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Impact analysis of wind farms on telecommunication services

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ABSTRACT

Wind power is one of the fastest-growing technologies for renewable energy generation. Unfortunately, in the recent years some cases of degradation on certain telecommunication systems have arisen due to the presence of wind farms, and expensive and technically complex corrective measurements have been needed. This paper presents a comprehensive review on the impact of wind turbines on the telecommunication services. The paper describes the potential affections to several telecommunication services, the methodology to evaluate this impact, and mitigation measures to be taken in case of potential degradation, both preventive and corrective. The telecommunication services included in this review are those that have demonstrated to be more sensitive to nearby wind turbines: weather, air traffic control and marine radars, radio navigation systems, terrestrial television and fixed radio links. The methods described in the paper allow a thorough case-by-case analysis before the wind farm is installed, taking into account the particular features of each installation and the involved services. The prediction of the potential impact makes it possible to propose alternative solutions in order to assure the coexistence between the wind turbines and the telecommunication services.

Contents

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1. Introduction

The assessment of suitability of a certain location for the installation of a wind farm requires the consideration of multiple impact issues: visual aspects, environmental effects such as the impact on wildlife and birds, shadow flicker from wind turbines and noise pollution [1–3]. Electromagnetic effects should also be considered, due to the fact that the presence of a wind farm near telecommunication transmitters or receivers may introduce distortions on the transmitted signals [1]. These distortions can cause different effects on the radiocommunications services depending on several factors such as the frequency band, the modulation scheme and the discrimination of the radiation pattern of transmitter and receiver aerials. The radiocommunication services that have proved to be more sensitive to the presence of wind turbines are the following: Air Traffic Control radars [4–10], weather radars [11–16] and maritime radars [17–21]; aeronautical navigation systems such as VOR [10,22] and ILS [23,24]; fixed radio links [25–27]; and broadcasting services (mainly analog television[25,28–35] and digital television to a lesser extent [25,37–39]).

Although the critical interference cases are not common, if they occur when the wind farm is already installed, the posteriori corrective measurements are normally technically complex and/or cost prohibitive [40–42]. By contrast, the prediction of the potential impact of a wind farm on the telecommunication services before its installation allows the planning of alternative solutions in order to assure the coexistence between the wind turbines and the telecommunication services. This potential impact must be analyzed in a case-by-case basis, taking into account the particular features of each installation and the involved services, such as the accurate location of the wind turbines and the telecommunications infrastructure, terrain altimetry and topography, telecommunication towers height, service frequency and modulation, radiating systems characteristics and reception conditions.

In case of a potential problem being identified, preventive measurements can be taken in order to avoid it. These may include proposing safe-guarding zones, changing the location of a wind turbine in the preliminary design of a wind farm, choosing a model with different dimensions or selecting alternatives for the telecommunication services (new transmitter locations, different communication links, etc.) [1]. Whatever the case may be, the cost of preventive measurements is lower than the one of corrective measurements and prevents public opposition to wind energy development.

This paper presents a comprehensive review on the impact of wind turbines on the telecommunication services, with special dedication to the methodology to be applied in order to detect potential problems before they occur and propose possible solutions. The paper is organized as follows. First, some basic concepts on the electromagnetic effects of wind turbines are introduced in Section 2. Then, the potential affections to the different telecommunication services are presented in the three following sections. Each of these sections includes a brief description of the service, the possible interference effects due to a wind farm, the methodology to evaluate this potential impact, and mitigation measures to be taken in case of potential affection, both preventive and corrective. Finally, the main conclusions are summarized in Section 7.

2. EM effects of wind turbines

At microwave frequencies, when an electromagnetic wave reaches a body, it induces oscillating charges on its surface. These currents produce in turn a scattered wave that re-radiates energy in various directions. The spatial distribution of the scattered energy depends on the size, shape and composition of the obstacle, and on the frequency and nature of the incident wave [43]. The mechanism of the electromagnetic scattering is a complicated process that includes reflections, diffractions, surface waves, ducting, and interactions between them [44]. In this context, the total field at an observation point due to radiation by induced fields over the surface of the obstacle will be comprised of the direct fields (desired signal) and scattered fields (potential interference).

When the scattering direction is back toward the Source of the radiation, it is called monostatic scattering. By contrast, bistatic scattering is the name given to the situation when the scattering direction is any but the retro-direction. A particular case is forward scattering, which occurs when the bistatic angle is approximately 180° [43]. In general, the forward scattering from an obstacle is stronger than the backscattering. However, the forward scatter is nearly out of phase with the direct field; therefore, it is subtracted from the direct field, creating a shadow behind the wind turbine [43]. As an example, Fig. 1 shows the horizontal and vertical scattering patterns of a wind turbine for certain illumination conditions and static position of the blades.

As observed in Fig. 1, the scattering patterns show great variability mainly due to the complex design of the nacelle and the blades. Moreover, the amplitude of the scattered signal varies with the blade rotation. Fig. 2 shows an example of the time variability of the signal scattered by a wind turbine with rotating blades, obtained from empirical data [38,45]. It can be observed that there is a periodic variation with a repetition period of approximately 1 s, corresponding to 1/3 of the rotation rate of the wind turbine, as expected for a three-blade rotor. Both the mean level and the time variability due to blade rotation are dependent on the orientation of the wind turbine with respect to the transmitter and the receiver.

Furthermore, due to the moving blades of the wind turbine, the frequency of the signal will be shifted according to the Doppler effect. The Doppler frequency shift depends on the radial velocity of the moving object with respect to the receiver. As a consequence, a frequency spread will be caused in the signal spectrum, which will depend not only on the rotation angular speed of the blades, but also on the blade length and on the relative orientation of the nacelle with respect to the transmitter and the receiver.

In summary, a wind turbine may cause a scattered signal of dynamic nature which is both amplitude and frequency modulated due to the rotating blades. The time and frequency characteristics of this scattering signal will depend on multiple factors.