A cyclic time-dependent Markov process to model daily patterns in wind turbine power production

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Abstract

Wind energy is becoming a top contributor to the renewable energy mix, which raises potential reliability issues for the grid due to the fluctuating nature of its source. To achieve an adequate reserve commitment which mitigates wind integration costs as well as to promote market participation, it is necessary to provide models that can capture daily patterns in wind power production. This paper presents a cyclic inhomogeneous Markov process, which is based on a three-dimensional state-space partition of the wind power, speed and direction variables. Each transition probability is a time-dependent function, expressed as a Bernstein polynomial. The model parameters are estimated by solving a constrained optimization problem: The objective function combines two maximum likelihood estimators, one to ensure that the Markov process long-term behavior reproduces the data accurately and, another to capture daily fluctuations. The paper presents a convex formulation for the overall optimization problem and demonstrates its applicability through the analysis of a case-study. The proposed model is capable of reproducing the diurnal patterns of a three-year dataset collected from a wind turbine located in a mountainous region in Portugal. In addition, it is shown how to compute persistence statistics directly from the Markov process transition matrices. Based on the case-study, the power production persistence through the daily cycle is analysed and discussed.

Keywords:
Cyclic Markov process, wind power, persistence, diurnal pattern

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