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A reward semi-Markov process with memory for wind speed modeling

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The increasing interest in renewable energy leads scientific research to find a better way to recover most of the available energy. Particularly, the maximum energy recoverable from wind is equal to 59.3\% of that available (Betz law) at a specific pitch angle and when the ratio between the wind speed in output and in input is equal to \$1/3\$. The pitch angle is the angle formed between the airfoil of the blade of the wind turbine and the wind direction. Old turbine and a lot of that actually marketed, in fact, have always the same invariant geometry of the airfoil. This causes that wind turbines will work with an efficiency that is lower than 59.3\%. New generation wind turbines, instead, have a system to variate the pitch angle by rotating the blades. This system able the wind turbines to recover, at different wind speed, always the maximum energy, working in Betz limit at different speed ratios. A powerful system control of the pitch angle allows the wind turbine to recover better the energy in transient regime. A good stochastic model for wind speed is then needed to help both the optimization of turbine design and to assist the system control to predict the value of the wind speed to positioning the blades quickly and correctly. The possibility to have synthetic data of wind speed is a powerful instrument to assist designer to verify the structures of the wind turbines or to estimate the energy recoverable from a specific site. To generate synthetic data, Markov chains of first or higher order are often used [1,2,3]. In particular in [1] is presented a comparison between a first-order Markov chain and a second-order Markov chain. A similar work, but only for the first-order Markov chain, is conduced by [2], presenting the probability transition matrix and comparing the energy spectral density and autocorrelation of real and synthetic wind speed data. A tentative to modeling and to join speed and direction of wind is presented in [3], by using two models, first-order Markov chain with different number of states, and Weibull distribution.
All this model use Markov chains to generate synthetic wind speed time series but the search for a better model is still open. Approaching this issue, we applied new models which are generalization of Markov models. More precisely we applied semi-Markov models to generate synthetic wind speed time series.

The primary goal of this analysis is the study of the time history of the wind in order to assess its
reliability as a source of power and to determine the associated storage levels required. In order to assess this issue we use a probabilistic model based on indexed semi-Markov process [4] to which a reward structure is attached. Our model is used to calculate the expected energy produced by a given turbine and its variability expressed by the variance of the process. Our results can be used to compare different wind farms based on their reward and also on the risk of missed production due to the intrinsic variability of the wind speed process.

The model is used to generate synthetic time series for wind speed by means of Monte Carlo simulations and backtesting procedure is used to compare results on first and second oder moments of rewards between real and synthetic data.

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