Institute for Energy Systems, Energy Efficiency and
Energy Economics (ie3)

Master Thesis: Minimal Control of Probably Feasible Power Systems for Enabling the Grid Integration of Renewable Energies

The flow of power in electricity networks depends on various stochastic factors, e.g. renewable energy feed-ins or time-varying loads. Their importance is recently growing with the introduction of more wind and sun to our energy systems. At the same time, however, the range of options to counteract the fluctuations is also growing, since more and more in-feeds become controllable, in addition to the traditional conventional generators, e.g., electric vehicle chargers of power-to-heat converters.

Grid operators have to ensure that the grid remains feasible under variations, i.e., that line flows, voltages, and the system frequency remain in an acceptable range. To this end, they can measure the grid's state at different locations to influence some of the controllable in-feeds accordingly. We ask:

What is the minimal number of controllable in-feeds to influence and the minimum number of measurement locations such that the grid is guaranteed to remain in a feasible state with high probability?

To attack this control challenge, we first linearize the power flow equations. We also assume that the grid operator uses a linear feedback controller for setting the values of the controlled in-feeds given the measurements. The resulting linear constrained system [1] with stochastic inputs can be analyzed and optimized based on the so-called polynomial chaos expansion (PCE) [2]. The key idea of PCE is to interpret the involved random variables as functions and to decompose them along different functional components.

The proposed thesis shall formulate these points formally and numerically compute controllers for different example settings. A code toolbox for various steps will be provided. The work will require the knowledge and understanding of some probability/measure theory as well as numerical convex optimization techniques.

The thesis is to be jointly supervised by Prof. Dr. Timm Faulwasser (TU Dortmund) and Prof. Dr. Florian Steinke (TU Darmstadt).

References

[1] E. C. Mora Gil. "Minimal Admissible Control of Constrained Static Linear Systems with Applications to Power Systems". PhD thesis. Technische Universität Darmstadt, 2022.

[2] T. Mühlpfordt, T. Faulwasser, and V. Hagenmeyer. "A generalized framework for chance-constrained optimal power flow". In: *Sustainable Energy, Grids and Networks* 16 (2018), pp. 231–242.