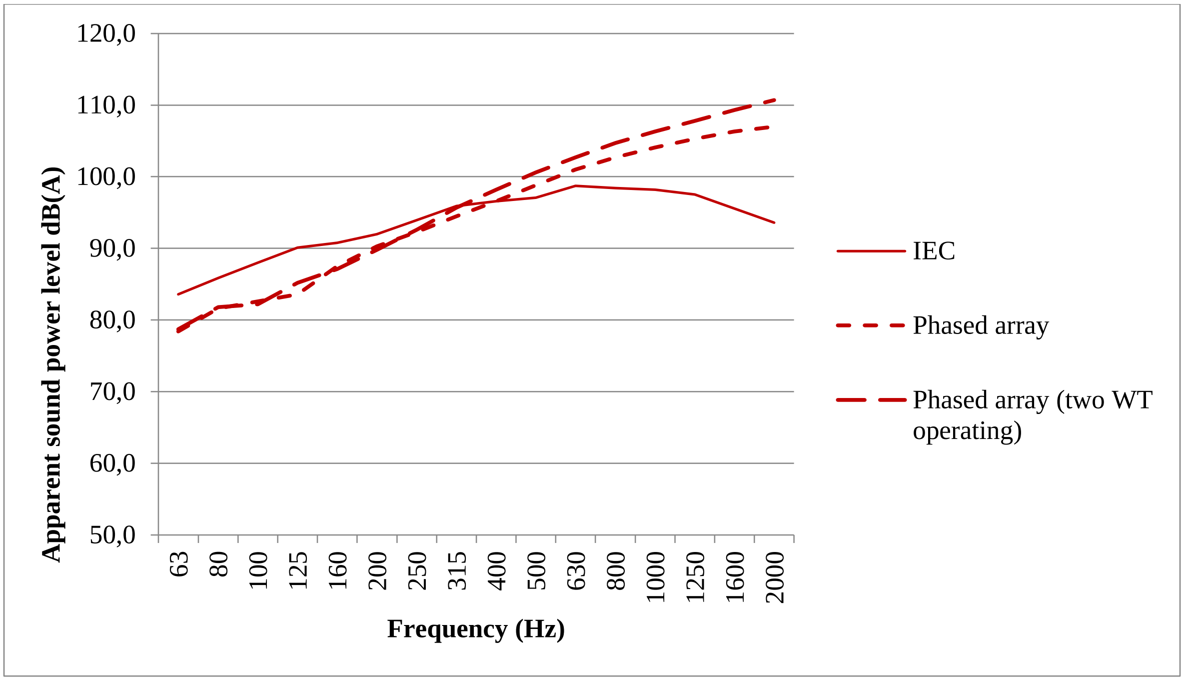

Fig. 11 – Wind Turbine Noise Measurement for IEC and phased array

Important differences are observed. Probably high frequencies are increased in the acoustic camera product of the wind induced by the structure or windshields of microphones. Also, it is possible to see that low frequencies are not well characterized.

Figure 12 presents the acoustic images obtained with the acoustic camera. It is possible to notice that at very low frequency the array has a poor resolution.

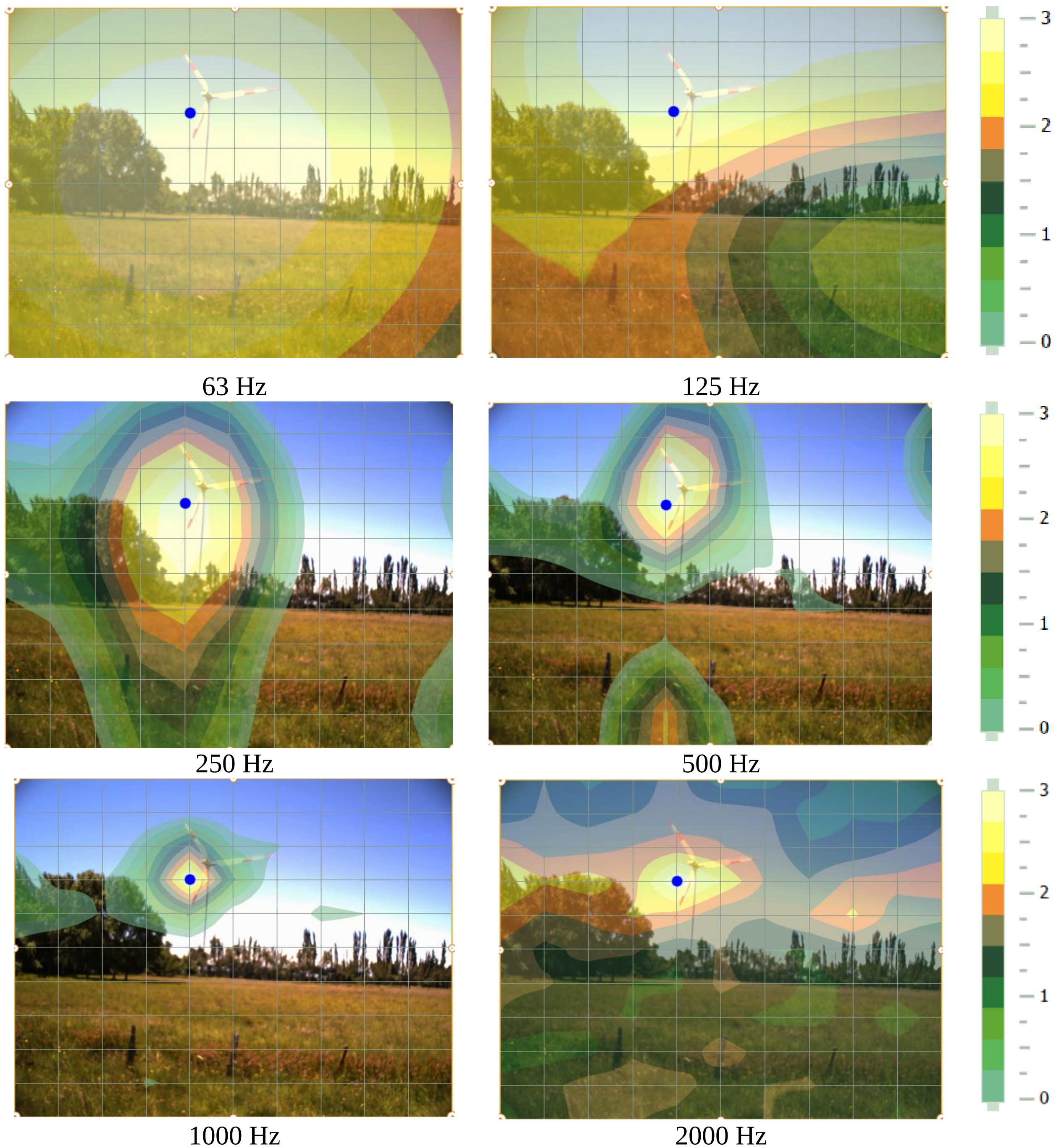

Fig. 12 – Wind Turbine Noise acoustic images

Figure 13 presents the acoustic images obtained with the acoustic camera for the two wind turbines operating. It is possible to notice same situation as before. Particularly at 250 Hz, 500 Hz, and 1000 Hz it can be noticed the contribution of each wind turbine.

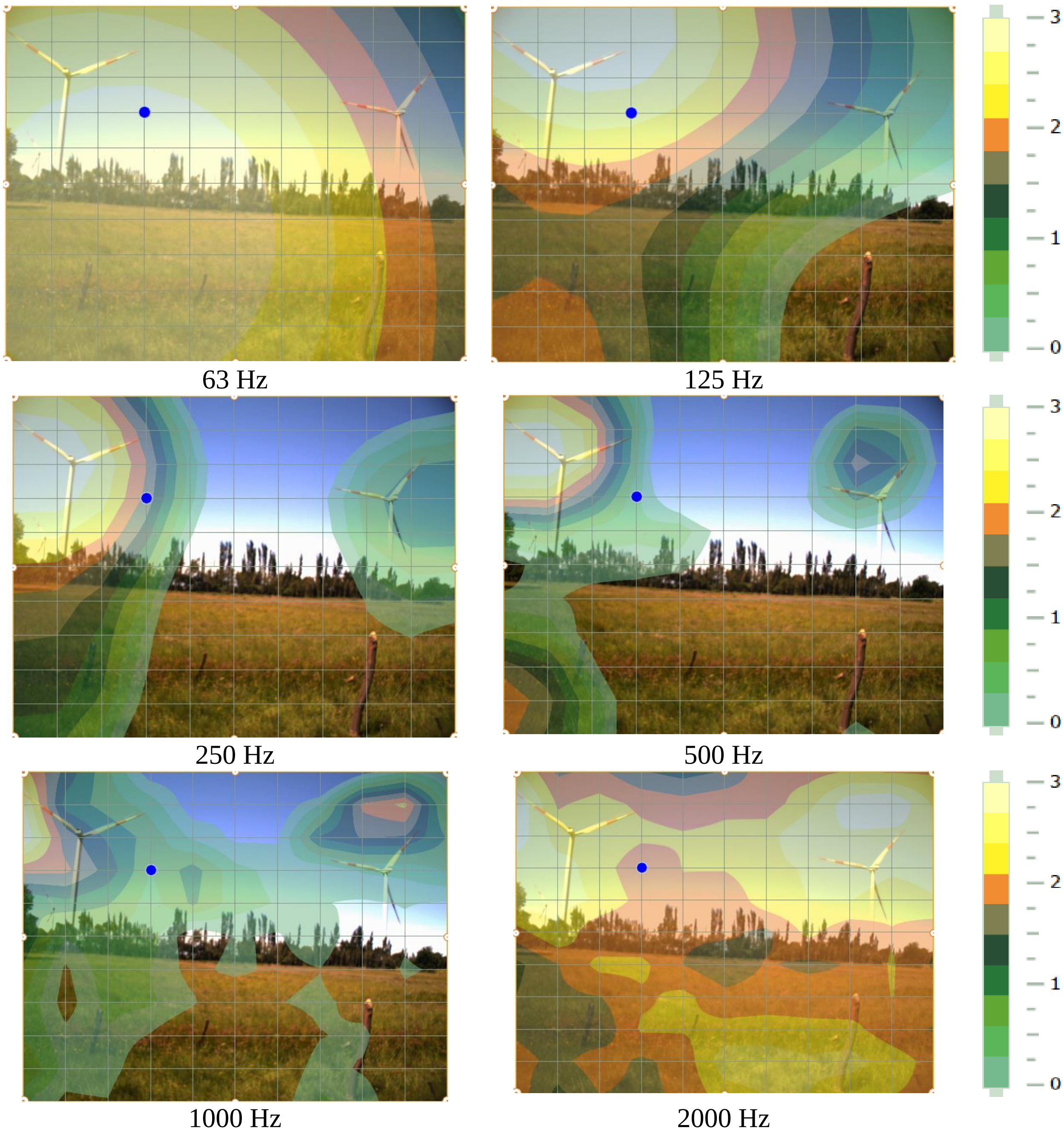

Fig. 13 – Wind Turbine Noise Measurements for Case 1, Situation 2 (Two wind turbines operating)

4 ANALYSIS AND DISCUSSION

It is a fact that wind turbine noise increase with wind speed, but also it is possible to observe that wind turbine noise does not increase over 10 m/s. Below 10 m/s noise presents more variation. This is product of the background noise generated by other sources, due to wind speed close to the ground. An important contribution of background noise is observed below 6 m/s, as shown in Figure 14.

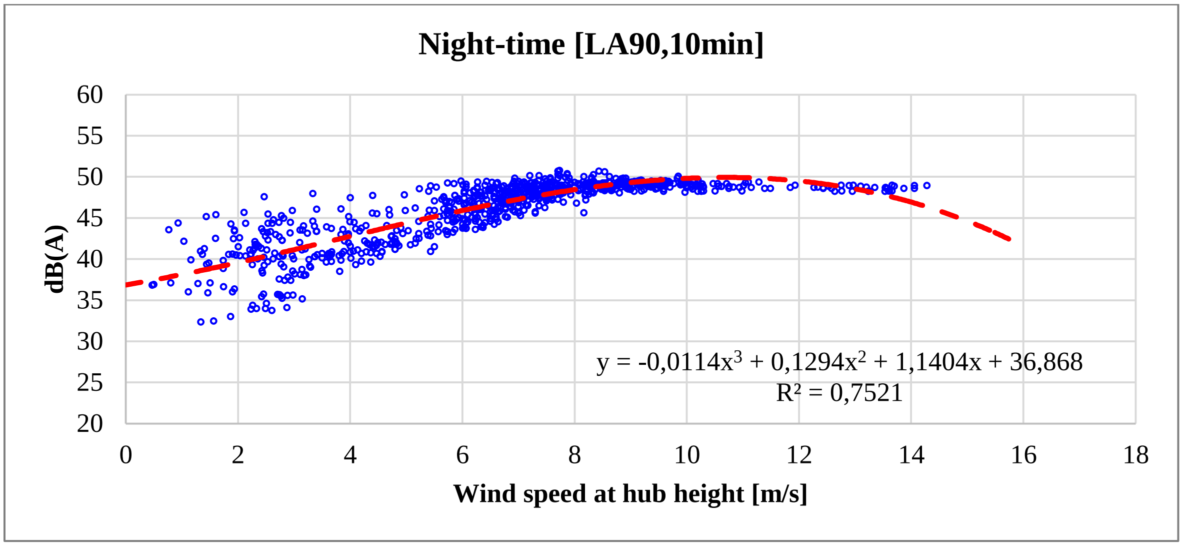

Fig. 14 – Wind Turbine Noise measurements during Night-time

The use of the L(A)90 descriptor increase the correlation factor for a continuous monitoring of a wind farm, which generates a curve of imission that is more representative of all the samples, excluding sporadic noises that do not contributes to the turbine noise. This is very important when noise data is not recorded as an audio signal and also there is thousands of samples to process.

A good characterization of the source is very important to generate conclusive results. As a part of this study it was incorporated a short analysis of noise emissions from wind turbines with two different techniques. It was noticed that it is necessary to generate a deeper analysis to generate very conclusive results. However, wind turbine noise can be discriminated with an acoustic camera, which is not possible with the IEC technique and usually there is no provision to stop wind turbines for measurement in Chile. On this way, the use of an acoustic camera can be the solution to characterize the emission of a wind turbine without stopping the entire park.

5 CONCLUSIONS

The wind speed is an important parameter, but not the only one that determines the noise level. There are other factors (e.g. thermal inversion and propagation issues, variations in background noise, variations in the wind farm emissions not associated with wind speed) were not investigated as part of the present study

According to the measurements, wind turbine noise could be well described for wind speeds over 6 m/s to 10 m/s. Samples between 4 m/s and 6 m/s are a mix of noise samples from wind turbines and other sources (i.e. background noise). In general, it does not make any sense to use the data below 6 m/s due to the high background noise level contained in the measurements, or over 10 m/s in this case, to characterize the maximum noise emission of wind farms. In some of the cases, the information contained over 10 m/s could be useful, since there exists wind turbines that reach its maximum emission level around 14 or 15 m/s. This depends on the characteristics of the wind turbines.

L(A)90 works better than L(A)eq for wind turbine noise, since it eliminates noise that is not part of the turbine sound, increasing the accuracy of the data which generates more representative noise imission levels. Wind turbine noise is well described by L(A)90 descriptor.

Results with the phased array are not very conclusive. It is necessary to study the specific location that the acoustic camera requires to coincide with sound power levels of the source. As IEC standard defines a location to characterize de noise emission of the source which depends of the hub height of wind turbines and wind speeds at the wind farm, to apply beamforming technique on wind turbine noise it is necessary to define a standard of measurement that also defines the specific location and wind speed, at hub height and at the measurement point. Also a larger number of wind turbine it is necessary to analyze. Future work will consider an analysis of these variables with a specific methodology to measure wind turbines noise with an acoustic camera, which will contribute to the development of methodologies to measure the apparent sound power levels of a wind turbine in the middle of an operating wind farm.

6 ACKNOWLEDGEMENTS

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