Countinous-time ARMA Models for Data-based Wind Speed Models

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Wind power generation has increased significantly in recent years and has become a relevant part of the energy production portfolio. Wind energy has a considerable impact on power system dynamics for this reason accurate stochastic models are required to properly simulate wind speed fluctuations [1].

From a statistical viewpoint, wind speed can be characterized by its probability distribution and autocorrelation. The probability distribution gives the likelihood of the occurrence of all possible wind speeds at a specific location. The autocorrelation indicates how much the speed is likely to change, based on its current value. The autocorrelation measures the relation between the wind speeds current value and its past and future values. Two approaches are traditionally utilised to model wind speed fluctuations: (i) discrete-time models e.g. Autoregressive Moving Average (ARMA) and (ii) continuous-time Stochastic Differential Equations (SDEs).

ARMA models have been widely utilised to forecast wind uncertainty [1]. These models are well-established and offer extensive tools to fit the model to the data and reproduce both the distribution and the autocorrelation. ARMA models have a fixed time step which is required to match the sampling interval of the available data. Thus, ARMA models are not suitable for transient stability analysis of power systems, which typically have a smaller time step than the available data and sometimes require varying time steps.

Continuous-time models, such as SDEs, do not require a fixed time step, making them a more promising option to simulate the volatility of wind speed fluctuations in short-term time domain simulations. Wind speed SDE models available in the literature are most often designed to capture the probability distribution but often neglect the autocorrelation. Some recent works have shown that the autocorrelation and the probability distribution that best fit the wind speed are both dependent on the location and on the sampling time [2], [3]. In particular, [3] outlines a systematic procedure to build SDEs with an exponentially decaying autocorrelation. Such procedures often provide a good fit to hourly wind speed data, but not in all cases.

This paper aims at combining together the advantages of ARMA and SDE-based approaches to model the wind speed. The proposed approach is based on the observation that if a ARMA model is stationary then it has an equivalent SDE, termed a Continuous-Time ARMA (CARMA) [4].

Figure 1 shows a comparison of wind speed measurements gathered with hourly and minutely sampling times [5]. The hourly data fails to capture the faster wind variations, which have to be taken into account for transient stability analysis. Such short-term wind speed variations, e.g., turbulance and gusts, typically occur within a 10 minute time frame and result in the autocorrelation initially decreasing rapidly before settling to the same slope as the hourly data. The resulting autocorrelation is thus not exponentially decaying. The main goal of the paper is to simulate short-term fluctuations of the wind speed with the correct autocorrelation.

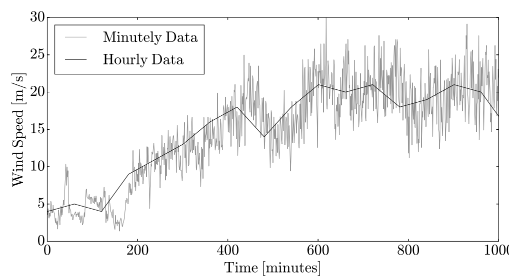

Figure 1. A comparison of wind speed data gathered hourly and minutely in the Valentia Observatory, Kerry, Ireland [5].

In the final paper, CARMA models will be utilised to model wind speed based on measured data from Met Éireann in Ireland [5]. The CARMA approach to construct an SDE to model hourly data will be compared to the approach based on the stationary Fokker-Planck equation presented in [3]. We will consider their ability to match the autocorrelation and the probability distribution. The CARMA models will be utilised to model minutely wind speed data. Preliminary results indicate that CARMA processes can accurately capture both the autocorrelation and the probability distribution of the minutely data. Finally, transient stability and sensitivity analyses of a power system will be performed with the proposed CARMA-based models.

References

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