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Implementation Of The Issue Of Noise From Wind Turbines At Low Frequencies

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ABSTRACT

The enduring energy scenario leads to further promote the development of the exploitation of renewable energy sources. Recent European standards, have been defining a path to reach in 2050 a level of decarbonization lower of 80% compared to 1990. Wind farms have been growing quickly for last decade with individual wind turbines getting larger and larger. In addition to the benefits of containing greenhouse gas emissions and restraining the use of depletable resources drawbacks have also appeared, due to noise generation from wind turbines and adverse reaction of some nearby residents. The noise generated by wind turbines has a broad spectrum character but the low frequency noise causes special problems. It is a fact that in different European countries special laws have been adopted to impose noise limits and evaluation methods for the assessment of environmental low frequency noise from this kind of sound sources. Other countries are still lacking specific rules but in the authorization procedure such analysis is required by environmental control agencies. The purpose of this study consists of comparing the assessment procedures currently used in different European countries for the prediction of low frequency noise from wind turbines and its propagation. The comparison of procedures gives a chance to put forward progressions in low frequency noise emission and reception.

Keywords: Sound, low frequency, regulations

1. INTRODUCTION

Global warming and greenhouse gas emissions are matters of great concern. To keep under control and reduce such emissions, a global trend towards cleaner energy sources can be found. Concrete alternatives for coal and other fossil fuels are nuclear power and renewable energy sources. Therefore the present energy scenario has led to an acceleration in the development of the use of renewable energy sources. Recent European standards, such as communications COM/ 2011/112 "Roadmap for moving to a competitive low-carbon economy in 2050" [1] and COM/2011/885 "Energy Roadmap 2050 " [2], have raised the concern of defining a path to reach in 2050 a level of decarburization that is lower than 80% when compared to 1990. One of the most promising renewable sources is to harness energy from the wind through wind turbines.

However, the widespread use of wind turbines is significantly hindered by the noise they produce. The technology to make full use of this source is based on large wind turbines, with a size as well as a rated capacity which keeps on increasing. A wind farm does not produce any polluting emissions but

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even so it has an impact on the environment that has to be assessed since the design stage: a careful evaluation of the acoustic impact is required. In order to prevent the noise generated or at least to significantly reduce it, the sources of noise have to be identified. Two major types of sources of noise are present during operation: mechanical and aerodynamic. Mechanical noise comes from the many different components within the wind turbine, such as the generator, the hydraulic systems and the gearbox. Aerodynamic interaction between blades and wind stream and is the dominant source of noise from wind turbines.

The main contributor to aerodynamic noise originates from the trailing edge of wind turbine blades. Strategies to reduce aerodynamic noise include various adaptive solutions and wind techniques to modify turbine blades. Different adaptive noise reduction techniques have been developing for latest years, they include by the way varying the speed of rotation of the blades and increasing the pitch angle. Strategies like these have been successfully implemented for noise reduction purposes but they are not free from disadvantages as they can cause significant power loss [3].

Sounds consist of waves of fluctuating pressure, superimposed to the standard atmospheric pressure, and are usually characterized in terms of frequency spectrum [4]. Although the broad spectrum of the noise generated by wind turbines a special interest in recent years has been directed to the low frequency range.

Sounds with frequency between 20 Hz e 20 kHz are those that are normally audible by human beings and they are classified as the sound pressure disturbances to include into the audible range. Sounds with a frequency lower than audible threshold (i.e. with wide wavelength) are called infra sounds [5]. Infra sounds grow into perceivable when their pressure level is high and no physical difference between sound and infrasound can be detected in the audible frequency range. Low frequency noise (LFN) refers in some cases to a frequency range between 10 Hz and 200 Hz, in other cases to a range between 10 Hz and 160 Hz (Danish legislation).

In the following the regulations for wind turbines in different European countries are considered at first together with some insights into noise generation from wind farms and noise propagation. After such a framework for the subject the present work consists of evaluating how the acoustic emissions in the low frequency range generated by large wind turbines affect sensible receptors (usually rural or industrial buildings).

2. REGULATIONS FOR NOISE FROM WIND TURBINES

In Europe, and all around the world, each country has taken its own individual approach to regulate noise generated by wind turbines. At first a we focus on noise limits and calculation methodologies that are mandatory in the different countries.[6]

Noise is a factor which plays a considerable role in territorial planning and social acceptance of wind projects in Europe. However various studies have associated concerns over noise with visual impact and perception which has to be assumed as the main factor for annoyance. In most countries, noise legislation is based on national regulations, with allowable environmental noise limits categorised by area and timing. Numerous countries have set night limits and, some, evening limits. The level is normally calculated:

$$L_{p,A} = L_{W,A} + K - A - C_{met} \tag{1}$$

where $L_{p,A}$ is the A-weighted sound pressure level at the receiver, $L_{W,A}$ is the A-weighted sound power of the source, K the penalty for tonal or impulse noise, A is the attenuation during propagation from source to receiver, C_{met} is the meteorological correction.

The term A is made up of different contributions that impact on the transmission of sound from source to receiver. For wind turbines three of them are enough, corresponding respectively to attenuation due to geometrical divergence, to atmospheric absorption and to ground effect:

$$A = A_{div} + A_{atm} + A_{gr} \tag{2}$$

The limit for total noise in Denmark applies at a measured wind speed of 6 and 8 m/s, on a height of 10 m taken as reference in IEC standards. For a wind speed of 8 m/s the allowed values are 2dB higher as wind turbines are assumed to produce more noise at larger wind speeds. Denmark provides different limits for homes in rural areas and noise sensitive areas:42 dB and 37 dB (v_{10}=6 m/s) for open countryside and for noise sensitive land use respectively.

In the Netherlands the noise from wind turbines is evaluated with the aid of the noise indicator L_{den} based on the average noise emission, from local wind conditions. The same limit is applied no matter what is the area type, but the L_{den} must comply with a limit of 47 dB by day and 41 dB by night.

In Germany wind turbines obtain the same treatment as other technical installations. At night noise in pure residential areas has not to exceed 35 dB(A), 40 dB(A) in small urban areas, 45dB(A) in villages and mixed areas. The noise limits concern the cumulative noise of all the business activities. The Directive includes requirements about the quality of calculation, as uncertainties in determining sound power and of the transmission model.

In Belgium, with differences between Flanders and Wallonia, there is an extensive differentiation of noise limits for each destination area. Calculations are based on the noise level at 95% of wind turbine reference rated power.

Noise limits are regulated by specific noise metrics in order not to jeopardize the quality of life in nearby local communities. Looking also at United States the A weighted equivalent sound level is the most common metric but also statistical noise metrics and possible tonal issues associated with wind turbines are considered [7].

3. SOUNDS AND INFRASOUNDS FROM WIND TURBINES

Low frequency noise, usually known as infrasound, can become particularly bothersome and has to be regarded with special attention [8-10]. In the early stage of a wind farm design the noise given off by wind turbines must be predicted accurately and compared with the limits by law enacted.

In several European countries special laws or legal requirements have been adopted to impose noise limits and evaluation methods for the assessment of environmental noise due to this type of sound sources. Other countries are now lacking specific rules about this problem but in the authorization procedure for wind farm planning such analysis is required by environmental control agencies.

Here the calculation procedure, reported in UNI ISO 9613 part 2 [11,12], is analyzed and extended to the spectrum range above quoted. At the same time the predictive calculation procedure recently issued in Danish legislation about such a subject is analyzed and a comparison between the procedures, for the prediction of the acoustic impact of the low frequency noise produced by WECS, has been discussed with reference to a wind farm project in Sardinia, Italy [10].

Sounds are usually defined in terms of spectral components. Sounds in the frequency range between 20 Hz and 20 kHz are those which are typically audible by human beings: they are named sound waves that fall in the audible frequency range. Sounds with a frequency below the lower limit of the above range are called infrasounds, however infrasounds become perceivable as the sound pressure level becomes high [13].

The Italian legislation on noise pollution, until 1995, was based on the Ministerial Decree, March 1st 1991, stating the maximum levels of noise exposure in the living environment. With the enactment of Law 447/95 the fundamental principles are defined for the safeguard of external living environment from noise pollution, referring to several decrees for the completion of the regulatory framework. As infrasounds are concerned no reference law is currently providing limits for impacts of this physical phenomenon. Most of the present rules in acoustics treat and dictate procedures for the normal field of hearing spectrum (20Hz-20kHz). Other standards reduce the range of evaluation frequencies to third octave bands with the central frequency ranging from 100 Hz to 3150 Hz.

The decree of 16/03/98 from Ministry of the Environment deals with the techniques for detecting and measuring noise pollution by defining various environmental noise indicators and applying the minimum requirements with which measuring instruments must comply to ensure measurements validity.

Searching for details concerning low frequency noise, in paragraph 11 of Annex B to the Decree the LFN treatment is dealt with: "Presence of spectral components in the low frequency range: if the frequency analysis, carried out in the manner referred to in the previous point, detects the presence of Tonal Components such as to enable the application of the correction factor K_T in the range of frequencies between 20 Hz and 200 Hz, also the correction K_B ,as defined in paragraph 15 of Annex A, is applied but only in the night reference time ".

From what reported in this annex of the MD above mentioned, it appears that the same decree takes into account the low frequencies in the range between 20Hz and 200Hz, exclusively for any present tonal component. The MD says nothing except what is reported above, on how to estimate the noise in the whole frequency range of 20-200Hz. The survey and estimation methods of the various indicators included in the MD must comply with what is covered in the section 7 of the said Annex B: “The measurements have to be performed in the absence of rainfall, fog and / or snow; the wind speed has to be not greater than 5 m/s. The microphone must be equipped with windshield. The chain of measures must be compatible with the weather conditions of the period when measurements are carried out and in any case in accordance with CEI 29-10 (Italian norm) and EN 60804/1994".

From that it can be observed that such survey methods are not applicable whenever the wind speed is greater than 5 m s, which is contrary to the normal operation of a wind turbine which operates in nominal conditions with wind rated speeds of 12-15 m/s, even though the wind speed at the rotor hub is different from that at measurement site. The cut in speed of the wind enabling the wind turbine to start operation and generation of power for large size turbines as those concerned, ranges on average from 4 to 6 m/s.

Other European countries have established somewhat different LFN regulations. Sweden has designed maximum LFN levels for each octave band and has incorporated them into 1999 indoor building regulations with established L_{Aeq} values for every frequency. German national standard DIN 45680 adopted in 2002 has been already quoted [14], its values are based on a 1/3 octave band levels on the range of 10 to 100 Hz; the night time and daytime limits corresponds to the 50% of auditory threshold.

Noise from wind turbines in Denmark has been regulated by a Statutory Order since 1991 by setting fixed limits for the total noise level from all wind turbines [15]. The results of field measurements in Denmark confirm the that the spectrum of wind turbine noise moves down in frequency as the turbine size increases. The relative amount of the noise emitted in the low-frequency range is higher for large turbines (2.3–3.6 MW) than for small turbines (<2 MW). The difference is statistically significant in the frequency range below 250 Hz[13].

Revised in 2006 and later in 2011, a draft of the Statutory Order was subject of a public consultation and put into force by the Minister. Subsequently Denmark enacted a law entitled "Statutory Order on Noise from Wind Turbines" [16]. Such a standard deals with installation, modification and operation of wind farms. Point 8 of section 2 of this legislation, reads: “Low-frequency noise: Noise in the frequency range from 10 to 160 Hz. Low-frequency noise is characterized by the A-weighted level of noise in one-third octave bands from 10 up to and including 160 Hz, calculated indoors using the method set out in Annex 1”.It deals with, the assessment of low frequency noise, more precisely sets a range of frequencies of interest between 10Hz and 160Hz. Finally, it refers to Annex 1 where, in Part I point 1.4, a method of calculation, is shown.

The method of calculation for the propagation of low frequency noise, proposed in the Danish norm, is based on the following equation including various contributions:

$$L_{p,ALF} = L_{WA,ref} - 10 \cdot \log\left(l^2 + h^2\right) - 11 - \Delta L_{gLF} - \Delta L_{\sigma} - \Delta L_{a} \quad (3)$$

where:

l	is the distance from the wind turbine base to the calculation point;
h	height of wind turbine hub
11 dB	is a correction due to distance, i.e 10 log 4π;
ΔL_{gLF}	is the correction for the sound attenuation due to ground effects in the low frequency range;
ΔL_{σ}	is the correction due to sound insulation in the low frequency range;
ΔL_{a}	is the correction due to air absorption ($\alpha_{\alpha}\sqrt{l^2 + h^2}$)

1/3 octave f_c	10	12,5	16	20	25	31,5	40	50	63	80	100	125	160
ΔL_{gLF}: onshore(dB)	6	6	5,8	5,6	5,4	5,2	5	4,7	4,3	3,7	3	1,8	0
ΔL_{gLF}: offshor.(dB)	6	6	6	6	6	5,9	5,9	5,8	5,7	5,5	5,2	4,7	4
ΔL_{σ}: (dB)	4,9	5,9	4,6	6,6	8,4	10,8	11,4	13	16,6	19,7	21,2	20,2	21,2

α_a in dB/km	0	0	0	0	0,02	0,03	0,05	0,07	0,11	0,17	0,26	0,38	0,55

It is necessary to specify that the third is term ΔL_σ, due to the sound insulation provided with the building envelope at low frequencies, has been defined with reference to the Danish standard constructive methodology which differs in a significant way from the national (Italian) standard construction type.

The Danish indoor evening/night limit for Lp_{ALF} in dwellings is at 20 dB and it does not apply to measurements in single positions but to levels measured by the method which uses the power average of measurements in three positions: one position near a corner of the room and two positions where the complainant perceives the noise as the loudest.

4. CONCLUSIONS

The regulations concerning limits to wind turbine noise are not the same in the various countries and to compare them is of a certain interest to better understand their rationale. Low frequency noise lacks usually a specific processing even though it got attention from stakeholders and from a medical point of view. The procedure of calculating low frequency noise levels according to Italian and Danish standard has been considered as a significant part in the development of the design of a wind farm, characterized by individual wind turbines with increasing size.

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