Abstract

This work describes stochastic analysis methods for the evaluation of uncertainties in power system applications. The conventional Monte Carlo simulation method is computationally expensive, because it requires multiple sampling of the source of uncertainty and multiple simulations. In contrast, the Non-Intrusive Polynomial Chaos method can describe the uncertainty behavior of a system as a deterministic function consisting of polynomials. By replacing the direct simulation of the system with the Polynomial Chaos Expansion function, a significant computational burden can be relieved. Non-Intrusive Polynomial Chaos is a black-box simulation method, where it calculates the coefficients of the Polynomial Chaos Expansion function by sampling the system.

Based on Gaussian and uniform distributions, this thesis introduces the Hermite polynomials and Legendre polynomial basis. The Gauss-quadrature method is applied to calculate the Non-Intrusive Polynomial Chaos expansion coefficients. This work further presents the Tensor-Product method and the Smolyak Sparse method for calculations of the high dimensional expansion coefficients.

Non-Intrusive Polynomial Chaos and Monte Carlo are tested on systems, which are represented by mathematical functions. The results illustrate that for a one-dimensional and continuous system behavior, Non-Intrusive Polynomial Chaos can reduce the computational cost while ensuring accuracy. For a discrete system, it shows more computational cost than Monte Carlo. Tests on multidimensional systems show that the computational cost of the Tensor-Product method increases fast with dimensionality, and the Smolyak Sparse method can slow down the increase. The parametric studies of the Non-Intrusive Polynomial Chaos illustrate that the behavior of the system and the distribution of uncertainty sources need to be considered when choosing the free parameters of the method.

Finally, this thesis presents two use case application scenarios. The first application is about the future power system at Campus West of RWTH Aachen University. Non-Intrusive Polynomial Chaos can produce similar results compared to the Monte Carlo method with less computational cost. The second application is about an electric vehicle charging system. The result of Non-Intrusive Polynomial Chaos deviates significantly from the benchmark result of Monte Carlo, because of the discrete behavior of this system, which demonstrates the limitations of the Non-Intrusive Polynomial Chaos approach.

Keywords: Monte Carlo Simulation, Non-Intrusive Polynomial Chaos, Polynomial Chaos Expansion, Stochastic Analysis, Complex Power Systems