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Noise Impact of Wind Farms: Uncertainties due to wind data reference at 10m

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Noise impact prediction or measurement of wind farms requires wind reference data at 10 meters. From data collected on more than 200 farms in France, over the last 5 years, this paper shows that, in the sampling of noise and meteorological data for noise prediction and assessment, differences in the wind profile from one site to another, in the period of the day (day, night) can lead to different estimations of emission data selection and impact assessment. Different parameter studies are presented both with regard to the effect on impact studies and farms impact monitoring and control. The work presented is in accordance with the project of acoustic standard for the assessment of noise impact of wind farms under study in France.

1 Introduction

Noise prediction and assessment of wind farms is today of strong concern. Wind farm noise is controlled by the application of noise limits at the nearest noise-sensitive properties. Two methods to set limits for wind turbine noise are used internationally. In France, there is a neighborhood noise regulation where the limit is related to the background noise level. The allowed increase in noise level is 5 dB(A) at daytime, 3 dB(A) at night and in housing 5 dBLin at high and mid frequencies and 7 at low frequencies. It is also specified that, at the measuring points, wind speed should be below 5 m/s. A project of French standard to assess noise impact from wind farms is under study at AFNOR.

This paper illustrates our experience obtained on more than 200 wind farms. It describes our proposed methodology and focuses on key parameters, especially the wind speed reference at 10 meters. Since noise impact is strongly linked with wind speed, the correlation between wind and noise data is a key parameter of the method of investigation to be developed.

2 Background noise measurements

Measurements need to be carried out as a function of time and wind parameters (speed and direction) with commonly 10 min sample. The wind speed considered in the analysis is the wind speed at a reference height of 10m. A night period between 10 pm and 7 am represents 54 possible samples. Considering a scaling of 10 wind speed intervals of one m/s, an equal distribution of wind speed during a night would provide roughly 5 samples per wind speed interval. Clearly, such equal distribution is never met and therefore, measurements should be carried out during several 24 hour periods. From our experience, simultaneous measurements on several representing points during 7 to 14 days are often required for a representative assessment of background and ambient noise. Measurement duration less then 4 days requires in most situation strong extrapolation of the data. When selecting a measurement period, it is also recommended to check the month local compass-card. Certain directions or wind speeds occurrence are often season dependant. It is often so that developers and planners ask for measurements in a fixed period of the year within which the overall expected range of wind occurrences is unlikely to occur!

Figure 1 shows an illustration of a time histories (LAeq and L50 samples of 10 min) over a period of 8 days together with the wind speed measured on site.

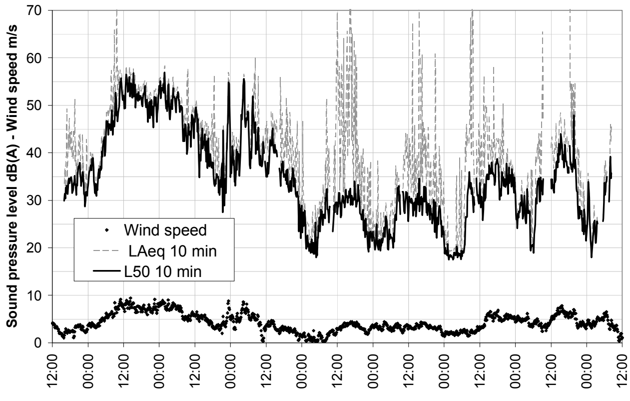

Fig.1 Illustration of noise levels and wind speed versus time over a period of 8 days

After suppression, of non representative noise samples, one obtains a representative correlation between noise and wind data as illustrated in Figure 2 for two dominant wind directions. This set of data is representative of many cases with a fairly large variation of noise level (even in L50) at a given wind speed (5 to 10 dB(A)).

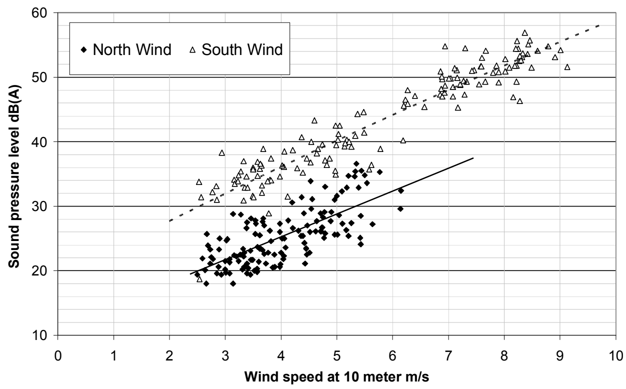

Fig.2 Noise levels and wind speed versus time for the 2 dominant wind directions

3 Commissioning of wind farms

Once the wind farm is in operation it is necessary to compare the ambient noise level with the background noise level. Although companies operating wind farms are not happy with it, we recommend a specification of "stop and go" set up of the wind turbines. It can consist of stopping the turbines 2 hours every 3 or 4 hours during a week or more. A similar analysis to that described in the previous chapter can be done for both the ambient and the background noise level as shown in Figure 3. The noise limit is also presented in the Figure. On this example, it is clear that the farm exceeds the limit in the range of wind speed 5 to 7 m/s.

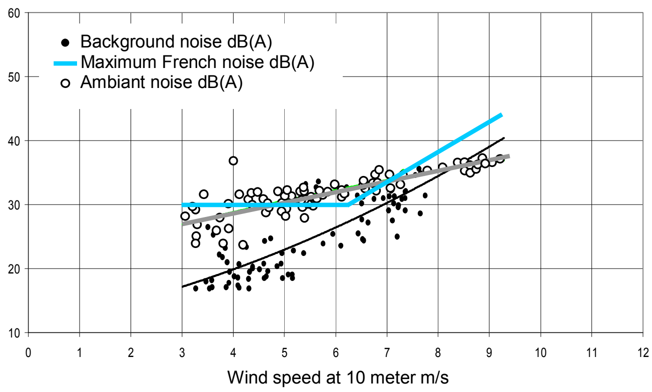

Fig.3 Example of noise commissioning of an operating wind farm

This methodology was applied successfully to more than 15 wind farms en France, and could be generalized.

4 Noise predictions

Methods for noise predictions are discussed in many papers at this conference. Usual methods like ISO 9613 and even Harmonoise provides erroneous results upwind. In many cases, it is not so critical in practice, because wind farms are often implemented at location with two dominant and opposite wind directions. Therefore, it is always necessary to consider neighbors downwind (usual models works well) to characterize the maximum emission of the wind farm.

In impact studies, we propose to characterize the acceptability of the wind farm with an indicator based on the predicted noise levels per wind speed and the background noise level measured. The idea is to work on a long term rather than "instantaneous (10 or 30 min) excess above background level. With the spread distribution of housing in France, it is always possible to find a noise sensitive property with ONE 10 min or 30 min sample above regulation limit. It could even be possible to demonstrate that with an "instantaneous" exceed above background, it is impossible for France to fulfill the renewable energy target set by the EEC for 2012. We suggest therefore to apply an annual wind speed occurrence weighting, on the exceed above background, for each wind speed. This indicator Io is called an "acceptability noise criteria" for the wind farm.

The prediction of the noise impact of the wind farm can be presented in terms for this global indicator as shown in table 1.

Night sensibility Lw machine = 102,5 dB(A)		Wind speed at h=10m										I_0 dB
		<3 m/s	3 m/s	4 m/s	5 m/s	6 m/s	7 m/s	8 m/s	9 m/s	10 m/s	>10 m/s	
Wind statistics %		21,2	22,9	23,4	13,7	7,0	4,7	2,9	2,1	1,1	1,0	
Background noise point 1		< 22	22	24	27	30	33	36	37	37	37	
POINT 1	Wind farm noise	Machines OFF	26,2	28,3	31,3	36,8	38,2	39,6	39,8	40,1	40,1	1,3
	Ambiant level		27,6	29,7	32,7	37,6	39,3	41,2	41,6	41,8	41,8	
	No conformity		0,0	0,0	2,7	4,6	3,3	2,2	1,6	1,8	1,8	
Background noise point 2		< 24	24	28	31	34	36	38	39	39	39	
POINT 2	Wind farm noise	Machines OFF	27,2	29,3	32,3	38,0	39,4	40,8	41,0	41,3	41,3	0,7
	Ambiant level		28,9	31,7	34,7	39,5	41,0	42,6	43,1	43,3	43,3	
	No conformity		0,0	0,7	0,7	2,5	2,0	1,6	1,1	1,3	1,3	
Background noise point 3		< 22	22	26	31	39	45	47	48	48	48	
POINT 3	Wind farm noise	Machines OFF	25,2	27,3	30,3	36,0	37,4	38,8	39,0	39,3	39,3	0,0
	Ambiant level		26,9	29,7	33,7	40,8	45,7	47,6	48,5	48,5	48,5	
	No conformity		0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	

Table 1: Io acceptability criteria

5 Reference wind speed at 10 m

All the previous analysis, as well as the IEC 61400-11 standard concerning the measurement of the sound power of wind turbines are based of a reference wind speed at 10 meters. It is a theoretical wind speed for a ground roughness Zo=0.05 and for a standard wind profile. This reference is a key factor of the analysis since it links the sound power of a turbine and the wind speed. Thus, when on site measurements need to be correlated to the sound power of wind turbines; this reference should be well understood.

The first method, recommended by the standard is relatively simple. It consists in obtaining the wind speed at turbine level V_H from the electrical power generated by the machine. The standard wind speed V_S is calculated from the roughness factor Zo (2). This roughness is expressed in terms of a alpha coefficient (3) (for example 0.16 at a height of 75 meters).

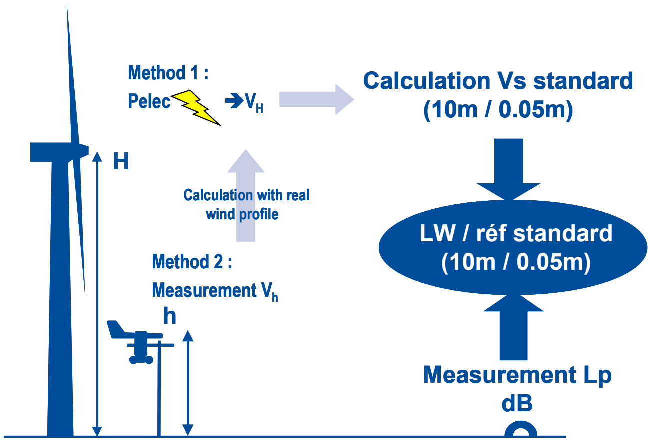

Fig.4 Illustration of the standard wind speed Vs at 10 m

$$V_H = V_h.(H/h)^{\alpha} \quad (1)$$

$$V_S = V_H.(10/H)^{\alpha_0} \quad (2)$$

$$\alpha_0 = \frac{\ln \dfrac{\ln(H/z_0)}{\ln(10/z_0)}}{\ln(H/10)} \quad (3)$$

The second method is used when the machine is off. The wind speed is measured at a height h, Vh and the wind speed at turbine level VH is obtained from Vh and the real wind profile of the site. When VH is obtained the calculation of the standard wind speed Vs is obtained according to method 1.

It must be well understood that a direct measurement of the wind speed at 10 meters should be weighted by a correction factor depending of the ground roughness in the standard situation and the actual roughness of the site. This is not often clear in the sound power commissioning reports of wind turbines. Such reports should therefore clearly specify in which roughness conditions the noise measurements are performed. Figure 5 shows an example of the variation of the alpha parameter on a given site over a period of 24 hours.

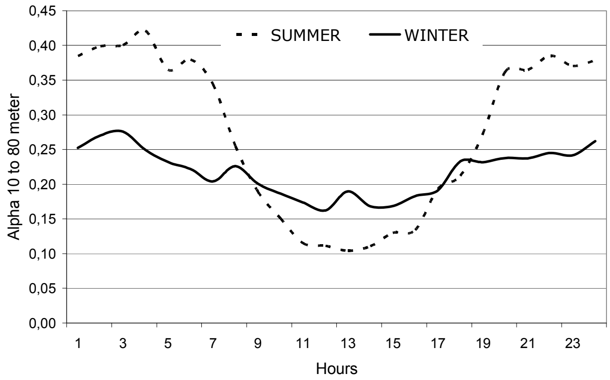

Fig.5 Illustration of the alpha parameter

Using a alpha value of 0.35 (summer nights) instead of 0.15 (winter nights) would lead to a variation of 4 dB(A) on the sound power of a 80 meters wind turbine over all the wind speed range as illustrated in Figure 6 below.

Alpha 1	0,15
Wind speed h=10m	Lw dB(A)
3	93
4	96,5
5	99
6	101
7	102,5
8	103,5
9	104,5
10	105
11	105,5
12	106

Alpha 2	0,35
Wind speed h=10m	Lw dB(A)
3	98,4
4	101,7
5	104,2
6	105,6
7	106,1
8	107,6
9	106,8
10	107,6
11	108,3
12	109,1

Hub height :	80	m

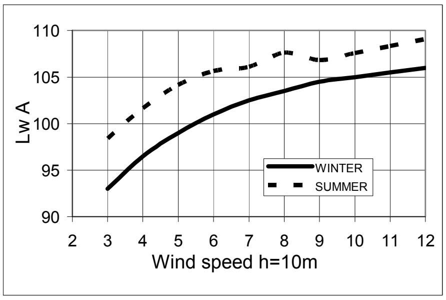

Fig.6 Illustration of the alpha parameter

6 Conclusion

This paper shows that great care should be given to noise studies of wind farms. The correlation between noise and wind data strongly depends on the theoretical wind speed reference at 10 meters. Furthermore, it is proposed to consider long term exceed above background noise indicators rather than short ones (10 or 30 min) to characterise the noise impact of wind farms. A Io criteria, defined as a an annual wind speed occurrence weighting on the exceed above background for each wind speed is proposed as an “acceptability noise criteria” for French wind farms.