5th International Conference
on
Wind Turbine Noise
Denver 28 – 30 August 2013

Noise's measure inside homes generated by the functioning of wind farm in southern Italy

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Summary

The inland areas of southern Italy are characterized by the mountains presence of medium height about 700-1000 meters above sea level, and with an average annual wind speed between 5-6 m/s. In these areas were built many wind farms which are often situated close to towns. The towns population it complains for the noise generated by the rotation of the blades of wind turbines. The present work reports the results of acoustic measurements made inside houses located near a wind farm. The acoustic measurements were carried out by open windows (in condition of maximum noise) in different positions respect to the wind towers. The acoustic measurements are carried out during the autumn season, the values of LAeq and L95 have been measured, for different wind speeds during the day and the night periods. It was also possible measure the value of the background noise (the noise due to the wind when the wind turbines are off) and assess the effects of background noise, the variation of the wind speed compared to the noise generated when wind turbines were on. Were evaluated also the conditions for which the wind speed generates a background noise superior to the noise generated by the rotation of the blades of the wind turbines. For modern wind turbines the main noise generation is the aerodynamic noise produced by the airflow around the rotor blades.

1. Introduction

In the southern Italy were built many wind farms, the success of this investments are spurred by clean energy policies and generous subsidies, and for the good value of average wind velocity during all year periods. The average mountains height is about 700 – 800 metres above sea level. The wind farms in a first time were built away from town and village, but the investment growth in wind energy has expanded the wind farm area, building them near houses, so the problems associated with noise disturbance, by the people who live near wind turbines have complained. In literature there are same paper in which are shown the result of acoustic measurements of noise emitted by wind turbines [1], [2]. In this paper are reported the results of acoustic measurements carried out with the aid of sound level meters placed in two houses near a wind farm. The acoustic measurements were performed during the day time (06:00 – 22:00) and during the night time (22:00 - 06:00), when the wind farm were operative, and when the wind farm is not in use (blades stopped). The measurements also were carried out with different wind speeds. The noise generated by the blades rotation and the background noise (the environmental noise, when in the same conditions of wind speed, the blades are stopped) was evaluated. The wind farm considered consists of four wind turbines of nominal power 2.0 MW each, with three blades with diameter of 90 meters, the hub height of 80 meters. The acoustic measurements were carried out in houses with open windows, because this is the noisier condition. The wind farm is located in a little village between the Regions Campania and

Molise in the southern of Italy. This village has fifteen hundred inhabitants, with an average height above sea level is about 700 meters. The prevailing wind directions is from south, while it is frequently the wind from north, with the wind speed only for few times during the year is higher than 25 m/s (this is a condition in which the wind turbines are stopped). Figure 1 and the Figure 2 show the geographical position of this place, with the average wind speed [3]. While Figure 3 shows a detail of the aerial view, with the position of the wind turbines, and the position of the houses in which the acoustic measurements were carried out, and the distance between the houses and the wind towers is about 200 metres. The ground is an agricultural area with free of vegetation, and the terrain isn't flat, but the wind turbines are positioned on an hill top, while the houses are down. Figure 4 shows the four wind turbines during the winter season.

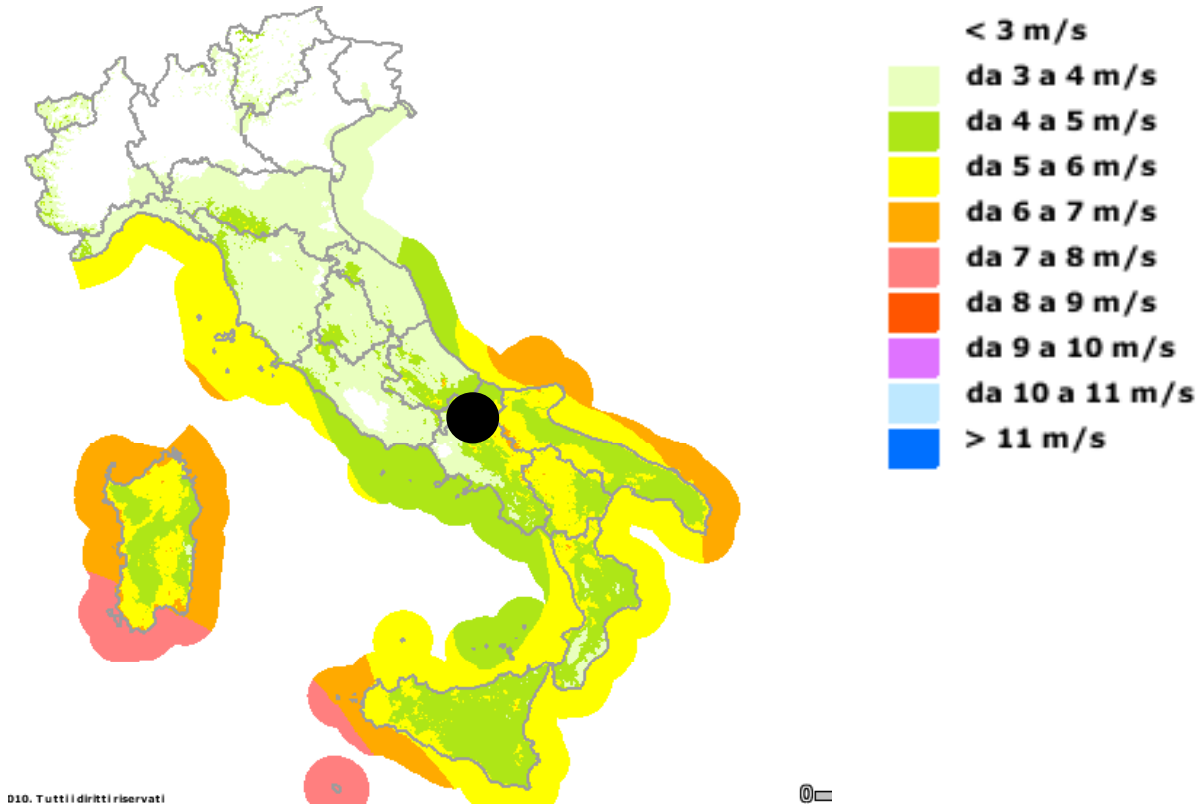

Figure 1 – Map of Italy, with the position of wind farm, and the average value of wind speed

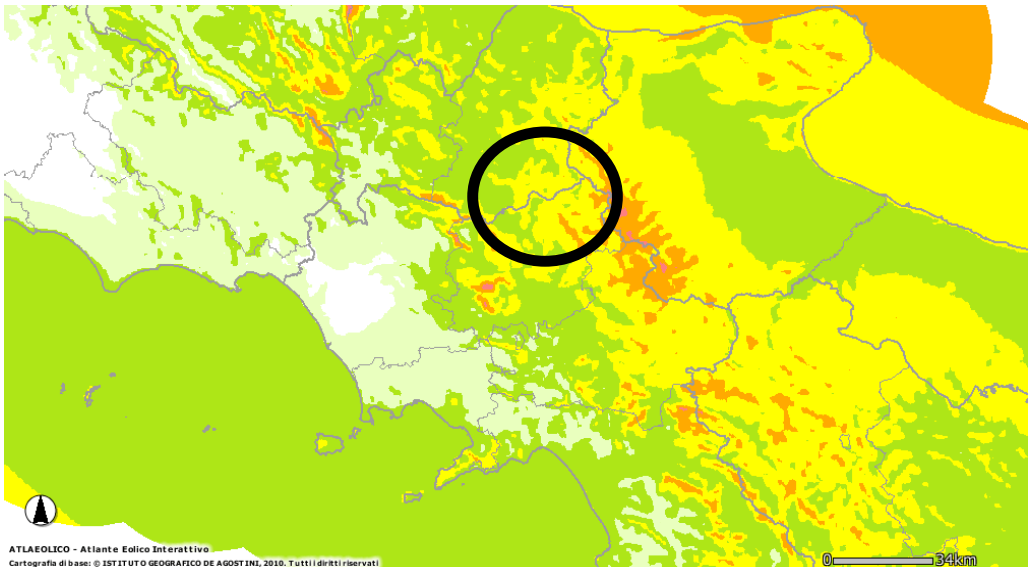

Figure 2 – Particular of south Italy wind map, and the area in which is installed the wind farm examined.

2.0 Acoustic measurements

The acoustic measurements were carried out inside houses, with open window, during the autumn season, because in this period the wind speed is greater than in other seasons. Two sound level meter were used for measuring the same acoustic events; the sound level meters were positioned in two rooms in two different houses. One room has the window toward East side, the other room has the window toward West side. Figure 5 shows the particular of the area with houses, with the indication of measurement points, one toward West side and the other one toward East side. The sound level meters are of Class 1 type: one model was a “01 dB Solo” the other one was a “Larson and Davis LD-824”. During the acoustic measurements the sound level meters were put on a tripods at height of 1.6 m from floor, while the distance from open window was 1.2 m, the dimensions of the window aperture were large 2,0 m and height 1.2 m. The decision to use two measurement points (East side and West side, Figure 5), is due to these considerations:

- from window toward East side, are seen three wind towers (Towers n. 2,3,4);
- from window toward West side, is seen only one wind tower (Tower n. 1).

Furthermore the house used for the acoustic measurements to the East side (Figure 5) overlook a common courtyard, where are other houses and some stables for cows, while the house toward East side overlooking the open countryside. The acoustic measurements were performed during the day time (06:00 – 22:00) and during the night time (22:00 - 06:00). The sound level meters have been configured for the acquisition of the equivalent weighted sound pressure level "A" LAeq, and the L95 statistical level, in order to detect the presence of tonal components a spectral analysis of the minimum values was performed for frequency bands normalized in 1/3 octave [4] [5].

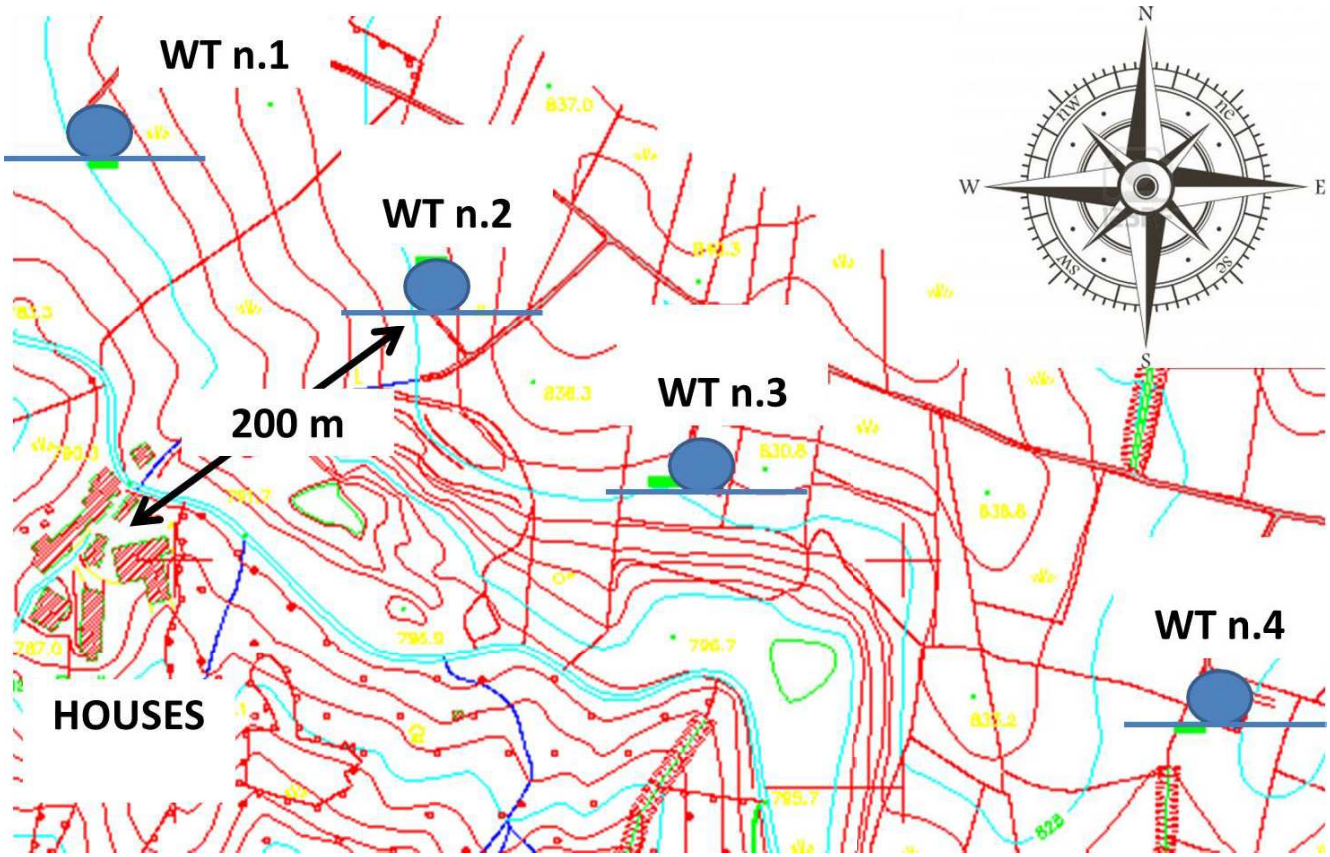

Figure 3. Aerial view of the wind farm, with four wind turbines and the houses and the distance wind towers - houses.

3.0 Acoustic measurements in day time

The acoustic measurements were carried out during the day time; the two sound level meters were installed inside two different rooms with the windows one toward East the other one toward West. During the acoustic measurements the wind speed was less than 12 m/s. Figure

6 shows a typical time history of acoustic events, while Figure 7 shows the 1/3 frequency octave bands spectrum of minimum and average values. The analysis of the spectra of the minimum level values, as shown in Figure 6, dos not indicate the presence of tonal components, which are normally present in the spectra obtained by acoustic measurements of blades rotation. During the acoustic measurements were present same disturbance noise generated by trucks, tractors, cars, voices,…. (noise anthropogenic).

Figure 4 – Particular of the wind farm during the winter season.

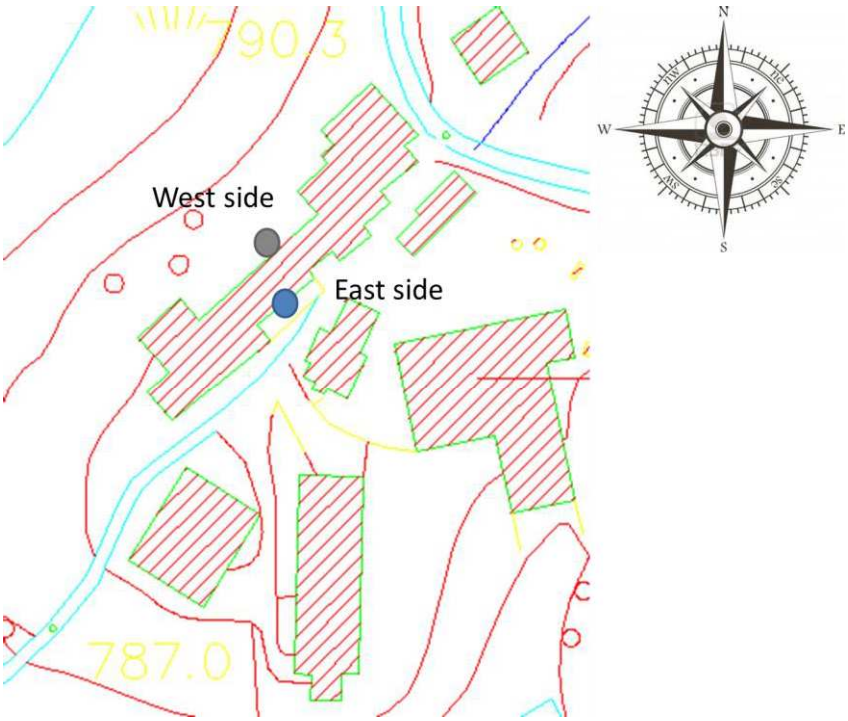

Figure 5 – Particular of the area, with houses and the indication of measurement points at West side and at East side.

Table 1 shows the value of LAeq, when the wind turbines are operating and when them are stopped, the analysis of the acoustic measurements do not give useful information about an evaluation of the increase of the noise due to the wind turbines, compared to the background noise (wind turbines were stopped) for the presence of anthropogenic noise.

Table 1 – Summary of the - East side window.

Measurement step	Turbines operating		Turbines stopped	
	Wind speed m/s	LAeq dBA	Wind speed m/s	LAeq dBA
1	12.0	45.5	5.3	45.0
3	7.1	45.5	6.0	45.0
4	5.0	39.0	5.0	38,5

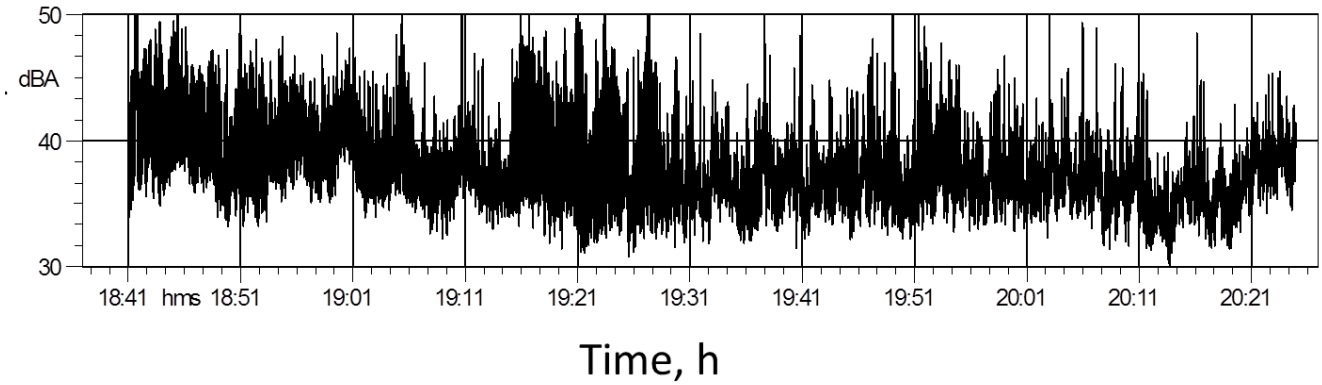

Figure 6 – East side. Typical time history of acoustical measurements (day time)

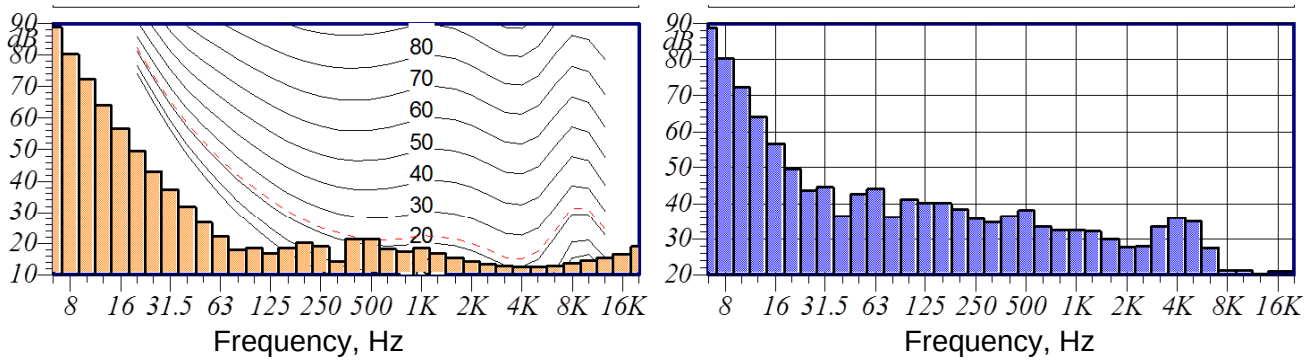

Figure 7 – Spectrum frequency in 1/3 octave band center frequency, Hz.

3.1 Conclusion Acoustic measurements in day time

During the acoustic measurements the average wind speed is reported in Table 1, the average value is not over 12.0 m/s. The component of noise due the rotation of the blades by wind turbines is difficult to evaluate from the presence of the effect of noise anthropogenic (cars, tractors, trucks, voices,…). Figure 6 shows the time history of acoustic measurements when wind turbines are operating, the continuous peaks are due to noise anthropogenic. Figure 7

shows the spectrum frequency in 1/3 octave band center frequency (Hz), the minimum spectra values give information about the presence of tonal component; for this type of wind turbines and for the distance source – receiver, the tonal component is absent.

4.0 Acoustic measurements in night time

One of the difficulties encountered during the day time measurements, has been the influence of anthropogenic noise. Near the houses there were noise by trucks, tractors and various mechanical means, activities related to the operation of the stables (milking machines, mills, conveyors, mechanical equipment, tractors) and agricultural activities with the operation of various mechanical means. For the assessment of the annoyance caused by noise due to the wind turbines operation, and that of the background noise (residual noise when the turbines are stopped), it has started an acoustic measurements campaign that have been agreed upon a series of shutdowns and re-start of wind turbine blades and the subsequent measurement of the noise level in houses during the night. The noise produced by the wind and the rotation of the blades (ambient noise level) was measured; and when the blades were shut down only the wind noise (background noise) was measured. Two sound level meters were used to measure simultaneously the same acoustic event, one sound level meter was placed in a room with a window open towards the East (Towers 2, 3, and 4 are seen) the other one was placed in a room whose window turns to West (Tower 1 is seen). The acoustic measurements were carried out in different meteorological condition: with different wind speed e with different wind direction. During the acoustic measurements each wind turbine was stopped singularly, for a time period necessary to evaluate the contribute of each wind turbine to the global noise, and when all four wind turbines were stopped, the background noise (the noise due from blowing of the wind) was evaluated. In fact some people that live nearby wind farm are annoyed by wind turbine noise only when the wind speed in not height (about 10 m/s). The acoustic measurements carried out during the night time, with the wind turbines (stopped and/or moved) give us information about the background noise (noise due only from blowing of the wind), is over the noise due to the wind turbines operations [6].

4.1 Acoustic measurements in night time with wind speed less 12 m/s

In this paragraph is reported the synthesis of acoustic measurements carried out with two sound level meter, LAeq and L95 were measured in night time. During the night wind turbines were stopped singularly and then started all together, so the contribute of each wind turbine was evaluated to the global noise generation; and when all wind turbines were stopped, the background noise was evaluated. The operative measurement conditions were:

- all turbines were operating from 20:30 to 00:00 (until the midnight);
- the turbine n. 2 was stopped from 00:00 to 00:30 (30 minutes)
- all turbines were stopped from 00:30 to 01:00, background noise was measured (30 minutes)
- all turbines were operating at 01:00.

For the window toward East side the Figure 9 shows the time history of sound pressure level when the turbine were stopped, Figure 9 shows, after the 06:00, a series of peaks, they are the wind gusts, and then the wind speed increases after 06:00. While Figure 10 shows the particular of time history. For the window toward West side the Figure 10 shows the time history of sound pressure level when the turbine were stopped, respect to the wind speed. While Figure 10 shows the particular of time history in the time interval 23:00 – 02:00, in this figure is possible evaluate the contribute to the noise generation due to the wind turbine n. 2, in fact from 00:00 to 00:30 the wind turbine n. 2 is stopped and the reduction of sound pressure level is about of 1.5 dB. Table 2 and Table 3 show the value of LAeq and L95 in different condition of wind speed and wind direction; in the step n. 3 is reported the background noise (the condition in which all turbines are off). This values are different from each position of microphone measure, in fact for the same weather condition in the window toward East side LAeq = 36.7 dBA, while for in the window toward West side LAeq = 28.8 dBA (Figure 4). The step n. 2 is the condition in which the turbine n. 2 is off, this values are not less to the step n. 1

and n. 4, this are the acoustic measurements values obtained when wind turbines are all on; the contribute dues by a single turbine, when it is stopped, to global noise is negligible. The difference of noise level when turbines are all on (step n.1 e n.4), compared to the noise level when all turbines are off, background noise (step n.3), is over of 5 dBA. This condition of wind speed and wind direction is very annoyance. Inside the analysis of spectrum frequency in 1/3 octave band center frequency (Hz) of minimum values doesn't show tonal component. Figure 11 shows the time history of the acoustic measurements of the West side window, only the all wind turbines stop is appreciable.

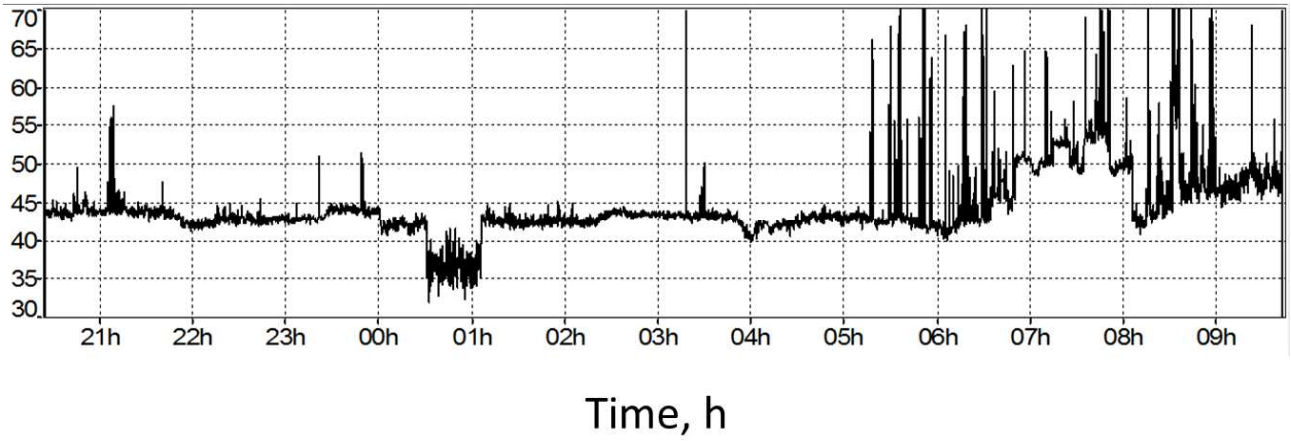

Figure 9 – East side. Time history of acoustical measurements.

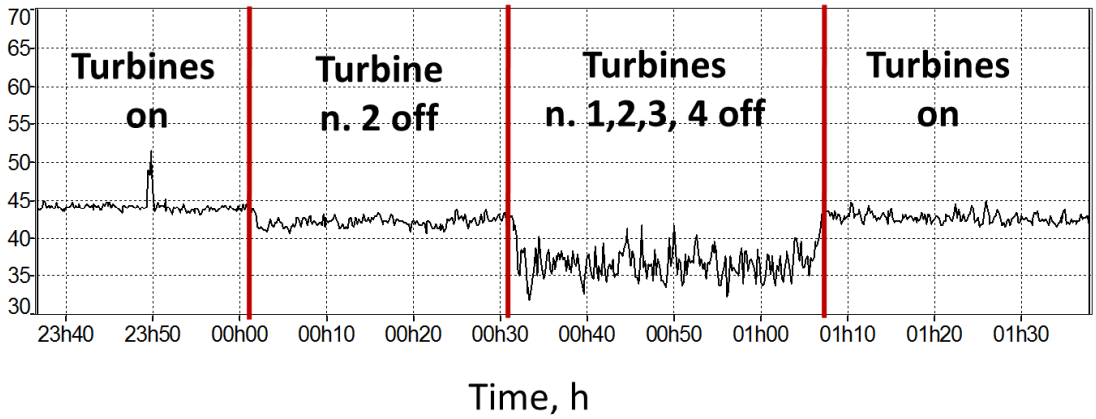

Figure 10 – East side. Particular of time history, with operative phases.

Table 2 - Summary of East side window, wind speed less 12 m/s.

step		LAeq dBA	L95 dBA	Average wind speed	Average wind direction
1	Turbines all on 20:30 – 24:00	43.7	41,5	12 m/s	South-west
2	Turbine 2 off – 00:00 – 00:30	42.0	40.1	10.8 m/s	South
3	Turbines all off – 00:30 – 01.00 Background noise	36.7	32.5	10.5 m/s	South-west
4	Turbines all on 01:00 – 06:00	45.8	40.9	10.7 m/s	South-west

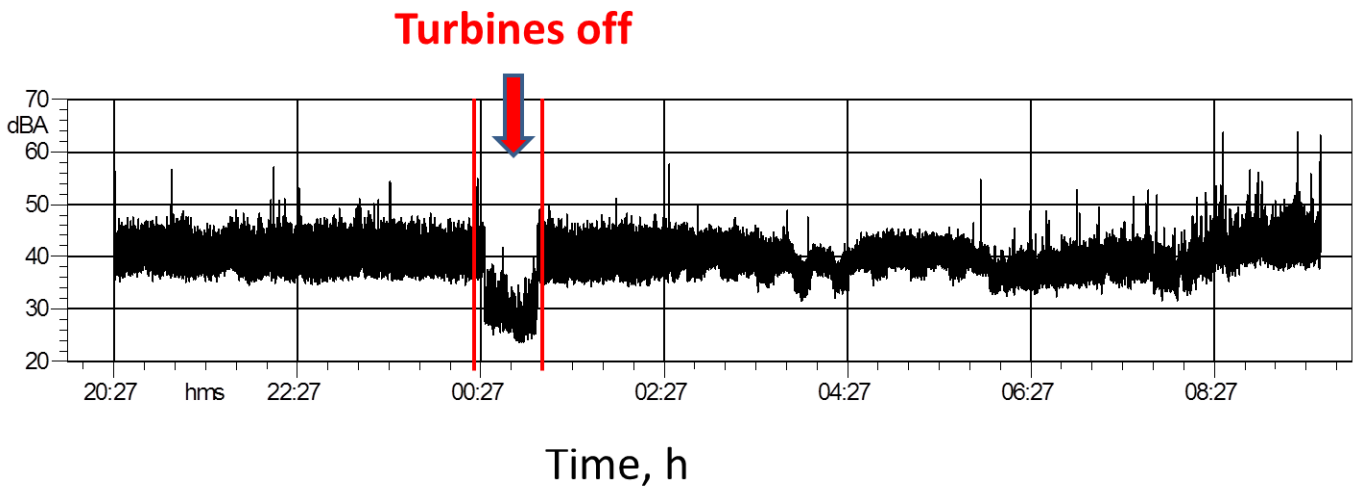

Figure 11 – West side. Time history of acoustical measurements.

4.2 Acoustic measurements in night time with wind speed over 12 m/s

During the night the wind turbines were stopped singularly, and then the wind turbines started all together, so the contribute of each turbine was evaluated to the noise generation; and when wind turbines were stopped, the background noise was evaluated. The operative condition measured, were:

- all turbines are operating (until the midnight);
- the turbine n. 3 was stopped from 00:00 to 00:30;
- the turbines n. 3 e n. 4 were stopped from 00:30 to 1:00;
- all the turbines were off from 01:00 to 01:30 (background noise);
- all turbines were on from 01:30 to 05:00;
- all the turbines were off from 05:00 to 05:30 (background noise);
- all turbines were on at 05:30.

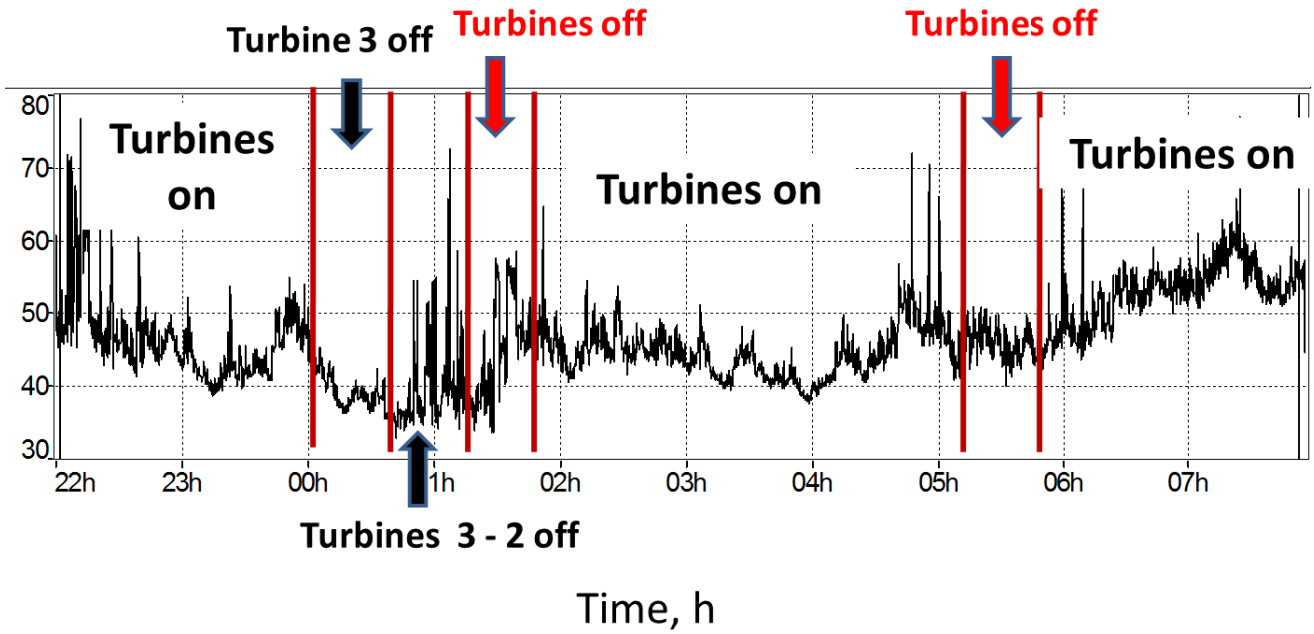

Figure 12 – East side. Time history of acoustical measurements.

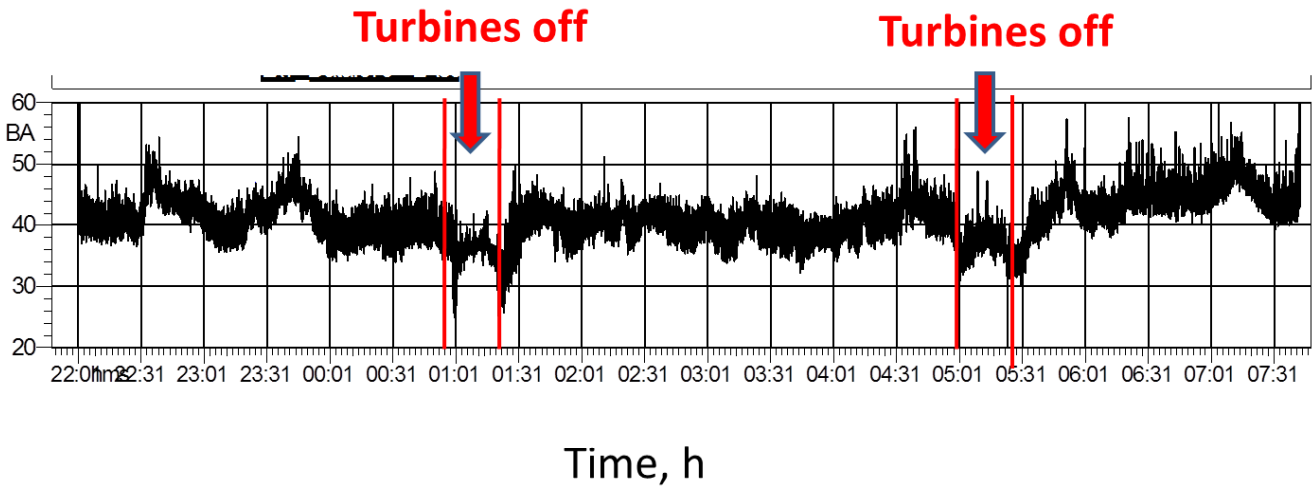

Figure 13 – West side. Time history of acoustical measurements

The steps n. 4 and n. 6 reported in Table 4 and Table 5, are the background noise measurement (red line), this noise is due only to presence of blowing of the wind, in the time history (Figure 12 and Figure 13) are shown some peaks due to the wind gust, in fact, for the same step (4-7) the values of LAeq and L95 are different. This values are different for the position of measurement points. The sound level is higher for the window towards East, because the house in which the measurements were carried out, is oriented to the east, so that side is more exposed to the wind gusts. The background noise sound levels are similar to noise emitted by turbines when them are on. For the window at East side when the turbine n. 2 or the turbines n. 3 are off, the sound pressure level decrease, while for the window at West side (Figure 13) when the turbine n. 2 or the turbines n. 3 are off there isn't an appreciable reduction of sound pressure level, in fact from Figure 13 is appreciable only the stop of all turbines (time interval between two red vertical lines).

5.0 Conclusions

In this paper is reported a first step of acoustic measurements in some houses near a wind farm. The acoustic measurements were performed in the day time and in the night time, the measurements were carried out with open window, because it is the more annoyance condition. Two sound level meters were used, they were positioned in two different rooms, one has the window toward East side, the other one has the window toward West side, in this manner the same acoustic event was measured in two different point . The day time measurements were influenced by the presence of anthropogenic noise (cars, tractors, human voices, ...), so it isn't possible divided the noise component due to wind turbines respect to the anthropogenic noise component. While during the night time the anthropogenic noise component is absent. Two wind speed condition are considered, one with wind speed less 12 m/s the other one with wind speed over 12 m/s. For wind speed less 12 m/s the difference between the LAeq or L95 measured when wind turbines were on, respect the LAeq or L95 of background noise (wind turbines off) is over 5 dBA, this difference is a very high value, we can suppose that the noise emitted by blades rotation is over to the background noise (noise produced only by blowing of the wind). For wind speed exceeding the 12 m/s the background noise tends to be equal to the noise emitted by rotation of the blades, in this condition the background noise masks the aerodynamic noise produced by the airflow around the rotor blades. Other acoustic measurements were performed, but for space requirements will be published in a next work.

Table 3 - Summary of the West side window, wind speed less 12 m/s.

step		LAeq dBA	L95 dBA	Average wind speed	Average wind direction
1	Turbines all on 20:30 – 24:00	40.3	34.6	12 m/s	South-west
2	Turbine 2 off – 00:00 – 00:30	40.7	37.6	10.8 m/s	South
3	Turbines all off – 00:30 – 01.00 Background noise	28.8	25.5	10.5 m/s	South-west
4	Turbines all on 01:00 – 06:00	40.0	37.2	10.7 m/s	South-west

Table 4 - Summary of the East side window, wind speed over 12 m/s.

step		LAeq dBA	L95 dBA	Average wind speed	Average wind direction
1	Turbines all on 22:00 – 24:00	55.8	39.9	16.5 m/s	South-west
2	Turbine 3 off – 00:00 – 00:30	41	36.2	14.0 m/s	South-west
3	Turbines 3 and 2 off – 00:30 – 01:00	43.2	33.7	12.0 m/s	South-west
4	Turbines all off – 00:30 – 01.00 Background noise	53.6	34.0	13.0 m/s	South
5	Turbines all on 01:30 – 05:00	48.5	39.4	14.0 m/s	South
6	Turbines all off – 05:00 – 05:30 Background noise	46.5	41.2	17.0 m/s	South
7	Turbines all on 05:30 – 07:30	55.6	43.5	19.0 m/s	South

Table 5 - Summary of the West side window, wind speed over 12 m/s.

step		LAeq dBA	L95 dBA	Average wind speed	Average wind direction
1	Turbines all on 22:00 – 24:00	43.1	38.3	16.5 m/s	South-west
2	Turbine 3 off – 00:00 – 00:30	39.1	36.5	14.0 m/s	South-west
3	Turbines 3 and 2 off – 00:30 – 01:00	39.6	36.5	12.0 m/s	South-west
4	Turbines all off – 00:30 – 01.00 Background noise	35.7	28.0	13.0 m/s	South
5	Turbines all on 01:30 – 05:00	40.8	37.0	14.0 m/s	South
6	Turbines all off – 05:00 – 05:30 Background noise	37.0	32.7	17.0 m/s	South
7	Turbines all on 05:30 – 07:30	45.4	39.5	19.0 m/s	South

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