Characterization of Wind Velocities in the Upstream Induction Zone of a Wind Turbine using Scanning Continuous-Wave Lidars

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1 Abstract

As a wind turbine extracts energy from the wind, induced wind velocities, lower than the freestream velocity, will be present both upstream and downstream of the rotor. In this study, the upstream induction zone of a 225 kW horizontal axis Vestas V27 wind turbine located at the Danish Technical University’s Risø campus is investigated using a scanning Light Detection and Ranging (lidar) system. Three short-range continuous-wave “WindScanner” lidars are positioned in the field around the V27 turbine allowing detection of all three components of the wind velocity vectors within the induction zone. The mean wind speeds in the upstream induction zone are measured by scanning a horizontal plane at hub height and a vertical plane centered at the middle of the rotor extending roughly 1.5 rotor diameters upstream of the rotor. Turbulence statistics in the induction zone are studied by more rapidly scanning along individual lines perpendicular to the rotor at different radial distances from the hub. The mean velocity measurements reveal that the longitudinal velocity reductions become greater closer to the rotor plane and closer to the center of the rotor. The relative velocity reductions become smaller when the turbine’s coefficient of power decreases. Additionally, the mean radial wind speeds were found to increase close to the edge of the rotor disk indicating an expansion of the incoming flow around the rotor. Turbulence calculations in the induction zone suggest that the standard deviation of the longitudinal wind component appears to decrease close to the rotor, while the standard deviation of the radial wind component increases.