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Multifractal analysis of wind velocity and output power from a wind farm, for high and low frequencies.

Rudy Calif (1) and François G. Schmitt (2)

(1) EA, 4098 LARGE laboratoire en Geosciences et Energies Université des Antilles et de la Guyane 97170 P-à-P, France, (2) CNRS, UMR LOG 8187 Station Marine de Wimereux Université de Lille 1, 28 avenue Foch 62930 Wimereux, France

Wind generated power is subject to fluctuations due to the intermittent nature of wind. However, accurate long-term and short-term forecasting of wind speed or output wind power is vital for wind power generation systems efficiency. Consequently, the understanding of intermittency effects in fully developed turbulence and the associated multiscaling of exponents, is essential. In this study, we perform a spectral and multifractal analysis of atmospheric wind velocity and output power from a wind farm at high and low frequencies. The spectral analysis reveals the presence of two scaling regimes for each data: for 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, $\beta = 1.65$. The absence of characteristic time sales and the presence of scaling behavior, for low and high frequencies, indicate that the multifractal analysis may prove to be successful. Thus, we consider the structure functions $S_q(\tau)$ for the fluctuations of wind velocity $\Delta v_\tau = v(t+\tau) - v(t)$ for small temporal scales $(0.1s < \tau < 2s)$ and for large temporal scales $(2s < \tau < 10^7 s)$, and for the fluctuations of output wind power $\Delta P_\tau = P(t+\tau) - P(t)$ for small temporal scales $2s < \tau < 5000s$ and for large temporal scales $\tau > 5000s$. The statistical moments of and are expected to obey power laws : $S_q(\tau) \sim \tau^{\zeta(q)}$ Then, the values of the function $\zeta(q)$ is estimated from the slope $S_q(\tau)$ of versus τ in log-log diagram for all moments q between 0.15 and 5 with time increment 0.25. The function $\zeta(q)$ defines the types of scaling behavior, in other words, this exponent function is very useful to characterize the statistics of the random process. The analysis presented in this study, is perform with 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. From these data, the function exponent $\zeta(q)$ are estimate, highlighting the main statistical properties and long-range dependance for velocity and output power data, for low and high frequencies.