Infrasound emission generated by wind turbines

Abstract

Aerodynamic noise emissions from the continuously growing number of wind turbines in Germany are creating increasing problems for infrasound recording systems. Such systems are equipped with highly sensitive micro pressure sensors, which are accurately measuring acoustic signals in a frequency range inaccessible to humans. At infrasound station IGADÉ, north of Bremen, a constantly increasing background noise has been observed throughout the years since its installation in 2005. The spectral peaks are reflecting well the blade-passing harmonics, which vary with prevailing wind speeds. Overall, a decrease is noted for the infrasound array’s detection capability. This aspect is particularly important for the other two sites of the German infrasound stations IGADÉ in the Bavarian Forest and IZTOE in Antarctica, because plans for installing wind turbines near these locations are being under discussion. These stations are part of the International Monitoring System (IMS) verifying compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT), and have to meet stringent specifications with respect to infrasonic background noise.

Therefore data obtained during a field experiment with mobile micro-barometer stations for measuring the infrasonic pressure level of a single horizontal-axis wind turbine have been revisited. The results of this experiment successfully validate a theoretical model which estimates the generated sound pressure level of wind turbines and makes it possible to specify the minimum allowable distance between wind turbines and infrasonic stations for undisturbed recording. Since the theoretical model also takes wind turbine design parameters into account, suitable locations for planned infrasonic stations outside the determined disturbance range can be found, which will be presented; and vice versa, the model calculations’ results for finding the minimum distance for wind turbines planned for installation in the vicinity of an existing infrasonic array.

Observations at IGADÉ

Figure 4: The time-frequency analysis clearly demonstrates the correlation between the emitted sound pressure level and the rotational speeds and wind speeds. For a period of 72 hours, the average SPL, calculated every five minutes, is plotted against the rotational speed, as well as the wind speed measured at the hub. The strong impact of the aerodynamic noise generated by wind turbines on infrasonic recording systems becomes dominant at the time interval from 30 to 60 hours in particular. At site 3, about 300 m from the wind turbine, the signal amplitudes (blade passing harmonics - BPH) exceed the background noise by up to 20 dB and 10 dB at high and moderate wind speeds, respectively.

Field campaign – infrasound measurements at a single wind turbine

Figure 5: Comparison between the measured and theoretical SPL ([Vitera, 1981, NASA CP 2815]) is made for the whole range of 2 km considering rotational speeds of 20 and 26 rpm during windy winds. The 2nd BPH is considered because it has the strongest spectral amplitude and therefore is most likely of being observed at all sites. In general, good agreement is observed, except at location 1 due to the fact that the signals were recorded in the proximal field at distances of a single wavelength. However, our theoretical model describes the SPL in the distal field of a wind turbine, hence overestimate the measured values of infrasonic noise.

Estimating noise amplitudes

Figure 6: Based on the theoretical model sound pressure levels (SPL) are computed for the second blade-passing harmonic (BPH) as a function of distance and the wind turbine design parameters. Obviously, modern wind turbines with hub heights of 80 m and blade diameters of 150 m, generating about 400 kW output can emit aerodynamic noise signals in the 1 to 2 Hz frequency range which can be recorded at distances of more than 10 km. At such large distances, the SPL still exceeds the background noise level between 1 and 3 Hz at the German IMS station IGADÉ, which is located by horizontal line. The same reasoning is applied to the BPH which shows its variation. Considering wind farms of 1.5-MW turbines the computed SPL of the second BPH at the signal amplitudes exceed background noise level even at distances larger than 30 km.

Results & Conclusions

The effects of a wind farm on the detection capability of a near-by infrasonic array become apparent at station IGADÉ. The 4-element array with an aperture of about 800 m is only 4 km away from a small wind farm. This causes a partial blinding of a 10° segment; whereas the detection capability of an infrasonic array with respect to transient signals is only reduced by noise disturbances if both been are located in a distance of more than 3 km. Therefore all the necessary procedures have been collected for estimating the minimum allowable distance between wind turbines and infrasonic stations to guarantee undisturbed recordings. Vital data was provided by the measurements at a wind turbine north of Hannover, and the experience gained from other infrasonic stations.

The theoretical model for computing the SPL of the aerodynamic noise generated by wind turbines as a function of their design parameters, as well as the verification of this model for the infrasonic frequency range of more than 2000 Hz also makes a valuable contribution. As a rule, a distance of 15 to 20 km should be kept between an infrasonic station and wind turbines to guarantee unhindered recording and detection conditions. The distance might need to be larger in the case of wind farms, which are comparable to the considered 33 turbine facility with 1.5-MW turbines. However, geometrical spreading, turbulence, and terrain effects might yield that a distance of 20 km also appears to be adequate for every kind of wind farm.