Developing Solutions to Tonal Noise From Wind Turbines Using COMSOL Multiphysics® Software

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Abstract

Wind turbine towers can often become modal if matched closely in frequency with the excitation associated with rotating components in the drive train, such as gearboxes and generators. When these conditions are met, the modal response is greatly amplified due to the very low structural damping of the steel structure resulting in undesired audible tones. Furthermore, the steel structures have large surface areas making them very efficient at radiating tonal noise. Tonal noise can have adverse effects on neighboring residences and its emission can result in strong regulatory penalties that can include the closure of wind farms.

A structural-acoustic interaction model was developed in COMSOL Multiphysics® to model the dynamics of wind turbines and the radiation of tonal noise. A three-dimensional structural model was constructed with beam elements to model the blades, shell elements to the model the tower and solid elements to model the drive train. The model was excited by forces that were applied to the gearbox and represent those related to gear teeth meshing. The forces used to excite the gearbox in the 3D model were calibrated using drive train vibration measurements and far-field acoustic recordings. The model was solved in the frequency domain and surface acceleration of blades and the tower were extrapolated to the far-field using 2D acoustic models that were coupled to the structural model using LiveLink™ for MATLAB®.

The models are then used to determine the effectiveness of noise and vibration mitigation techniques including constrained layer damping (CLD), tuned mass damper (TMD) and an innovative technique referred to as advanced particle damping (APD). These showed that these mitigation techniques can by very effective in reducing tonal noise and reductions of 10-15 dB were found. However, retrofitting a wind turbine using CLD can be challenging as it requires rope access engineers working in confined spaces with chemical adhesives and TMD were only effective over small frequency ranges and actually amplified tones outside of their effectiveness band. This is problematic as tonal noise from variable speed wind turbines tends to change over a large frequency range as the turbine changes speed to accommodate different wind conditions. Conversely, lab-based experimental data show that both CLD and APD are effective over broad frequency ranges. The results from COMSOL® models combined with commercial considerations lead to the conclusion that APD is the most viable mitigation candidate.

Figures used in the abstract

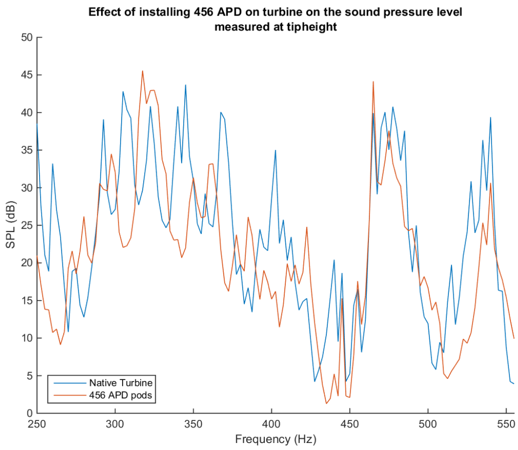

Figure 1: Energy mean of the sound pressure level (SPL) in dB rel. 20 µPa modelled downwind, 30° off downwind, 60° off downwind and crosswind, at a distance equal to the tip height of the turbine for frequencies in the range 250-550 Hz.