Wind turbine noise analysis

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The impact of wind turbine noise on human health is a growing concern. Continuous exposure to low-frequency noise and infrasound waves with frequencies below the threshold of human hearing can cause sleep disturbances, stress, and chronic annoyance. Some residents living near wind farms report symptoms like headaches, dizziness, and a sense of pressure in the ears, conditions often referred to as ”wind turbine syndrome.”

Beyond human health, wind turbine noise can disrupt local wildlife. Birds and bats, as well as fish, rely heavily on sound for communication, navigation, and hunting. The constant noise produced by turbines can interfere with these activities, potentially leading to changes in behavior, habitat displacement, or even population decline in sensitive species.

Mitigating these issues requires a multi-faceted approach. From a technical standpoint, manufacturers are developing quieter turbines with optimized blade shapes and improved materials that reduce noise production. Moreover, establishing setback distances the minimum distance between turbines and residential areas can help limit exposure to harmful noise levels. Advanced control strategies, such as adjusting the pitch of the blades or temporarily shutting down turbines under certain wind conditions, can also minimize noise impact.

Wind turbine noise pollution primarily stems from two sources: aerodynamic noise and mechanical noise. Aerodynamic noise is generated by the interaction of the turbine blades with the air. The aerodynamic noise produced by wind turbines is categorized into three groups, namely *low-frequency noise*, *inflow turbulence noise*, and *airfoil self- noise* (Wagner (1996)). Nevertheless, the acoustic characterization of wind turbines remains a significant challenge.

Collaboration between researchers and companies working in the wind energy sector can significantly enhance both practical and applied aspects of scientific research. The purpose of this collaboration between the aeroacoustics research team from the University of Trieste and Valorem in the context of the ARIA European project is to develop and validate a numerical method for the acoustic characterization of wind turbines, and further the propagation modeling considering complex noise source and realistic environment with the goal of acoustic pollution reduction.

The manufacturers provide statistical data regarding sound pressure levels in the 1/3 octave frequency domain. The data are available depending on the wind turbine model and the wind speed in the frequency range of 6.3 Hz to 10 kHz. The purpose is to perform a comparison between the technical data, provided by Valorem, and the numerical modeling of a similar wind turbine with the aim of numerical model validation. We modeled the aeroacoustics of the benchmark wind turbine designed by the National Renewable Energy Laboratory (NREL), namely the NREL offshore 5-MW baseline wind turbine. The modeling of the fluid dynamic field of the wind turbine is achieved using numerical simulations, such as Large Eddy Simulation (LES) using the open-source software OpenFOAM.

Meanwhile, the acoustic measurements are performed considering the acoustic analogy and the Ffowcs-Williams and Hawkings equation within a homemade utility developed in OpenFOAM by the aeroacoustic research team from the University of Trieste. Finally, we compare the measurements of the numerical modeling and the technical data of a similar wind turbine, such as the V117-4.0-4.2 MW wind turbine designed by VESTAS, to validate the numerical modeling and we found a close alignment, especially for the higher frequency range. Further developments consist of characterizing the acoustic signature of the wind turbine as a complex noise source.

Finally, we want to propagate this complex noise source using simplified propagation modeling in order to characterize the noise emitted by multiple wind turbines in different configurations.