DOI: 10.61782/fa.2023.0802

forum acusticum 2023

APPLICATION OF CURRENT NOISE LIMITS IN ITALY TO THE RECENT LAW FOR WIND TURBINE NOISE ASSESSMENT

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ABSTRACT

On 1 June 2022, the Italian Minister of the Ecological Transition issued a law for the "Determination of the criteria for measuring the noise emitted by wind farms and for containing the related noise pollution". Based on scientific studies, the law set procedures to assess noise emitted at the receivers by operational wind farms. The regulation gives a measurement protocol requiring the turning on and off of wind turbines to determine the level of residual (other than wind turbine) noise and a second protocol that allows for an estimate of residual noise without the plant shutdown. However, the political decision-making process did not lead to specific wind turbine noise limits at the receivers and the issued law is ambiguous on some aspects concerning the comparison with the existing ones. This work suggests a procedure to compare the results obtained with the new assessment procedure to the limits currently in force in Italy, derived from the acoustic zoning. The methodology is intended to be useful to technicians who, in this transitional phase of waiting for specific limits, want to calculate indicators suitable for comparison with the limits to determine possible exceedances.

Keywords: *wind turbine noise, noise limits, noise assessment.*

1. INTRODUCTION

Policy makers finally recognized climate change as a true global emergency and the United Nations promptly called for urgent action toward green energy transition with the Glasgow Climate Pact, promising to revisit the emission reduction plans in 2022 in order to try to keep the Paris Agreement targets set for zero greenhouse gas emissions by 2050. Renewables generated more electricity in the EU than fossil fuels for the first time in 2020, which was the best year for the global wind industry showing a year-to-date growth rate of 53%, bringing global cumulative wind power capacity up to 743 GW. However, the wind market must rapidly expand over the next decade to reach the target on time, with Italy expected to double its production by 2030. Italian wind power at the end of 2022 was 11.7 GW, produced by over 7000 Wind Turbines (WT), with 90% in the south. A boost in wind energy is in the perspectives outlined by the Mission 2 of the National Recovery and Resilience Plan in order to work towards the clean energy transition promoted by the European Green Deal. Considering that Italian WT mainly have power <200 kW and almost 15% are over 15 years old, and only 342 Wind Farms (WF) are over 10 MW, repowering and revamping are the solutions going for the most rather than building new WF. New WF are also disadvantaged by the expensive Strategic Environmental Assessment (VAS) leading farm owners to the fragmentation of WFs in favor of single WT under 1 MW power in order to undergo the simpler single environmental authorization (VIA). A historical passage of WT repowering is thus taking place but, for economic reasons, it is based on the replacement of old Italian WTs with used ones from northern Europe. Although this process improves the power, the WFs remain old and subjected to relevant risk of faults.
New or old, all WFs should comply with the noise limits, but the latter have a greater potential to be disturbing as they are subject to the onset of mechanical components of noise.

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Given the well-known peculiarities of Wind Turbine Noise (WTN) [1-3], which lead to a significantly annoying sound [4-6], and the difficulties in its measurements [8-9], specific noise measurements and procedures are needed. In 2022, the Italian Minister of the Ecological Transition issued a law for the "Determination of the criteria for measuring the noise emitted by wind farms and for containing the related noise pollution" [10]. The decree provides a separate measurement and analysis procedure depending on whether or not it is possible to turn on/off the WF or according to the type of check being performed (authorities control or self-check). In the case of impossibility, the decree implemented (Annex 3), with minor changes, the ISPRA procedure [11], which was derived and validated by works published in the literature [12-15]. Although it was foreseen in the political decision phase, the correct definition of the regulatory limits has not yet been defined and the law, at the moment, appears truncated.

The present work, therefore, wants to show a transitional solution that allows to compare the results obtained with the new assessment procedure to the limits currently in force for acoustic zoning in Italy.

2. SUMMARY OF THE PROCEDURE

The decree provides a detailed description of the requirements for measurements instrumentation and a list of all the parameters to be acquired at the receiver. They include meteorological data, WF operational information (provided by the plant manager) and noise data. After measurements of environmental noise levels (LA) near a receiver, at first detailed phase of spurious events removal is necessary. At present stage, this operation is manually performed by the operator over the time history of data acquired. However, the procedure for separating the wind turbine noise contribution (L_E) from residual noise (L_R) at receiving sites has many difficulties. Their similar sound spectra and the dependence of both on wind speed make their identification and separation a challenging task if only the results of the measurements performed when the WF is operational are used. This is especially true in a complex orography with many WTs and an unpredictable wind shear. Nevertheless, many countries require such a procedure to verify compliance with regulatory noise limits. The outright method requires the WF shut down to easily measure the residual noise at different wind speeds at receiver and at ground height (v_{gr}), but this involves costly consequences on WF's performance. Other methods use L_R measured in a different time period or in a close and similar site, but this leads to incorrect noise evaluation as vgr and direction are affected by time and space variations, particularly in complex terrain. Annex 3 of the Italian Decree, i.e. the ISPRA procedure, does not provide for the shutdown of the WF but requires noise and weather measurement lasting at least 3 weeks. This is a sufficient period to observe time intervals in which the WTs have a rotor speed (N) low enough not to alter the environmental noise, thus allowing a first estimate of the residual. The subsequent automatic and iterative phases allow to compute the final estimates, more accurate, of L_R as a function of v_{gr} and of L_E as a function of an '*equivalent blade rotational speed*' ($N_{eq,Tot}$). $N_{eq,Tot}$ is a parameter introduced to considers the rotation of all the WTs of a multi-turbine WF and it is weighted over geographical, weather and operational parameters. It is defined in Eq. 1 and 2.

$$N_{eq,TOT} = \sqrt[5]{\sum_i^m N_{eq,i}^5} \quad (1)$$

$$N_{eq,i} = N_i \left(\frac{r_1}{r_i}\right)^{2/5} K_i C_i \quad (2)$$

With:

- N_i is the Rotation speed [rpm] of the i^{th} impacting WT averaged over 10';
- r_i is the plan distance between the i^{th} impacting WT and the receiver;
- r_1 is the plan distance between the closest WT (i = 1) and the receiver;
- K_i and C_i are parameters that take into account the sound propagation modes and depend on atmospheric absorption, ground effect and weather conditions at the wind turbine hub (wind direction and night-time thermal inversion).

Using $N_{eq,Tot}$ is like shifting the sound emission of all the WTs to the closest WT, reducing a multi WTs approach to a singular one.

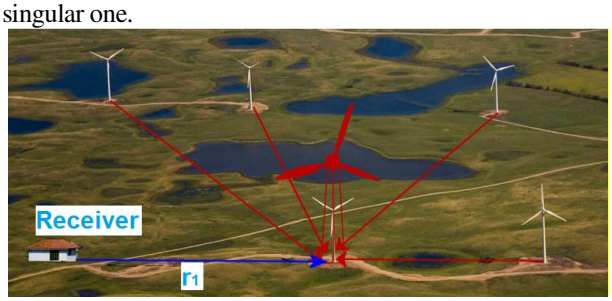

Figure 1. Reduction of a multi WTs approach to a singular one using $N_{eq,TOT}$.

3. CONCLUSION OF THE ITERATIVE PROCEDURE

The detailed description of the Italian procedure is beyond the scope of this work, but the focus is on its final stages In summary, the initial part of the procedure consists in removing spurious events and creating, at first, an "*Environmental Noise Table*" in which each valid datum, which refers to a measurement interval of 10' and is free of spurious noise events, is associated with the measured environmental noise level ($L_{A,10min}$), the wind speed value at the receiver (v_{gr} = k) and the value of parameter $N_{eq,Tot}$ = x. Then, the procedure involves creating new tables with the first estimate of $L_{E,x}$ and $L_{R,k}$ as a function of the classes of N_{eq} (x, ranging from the activation N_{act} to the Maximum N_{max}) and of v_{gr} (k, ranging from 0 to 5 m/s). In the subsequent iterative phase, the procedure is repeated to refine the estimates of those levels. In every steps, the outputs of the previous round are used as input to be energetically subtracted from the starting matrices. During the process, some conditions to check are inserted in order to maintain a sufficient statistic on each considered bin. The iterative procedure is considered concluded when both $L_{E,x}$ and $L_{R,k}$ stabilize, i.e. when the results obtained with an iteration, for each x and for each k, differ by no more than 0.1 dB(A) from the previous iteration. In order to compensate for possible oscillating trends, a least squares fit must be performed on the emission data resulting from the iterative procedure. The fit is performed after eliminating the L_E data which are negligible compared to the minimum L_R levels detected at the receptor, and those for which there is an insufficient number of data for an adequate degree of statistical validity. For the fit (Figure 2), a logarithmic function of the type of Eq. 3 must be used, or a polynomial curve of degree not higher than the 3rd.

$$L_{E,x,fit} = A \cdot \ln x \cdot + B \tag{3}$$

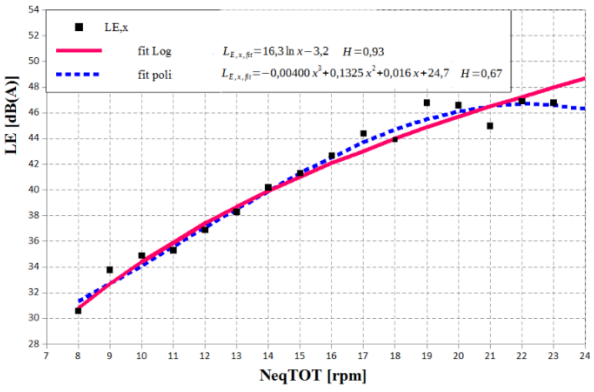

Figure 2. Example of fit phase on L_E.

The fit is considered valid if the condition reported in Eq.4 is respected. n_{fit} is the number of data considered in the fit and n is equal to 2 in the case of a fit with a logarithmic curve and, in the case of a polynomial curve, it is equal to the degree of the polynomial increased by 1.

$$H = \left(\frac{\sum_{x=N_{act}}^{N_{max}} \left(L_{E,x,fit} - L_{E,x} \right)^2}{\left(n_{fit} - n \right)} \right) < 2 \tag{4}$$

The curve which corresponds to the lowest value of H in the above validity condition must be chosen. If the fit does not meet the validity condition, i.e. it is not sufficiently reliable, it is advisable to check again the phase for removing spurious events and data synchronization, before possibly repeating the whole measurement campaign.
The $L_{E,x,fit}$ data extrapolated from the fit curve are those to be used for the calculation of the specific parameter necessary for the verification of the regulatory limits, while $L_{R,k}$ can be directly used without fit.

4. COMPARISON WITH NOISE LIMITS

Since the Italian decree was drawn up to evaluate parameters to be compared with legal limits not yet issued and since the decree itself is not very clear on how to verify compliance with the current legal limits valid in the transitional phase, this chapter is dedicated at providing a transitory method for comparing the outputs of the procedure with the limits defined by the actual law in force in Italy [16], and set by the acoustic zoning of where the WFs are positioned.

4.1. Absolute Emission Noise Limit

The *Environmental Noise Table* defined by the Italian decree and described above should be enlarged by two new columns in order to include the results of the iterative procedure and of the fit, as reported in the example of Figure 3. Each value of k must be associated with the corresponding residual noise level ($L_{R,k}$) and each value of x with the corresponding plant noise emission level ($L_{E,x,fit}$).
Then, for each day of measurement, the energetic average of the emission level data $L_{E,x,fit}$ is calculated following a day (6:00 ÷ 22:00) and night (22:00 ÷ 6:00) period division. The results obtained are comparable, respectively, with the day and night emission limits. Each daily values obtained must respect the limit, which is equivalent to respecting the limits in the case of the worst conditions among those present during the weeks of measurement.

ID	Date and time	L_A	V_{gr} (k)	$N_{eq,TOT}$ (x)	$L_{R,k}$	$L_{E,x}$
6	...	45,5	1	21	33,7	46,5
7	...	43,0	1	19	33,7	44,9
8	...	44,5	1	19	33,7	44,9
9	...	46,0	1	21	33,7	46,5
10	...	46,5	0	21	32,0	46,5
11	...	47,0	0	22	32,2	47,2
12	...	47,0	0	22	32,2	47,2
13	...	48,0	0	22	32,2	47,2
14	...	48,0	1	21	32,2	46,5
15	...	48,5	1	21	33,7	46,5
16	...	45,5	1	20	33,7	45,7
17	...	42,5	1	16	33,7	42,1
18	...	43,5	1	17	33,7	43,1
19	...	48,0	2	21	33,7	46,5
20	...	46,5	1	21	44,8	46,5
21	...	46,0	1	20	33,7	45,7
22	...	44,5	1	18	33,7	44,0
23	...	47,0	1	21	33,7	46,5
24	...	46,5	1	20	33,7	45,7

Figure 3. Example of Environmental Noise Table, with in blued the added columns for $L_{R,k}$ and $L_{E,x,fit}$.

4.2. Absolute Immission Noise Limit

The initial *Environmental Noise Table* already includes the measured sound level data cleansed of spurious events and referred to successive 10' intervals ($L_{A,10min}$). Therefore, for the verification of the absolute limit it is sufficient to directly calculate the energy average of the L_A noise data in the initial *Environmental Noise Table*, dividing them for each day and night periods. In fact, for the evaluation of this limit, only the measurement correctly free from spurious events is needed, while the procedure can only be of support in the presentation and organization of data.

4.3. Differential Immission Noise Limit

In accordance with its definition in Italian law, as modified by the new Decree for the specific case of wind noise, the verification of compliance with the differential immission limit is carried out only if the environmental noise level measured on the facade of the receiver during the entire day or night period exceeds a certain applicability threshold level for each reference period (day/night). These applicability threshold levels are: 50 dB(A) during the day and 40 dB(A) during the night.

If the threshold level is exceeded, the residual noise level should be calculated during the reference period and, to verify the differential limit, the algebraic difference between the environmental and the residual levels is performed. This difference must not exceed 5 dB(A) during the day and 3 dB(A) during the night. Thanks to the procedure, this can be done using the data present in the enlarged *Environmental Noise Table*, calculating the energy averages L_A and L_R for each day and night of measurement and finally carrying out the required checks (thresholds verifications and differential). According to the indications of the law, all measurement days must be considered in order to identify the reference period (day/night) with the worst exposure conditions for the receiver.

5. CONCLUSIONS

With the recently issued decree, Italy is among the first countries to have a law for the evaluation of wind turbine noise levels at receivers in order to estimate the exposure. However, the political decision-making process did not yet lead to specific limits. These process will have to take into account not only the possible differences in the exposure conditions, but also that too low limits could penalize the development of this clean technology in industrial areas and too high limits could be unacceptable for quiet rural areas. Finally, the definition of the limit cannot fail to take into consideration the wind noise disturbance much higher than other sources at the same level, in an approach as defined in [17].

Given the current transitional phase in Italy, in this works the authors intended to provide some suggestions to support technicians who have to apply the decree and need to evaluate the indicators suitable for comparison with the limits to verify any exceeding and, consequently, assess the need for noise mitigation measures.

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