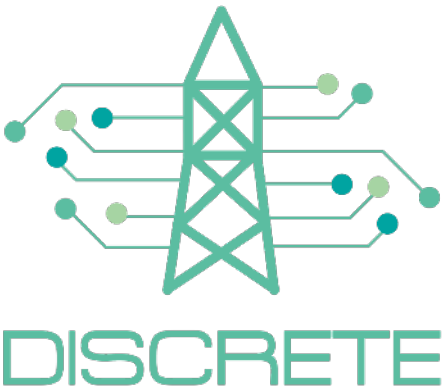

D1.1. Mathematical framework to compare efficiency of non-sampling based methods and alternative power flow formulations

Author: Kaan Yurtseven, Hakan Ergun

Date: 28.11.2023

Table of Contents

1. Description of the mathematical framework

This document provides a short summary of the academic work carried out, and provides information on the implementation of the developed mathematical framework.

1.1. Description of the mathematical model

The increasing penetration of renewable energy sources introduces severe uncertainty in the power system optimization. Given the intermittent nature of renewable resources like wind and solar energy, the power output can vary significantly, which presents a challenge for maintaining the reliability and stability of the grid. Therefore, to effectively manage and predict the performance of the power system under these uncertain conditions, it is essential to employ stochastic optimization methods in contrast to the deterministic models, which presume fixed values for all input variables and parameters. This shift towards a stochastic framework is critical as it captures the real-world variability in renewable generation and demand, providing a more secure and realistic characterization of the power system operations.

Monte Carlo (MC) simulations have been a traditional tool for dealing with uncertainties in power systems. These simulations employ repeated random sampling to compute the outcomes under various scenarios, thus offering a probabilistic understanding of system behavior. While the Monte Carlo method is valuable for its simplicity in implementation and broad applicability, it is also known for requiring a large number of samples to achieve a high level of accuracy, leading to extensive computational efforts and high execution times. In this context, the general Polynomial Chaos (gPC) approach is introduced as a more computationally efficient alternative to MC simulations. The gPC methodology represents uncertain inputs using a polynomial basis, which is then used to reformulate the stochastic problem into a deterministic one. The advantage of using gPC lies in its ability to accurately model the uncertainties with a significantly reduced number of simulations, thereby decreasing the computational burden. By constructing a polynomial representation of random variables, the gPC method transforms the stochastic problem into a set of deterministic problems, which are easier to solve and require fewer computational resources. The transition from MC simulations to the gPC framework is driven by the necessity for fast computational tools that are capable of real-time operation in power systems. By significantly reducing the computational time while maintaining accuracy, the gPC method facilitates the efficient handling of complex calculations, enabling operators to make informed decisions rapidly.

The gPC methodology is implemented for hybrid AC/DC grids as well as by including discrete switching actions in the problem formulation. This allows us to conduct a number of different case studies where we can represent RES uncertainties in an accurate way. Some examples for such case studies are:

- How do HVDC links and other power flow controlling devices increase the hosting capacity for RES?
- What is the economic benefit of utilizing topological actions power grids by means of decreasing dispatch and redispatch costs?
- What is impact of the TSO risk level w.r.t. congestion occurrence on the dispatch and redispatch costs in the grid?

The mathematical model has been implemented in an open-source toolbox, *StochasticPowerModels.jl*[1], developed in the Julia/JuMP environment. Following publications outline the details of the developed models and provide case study details:

K. Yurtseven, A. Koirala, H. Ergun and D. Van Hertem, “Controllability and Flexibility of HVDC Converters in Hybrid AC/DC Grids: A Stochastic Approach”. TechRxiv, 2023, doi: 10.36227/techrxiv.22606840, submitted to IEEE Transactions on Power Systems.

[1] https://github.com/Electa-Git/StochasticPowerModels.jl

K. Yurtseven, A. Koirala, H. Ergun and D. Van Hertem, “Stochastic Optimal Transmission Switching For AC/DC Grids Using General Polynomial Chaos”, submitted to Power System Computation Conference 2024.