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Stochastic modelling of the energy output of a wind turbine

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Wind turbine systems are rapidly becoming an economically viable source of renewable energy. A key element in making wind energy both a technical and commercial success is the ability to develop an accurate modelling and simulation framework, which will serve as a basis for design and performance optimization. In practice, the wind turbine power performance curve is obtained by applying the IEC standard, which provides a nonlinear relation between the measured wind speed and the corresponding power output of the turbine. Then, the energy production of a wind turbine can be obtained by transforming the wind speed values via the power curve of the turbine. For practical reasons, some simplified assumptions on the stochastic behavior of the wind fields are made, which render this standard procedure insufficient to accurately predict the wind power output on different time scales. This is due to the fact that, wind fluctuations produced by flow distortion and specific meteorological conditions are not taken into account. In this work a stochastic analysis is performed, where the Monte Carlo simulation technique is employed in order to simulate artificial wind time-history records and, subsequently, estimate the power output of wind turbines through a time-series analysis. For this purpose, a stochastic series expansion method, namely, the Spectral Representation method, was employed in order to generate the artificial records of wind loads based on the Kaimal spectrum, the Improved von Karman spectrum and an empirical power spectrum obtained from actual recordings of wind fields. Then, the resulting power output time-histories were statistically processed in order to obtain their probabilistic characteristics and to measure the extent wind speed fluctuations affected their power performance characteristics. The conclusions of this study are summarized and further discussed, while future research opportunities are proposed.

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