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Dependence of Wind Turbine Curves on Atmospheric Stability Regimes – An Analysis of a West Coast North American Tall Wind Farm

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Abstract

Tall wind turbines, with hub heights at 80 m or above, can extract large amounts of energy from the atmosphere because they are likely to encounter higher wind speeds, but they face challenges given the complex nature of wind flow in the boundary layer. Depending on whether the boundary layer is stable, convective or neutral, mean wind speed (U) and turbulence (σ_U) may vary greatly across the tall turbine swept area (40 m to 120 m). This variation can cause a single turbine to produce difference amounts of power during time periods of identical hub height wind speeds. Our study examines the influence that atmospheric mixing or stability has on power output at a West Coast North American wind farm. We first examine the accuracy and applicability of two, relatively simple stability parameters, the wind shear-exponent, α, and the turbulence intensity, I_u, against the physically-based, Obukhov length, L, to describe the wind speed and turbulence profiles in the rotor area. In general, the on-site stability parameters α and I_u are in high agreement with the off-site, L stability scale parameter. Next, we divide the measurement period into five stability classes (strongly stable, stable, neutral, convective, and strongly convective) to discern stability-effects on power output. When only the mean wind speed profile is taken into account, the dependency of power output on boundary layer stability is only subtly apparent. When turbulence intensity I_u is considered, the power generated for a given wind speed is twenty percent higher during strongly stable conditions than during strongly convective conditions as observed in the spring and summer seasons at this North American wind farm.

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