The Influence of Turbulence and Vertical Wind Profile in Wind Turbine Power Curve

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Abstract. To identify the influence of turbulence and vertical wind profile in wind turbine performance, wind speed measurements at different heights have been performed. Measurements have been developed using a cup anemometer and a LIDAR equipment, specifically a pulsed wave one. The wind profile has been recorded to study the effect of the atmospheric conditions over the energy generated by a wind turbine located close to the LIDAR system. The changes in the power production of the wind turbine are relevant.

1 Introduction

It is known that both anemometers and wind turbines respond to turbulence in very specific ways. Hence, measurements of the power curve will naturally be affected by turbulence, [1], which is related to the topography where the wind turbine is located and, on the other hand, turbulence intensity as well as wind shear, are linked by the atmospheric stratification. In stable conditions, a low turbulence intensity and a high wind shear are found, whereas in unstable atmospheric conditions, the turbulence intensity is high and the wind speed hardly varies with height, [2–6].

In wind energy, turbulence is evaluated by the turbulence intensity, calculated by dividing the standard deviation of 10 minute wind speed series by its mean wind speed, according to eq. 1:

$$I_v = \frac{\sigma_v}{\overline{V}_{mean}} \qquad (1)$$

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The aim of the present paper is to study the changes in turbulence intensity at different heights above the ground and the impact of such variations over the production of a wind turbine. To measure the changes in wind speed, a LIDAR equipment has been used covering a period of three months, from june to august 2009, instead of installing several common wind speed meters because a high correlation degree between these devices is proven, [7]. The test was performed in a wind farm located in the south of Spain where a complex terrain is found, [8]. Close to the LIDAR was installed a meteorological mast equipped with a cup anemometer. Both were located at a distance less than 4 rotor diameters from the wind turbine used hereinafter.

2 Power Curve Performance

Firstly, to illustrate the importance of the wind profiles as a whole on the power production, figure 1, in the upper part shows a wind shear measurement during the 5th of June 2009. Whereas, the turbulence intensities are shown at the bottom.

It can clearly be seen in figure 1 that in the daytime, when the temperature near the ground is greater than at upper heights due to solar irradiation, the difference between the wind speed is small. Though, during nightime, the opposite happens, which is called *Thermal Stratification*, [9].

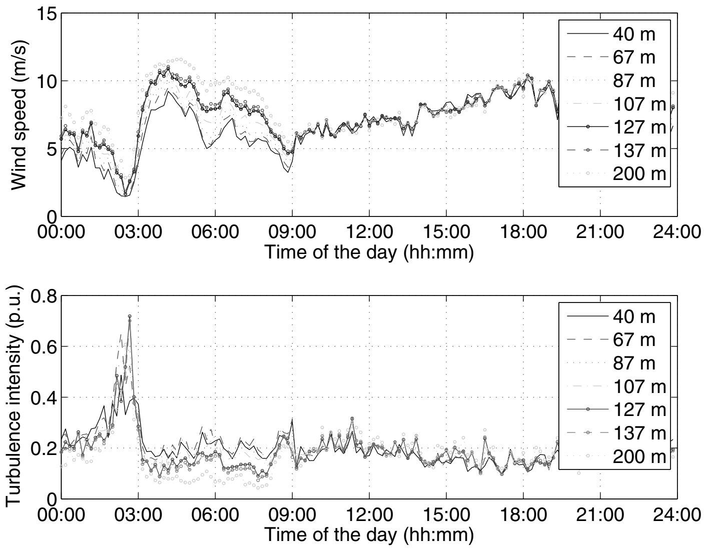

Fig. 1 Wind profile and turbulence intensity during the 5th of June 2009.

An analysis over the power generated by a wind turbine according to the wind profile and turbulent intensity is developed. In the current Standard for power curve characterization, IEC 61400-12-1, is outlined a method called “bin method”. In the

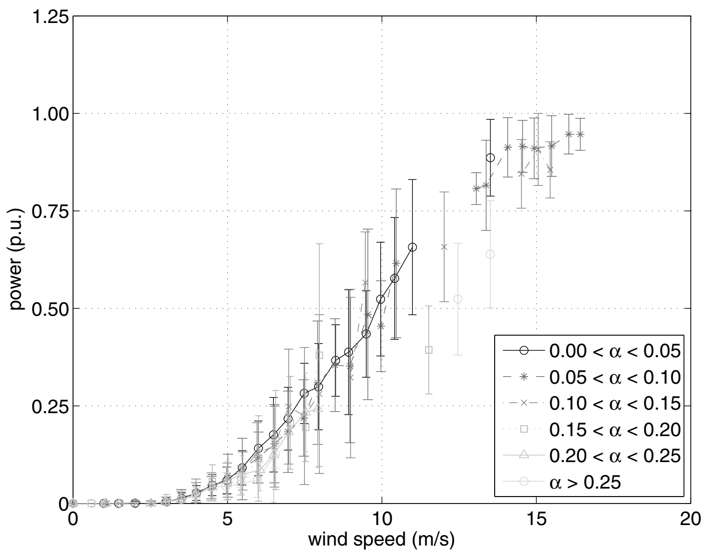

Fig. 2 Power curve related to different shear exponents, α.

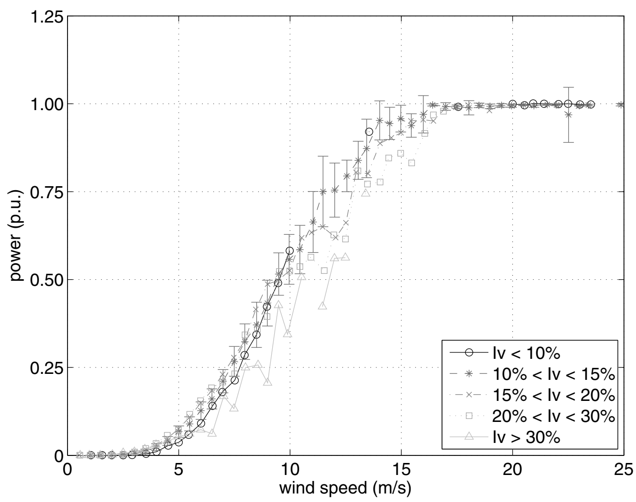

Fig. 3 Power curve according to several turbulent intensities.

present work the minimum number of points for each bin is 5. Besides, the error bars show the standard deviation of the power fluctuations in each bin.

In figure 2 is shown the power produced according to Hellman's exponent or shear exponent, α, obtained from the wind speed recorded by the LIDAR equipment at 40 m and 64 m above the ground using two months data. The figure shows that the higher the shear exponent –equal to say “high wind shear” or “noflat wind profile”– the higher uncertainty in the power produced.

According to four months measurement period performed by cup anemometer, figure 3 shows the changes in the power output of the wind turbine when different turbulent intensities appeared. It can be noticed that for low wind speeds the higher turbulence intensity the higher production. Whereas, at medium-high wind speed, the turbulence influence is the opposite. However, due to the low amount of data measured, this trend needs further attention.

3 Conclusions

Based on an average of 3 months measuremnt period, results show an anomalous behavior of the power curve related to both turbulence intensity and wind shear. However, further investigation with larger measurement periods is needed to prove it.

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