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Estimating of a nonlinear power curve for a Wind Turbine Generator

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The output power from a Wind Turbine Generator (WTG) is an intermittent resource, due to the high variability of the atmospheric wind at all spatial or temporal scales ranging from large scale variations to very short variations. Generally, a function transfer or a power curve of WTG is estimated with the IEC standard $61400 - 12$ giving a relation of coupling between the measured wind speed and the output power for the considered WTG. However, this relation is a statistical representation and not takes into account the dynamics of the power output, more precisely on small time scales. The goal is to provide a method to estimate and to model the function transfer of a WTG, in order to synthesize the output power mimicking the statistical and the dynamical properties of the real output power. For that, we study the statistics of power curve in the multifractal framework motivated by the presence of spectral scaling for the wind speed and the output power data from a WTG. The first step consists to quantify the power curve or the transfer function of two intermittent stochastic processes such as the wind speed $u(t)$ and the output power $p(t)$ at all temporal scales and at all intensities. In this study, firstly, we define the time increment of the wind speed measurement $u'(t) = u(t + \tau) - u(t)$ and the time increment of the output power measurement $p'(t) = p(t + \tau) - p(t)$ characterized by m^{th} and n^{th} order structure functions to estimate the exponent functions $\zeta'_u(m)$ and $\zeta'_p(n)$ that characterize respectively the multifractal properties of the wind speed fluctuations $u'(t)$ and the output power fluctuations $p'(t)$ from the WTG. The exponent function ζ defines the types of scaling behavior of a process: if ζ is linear the statistical behavior is monoscaling corresponding to a monofractal process. If ζ is nonlinear and concave, the statistical behavior is multiscaling corresponding to a multifractal process. The concavity of this function is a characteristic of the intermittency, the more the curve is concave, the more the process is intermittent $[1, 2]$. Secondly, we apply a technique given in Seuront & Schmitt 2005 [3], to estimate the power curve of joint fluctuations $< u'(t)^m p'(t)^n >$ at all scales and at all intensities, by the function $S_{u'p'}(m, n)$:

$$S_{u'p'}(m, n) = \zeta_{u'}(m) + \zeta_{p'}(n) - r(m, n) \quad (1)$$

where $r(n, m)$ is estimated as the slope of the power law of $c(n, m)$ versus τ in a log-log plot, that is defined as [3]:

$$c(m, n) = \frac{< u'^m p'^n >}{< u'^m >< p'^n >} \sim \tau^{-r(m,n)} \quad (2)$$

the brackets $< . >$ defines the statistical average.

The analysis presented in this work, is performed with simultaneous time series of wind speed $u(t)$ and output power $p(t)$ for two types of WTGs, loaded from the Database of Wind Characteristics of the Technical University of Denmark [4]: i) a 300 kW Nordtank wind turbine located in the North Jutland, on the south bank of the Limfjord, about 36 km west of Alborg and 8 km north east of Loegstoer, Denmark. The wind speed and the output power are measured with a sampling rate at 20 Hz during 746 hours. The measurement are obtained at 31 m above the ground. ii) a 2 MW wind turbine at Tjaereborg, Esbjerg, Denmark. The wind speed and the output power are measured with a sampling rate at 25 Hz during 64 hours. The measurement are obtained at 90 m above the ground.

References

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[4] See http://www.winddata.com/