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## Highlight results

- **New method to account for the vertical wind shear in AEP estimate**
- **Reduction of uncertainty in AEP estimate**

## Background

The Annual Energy Production (AEP) estimate is obtained by combining the wind speed distribution measured at a proposed site with a wind turbine power curve, measured at the manufacturer's test site. Even if the wind speed is measured at (and below) hub height during the site assessment, the wind speed shear can significantly affect the AEP estimation, since the wind energy available actually depends on the kinetic energy contained in the whole wind speed profile. Given the large variation in speed profiles from one site to another and from one season to another, the kinetic energy estimated from the hub height wind speed is rarely truly

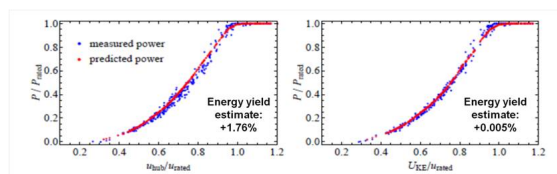
representative of the total kinetic energy impinging the wind turbine.

### Equivalent wind speed

An equivalent wind speed concept has previously been introduced where the kinetic energy impinging the entire rotor disc is represented as a single, equivalent wind speed ( $U_{eq}$ ) [1].

The use of this equivalent wind speed has been shown to improve the power curve measurements as it accounts for the variations of wind shear over the entire rotor disc. Clearly, this equivalent wind speed is a better representation of the available energy than the wind speed at hub height ( $U_{hub}$ ) when there is wind shear.

This method is now proposed in the revision of the IEC 61400-12-1, especially since wind speed profiles can now easily be measured over the whole rotor span of even large wind turbines by using lidars or sodars. Probably, in the foreseeable future, two power curves will be available for each wind turbine type: one traditional with the wind speed at hub height and one, independent of the shear, with the equivalent wind speed. The novelty presented here is the use the equivalent wind speed also in the site assessment.



*Figure 1 Power curves for dataset 2: predicted from dataset 1 (red) measured (blue); using the with wind speed at hub height (left), the equivalent wind speed (right). Better agreement between prediction and measurements with the equivalent wind speed than with the wind speed at hub height.*

### Proof of concept

The wind speed profile has been measured in front of a wind turbine with a lidar. The data were divided in two datasets according to the shape of the wind speed profiles [1]. The two datasets resulted in two different power curve due to the effect of the shear. The power curve from the first group was used to estimate the energy yield corresponding to the wind speeds of the second group. This was achieved first by considering only the wind speed measured at hub height for each group (Figure 1, left) and secondly considering the equivalent wind speed (Figure 1. right). The equivalent wind speed results in a better estimate of the energy yield than the wind speed at hub height.

### What if only the wind speed at hub height has been measured at the assessed site?

In the two following cases, both the wind speed at hub height and the equivalent wind speed was measured during the power curve, giving  $P_{Chub}$  and  $P_{Ceq}$  respectively, but only the wind speed at hub height ( $U_{hub}$ ) was measured during the site assessment. Is it then better, in terms of energy yield estimate, to combine the distribution of  $U_{hub}$  with  $P_{Ceq}$  or to remain with the conventional combination of the distribution of  $U_{hub}$  with  $P_{Chub}$ ? The answer depends on the wind speed profile distributions at the power curve site and at the assessed site, as shown with the two following test cases, see Figure 2.

### Conclusions

- It is necessary to measure the wind speed profile during the site assessment.
- Using the equivalent wind speed during the power curve measurement reduces the sensitivity of the power curve to the shear. Using the equivalent wind speed during the site assessment gives a better estimate of the available energy. Combining both results in a better AEP estimate.
- If only the wind speed at hub height has been measured during the site assessment, a better AEP estimate is obtained with the standard power curve if the shear distribution is similar at both sites; but a better AEP estimate is obtained with the equivalent wind speed power curve if the wind speed profile distributions at the two sites are very different.

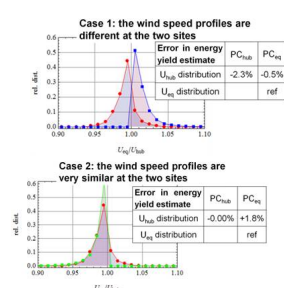


Figure 2 (a) and (b): Distribution of  $U_{eq}/U_{hub}$  during the power curve measurement (red) and during the site assessment (blue/green). In case 1, the equivalent wind speed results in a better estimate of the energy yield; in case 2, the traditional hub height power curve results in a better energy yield estimate.

## Bibliography

[1] Wagner R. et al., Accounting of for the wind speed shear in power performance measurement, Wind Energy 2011; 14:993—1004.

## Improved energy production estimates by accounting for the wind shear

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