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Probabilistic load flow with correlated wind power injections

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ABSTRACT

The non-dispatchable nature of wind generation implies that system operation depends on wind power prediction programs that forecast wind farms production with high levels of uncertainty. This means that probabilistic power analysis tools become more and more necessary in systems with high wind penetration. Probabilistic load flow becomes especially difficult when wind generation is considered. The high uncertainty of the production, the non-Gaussian probability density function (PDF) and the clear dependence among the wind farms poses a challenge for conventional tools. The paper proposes an approximation that makes use of the properties of statistical moments and Cornish–Fisher expansion to tackle these new problems.

1. Introduction

The great proliferation of intermittent generation in power networks has increased the uncertainty in power systems. This uncertainty affects both the long and medium term system planning, and the day-ahead operation. This is why the importance of probabilistic tools for power system analysis is growing. For long-term studies, to consider the uncertainty in power planning may lead to a less expensive and more secure network. For the daily operation, an adequate assessment of the system variables may lead to a better management of congestions, among other important advantages.

Probabilistic power flow is one of the best-known probabilistic analysis tools. To study all possible combinations of generation and load is impractical due to the great size of real networks, and this is why analytical methods should be used to adequately assess the variability of the grid variables. From the first proposals in 1970s [1,2], a great deal of literature can be found about this subject. In these early references, it was the uncertainty of the load what was considered.

The most straightforward method of solving this problem is Monte Carlo simulation. This technique involves repeated simulation with values obtained from the probability density function (PDF) of the random variable considered. But for an adequate representation, a great deal of simulations must be considered in real systems. One of the alternatives to this is the convolution of the PDF of the random variables involved, when they are independent of each other, and linearly related. Although this reduces the computational burden, it is still costly to obtain the PDF of a single line when several random power injections are considered. Fast Fourier Transform (FFT) techniques were proposed to reduce the computational burden [3], but this method is linked to the convolution technique, and does not solve the problem efficiently. The use of cumulants and the approximation of resultant PDF by orthogonal series (Gram Charlier expansion series) have also been proposed [4]. It has interesting properties, and is computationally inexpensive. Another recent proposal is the point estimate method [5] that approximates the moments of the system variables of interest. A series expansion is apparently used for obtaining the PDF in this paper. All these approaches assume that the random variables considered are uncorrelated. The main drawback of point estimate method is that it needs a very complex formulation if correlation between random variables is considered.

Probabilistic load flow has mostly included the uncertainty of load. This uncertainty is not very high, and can be modeled using Gaussian probabilistic density functions. Wind energy proliferation, however, poses new challenges, since the variability of wind power production is much higher, and usually the PDF are not Gaussian. Long-term planning studies must consider PDF based on Weibull distributions, while short-term operation analysis need to use PDF whose estimation is still under study. Reference [6] proposes the use of FFT and convolution in distribution networks, and makes a simplified estimation of the PDF for short-term wind power prediction.

Dependence between random variables must be inexcusably considered when wind farms production is to be included, since the power injected by one farm is clearly correlated to other farms of the same area. Dependence between loads' uncertainty is also clear, because their variations are normally due to similar causes. This dependence has been considered, only between loads, in [7], where it is modeled with a linear relation, and in [8], where the covariance has been taken into account in the equations.

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