Accounting for the speed shear in wind turbine power performance measurement

The power curve of a wind turbine is the primary characteristic of the machine as it is the basis of the warranty for its power production. The current IEC standard for power performance measurement only requires the measurement of the wind speed at hub height and the air density to characterise the wind field in front of the turbine. However, with the growing size of the turbine rotors during the last years, the effect of the variations of the wind speed within the swept rotor area, and therefore of the power output, cannot be ignored any longer. Primary effects on the power performance are from the vertical wind shear and the turbulence intensity. The work presented in this thesis consists of the description and the investigation of a simple method to account for the wind speed shear in the power performance measurement. Ignoring this effect was shown to result in a power curve dependent on the shear condition, therefore on the season and the site. It was then proposed to use an equivalent wind speed accounting for the whole speed profile in front of the turbine. The method was first tested with aerodynamic simulations of a multi-megawatt wind turbine which demonstrated the decrease of the scatter in the power curve. A power curve defined in terms of this equivalent wind speed would be less dependent on the shear than the standard power curve. The equivalent wind speed method was then experimentally validated with lidar measurements. Two equivalent wind speed definitions were considered both resulting in the reduction of the scatter in the power curve. As a lidar wind profiler can measure the wind speed at several heights within the rotor span, the wind speed profile is described with more accuracy than with the power law model. The equivalent wind speed derived from measurements, including at least one measurement above hub height, resulted in a smaller scatter in the power curve than the equivalent wind speed derived from profiles extrapolated from measurements at hub height and below only. It is well established that the turbulence intensity also influences the power performance of a wind turbine. Two ways of accounting for the turbulence were tested with the experimental data: an adaptation of the equivalent wind speed so that it also accounts for the turbulence intensity and the combination of the equivalent wind speed accounting for the wind shear only with the turbulence normalising method for turbulence intensity suggested by Albers. The second method was found to be more suitable for normalising the power curve for the turbulence intensity. Using the equivalent wind speed accounting for the wind shear in the power performance measurement was shown to result in a more repeatable power curve than the standard power curve and hence, in a better annual energy production estimation. Furthermore, the decrease of the scatter in the power curve corresponds to a decrease of the category A uncertainty in power, resulting in a smaller uncertainty in estimated AEP.

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