Rozenn Wagner from VEA will defend her PhD thesis

Accounting for the speed shear in wind turbine power performance measurement

on Monday 21 June 2010 at 13:00 in the HH Koch Auditorium at Risø DTU.

The opponents will be

Troels Friis Pedersen, Risø DTU (Chairman)
Stephan Barth, ForWind
Jørgen Højstrup, Suzlon Energy.

Short summary of the thesis

A wind turbine 'power curve' is a graph that describes the electrical power output as a function of the upstream wind speed. This is the most fundamental characteristic of the wind turbine and the power curve has a central role in commercial wind turbine activities. The international standard defining how to perform the power curve measurement stipulates that the wind speed should be measured at hub-height only. Contemporary wind turbines are now 4 to 5 times larger than when the standard was written and it is suspected that for such large machines the power output depends not just on the hub-height wind speed but on how the wind speed varies with height – the so-called wind shear. This suspicion is analysed and confirmed by the work reported in the thesis. Firstly numerical simulations were used to predict changes in power output with different wind shear. This result is somewhat unsure since it is also identified that different numerical models of the wind turbine aerodynamics respond very differently to wind shear.

In order to account for the wind shear in power performance measurements, it is proposed to measure the wind profile in front of the wind turbine and represent, in some way, this profile to as one 'equivalent wind speed'. Ideally the power curve plotted as a function of the equivalent wind speed would be independent of the wind shear. In practice it is recognized that some shear dependence will remain since the aerodynamic efficiency of the wind turbine will depend on how optimised the machine is for extracting energy from sheared flows.

Experimental verification was then performed. In order to measure the entire wind profile in front of a modern multi-megawatt wind turbine using a conventional meteorological mast, it would be necessary to erect a tower close to 150m tall. Fortunately new wind sensors known as lidar wind profilers can perform this task remotely from the ground. Lidar profilers have, in the past few years, advanced considerably in accuracy. It was shown from experimental data that the equivalent wind speed does indeed largely remove the wind shear dependence from the power curve.

The implications of the new power curve definition on estimating energy production (AEP) were then examined. It is recommended that site resource assessments are also carried out (using a lidar or tall mast) so that an equivalent wind speed distribution can be measured. Lastly the uncertainties of the equivalent wind speed were compared to a conventional hub-height measurement. An important conclusion is that the existing uncertainty calculation as indicated in the international standard, neglects to include a term representing the uncertainty if the wind profile is unknown.

Results

The thesis proposes a new paradigm for measuring a wind turbine power curve and calculating the potential energy production using a wind speed definition that accounts for the effect of the wind speed shear. This increases the repeatability of power curve measurements and makes them more truly independent of site and season. Ultimately this reduces the uncertainty in the estimation of the energy that can be produced by a wind turbine or from a wind farm giving clear economic advantages.

Another major result is a demonstration that lidar wind profilers can be successfully used for power curve measurements with an uncertainty close to those performed with traditional cup anemometry. If the reduced uncertainty arising from knowledge of the wind shear is also taken into account, the lidar instrumentation should result in significantly more certain power curves and energy production estimates.

Potential usefulness

A revision of the international standard for power curve testing (IEC 61400-12-1) is currently underway. One central aspect of the revision is the inclusion of the affect of secondary parameters, most notably wind shear and turbulence intensity. The thesis addresses these issues, with weight on the wind shear but proposes a method for combining both the effects of shear and turbulence. Much of this work has already been presented by the author at meetings addressing the power curve standard revision. The concept for an equivalent wind speed based on kinetic energy flux considerations as proposed by the author, has been adopted as a de-facto working proposal by this revision committee. It is unusual that a PhD thesis has such an immediate relevance on an international standard of such significance.