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Volumetric LiDAR scanning of a wind turbine wake and comparison with a 3D analytical wake model

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A correct estimation of the future power production is of capital importance whenever the feasibility of a future wind farm is being studied. This power estimation relies mostly on three aspects: (1) a reliable measurement of the wind resource in the area, (2) a well-established power curve of the future wind turbines and, (3) an accurate characterization of the wake effects; the latter being arguably the most challenging one due to the complexity of the phenomenon and the lack of extensive full-scale data sets that could be used to validate analytical or numerical models.

The current project addresses the problem of obtaining a volumetric description of a full-scale wake of a 2MW wind turbine in terms of velocity deficit and turbulence intensity using three scanning wind LiDARs and two sonic anemometers.

The characterization of the upstream flow conditions is done by one scanning LiDAR and two sonic anemometers, which have been used to calculate incoming vertical profiles of horizontal wind speed, wind direction and an approximation to turbulence intensity, as well as the thermal stability of the atmospheric boundary layer.

The characterization of the wake is done by two scanning LiDARs working simultaneously and pointing downstream from the base of the wind turbine. The direct LiDAR measurements in terms of radial wind speed can be corrected using the upstream conditions in order to provide good estimations of the horizontal wind speed at any point downstream of the wind turbine. All this data combined allow for the volumetric reconstruction of the wake in terms of velocity deficit as well as turbulence intensity.

Finally, the predictions of a 3D analytical model [1] are compared to the 3D LiDAR measurements of the wind turbine. The model is derived by applying the laws of conservation of mass and momentum and assuming a Gaussian distribution for the velocity deficit in the wake. This model has already been validated using high resolution wind-tunnel measurements and large-eddy simulation (LES) data of miniature wind turbine wakes, as well as LES data of real-scale wind-turbine wakes, but not yet with full-scale wind turbine wake measurements.

[1] M. Bastankhah and F. Porté-Agel. A New Analytical Model For Wind-Turbine Wakes, in Renewable Energy, vol. 70, p. 116-123, 2014.