WindSTAR
Wind-Energy Science, Technology, and Research
Industry/University Cooperative Research Center

Proactive Detection of Under-Performing Wind Turbines Combining Numerical Models, LiDAR and SCADA data

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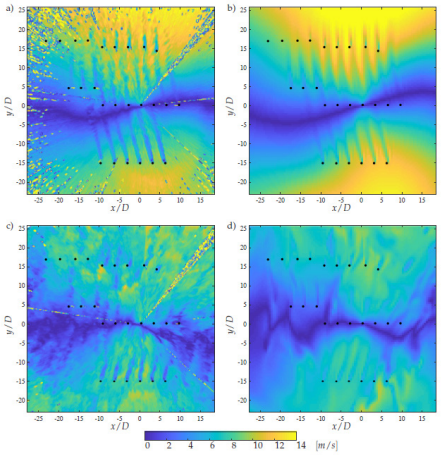
This project focuses on the development of a framework for proactive detection of underperformance of individual turbines in a wind turbine array. This research endeavor encompasses an experimental campaign for an onshore wind farm, development of a RANS model for prediction of wind turbine wakes, wake interactions and power capture, and simulations carried out through WRF to predict the wind field around and within the wind farm, and turbine power production.

For this project, a wind farm in North Texas was made available for LiDAR deployment, while providing meteorological and SCADA data as well. The LiDAR was deployed on site for a total duration of eight months. Wake measurements were performed for a broad range of wind atmospheric conditions and turbine settings. The diagnostic study has shown that the wind farm under examination is characterized by an average power loss due to wake interactions equal to 4% of the total power production under nighttime stable atmospheric conditions, while of only 2.4% for daytime convective conditions. Wind turbines have generally collected higher wind power under convective regimes than stable conditions.

We were able to successfully developed a 2D parabolic RANS solver for simulations of wind turbines wakes produced by the entire wind farm, while predicting power harvesting from each wind turbine. At this stage, accuracy in predicting power capture is about 2.8%, while for hub height wind velocity at turbine location is 4% (50th percentile), with a computational cost of about 8 minutes to predict 10-minute operation of the entire wind farm.

The WRF simulations showed a good level of accuracy in reproducing the meteorological data acquired during the experiment by a met-tower present on site. Furthermore, ad-hoc modeling of the wind turbines allowed accurate simulations of the wind farm power capture for the entire daily cycle of the atmospheric stability.



Color Contours of the absolute value of the radial velocity obtained from the LiDAR measurements (a,c) and virtual LiDAR from MTKE numerical simulations (B,d) during stable (a,b) and unstable (c.d) atmospheric boundary conditions at an elevation angle of 3 degrees, synchronized in time. The turbine position is denoted by a solid circle.

Photos of the site and experimental setup.

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