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Spectral analysis of wind velocity and output power from a wind farm.

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Wind energy production is very sensitive to atmospheric turbulent wind. Thus, the high variability of the wind wind velocity can lead to electrical power variations of the order of the nominal power output. Consequently, for the forecasting of wind power for the next minutes or next days, for the modeling of the dynamics and for the optimisation of design and material of wind turbines, a precise understanding of small and large scales turbulent wind field is very important. The wind in the atmospheric boundary layer has a Reynolds Number (ratio of inertial to viscous force) $Re \simeq 10^6$ characterizing a huge intermittency of the wind velocity at all temporal or spatial scales. These scales range from large scale variations (years) to very short variations (few minutes down to seconds). In this study, we present a spectral analysis of the wind velocity and wind power data. Spectral analysis allows to detect the scaling behavior. For a scaling process, the following power law is obtained over a range of frequency f, $E(f) \sim f^{-\beta}$, with β the slope of the power spectrum. The power spectra are determined for wind velocity and wind power data from the wind energy production site of Petit-Canal in Guadeloupe (French West Indies). The wind velocity was measured with an ultrasonic anemometer during July 2005 sampled at 20Hz, and a cup anemometer during the year 2006 sampled to 1Hz. These measurements are obtained at 38m (125ft) above the ground, from the cliff edge. The wind power delivered by a wind farm was recorded with a sampling rate $f_s = 1Hz$, during three years (January 2006 to January 2009). It was found that the wind velocity and wind power spectra could be broken into high and low- frequency regimes according to the parameters given by this analysis. Firstly, the turbulent velocity, for low frequencies $10^{-7}Hz < f < 0.5Hz$ corresponding to time scales $2s < t < 10^7 s$, the spectrum possesses a spectral slope parameter $\beta = 1.29$ and for the high-frequencies $0.5Hz < f < 10Hz$, corresponding to time scales $0.1s < t < 2s$ possesses a spectral slope slightly greater than $5/3$, $\beta = 1.67$. Concerning the output power of the wind farm, for low frequencies $f < 2.10^{-4}Hz$ corresponding to time scales $t > 5000s$, the power spectra shows a power-law with $\beta = 1.22$ and for the high frequencies $2.10^{-4}Hz < f < 0.5Hz$ corresponding to time scales $2s < t < 5000s$, the power spectra displays a power-law near the exact value 5/3, $\beta = 1.65$. Finally, to highlight temporal correlation between velocity and power data, the cross-correlation is given for times scales corresponding to low- frequencies.