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Noise

Session 3pNSa: Wind Turbine Noise II

3pNSa1. Wind Farm - Long term noise and vibration measurements

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Most of the energy produced in Quebec comes from renewable sources. The concept of wind energy emerged in the late 1990's and has since become a complementary source of energy alongside hydroelectricity. Wind farms are generally seen as a good sustainable way to produce energy. However, they are not implemented without some impact on the environment. SNC-Lavalin Environment has performed many surveys in recent years for wind farm projects, including noise measurements both before and after their commissioning. This presentation will give an overview of one such project where long term noise and vibration measurements where conducted. Vibration measurements, as well as outdoor, indoor and low frequencies noise measurements were completed both with and without the wind turbines in operation. Data will be presented showing different problems encountered in the analysis phase. For example, multiple intermittent and non-steady noise sources were present during measurement (wind turbines, car pass-bys, wind in the trees, human activities). Methods used to overcome these obstacles will be discussed (use of statistical parameters, linear regression), and the effect of the wind turbine operation on the noise level (including low frequencies) and vibration level will be presented.

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INTRODUCTION

Most of the energy produced in the province of Quebec in Canada comes from renewable sources. Among these renewable sources, the concept of wind energy has emerged more concretely in the late 1990's, with the project Énergie Le Nordais **[1]**. Now, there are more than 20 wind farms in Quebec either in operation or in development.

Wind farms are generally seen as a good sustainable way to produce energy. However, their construction and operation are not without some alleged impact on the environment, for instance, noise and vibration.

SNC-Lavalin Environment has performed many surveys in recent years for wind farm projects, including noise measurements both before and after their commissioning. For one of these projects, complaints were filed regarding both excessive noise levels (particularly in low frequencies) and vibration. In this context, SNC-Lavalin Environment received a mandate to perform long term noise and vibration measurements. Measurements were performed both outdoors and indoors, with and without the wind turbines in operation.

Data are presented outlining the problems encountered in the analysis phase, and the main conclusions drawn from the results.

THE MEASUREMENTS

Noise measurements were performed with a Larson Davis sound level meter, model LxT1 (type I), with a low level microphone protected by an oversized wind screen of a diameter of 175 mm. The principle metrics recorded in the memory of the instrument were the $L_{\mathrm{Aeq}\,5s}$, $L_{\mathrm{Aeq}\,10min}$, $L_{50\ 10min}$, and finally, the L_{Zeq10min} in ⅓ octave bands.

A weather station was also installed at the measuring point to register the wind velocity and direction at the microphone height (1.5 m from the ground), along with the temperature, the relative humidity, and the amount of precipitation. Finally, a digital audio recorder was connected to one of the outputs of the sound level meter, to be able to identify noise events during data analysis.

Regarding the vibration measurements, 2 seismographs were installed; one at the foot of the closest wind turbine, and one close to the house at the measurement point for noise. Both were installed directly on the ground. Peak particle velocity was recorded in the memories of the instrument for all three orthogonal axes.

THE SITE

The measuring point is located in the vicinity of a house, surrounded by small buildings. The local area is composed either of forest or agricultural land. The forest is mature, and composed of a mix of leafy and resinous trees. The only significant noise sources are traffic noise on the single road in front of the house, and the wind turbines. The traffic is light and intermittent, and mainly concentrates during daytime. There are 6 wind turbines visible from different angles at the house under study.

CRITERIA

The noise emissions from a wind park, along with all the other industrial activities in the Province of Quebec, have to comply with certain criteria. However, unlike other provinces in Canada or in some other countries, there are no specific criteria for wind farms. For a low-density occupied territory, the noise limits are 45 dBA $L_{\mathrm{Aeq}\,1h}$ during daytime (7AM to 7PM), and 40 dBA $L_{\mathrm{Aeq}\,1h}$ during nighttime (7PM to 7AM), or the residual noise level if higher. These limits are applicable solely on the specific noise from the facility under study. There are also adjustments that may apply if, for example, impact, tonality, or low frequencies emphasis are present.

The main concerns in the analysis of noise results are to distinguish the particular noise (noise from the source under study) and the residual noise (noise from every other sources), which together form the ambient noise. Different strategies were adopted to perform these evaluations. First of all, it was clear that even if the measuring point was located in a remote area, the traffic noise was significant, in comparison of the low-level criteria. This noise was typically a fluctuating and intermittent noise source. The use of the statistical metrics recorded by the sound level meter allowed for the elimination of the contribution of the isolated vehicles pass-bys (L_{A50}). The aerodynamic noise expected on the microphone was also deducted from the noise levels measured, by using the correlation between the wind speed at the microphone height, and the aerodynamic noise, as measured in a wind tunnel **[2]**. The other residual noise source contributing to the ambient noise measured is the wind in the trees. A linear regression was performed to determine the noise level of this source and deducted from the measured noise level.

Finally, after having proceeded with these calculations, time periods were identified where there were possible exceedances of the criteria. Audio recordings then allowed for the determination of whether the wind turbine noise was responsible for them.

Vibration measurements have also been completed following the reception of a complaint even if there is no vibration criteria applied to wind farms or any other industrial activities in Quebec. There is one, however, for the blasting operations in quarries.

NOISE RESULTS

Overall Levels

An example of the results obtained during the noise measurement campaign is shown in Figures 1 and 2.

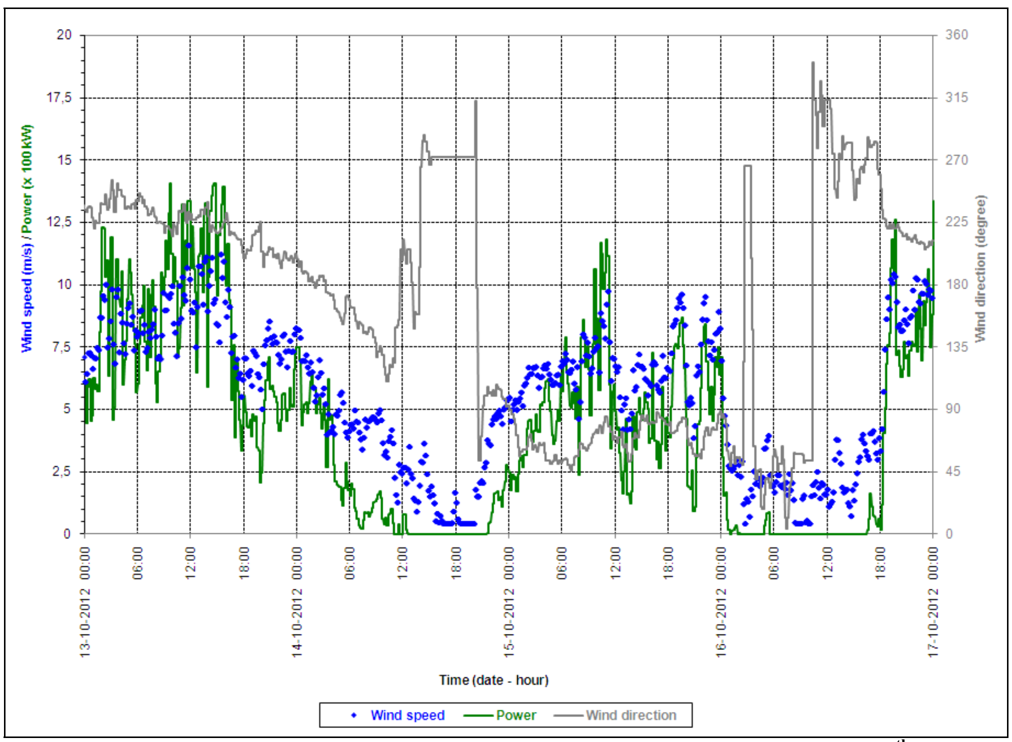

FIGURE 1: Parameters measured at the hub of a wind turbine, October 13th to October 17th, 2012.

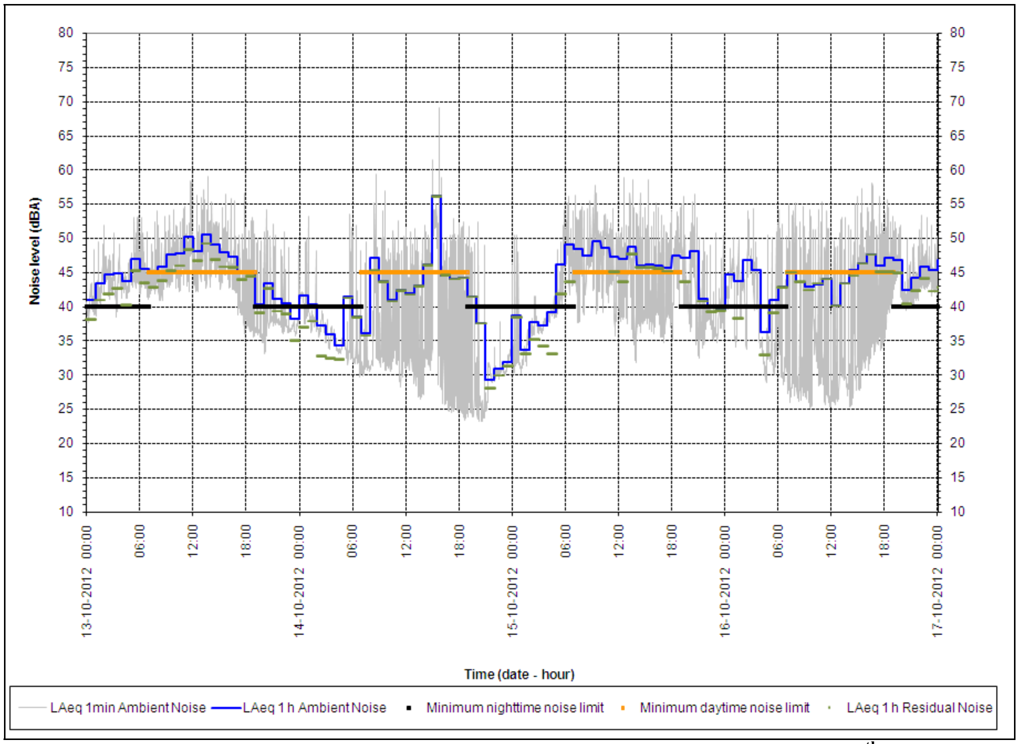

FIGURE 2: Noise levels measured outdoor at a residence, October 13th to October 17th, 2012.

The main observations gathered from these figures are:

- The L_{Aeq} is controlled mainly by intermittent traffic; and
- The background noise is controlled by the presence of the wind and the operation of the wind turbines. Noise levels may get very low (25 – 30 dBA), which is typical for a rural area, with no consistent anthropogenic noise sources other than the intermittent traffic.

Results of the measurement were compared with a predictive model of wind turbine noise under the same operating conditions as the wind turbines in the study. The noise modeling results were within ± 3 dBA of the levels measured. However, in order to be conservative in the prediction, the upper limit on the margin of error of data provided by the manufacturers will be used in our future calculations for wind farm projects.

Low Frequencies

During another session of measurements, a second sound level meter was installed in the living room of the plaintiff, who was reported to be affected by 'wind turbine syndrome'. These measurements aimed to determine if the low frequency content of the noise within the house was related to the noise produced by the wind turbines, and if the levels were significant. In the analysis, we evaluated the low frequency content by adding the ⅓ octave bands in the L_{Zeq} metric from 6.3 to 200 Hz.

The results for one week are presented in Figures 3 and 4.

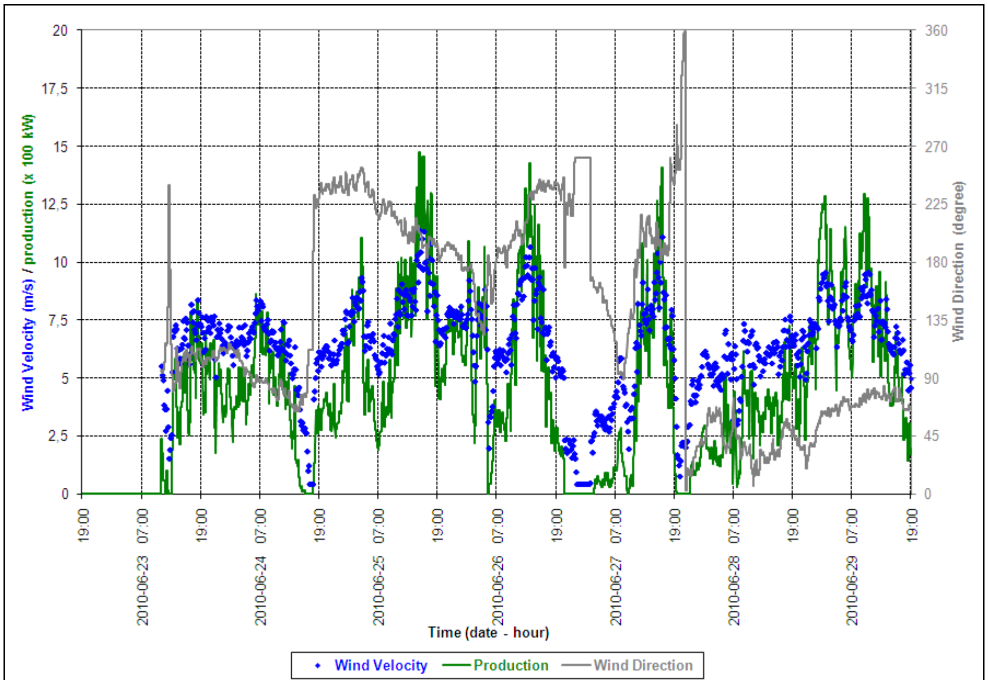

FIGURE 3: **Parameters measured at the Hub of a wind turbine, June 22nd to June 29th, 2010.**

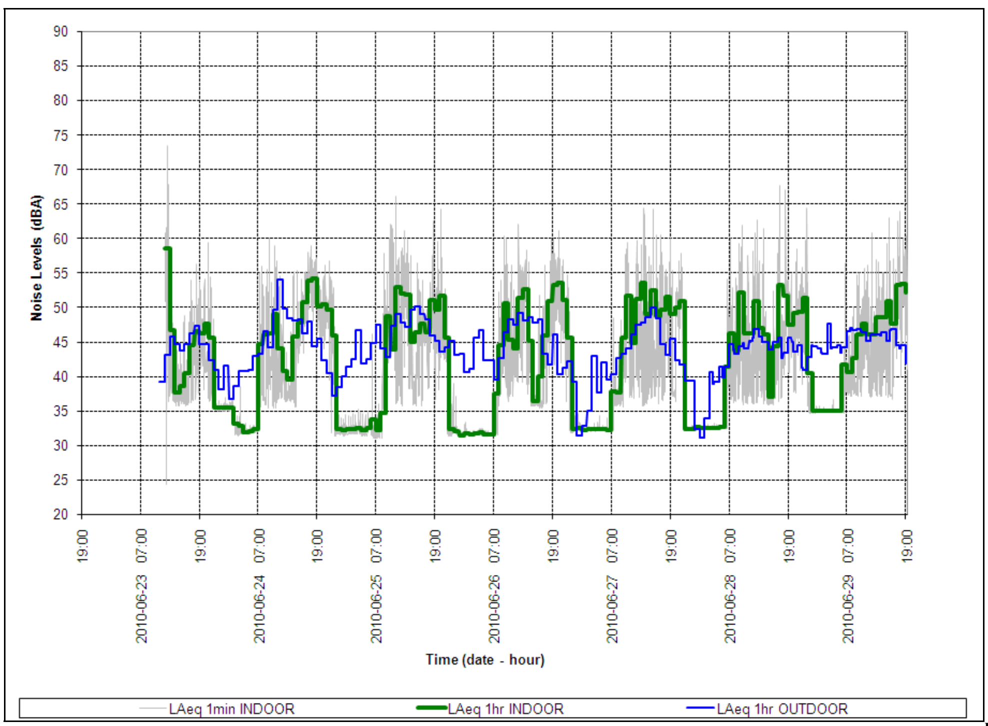

FIGURE 4: Noise levels measured outdoor and indoor of a residence, L_{Aeq} 1hr, June 22nd to June 29th, 2010.

There is no clear relation between the indoor and outdoor noise levels, although there is an increase during the daytime due to anthropogenic activities. To get a better view of a possible relation, the time sampling of the noise levels measured was reduced from 1 hr to 10 min. The results are shown in Figure 5, along with the noise levels of the low frequency content (L_{Zeq}, ≤ 200 Hz).

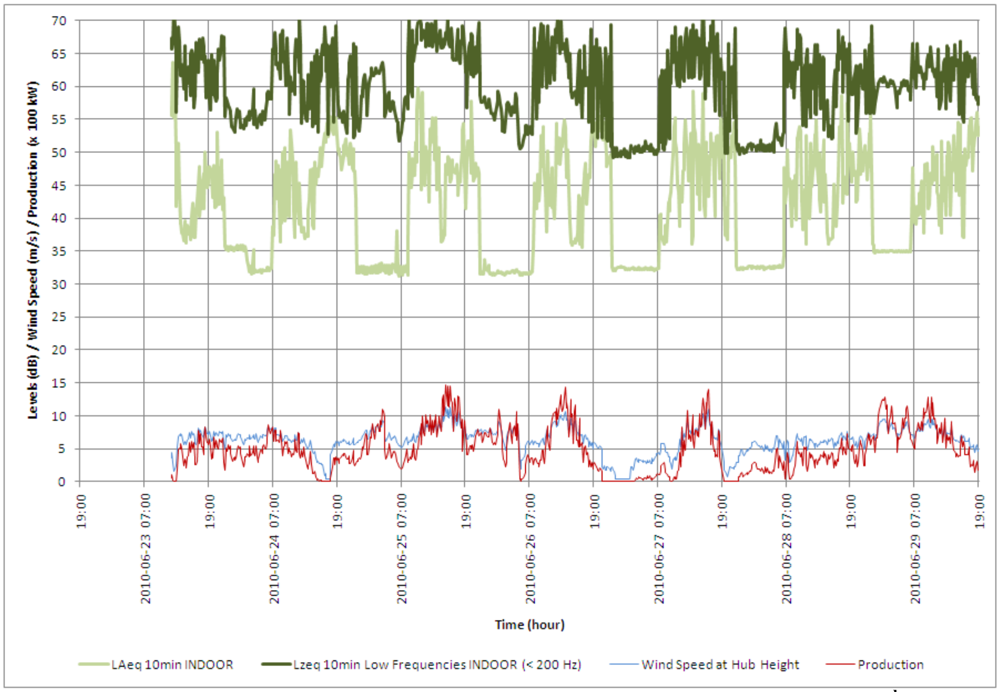

FIGURE 5: Noise levels measured indoor of a residence, L_{eq} 10 min, June 22nd to June 29th, 2010.

On figure 5, the wind velocity and the production rate of the wind turbines tend to correlate more with the indoor low frequency noise level at night (10PM to 7AM). The overall dBA level does not correlate well during daytime and nighttime periods.

The most important sources of low frequencies inside the house seem to be the activities of the occupants. However, the levels are low. But based solely upon Figure 5, it could be possible that the wind turbines are responsible for low frequency noise inside the house of the plaintiff.

To be able to separate the effect of the wind itself on the production of low frequencies inside the house from the contribution of the nearby wind turbines, we analyzed the period of the measurements, when the wind turbines were shut down for maintenance, which was during the daytime, July 5th, 2010. Thankfully, during this period, there was some wind. Typically, wind turbines are in operation only during windy conditions.

Figure 6 shows the results obtained during the week when the shutdown was scheduled.

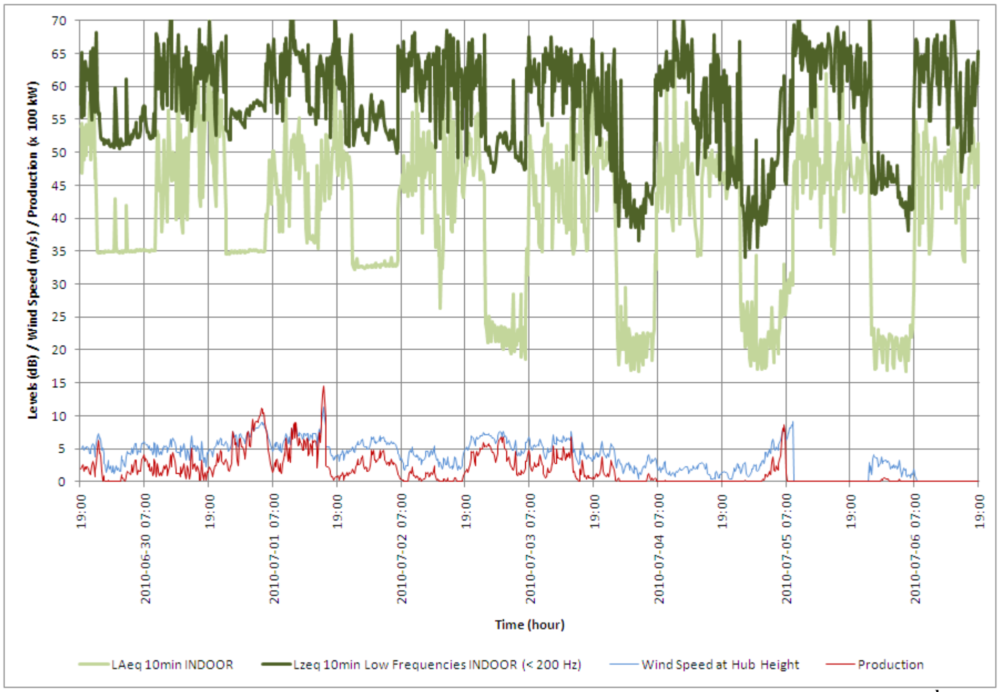

FIGURE 6: Noise levels measured indoor of a residence, L_{eq} 10min, June 29nd to July 6th, 2010.

A more optimal situation would be to have the shutdown during nighttime hours, when the anthropogenic activities are at a minimum, in windy conditions. However, Figure 6 shows that there is no reduction in indoor noise when the turbines are shut down and windy conditions are present, which was the case during daytime on July 5th. The calm period during the day, at 35 dBA, has a dBZ at low frequencies in the 60's, which is similar to the level obtained in windy conditions and with the wind turbines running.

VIBRATION RESULTS

One of the aspects of the complaint was that the wind turbines produce ground vibrations that could be felt through the feet of the bed. Two seismographs were installed directly on the ground for a long term measurement session, one at the closest wind turbine, and one close to the house at the measuring point for noise.

Figure 7 shows an example of the results obtained.

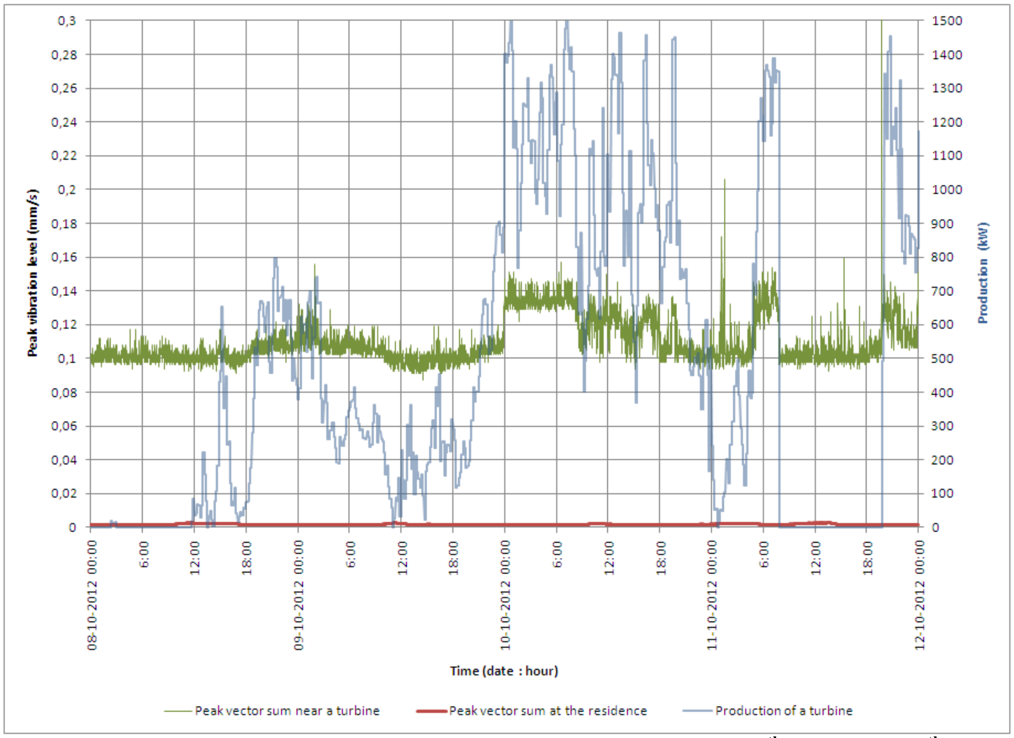

FIGURE 7: Ground vibration levels measured, October 8th to October 12th, 2012.

The ground vibration levels measured were very low, even at the foot of the turbine. Moreover, the vibration levels at the foot of the turbine correlate with the production level of the turbine; at the residence, no such relation was observed.

CONCLUSIONS

The main conclusions drawn from the comprehensive surveys performed at a wind farm are the following:

- The particular noise levels from the wind turbines determined from the measurements were within ± 3 dBA from what was established with noise simulations;
- The low frequency content inside the closest residence was related to the wind velocity, and not to the production rate of the nearby turbines; and
- The wind turbines do not produce significant ground vibration levels, even at the foot of them.

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