MINI-WIND TURBINE NOISE MEASURED INSIDE NEAR-BY HOUSES

Gino Iannace *1, Umberto Berardi †2, Giuseppe Ciaburro ‡1 , Dario D'Orazio 3 et Amelia Trematerra♦1
[1]Università degli Studi della Campania Luigi Vanvitelli, Aversa, Caserta, Italy
[2]Department of Architectural Science, Ryerson University, Toronto, Ontario, Canada
[3] Dipartimento di Ingegneria, Università di Bologna, Bologna, Italy

1 Introduction

The possibility of using the wind to rotate blades and to obtain the lifting of the water or to operate millstones is an ancient technique. Today, wind power keeps being fundamental to the increased importance of renewable energy. In Italy, the country of the present study, there were 81 wind farms installed in 2001, with a total capacity of 664 MW; in 2015, there were 2,734 wind farms with a capacity of 9,162 MW. The environmental impacts caused by the construction of wind farms include the occupation of the territory, visual impact, acoustic emissions, electromagnetic emissions, possible interference with flora and fauna, and discomfort for the populations living near the wind farms. In particular, one of the main complaints reported by the resident population is the noise generated by the rotation of the wind turbine blades [1]. The functioning of a wind tower generates the aerodynamic noise produced by the rotating blades and the mechanical noise inside the nacelle. The noise generated by the operation of the wind towers, with the same perceived sound level, is more annoying than other anthropic noises. Although the sound levels caused are modest in the order of 30-50 dBA, this type of noise, due to the particular tonal component, is highly annoying. Usually, the noise emitted by a wind turbine is a broadband noise concentrated in the frequency range 300 Hz – 2000 Hz [2,3]. In this paper, the acoustic measurements inside a house of the noise produced by the operation of a 200 kW wind turbine are reported.

2 Methodology

The house in which the acoustic measurements were carried out is located in a small rural municipality. The area is a plateau within a large basin at about 700 meters above sea level, located in the central area in the South Italian Apennines. The height of the gearbox is 30 m, the rotor diameter is 20 m, and the blades rotation speed is 20 – 60 rpm. Blades began to move with wind speed around 3 m/s; and the rotation is stopped for safety conditions when wind speed is 25 m/s. The highest power production starts for wind speeds over 15 m/s. The tower is located to the east of the house, and the land is flat and has modest vegetation. The distance between the home and the tower is 250 m. During the measurements, the window was open to assess the maximum disturbance.

The acoustic measurements were carried out using a sound level meter model Larson Davis LXT1, which was calibrated with a Larson Davis CAL 200. The instruments were compile with the requirements of the IEC 61672-1 standard "Class 1". The sound level meter was configured to acquire the sound equivalent level of the "A" weighted and the L95 statistical level; this parameter is defined as the level exceeded for 95% of the observation time. The "A" -weighted filter (dBA) was used because the annoyance response to due to wind turbine nose, is related to "A"-weighted levels.

The following regulatory approaches were adopted to evaluate the annoyance produced by the wind turbines [4,5]:

- Differential criterion: the differential noise level is represented by the difference between the ambient noise level and the residual noise level. If the difference between the level of environmental noise and the residual level (wind turbines turned off) is less than 5 dBA daytime and 3 dBA nighttime, then the noise generation is considered acceptable.
- Normal tolerability criterion: the background noise (L95) is measured when wind turbines are stopped, and the equivalent level is evaluated. The normal tolerability limit is 3 dB.

3 Sound propagation theoretical models

One of the problems encountered during the installation of a wind tower is the theoretical evaluation of the noise introduced into the living environment. This evaluation is necessary to establish if the installation of the wind tower will cause annoyance to the people living in the chosen area. The most used model is based on ISO 9613-2 [4]. It considers the sound source as a point, although a wind turbine is a complex system that can be considered a point sound source only when there is a considerable distance between the sound source and the receiver. For the determination of the noise levels inside a receiver point, the standard ISO 9613-2 provides a theoretical method to evaluate the sound attenuation, with the source - receiver distance, in outdoor propagation. The standard calculates the equivalent sound pressure level assuming meteorological conditions that favor sound propagation, by applying the following relationship:

$$Lp = Lw + DI\theta - A_{div} - A_{atm} - A_{gr} - A_{bar} - A_{misc}$$

where Lp: sound pressure level (dBA); Lw: sound power level (dBA); Diθ: directivity; A_{div}: attenuation due geometric divergence; A_{atm}: attenuation due to atmospheric absorption; A_{gr}: attenuation due to ground effect; A_{bar}: attenuation due to a barrier; A_{misc}: attenuation due to foliage or industrial sites.

The application of the calculation model of noise propagation appears to be precautionary as it provides an overestimation of the levels when considering only the attenuation of the noise caused by the geometric divergence, not conside-

* gino.iannace@unicampania.it
† uberardi@ryerson.ca
‡ giuseppe.ciaburro@unicampania.it
♦ amelia.trematerra@unicampania.it

ring the other attenuating factors such as atmospheric absorption, as well as the presence of obstacles and vegetation. Numerical simulations based on engineering approaches are, in many cases, a rapid application. In a simplified way, the sound pressure level is given by the formula: $Lp = Lw - A_{div}$ with $A_{div} = 20 \text{ Log}(D) + 11$, where D is the distance between the sound source and the receiver and A_{div} is the sound attenuation which occurs during propagation. For a wind tower of nominal power of 200 kW, Lw is 100 Dba; so, the theoretical sound pressure levels is $Lp = Lw - A_{div} = 41$ dBA.

With the ISO 9613, it is possible to evaluate the sound pressure level at the receiving point located in a home. For the evaluation it is necessary to estimate the effect of the attenuation of the open window or the value of the difference between the sound level measured externally and the level measured internally in the home. This value is estimated to be around 4 or 5 dBA [3]. The sound level inside the house is equal to the sound level estimated in the receiving point subtracted from the attenuation value of the open window. A theoretical level inside a home of 37 dBA was predicted.

4 Acoustic measurements and discussion

The acoustic measurements were made by placing the sound level meter at about 1.6 m from the floor, and 1.0 m from the balcony in the first-floor room used as a bedroom. Measurements were performed with windows open in the maximum disturbance condition. Several sessions of measurements were performed corresponding to two operating conditions of the wind turbine. Figure 1 shows a typical measurement session with the time history of the measured sound pressure level. The environmental noise when the source is turned on, the residual noise when the source is turned off, the background noise L95 when the source turned is off and the wind speed are shown in Table 1.

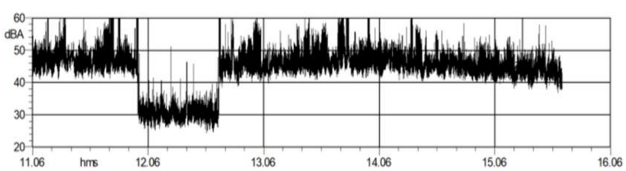

Figure 1: Time history of the sound pressure level.

When the wind turbine is off, the residual noise level, measured inside the home, is equal to 30 dBA, while when the wind turbine is on, the measured sound pressure level is equal to 45-50 dBA. A neglected aspect regarding the emission of noise by small wind turbines with a cylindrical tower is that the noise emitted is not only due to the rotation of the blades. The noise emission is a complex phenomenon, also emitted by the entire tubular structure of the tower put into vibration by the rotation of the blades. The theoretical simulation model therefore underestimates the noise level inside home. Near the wind turbine the following problems were observed: the blade rotation speed is about 30 rpm; the rotation of the blades is discontinuous, it depends from the instantaneous wind speed, and this generates an intermittent noise. Intermittent rotation with a speed of about 30 rpm can-cause damage to the blade elements. Finally, it was considered the theoretical relationship for the evaluation of the noise introduced in the home due to the functioning of a tower, applying the ISO 9613 standard. In the hypothesis of point-sound source, it was found that the theoretical relationship gives a value of the sound pressure level of Lp = 37 dBA. Therefore it underestimates the measured value of the sound pressure inside the house. From the comparison, a difference of 13 dBA between measured and calculated values was obtained.

Table 1. Acoustic measurement results.

Time of the day	Environmental noise dBA	Residual noise dBA	Background noise L95 dBA	Average wind speed m/s
19:00 – 22:00	42.4			8
06:20 – 09:00	44.0			9
16:00 – 17:30	46.1			10
18:00 – 22:00	40			8
22:00 – 06:00	40			8
06:00 – 9.30	44.8			8
23:00 – 04:30		30.0	21.3	9
06:00 – 13:00	50.2			15
22:45 – 01:00	40			10
01:30 – 04:30		31.0	20.7	10
01:00 – 03:30	41.0			8
03:40 – 04:10		31.5	27.6	8
21:40 – 22:00	39.0			9
01:40 – 04:40		30.5	24.0	8
06:00 – 10:00	47.6			12
11:10 – 12:00	49.4			13
12:00 – 12:30		31	28	10
12:30 – 15:45	47.0			12
14:00 – 20:00	46.7			12
11:15 – 15:15	46.6			11
19:45 – 22:00	43.7			12
22:00 - 23:45	37.0			5
19:45 – 22:00	43.3			11
22:30 – 01:00	41.2			9
00:00 – 04:30	40.0			9
06:00 – 16:00	44.0			12

5 Conclusions

In this study, we report the acoustic measurements of the noise produced by the operation of a wind turbine with a nominal power equal to 200 kW performed inside a house. In the house, the wind tower increases the sound level of about 10 dBA. The theoretical model for the evaluation of the noise introduced in a house due to the functioning of a tower underestimates the measured value of the sound pressure level.

References

[1] E. Pedersen, K.P. Waye. Wind turbine noise, annoyance and self-reported health and well-being in different living environments. Occupational and environmental medicine, 64(7): 480-486. 2007.

[2] G. Iannace. Effects of noise from wind turbines inside home. Wind Engineering, 40(1): 25-30, 2016.

[3] G. Iannace, A. Trematerra, U. Berardi. Assessment of the noise produced by wind farms with the acoustically analogous techniques without stopping the noise source, Wind Engineering. 43(2), 2019.

[4] ISO 9613-2:1996, Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation

[5] G. Iannace. Wind turbines noise measurements inside homes. Building Acoustics. 25(4): 339-350, 2018.