Reactive Power Modeling for Building Systems to Support Building-to-grid Integration Studies

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Demand response (DR) of building systems is a promising approach to enhance the reliability of power grid operation, especially when there is a high penetration of renewable generation (Palmintier et al, 2017). Prior to large scale testing and deployment of DR it is necessary to evaluate the reliability level of power systems under DR control. However, common design practice or DR methods ignores their effect on reactive power for the sake of design simplicity. Existing power system models tend to ignore interactions between power grid systems with building loads while buildings models usually only consider the real power characteristics of building devices. Most simulation software was not developed to incorporate reactive power modelling. The lack of reactive power modeling for building loads at both individual level and aggregated level impedes evaluation of effects of DR on reactive power dynamics. Modelling reactive power is a challenging task as it requires not only cross-disciplinary knowledge to capture interactions between different systems or components when establishing the mathematic models, but also a flexible software setup to simulate the resulting models in a scalable and efficient manner.

In this presentation, we demonstrate an approach for modelling reactive power to support the study of buildings DR on power system reliability. This proposed approach consists of one set of high-fidelity models of building loads and one simulation software setup. The high-fidelity models are developed in Modelica, an equation-based and object-oriented modelling language. Modelica models offer flexibility and can be integrated in co-simulation frameworks as governing equations can be easily added to the system without affecting existing models. In addition, object-oriented implementation of Modelica models also makes them more suitable for large-scale simulation in power systems. The simulation software setup is for supporting the large-scale co-simulation among end-use loads, distribution systems, and transmission systems. When performing co-simulation, existing distribution and transmission models are leveraged. To realize the time synchronization between various simulators, a co-simulation engine, HELICS, and a data exchange protocol, Functional Mockup Unit, are included in this software setup. A Docker-based deployment method is also developed to further simplify the large-scale power system simulation. Finally, to demonstrate the usage of the developed approach, we perform a case study where commonly used DR methods are evaluated for standard IEEE test feeders. To facilitate the evaluation, metrics about the power system reliability are developed and implemented in the simulation software setup. The evaluation results could, on one hand, provide insights on how to enhance the existing DR method, and on the other hand, help identify the future power systems research challenges.

References

Palmintier, B., et al. 2017. “Design of the HELICS high-performance transmission distribution-communication-market co-simulation framework.” Proc. 2017 IEEE Workshop on Modeling and Simulation of Cyber-Physical Energy Systems