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Multivariate time series models for studies on stochastic generators in power systems

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ABSTRACT

This paper presents an applied statistics method for the synthesis of multivariate time series of stochastic generation for planning purposes in power systems. It is shown that a suited model should represent satisfactorily the individual univariate stochastic processes and also reproduce the stochastic dependence structure between them. In order to fulfill all requirements, the method proposes the transformation of a set of recorded time series to the multivariate normal domain, the identification of a vector autoregressive model, the synthetization of a multivariate time series with desired length, and subsequently the back-transformation into the initial domain. The method can capture density functions, chronological persistence, diurnal periodicities and dependence structures of and between an arbitrary number of distributed system infeeds. Application can be found in the expansion of short data records into statistically significant synthetic time series for power system studies with distributed and uncertain resources. A simple practical example is given for illustration.

1. Introduction

Stochastic generation is increasingly becoming a topic of interest in power system planning and operation, since the support for new renewable energy resources has triggered the development of new technologies and the installation of large capacities, especially in the wind power sector. Recently, in [1], the modeling of spatially dependent stochastic resources in the power system was addressed, based on modern concepts in uncertainty analysis and stochastic simulation. However, in addition to the modeling of spatial dependence, the chronological modeling of the stochastic system inputs is necessary if inert behavior in energy systems (such as plant ramp rates or energy storage time constants) shall be incorporated in the system analysis [2]. Then, the complexity of the posed problem increases considerably. In [2] it is shown in detail that for such studies, the direct use of short measured time series, simplifying assumptions about models for density and autocorrelation functions, and disregarding the spatial dependence structure between stochastic infeeds all endanger the accuracy of the results considerably.

The main interest is thus the development of methods for the synthesis of sets of stochastic infeed processes, which are not restricted to single types of generation technologies. Such methods should respect both the chronological persistence structures of the individual infeeds (including periodic phenomena in the 24-h time scale) as well as the spatial dependencies between them.

This paper presents a universal method that fulfills the above requirements. It is structured in three main sections that cover the desired features of the method, the development of the model, and its application to example data. Mathematical notations, symbols, and acronyms are explained in the sequence they occur in the text.

2. Desired features of a multivariate time-series model for dependent stochastic generators

2.1. General properties of the multivariate processes of interest

The stochastic processes of interest are streams of data, typically recorded at fixed intervals, often representing averaged values from a finer sampled local data set. For example, the data values are measured once in 5 s, but are transmitted and recorded as an average from the last 15 min to save memory or data transmission capacity. The result is a time series of random vectors, or, generally, a multivariate random process $\vec{X}_t$ [1]:

$$\vec{X}_{t-n}, \vec{X}_{t-n+1}, \ldots, \vec{X}_{t-1}, \vec{X}_t, \vec{X}_{t+1}, \ldots, \vec{X}_{t+m-1}, \vec{X}_{t+m}. \quad (1)$$

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[1] X_t can be a value in the prime mover or power domain. One of the two domains is more favorable for time series modeling, depending strongly on the type of model used, see [3].

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