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Renewable Energies Environmental Impacts: Wind Energy Case

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Abstract: The development of wind energy systems has a double impact (positive and negative) on the environment. On the positive side, wind energy is generally regarded as the friend of man and his environment, especially when the effects of emissions from power plants and industrial conventional large scales are considered. However, the negative sides, some aspects that are at the origin of wind energy systems have been noticed in large populated areas. Here, a number of projects in this field are delayed or canceled due to strong environmental opposition based on the negative effects of these systems. Aside from the positive impacts, our investigation in this study focuses on the negative impacts of a imply wind turbine or a wind farm.

Keywords: Wind energy; environmental impacts; noise; wildlife; land occupation.

1 Introduction

The intervention of man has consequences on the environment and wind energy is not an exception. Although the wind is less pertinent, its energy is now a major source in the production of electricity. In addition to increasing the economic attractiveness of wind energy, there are major ecological arguments for using it: i-Wind-power plants emit absolutely no CO_2, by far, the main pollutant produced when fuels are burned; ii - operation of wind turbines does not leave harmful residues; iii - decommissioning costs of wind turbines are much smaller than those of many other types of plants; iv - land occupied by wind farms may find other uses simultaneously as in agriculture. However the development of these wind energy systems poses environmental problems [1]. The potential negative impacts of wind energy can be divided into the following categories: i-interaction between wildlife and wind-ii the visual impact of wind turbines and wind turbine noise-iii, iv-effects of electromagnetic interference amongst turbines [2]. Energy demand continues to grow stronger [3]. General environmental benefits for wind energy are calculated by the limitation or elimination of emissions compared to emissions from other sources. The first three effects introduce more major environmental issues affecting the deployment of wind energy systems, but the other issues are also important and will be discussed in the following sections such as the land occupation by wind plants. These impacts of systems, associated to wind energy, will be discussed including general topics, relating to each type of environmental impact.

2 Wildlife and wind turbine interaction

2.1 Set up of the problem

Environmental problems associated to the interaction of wildlife and wind energy systems came to be noticed in the United States in 1980 when a strong opposition against the project in the Altamont Pass by many environmental activists and associations awakening those responsible for the protection of species of birds. There are two topics covered by this environmental issue: i-effect on the bird population because of the deaths caused by wind turbinre blades. ii- violation of the Migratory Bird Treaty act of endangered species. The development of wind energy can adversely affect flying wildlife in the following ways [4]: i- fatal collision or electrocution, ii- altering immigration habits iii- reduction of habitat availability, iv- disturbance of reproduction. At

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this point, the long-term consequences of these wildlife issues on the industry of wind energy systems are still unclear. The problem should occur in areas where large numbers of birds congregate or migrate to Tarifa, where the birds are threatened as in Altamont Pass [5].

2.2 Characterization of the problem

There is a close correlation between a community and its wildlife (birds). Many species have very specific habitats and are often particularly sensitive to change their. In addition, there is a close correlation between the site and the locality of wind, which is especially dependent on wind conditions. Studies in Europe and the U.S. [6,7] noted that the impact on birds is divided into two categories: i-direct impacts, including the risk of collision and ii-indirect impacts which include other disturbances such as noise from wind turbines. The risk of collision is the most obvious direct impact (figure 1), and many studies have focused on this issue. The results of such studies can be used to develop an index to the risk of collision of birds with wind turbines. This risk index of collision for a given bird species is given by [8].

$$I_R = UP_f.P_t \quad (1)$$

where U is a parameter used to adjust the tendency of

Fig. 1: Interaction between wind turbines and birds

visibility, P_f is the fraction of the total number of where the activity of the subject is flying and P_t is the fraction of all observations of flying height the band swept by the blades of wind turbines. The results of numerous studies in this direction can be found compiled in [2,7] and [9]. Indirect impacts can be summarized as: i- disorder and disturbance in breeding birds, ii- disorder in feeding birds and iii- the impact of disturbances on the migration of birds and fly.

2.3 Aspects of mitigation and case studies

A number of recent studies have specifically discussed the subject of measures to minimize the impact of wind energy systems on birds. The most detailed work took place in California and was supported by the California Energy Commission and the Association of American wind. Among the typical attenuation data from these studies [4,9] are: avoiding migration corridors, avoiding micro habitats within large wind towers. There are many existing reports and articles which are focused on the potential or actual environmental impacts of wind energy systems on birds in a specific site. We will only though summarize the one most appropriate ones which are listed below: i- California wind farm studies [6] ii- Recent U.S. Studies [10,11], iii- European studies [12,13]. In the Doñana national park, it was observed a diminution of the population of big birds, especially vultures, because Gamesa installed a wind farm very close to the border of the protected area. At the same time the population of foxes has increased, allegedly because they have more dead carcasses to eat. This seems positive, but it's an induced ecologic disequilibrium.

2.4 Environmental contribution on wildlife impacts

The literature review above indicates that such studies may require specialized expertise, and can add to the cost and time to construct a wind site. In general, this type of study can be divided into two parts: i- a complete definition of the study area ii- and an estimate of risk birds. The first part is a detailed definition of the topography and layout of the location of the wind machines farm. Another phase of this part is the sample selection of sites where detailed data on bird-wind interaction are collected. In the second part, more detailed risk assessment over the birds usually requires a comprehensive methodology to accomplish. We present below a summary of some important methods, actions and relationships that have been used for this type of work [14,15]. The access to calculations in this part of the study begins with an observer that notes the locality behaviour, and the number of birds using this space. Bird behaviour must also be included: flew, perched skyrocketed, driven etc... Utilization rate is defined as the number of birds, N, using the space during a given time, t.

$$T = N/t \quad (2)$$

Mortality is defined by the number of birds killed by the defined area, A

$$M = n_m/A.t \quad (3)$$

The "Risk" factor measures the probability of a bird using the space in question to be killed. It is defined by

$$R_{\text{ris}} = M/Z \quad (4)$$

In the above A is the rotor swept area. This parameter combines the size of the rotor surface, S, and the operating time in hours, t, as:

$$R_{SH} = S.t \quad (5)$$

2.5 impact on the agriculture

When the wind turbines operate their blades create turbulence, consequently an increase in turbulence should increase the evaporation rate of the soils and plants, because the exchange coefficient increases. This also is negative to agriculture, because more energy and water would be required for the same amount of harvest.

3 The wind noise

3.1 problem

The problems associated with wind turbine noise are certainly one of the most studied topics in environmental impact of wind turbines in the field of engineering. Noise is defined as unwanted sound. The case of the noise level depends on its intensity, its frequency, frequency distribution and the model or type of the sound source. The effects of noise on the population are classified into three categories[5]: i- subjective effects such as nuisance, say satisfaction and boredom, ii- interference with activities such as speech, sleep and playing, iii-physiological effects such as anxiety. In most cases the sound levels associated with environmental noise produces effects only of the first two categories. The noise produced by wind turbines has declined with advent from technology. Significant factors relevant to the potential environmental impact of wind turbine noise are shown in Fig. 2.

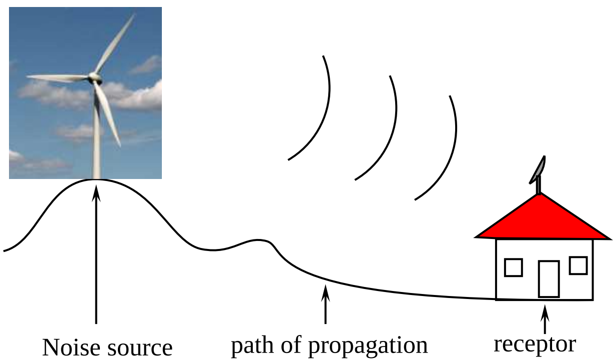

Fig. 2: Sound and noise fundamentals

3.2 Characteristic noise and sound

The sound is generated by many mechanisms and is always associated with the pressure fluctuations of small-scale and speed which produces sensations in the human ear. It is characterized by the wavelength, λ, the frequency, f, and the velocity, u, which is defined by

$$u = f.\lambda \tag{6}$$

The wind speed is a function of the environment where it propagates. The sound becomes noise when it is undesirable. There are many physical quantities that have been defined and cannot compare, and classify and also provide information on the human perception of sound[16]

3.3 Scale of power and sound pressure

It is important to distinguish between pressure level and sound power. The sound power level is a property of the sound source and gives the total power emitted by this source. The sound pressure level is a property of its relative position to a given observer and can be measured by a single microphone. In practice, the magnitude of an acoustic quantity is given in logarithmic form expressed as a decibel level above or below the zero reference. The sound pressure level in decibels unit is given by[17]:

$$L_P = 10\log(P/P_0) \tag{7}$$

and the sound power level in decibels unit is given by

$$L_W = 10\log(W/W_0) \tag{8}$$

3.4 Mechanism of wind turbine noise

We have four types of noise that can be generated by wind turbines during operation: tone, broadband, low frequency and impulsive. They are briefly described below: i- tone noise is defined as noise at discrete frequencies. It is caused by the components of the wind, the interaction between the non-linearity of instabilities in the boundary layer on the surface of the blades and emission swirls and blunt ends, ii- noise broadband: It is a noise characterized by a continuous distribution of sound pressure with frequencies greater than 100 Hz. It is often generated by the interaction of wind and atmospheric turbulence, iii-low-frequency noise: this noise type propagates with low frequencies in the range of 20-100 Hz, associated with low wind turbines. iv- impulsive: are short acoustic pulses that vary in amplitude over time characterizing this type. It is caused by the interaction between the blades and the disruption of the air flow around the mast of the wind turbine. Effect of noise from two different sources at a given point and at different distances is shown in Fig. 3.

3.5 Propagation of wind turbine noise and its mitigation methods

To predict the sound pressure level at a given distance from the source given its power, we must consider how

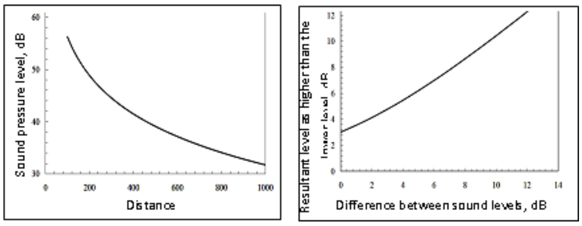

Fig. 3: Noise from a wind turbine at different distances at different distances (left) and combined noise effect (right)

Table 1: limits of pressure level of sound in (dB)

	Commercial	mixed	residential	Rural
Danemark			40	45
Germany day/night	65 /50	60/ 45	55 / 40	50 / 35
Netherland day/ night		50 / 40	45 / 35	40/ 30

sound waves propagate. Details about the propagation of these waves are in provided ref. [18]. In the case of the turbine support alone, we calculate the sound pressure level, assuming that the propagation is spherical, which means that the level is reduced by 6 dB when distance is doubled. For the development of a more realistic model of sound we must take into account the following parameters: characteristics of the source, the distance between the source and the observer, the air absorption, ground effect and climatic effects. A simple model, based on sound propagation along the reflecting hemispherical surface and the absorption parameter, the sound pressure level is given by

$$L_P = L_W - 10\log(2\pi^2) - \alpha.R \tag{9}$$

Where $\alpha = 0.005$ is the absorption coefficient (dB.m^{-1}), R is the distance between the emission source and the observer. Wind turbines must be designed to minimize the noise of any type issued by its various elements. This can be done by including the insulation systems of mechanical and aerodynamic vibrations of special teeth well finite of the gearbox [19]. However, the reduced noise should be standardized. At present, there are no common standards between countries that speak of such information. In many countries, however, the noise regulations define the upper noise to which people are exposed. These limits depend on the country and we show in Table 1 some examples.

4 Electromagnetic interference effects

The problem of the interaction of wind and radio communication systems is complicated because the mechanisms of dispersion due to wind are not easily characterized and the signal can be modulated by the conditions of rotation of the blades for their efficient operation. There are two basic mechanisms for EMI interference of wind turbines: the backscatter and forward scatter. These are shown in Figure 4. To provide an analysis of the electromagnetic interference caused by a wind turbine, we proceed as follows: The received useful signal, C, is a constant given by:

$$C = P_T + A_T R + G_T R \tag{10}$$

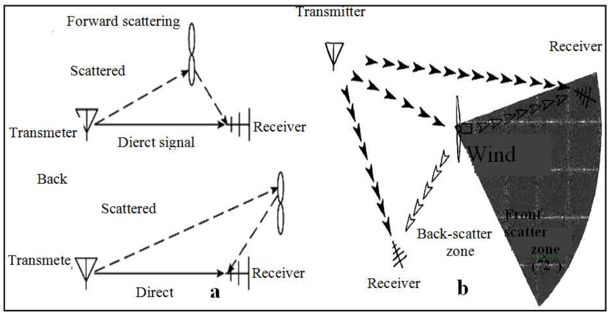

Fig. 4: Noise from a wind turbine at different distances: a- at different distances b - combined noise effect

where P_T is the transmitter power (dB), A_{TR} is the mitigation between transmitter and receiver, and the gain G_{TR} is a receiver antenna in the direction of the signal required. The interference signal, I, is given by:

$$I = -A_{TW} + 10\log(4\pi.\sigma/\lambda^2) + A_{WR} + G_{WR} \tag{11}$$

with A_{TW} is where the attenuation between the transmitter and the wind turbine, A_{WR} is the attenuation between the wind turbine and the receiver, G_{WR} is the receiver antenna gain in the direction of the reflected signal, $10\log(4\pi\sigma/\lambda^2)$ represents the contribution to the dispersion of the wind turbine, σ is the surface equivalent radar which can be understood as an effective sector of the wind turbine. It is a function of the geometry of the turbine and its dielectric properties as well as the signal wavelength, λ. It is obvious that the ratio of useful signal to interference is:

$$\frac{C}{T} = \frac{P_r r + A_t r + G_t r}{-A_T W + 10\log(4\pi.\sigma/\lambda^2) + A_{WR} + G_{WR}} \tag{12}$$

Supposing that the distance between the transmitter and the receiver is much greater than the distance from the obstacle to the receiver denoted as r, then $A_{TW} = A_{TR}$. Assuming that the loss of free space $A_{WR} = 10\log(4\pi\sigma/\lambda^2)$ and defining the antenna discrimination factor as $\Delta G = G_{TR} - G_{WR}$. Then

$$C/T = 10\log(4\pi) + 20\log(r) - 10\log(\sigma) + \Delta(G) \tag{13}$$

Thus, the ratio of signal to interference of a conveyor helpful, can be improved by:

–increasing in the distance, r, between the turbine and the receiver.
–reducing of the radar section, σ.
–Improving the discrimination factor of the antenna, ΔG.

5 Land occupation and visual impact of wind turbines

5.1 Land occupation

Wind turbines need to be placed in sites well exposed to the wind. Turbines are placed in rows with the direction of incoming wind perpendicular to it. The spacing depends on the terrain, the wind direction, the speed, and the turbine size. The optimum spacing is found in rows 8 to 12-rotor diameters apart in the wind direction, and 1.5 to 3-rotor diameters apart in the crosswind direction Fig. 5. These spacings may be further increased for better

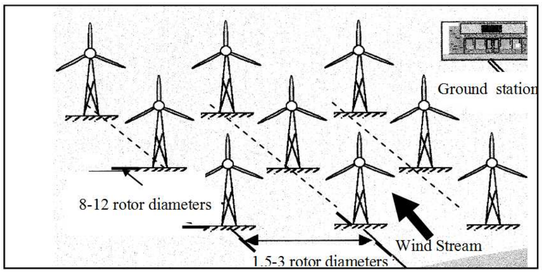

Fig. 5: Optimal spacing of wind turbines farm in flat terrain

performance but this results in occupation of additional land. A wind farm consisting of 20 towers rated at 500 kW each need 1 to 2 square kilometres of land area as seen in[20]. The number of turbines per row N_{TR} may be estimated as:

$$N_{TR} = (L_R/S_R) + 1 \qquad (14)$$

where L_R is the row length and S_R is the row spacing. If P_F is the total capacity of the wind farm and P_T is the rated power of a turbine, then

$$N_T = P_F/P_T \qquad (15)$$

where N_T is the total number of turbines in the farm. Hence the total number of rows is

$$N_T = N/P_T R \qquad (16)$$

Although the above calculations can give us some indication on the turbine placement, in practice, the final placement of individual turbines at a given site depends on several factors such as the shape and size of the available land and the existing electrical network.

5.2 Visual impact of wind turbines

The degree of visibility is influenced by factors such as the type of the landscape, the number and design of wind turbines, the mode of their arrangement in the farm as shown in Fig. 5, and the color and the number of blades. During rotation, the blades are projecting shadows that intermittently result in flickering and flashing on the surrounding area. This effect can cause problems for people near wind farms. This effect can cause trouble for the people close to wind farms Fig. 6. Its intensity

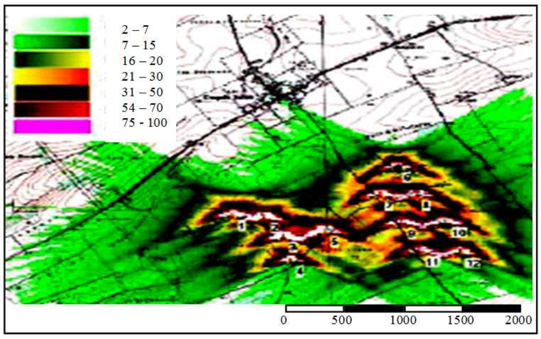

Fig. 6: exposure duration to flickering shadows

depends on the rotor speed and the direction, the number of hours of sunshine and the geographic location of the installation. Two main techniques are used. Firstly, the visibility analysis using the zones of the visual impact, and the second is the viewpoint of the analysis using frames and collages wire. Analysis point of view is based on selecting a number of important places from which the wind farm is obvious and applying professional judgment using quantitative criteria for evaluating the visual impact. The views are selected in consultation with planning and civil authorities and for a large farm of wind up to 20 locations can be chosen. Although approaches vary, the evaluation may involve the consideration of three aspects: i- the sensitivity of the landscape, ii- the sensitivity of perspective, and iii- the importance of changing the view. Representations of the rows of wind turbines in a park, give an indication of release flicker starting from the positions of the turbines, all photomontage are a standard tool used to give a general impression of the visual impact of a wind farm. The shadow flicker is the term used to describe the stroboscopic effect of shadows cast by turning the blades of wind turbines when the sun is behind them. Frequencies that may cause interference are between 2.5-20 Hz. The effect on humans is similar to that caused by changes in the intensity of incandescent electric light.

5.3 Impact of the turbulence in the aerial traffic

Apart from the nuisance, for commercial aircraft (probably negligible), wind farms are a danger to ultra light aircraft and deltas, creating a legal problem. This problem must be dealt by the legislation establishing the restriction of the right to use the aerial space with sportive scopes by private peoples.

6 Conclusions

To reduce these impacts, it is necessary to study the site, taking into account all these factors and then to study wind turbine design taking into account the constraints imposed by the environment. In existing wind farms, management options are available. This management must be based on knowledge of the following parameters:

–Species susceptibility to accidents collision
–The frequency and the height of passage of birds
–The ecological value of the area.

The crops near turbines could also influence the density of certain species of birds. It should be noted that this study be extended to other issues such as, offshore wind farms: the foundations will surely have a huge impact on the marine benthos. Also the turbulence induced by the blades breaks the thermal gradients in the atmosphere at ground level which can have negative impacts on agriculture.

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