DOI: 10.61782/fa.2025.0606

FORUM ACUSTICUM EURONOISE 2025

NOISE AND VIBRATION MEASUREMENTS EMITTED BY WIND TOWERS

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ABSTRACT

Wind turbines are a valid alternative to produce electricity in place of hydrocarbons, in this way it is possible to achieve the objectives set by the energy transition and limit the effects of greenhouse gas emissions. One of the problems that limit the spread of wind turbines are the effects of the impact on the environment. The problems identified are those of flicker shadow, noise and visual impact. The biggest problem is that due to noise. In fact, people who live near wind turbines complain about the negative effects of noise. This paper reports noise measurements carried out in proximity to wind turbines in different wind speed conditions.

Keywords: *wind turbines, acoustic measurements, wind speed, noise, annoyance.*

1. INTRODUCTION

Wind energy contributes significantly to reducing the use of fossil fuels in electricity production and is a valid contribution to the reduction of greenhouse gas emissions. Today, wind energy is spreading to achieve the goals of the energy transition. The first windmills were built in the Middle East around 600 AD and later spread to the countries of Northern Europe. The first wind towers for the transformation of wind energy into electricity were built in the United States in the 1950s and then spread in the 1970s, following the oil crisis. The areas with the greatest presence of wind farms are Asia (China and India), Northern Europe and the United States. In Italy the first wind towers were installed in 1990, but only from 1996 onwards has there been a significant number of plants connected to the electricity grid. In fact, in Italy in 2001 there were only 81 wind farms installed, with a total power of 664 MW (3% of the electricity produced from renewable sources). In 2015 there were 2,734 plants, with a power of approximately 10,000 MW (18% of the electricity produced from renewable sources). In Italy, due to the morphology, the areas with the greatest presence of towers are those in the south, where the average wind speed during the year exceeds 5 m/s. Many wind farms have been built near homes, creating problems for people living in those areas. Compared to other sources of noise (for example, airplanes, railways, etc.), the degree of annoyance of the noise emitted by wind turbines is the one that generates the greatest disturbance in the population. The noise due to the operation of wind turbines is potentially capable of causing sleep disturbances and other pathologies. The reason for these disturbances is due to the particular noise emitted that modulates over time, the type of noise concentrated in the medium - low frequencies and the fact that the towers are over 100 meters high, and the sight of these objects is not accepted by the populations living near the wind farms.

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Usually, the noise emitted by a wind turbine is broadband and concentrated in the frequency range between 300 Hz and 2,000 Hz, in the range in which the human ear is most sensitive and therefore the individual feels greater discomfort [1-2]. The types of noise produced are aerodynamic noise due to the rotation of the blades and mechanical noise inside the nacelle, due to the electromechanical components (generator, gear multiplier, cooling systems and other components) [3-4]. Aerodynamic noise is a very complex phenomenon and is due to the turbulence of the air generated by the rotation of the blades and the compression effect of the air on the tubular tower. Another possible discomfort that can be generated is that of the "flicker shadow", or the intermittent effect of the shadow, which occurs when the wind tower is placed between the sun and the observer. The effect of the intermittence of the shadow caused by the rotation of the blades is visible to the observer for over 300 meters from the tower. This phenomenon does not occur when the blades do not rotate. Furthermore, one of the problems that arises in the design phase of wind farms is the theoretical estimate of the acoustic impact generated by the operation of the towers [5-8]. The estimate of the noise produced is performed in accordance with the ISO 9613:2-20024 standard, but in the verification phase the numerical model underestimates the measured value of the sound pressure level [9]. Wind turbines, even if they are complex systems, are considered point sources of sound, since the source-receiver distance is considered sufficiently large compared to the dimensions of the towers. For the determination of environmental noise levels, the ISO 9613-2:2024 standard provides a theoretical method to evaluate the sound attenuation, with the source-receiver distance, in propagation in open-air. The standard provides for the calculation of the equivalent noise level "filtered A", assuming meteorological conditions favorable to the propagation of sound, through the application of the following simplified relationship:

$$Lp = Lw - 20 \, Log \, (d) - 11$$

Where d, is the distance in meters between the sound source (tower) and the receiver as the distance increases the sound pressure level Lp decreases. Furthermore, over time the rotating parts of the towers wear out with a consequent increase in the sound level emitted compared to the initial conditions. This condition has not yet been fully examined, but the effects of mechanical wear and the consequent increase in noise are a problem that needs to be analyzed.

2. ACOUSTIC MEASUREMENTS

The acoustic measurements were carried out with a sound level meter configured to acquire the equivalent sound level of the linear sound, A-weighted, of the statistical levels with a Fast constant time. The sound level meter was installed at a height of 1.70 m from the ground and more than 1.0 m from any vertical surfaces [10]. The wind turbines subject to acoustic measurements have a nominal power of 3 and 4 MW, with a total tower height equal to 100 m and a blade length equal to 60 m. The acoustic measurements were taken with the wind turbines are on (ambiental noise) and off (background noise), to evaluate, with the same wind speed, the noise contribution caused by the operating wind towers. in the condition in which the sound levels were acquired inside an house with open windows. The measured sound levels are reported as a function of time and a table indicating the value of the equivalent sound level LeqA in dBA, the statical sound level L95 in dBA and the wind speed in the condition in which the wind farms are in operation or are turned off. For wind speeds of about 9 m/s, when the towers are in operation compared to when they are turned off it is possible to notice a difference in the measured sound levels. This difference denotes that for this wind speed the towers in operation generate annoyance in the populations living in the vicinity of the wind farms. Table 1 shows the acoustic measurements when the wind speed is below 9 m/s. While Figure 1 shows the time history of the measured sound level (dBA) inside home when the wind speed is below 9 m/s.

Table 1. Acoustic measurements when the wind speed is below 9 m/s

Activities	Leq (dBA)	L95 (dBA)	Average wind speed (m/s)
Towers on Measurements 1	38.5	37.0	9.0
Towers off Measurements 2	25.0	21.5	9.0
Towers on Measurements 3	37.0	35.5	8.8

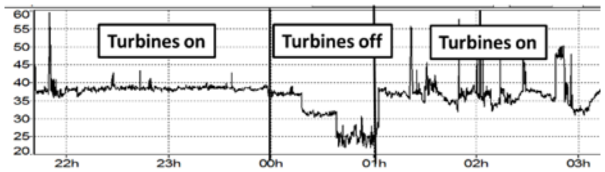

Figure 1. Time history of the measured equivalent sound level (dBA) inside home when the wind speed is below 9 m/s.

Table 2 and Figure 2 instead show the sound levels when the wind speed exceeds 12 m/s. It is noted that for the tower in operation or when it is turned off no differences in the sound level are detected. For these wind speeds the towers in operation do not generate annoyance. The wind's noise covers the noise emitted by the towers.

Table 2 Acoustic measurements when the wind speed between 12 m/s and 25 m/s.

Activities	LeqA dBA	L95 dBA	Average wind speed, m/s
Towers on measurement 1	40.5	37.0	12.0
Towers off measurement 2	40.5	36.0	15.0
Towers on measurement 3	39.0	36.5	14.2
Towers on measurement 4	45.0	37.5	14.4
Towers on measurement 5	51.0	47.0	21.3
Towers off measurement 6	54.0	47.5	23.1
Towers off measurement 7	52.5	48.5	24.4

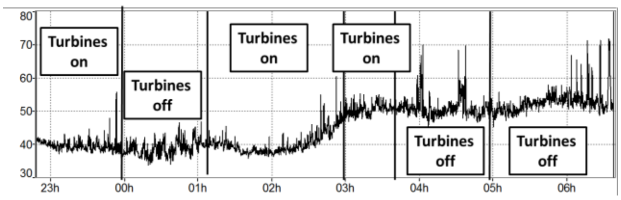

Figure 2. Time history of the measured equivalent sound level (dBA) inside home when wind speed is in the range between 12 m/s and 25 m/s.

The following are the results of measurements of noise generated by wind towers and the relative wind speed near the microphone, carried out outside a house. The distance from tower to home is 200 meters; the wind tower is 70 m height; the nominal power is 200 kW. The measurements are performed with a sound level meter and the equivalent sound levels have been grouped in function of the wind speed range (from 1 m/s to 5 m/s). The values of the ambient noise level (active source) are shown in solid line, while the background noise (source off) are shown in dashed line. Figure 3 shows the sound trends in the daytime period; Figure 4 shows the sound trends in the night period. The wind speed varies between 1 m/s to 5 m/s. For wind speed values above 5 m/s the measured sound level values are meaningless.

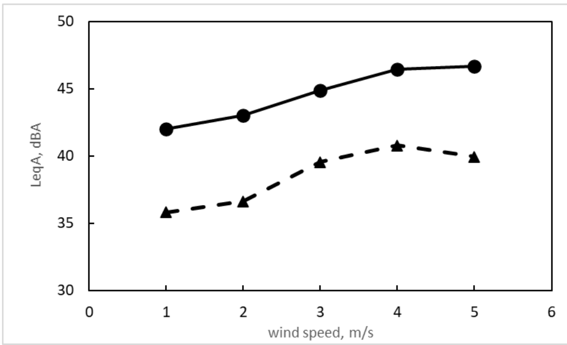

Figure 3. Sound level trends in the daytime period.

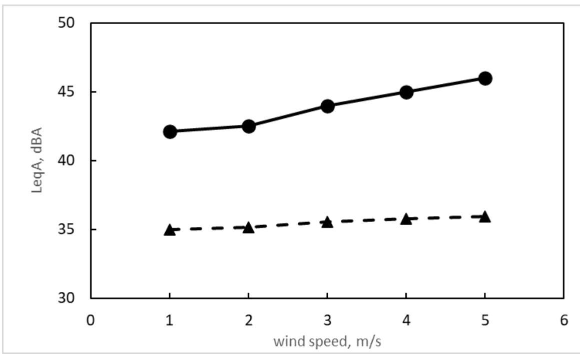

Figure 4. Sound level trends in the night period

The background noise during the day is higher than the night one due to the presence of human activities. While the environmental noise (tower in operation) increased with the increase of the wind speed as expected. It should be noted that the noise levels when the source is active do not change between the night and day periods. The noise of the wind tower is a stationary sound source, for each interval of the wind speed considered.

3. CONCLUSIONS

This paper reports the results of acoustic measurements performed near wind towers. The effects of wind on phonometric measurements have been analyzed. For measurements inside houses, it has been noted that the effects of noise disturbance are due to wind speeds up to 9 m/s. For higher wind speeds, the wind noise covers the noise emitted by the wind towers. Furthermore, the values of acoustic measurements performed outside a house are reported for different wind speeds both when the wind tower is in operation and when it is off. It is possible to note that as the wind speed increases, the effect of the wind tower emission increases.

4. ACKNOWLEDGMENTS

This research was financially supported by the European Union – Next Generation EU, the Ministry of University and Research (MUR) as part of the PRIN 2022 project 20223LMSZN, COMBINE "Sustainable condition monitoring of wind turbines using acoustic signals and machine learning techniques" and as part of the PON 2014-2020 "Research and Innovation" resources – Green/Innovation Action – DM MUR 1061/2022.

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