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Regular Session: Atmospheric Turbulence and Turbulence-induced Loads (II)

Site-specific analysis of on wind turbines in complex terrain: A case study

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This paper aims to analyse and understand how the structural and drivetrain loads on the turbines can vary within a wind farm situated in complex terrain. To this end, the flow field is studied using computational fluid dynamics (CFD) and the aeroelastic response of the turbine is simulated using a modified version of the FAST [1] software. Verification of the numerical results is performed by using data from turbine SCADA system for a case study of Röbergsfjället wind farm with 8 turbines located in the mid-western part of Sweden.
The flow-field around a wind farm was simulated using Large-Eddy Simulation (LES) with a rectangular domain of 9 x 6 km2 with 1.35 km height in average to predict the neutral atmospheric turbulence and time-varying wind profile for 90 minutes with the frequency of 10 Hz, aligned to the dominating wind direction, 216° w.r.t North. Three cases of wind conditions were used where the mean met-mast wind speeds were 7, 10 and 14 m/s. Available computational resource admitted a constant grid spacing of 17x17 m2 in the horizontal plane, and 2-17 m grid size in the vertical direction (smaller grid below 210 m from the ground), see Figure 1. The complex topography of Röbergsfjället wind farm was extracted from Airborne Laser Scanning (ALS) 3D-data with a horizontal resolution of 7x7 m2, obtained from SLU (www.slu.se) and it was imported into the commercial CFD software STAR-CCM+.

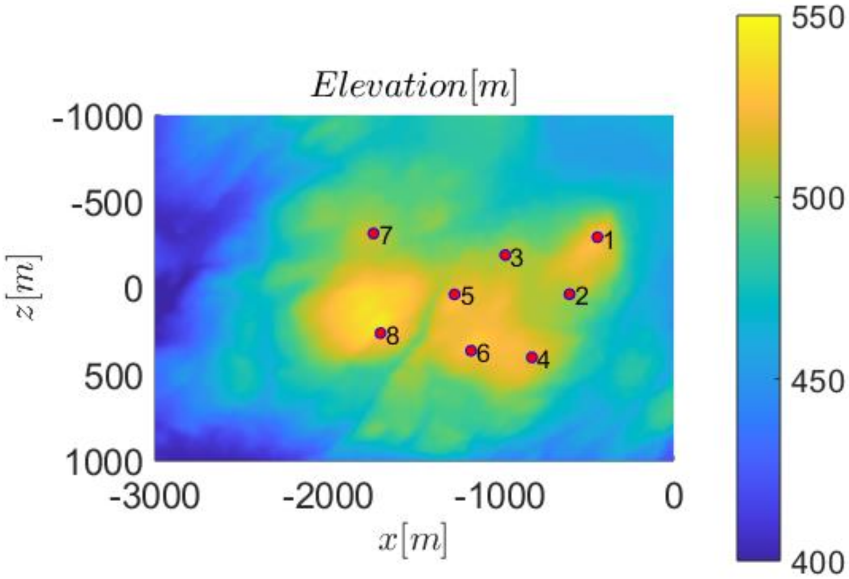

Figure 1: Turbine location and elevation at Röbergsfjället wind farm

A model representing a commercial 2MW turbine was implemented in FAST (Jonkman et al. 2005). The blade and tower properties were adjusted from the NREL 5MW reference wind turbine (Jonkman et al. 2009) and a generator torque-speed relation was chosen to match data available from the wind farm SCADA system. To determine internal loads of drivetrain, the FAST default 2-DOF drivetrain model is replaced by a 10-DOF model. This coupling is done in-house based on the method presented by (Girsang et al. 2014).

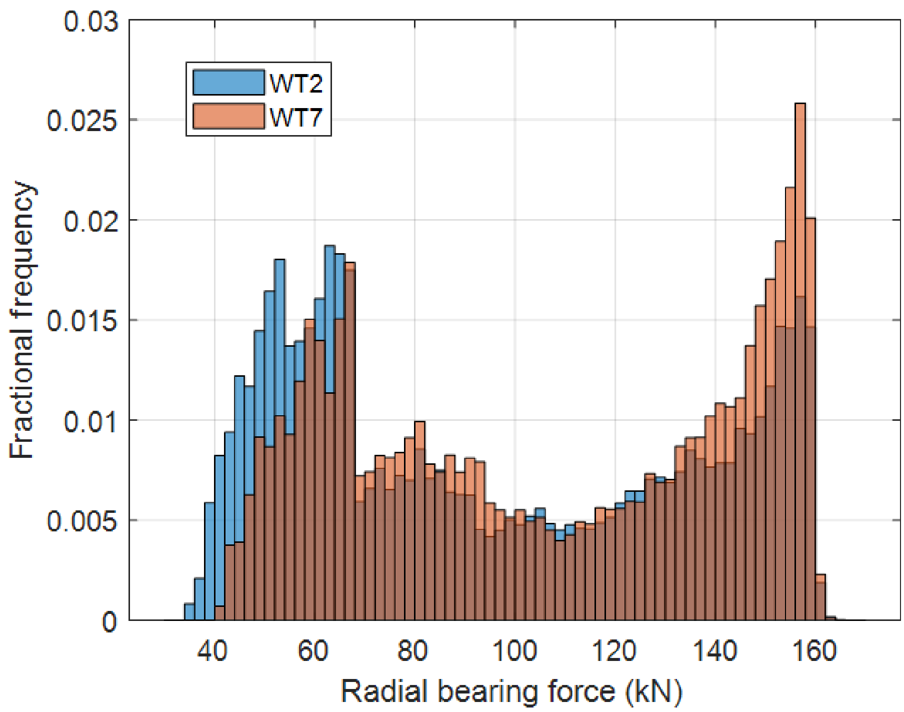

Figure 2: Distribution of high-speed-shaft radial bearing force

The findings of this study lead to two important conclusions. First, as expected, it is found that turbines experience different long-term loads depending on their location on the farm. Figure 2 shows that turbines exposed to favourable wind conditions (turbine 7) experience higher lifetime loads compared to turbines that experience lower wind speeds (turbine 2). This is a preliminary approximation of the long-term loads. This can also be verified visually by the location of the wind turbines in Figure 1. This higher exposure to wind takes away from the design margin of safety of the critically located turbines. Therefore, it is important to estimate the increase in long-term loads.

Typically, the use of LES simulations to predict the long-term wind field is computationally too expensive and infeasible. An attempt is made here to verify whether properly tuned spectral models (such as TurbSim (Jonkman and Buhl 2006)) can be used accurately to predict the wind flow in complex terrain. The findings show that forces from simulations using these synthetic wind fields with fitted mean wind speed, wind shear and turbulence intensity differ slightly from forces from simulations using CFD. Currently, research is underway to develop computationally inexpensive tools to estimate the difference in the long-term loads on the different wind turbines.

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