Advocating for the replacement of the hub height wind speed with a rotor equivalent wind speed

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Abstract

The wind speed measured at hub height is, as a rule, especially for multi-MW turbines, not representative of the wind profile over the whole turbine rotor [1]. The implication from this is that surplus or deficit in the wind will influence the expected AEP result [2]. We present power curve campaign results from fairly flat locations of varying roughness which demonstrate the need for considering the wind speed over the whole rotor. We supplement the measurement analysis with aeroelastic simulations using a BEM code. The analysis shows that an equivalent wind speed expression using LIDAR measurements over the whole rotor should be used for an objective assessment of the wind over the rotor. At the same time our analysis indicates that the choice of the wind speed expression may influence on our perception of the turbine’s operation, especially under high wind shear conditions. The results demonstrate the need of further investigations.

Objectives

Wind profiles influence the turbine performance. We will analyze measurement campaigns in order to show the influence of the atm. conditions, the topography and the surface roughness on the wind profile. At the same time we will perform BEM simulations using both measured profiles as well as simulations using an exponential shear profile of varying exponent, in order to show possible implications of the equivalent wind speed definition used. The two formulas, representing the wind speed corresponding to the energy (REWS, 1) and mass (WAWS, 2) through the turbine rotor will be used.

\[
V = \frac{1}{N} \sum_{i=1}^{N} \left( v(x_i) \cos(\varphi_i) k^A_i \right) A_i
\]

Case 1: Coastal flat terrain, wind towards land.

Case 2: Flat USA-Midwest low roughness site, driven by atm. stability events

Measurements and BEM simulations in flat forested terrain

In stability driven situations over flat terrain, there is almost a deterministic correlation between e.g. wind shear and TI, i.e. filtering away high TI will effectively remove low shear and vice-versa. Flat forested terrain sites are characterized by high surface roughness acting as a driver for high shear, high veer and high TI [3]. All three parameters decrease with increasing height above ground; hence we are dealing with a highly varying wind profile within the rotor area. In forested terrain filtering of the high wind shear below hub height, removes some, but not all wind veer incidents and removes also both low and high TI values, as seen in the figure below. The figures below come from such a site.

We have used the (LIDAR) measured profiles from this site to perform BEM simulations of the turbine performance and compare to the measured data. The table below presents measured and simulated AEP ratios when filtering for wind shear, by using the two equivalent wind expressions, REWS and WAWS. Both data and simulations show that the AEP ratio vs. the REWS exhibits a larger dependency when filtering on the shear values as compared to the WAWS. The results also show that BEM simulations can be used in a relative way in order to evaluate a turbine’s response to a certain profile relative to a “standard profile”.

Conclusions

It is essential to introduce a rotor equivalent wind speed which can provide information of the height variations of the wind profile. Two different alternatives for a rotor equivalent wind speed have been presented, the energy equivalent wind speed REWS (1) and the mass flux equivalent wind speed WAWS (2). In the presence of high sheared inflow, the REWS expression shows a larger dependency on shear relative to WAWS. In this respect both measurements and simulations suggest that the WAWS is a more consistent estimator of a rotor equivalent wind speed as its variability on high wind shear and veer conditions is significantly less for the specific cases that were investigated. In the absence of high shear values the difference between the two expressions seems not to be significant. The work presented has also underlined the consistency of BEM simulations to the measured data and suggests that simulations can be used to compare “standard” wind profile to site specific profile AEP results.

References

