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An experimental database for wind turbine noise propagation in an outdoor inhomogenous medium

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1 Introduction

Wind turbine noise is influenced by physical phenomena related to long-range sound propagation, i.e. ground effects (roughness, impedance), and micrometeorological effects (mean refraction, intermittency fluctuations, small-scale turbulence scattering). While acoustic modelling tools have developed considerably in recent years, little work has focused on wind power issues and on estimating the uncertainties associated with measurements nor acoustic forecasting. Quantifying the overall variability and uncertainties associated with the emission-propagation-reception chain thus appears essential for controlling the acoustic impacts of wind turbines in an inhomogeneous outdoor medium. In this context, a large-scale experimental campaign was carried out in 2017 by Cerema and Ifsttar (UMRAE) and Engie Green, in collaboration with Echopsy, in order to study the emission and propagation of wind turbine noise as a function of various influent parameters (wind and temperature fields, blade pitch, ground properties, etc.). For this purpose, more than 20 sound measurement points (sound pressure level meters, audio recordings) were carried out during one week (7 days, 24/24h), including "ON/OFF" phases of the wind turbines, both in the near field (characterisation of the sound power of the machines) and in the far field (up to 1.5 km) on a frequency range including infrasound (down to 1 Hz). Simultaneously, micrometeorological monitoring were carried out. These surveys were supplemented by in situ acoustic impedance measurements at different locations of the surrounding types of grounds.

2 Experimental protocol

The wind farm studied is located on a site with a low slope (<2%). It consists of 5 wind turbines of 2MW, whose hub is located 100m high with 3 blades 46m long. The site has the advantage of a fairly quiet sound environment, a good diversity of wind speeds and directions, as well as the presence of a 100m high meteorological mast. During the campaign, the wind farm was subjected to on/off cycles of

1 hour/1 hour during the 8 days of measurements, thus allowing a detailed analysis of the contribution of wind turbine noise to the measured noise. The site is presented in Figure 1.

Figure 1 Campaign site presenting the wind turbines and the acquisition devices (sonometers in blue, meteorological devices in green and acoustic power measurement in orange).

A total of 15 sound level meters were distributed on either side of the wind farm in a direction corresponding to the prevailing winds of the site over the intervals [-1000m ; -300m] and[+300m ; +1500m] (see Figure 1) with respect to the central wind turbine of the farm. This arrangement thus makes it possible to measure the sound level profile of the "upwind" sides (westerly direction, where the winds are mainly oriented in an opposite way), and the "downwind" side (easterly direction, where the winds are mainly downwind).
Also, 6 three-dimensional ultrasonic anemometers (Young and Campbell) are located on the campaign site (see Figure 1). They measure wind speed and direction at a height of 3m (5 devices) or 10m (1 device) in the vertical and horizontal planes. A WindCube WLS7 weather lidar was deployed behind Wind Turbine 2. This device allows wind profiles to be measured at different heights (up to 10 measurement points) between 40m and 200m. Finally, data from the 99m permanent weather mast located north of the park were recovered. This mast consists of 5 anemometers (30m, 50m, 75m, 75m, 97m, 99m) and 3 thermometers (5m, 48m, 95m).
As the campaign was carried out on an agricultural site divided into several cultivated plots, the soil properties (height and length of roughness, characteristic impedance) were not homogeneous over the entire acoustic propagation range. The properties of the terrain being a characteristic of major influence on the sound levels encountered, roughness (height and density of vegetation) and impedance measurements were carried out at several points on the site using a prototype system for in situ automatic acquisition and processing developed in partnership with Ifsttar/Cerema.

3 Conclusion

This communication presented the measurement campaign as well as the treatments and first results in terms of temporal evolutions of sound levels (in global A) and influential observables related to the propagation medium (atmosphere/refraction) and its boundaries (ground/impedance). This large database will support statistical analysis work planned as part of an ongoing Ifsttar/Cerema thesis (Bill Kayser, 2017-2020), which will also include the effects of atmospheric turbulence and ground roughness on acoustic propagation.