

Stochastic modeling of uncertainty in power systems

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Conventional power systems typically come with a small number of large-scale generation units and a large network. Future power systems, on the contrary, are typically associated with a large number of decentralized small-scale units with uncertain infeed. In addition, future power systems are rapidly transitioning toward high shares of variable renewable generation. This shift increases variability and interdependence across supply, demand, and markets. In order to ensure reliable and efficient operation of such systems, uncertainties, for example in the plant parameters, in renewable infeed and consumption must be explicitly taken into account in energy management systems. Therefore, uncertainties in the plant parameters as well as in renewable feed in consumption must be explicitly taken into account in the energy management systems.

Deterministic methods based on point forecasts can be insufficient under these conditions, as they overlook forecast dispersion, extreme events, and evolving component characteristics. Therefore, it is important to address these challenges by developing stochastic models that capture the uncertainties in consumption, renewable generation, and energy prices, alongside parameter uncertainties of key components (thermal and electrical storage, consumers, and generators). The resulting probabilistic descriptions are supposed to enable risk-aware planning, scheduling, and control, improving reliability and efficiency in systems with high share of renewables.

Goals

Within this thesis, the goal is to develop stochastic models for volatile input variables and parameter uncertainties. In other words, stochastic models to account for uncertainties in demand, power generation, energy prices and component parameters will be developed. Further, it also aims to quantify parameter uncertainties of the key components (thermal / electrical storage, converters, consumers, generators).

In summary, the following subtasks can be formulated:

- Literature research
 - Energy management systems in power systems / microgrids
 - System uncertainties in power system applications
 - Uncertainty representation (Monte Carlo, polynomial chaos)
 - Stochastic model predictive control (MPC)
- Development of methods to model uncertainties in

- demand
- renewable power generation, e.g., photovoltaics and wind power, using e.g., clear-sky irradiance with stochastic cloud cover residuals.
- energy prices
- Stochastic model for parameter uncertainties.
- Recommendations for integrating the models for controller design.