Electric Power Systems Research 80 (2010) 592–598

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Simulation of correlated wind speed and power variates in wind parks

P.F. Correia*, J.M. Ferreira de Jesus

IST, Technical University of Lisbon, D.E.E.C. Av. Rovisco Pais, 1049-001 Lisbon, Portugal

ARTICLE INFO

Article history:
Received 31 July 2008
Received in revised form 28 June 2009
Accepted 25 October 2009
Available online 25 November 2009

Wind speed
Power output
Wind park
Correlated variates
Vector auto-regressive model

ABSTRACT

In this paper, we develop a simulation procedure to generate realistic, synthetic wind speed variates for wind parks. These wind variates are defined by their marginal Weibull distributions and their auto- and cross-correlations only. In order to deal with these two types of correlation simultaneously, a vector auto-regressive (VAR) model is used. Power output variates are obtained by applying the nonlinear turbine power curves to the correlated wind speed samples. The complete procedure is illustrated through a numerical example with a few turbines. A comparison is established between real wind time series from a wind park and synthetic wind variates simulated with similar, estimated underlying parameters.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

Renewable power plants are being installed in increasing numbers around the globe. Wind parks, in special, have received huge interest by both private investors and governments [1]. For these reasons, it is becoming increasingly important to be able to simulate the fundamental characteristics of a set of wind turbines, namely the wind speed to which they are exposed and their corresponding power output.

The wind distribution function is a key characterization of wind in a specific location, but the correlations (both auto- and cross-correlation) of the wind time series felt by different turbines are also a fundamental characteristic. Turbines in wind parks can be either packed in a small area or scattered over a larger area, depending on geographical features. This geographic positioning of the wind turbines in wind parks determines cross-correlation (or spatial correlation), whereas wind gusts determine auto-correlation.

The focus of this work is on the simulation of wind variates (random vectors or time series) with appropriate specified features, so as to obtain realistic wind power generation variates for a wind park. The wind features that are specified are the marginal Weibull distributions and the auto- and cross-correlations between wind speed samples. Cross-correlation, or spatial correlation, and auto-correlation are known phenomena in wind speed data, addressed in the literature [2–4]. Synthetic models that use specified marginal distributions and specified auto-correlation have been developed [4,5]. Frequency-based approaches have also been used [6,7].

In this work, we make use of covariance-stationary vector auto-regressive (VAR) processes. This VAR modeling is what allows the specification of both auto- and cross-correlation together with the marginal distribution. The estimation of particular VAR parameters from real wind speed data by employing, for example, an ordinary least squares (OLS) regression [8], leads to a particular VAR model, whereas the procedure developed in the paper gives full control over the features of the simulated variates and the resulting VAR model.

With properly modeled wind speed variates, one can simulate realistic wind park power output variates. Turbine power output and wind speed are nonlinearly related, not only because of the cubic relation, but also because of discontinuities produced by, for example, cut-in and cut-out wind speeds. Although the cubic region has still a Weibull distribution (admitting a Weibull distribution for the wind speed), the power output has considerable probability masses at the zero and at the rated power values. Therefore, it makes sense to simulate wind speed variates, and obtain the power variates by applying a simple input–output, nonlinear, power function to all correlated samples.

The remaining sections of this paper are organized as follows: Section 2 describes the procedure, from the generation of wind variates to the calculation of the power output; Section 3 is used to give an example for a small wind park; Section 4 discusses the model as a prediction tool; Section 5 establishes a comparison between simulated variates using our procedure and real data series from wind parks; finally, in Section 6, we draw some conclusions from this work.

* Corresponding author. Tel.: +351 21 841 7703; fax: +351 21 841 7421.
E-mail addresses: pfcorreia@ist.utl.pt (P.F. Correia), fjesus@mail.ist.utl.pt (J.M. Ferreira de Jesus).

0378-7796/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.epsr.2009.10.031