Abstract

This thesis introduces a customer-centric Demand Response architecture for the deployment of operational flexibility within city districts. The architecture underlies a two-level hierarchy and links the providers of operational flexibility with operational flexibility users. Crucial challenges and requirements for such Demand Response architectures are identified and discussed. Within the proposed Demand Response architecture, a Demand Response aggregator performs an offline day-ahead scheduling for its customer portfolio. The Demand Response aggregator balances the electrical power demand and supply on the city district level and provides different flexibility services to third party actors such as the Balance Responsible Party, the Transmission System Operator or the Distribution System Operator. The coordination procedure between the Demand Response aggregator and its customers grounds on distributed as well as on decentralized optimization techniques. To this aim, this thesis adapts the convex Alternating Direction Method of Multipliers optimization algorithm, which is implemented to take advantage of parallel hardware architectures such as message passing multicomputers and distributed computer systems. On the basis of different city district use-case applications, the performance of the parallel Alternating Direction Method of Multipliers algorithm is evaluated and compared to a centralized coordination approach. It turns out that the parallel Alternating Direction Method of Multipliers algorithm satisfies the requirements on state-of-the-art Demand Response architectures. Further, the algorithm exploits operational flexibility to the same extent than it does a centralized computation, but tends to outperform the centralized computation in the terms of the runtime and the memory demand. This is the case even if Alternating Direction Method of Multipliers incentive message are lost during the scheduling process. Moreover, to let the coordination procedure cope with uncertain data sources such as the uncertainty in the weather forecast, this thesis investigates into a Robust Optimization strategy embedded in a Model Predictive Control rolling horizon framework. The impact of uncertainties on this robust scheduling approach is quantified via Monte Carlo samplings and Non-Intrusive Polynomial Chaos stochastic analyses. Findings show that Robust Optimization represents a beneficial tool for Demand Response aggregators as well as that a Non-Intrusive Polynomial Chaos stochastic analysis yields as accurate results as a Monte Carlo sampling with a sufficient number of samples, but significantly decreases the simulation runtime.

Keywords: Operational Flexibility, Demand Response, Distributed Optimization, Alternating Direction Method of Multipliers, Proximal Message Passing, Robust Optimization, Parallel Processing, Non-Intrusive Polynomial Chaos