



Modeling and Coordinating Distributed Energy Resources in Power Systems and Markets

Final Project Report

M-42

Power Systems Engineering Research Center

*Empowering Minds to Engineer
the Future Electric Energy System*



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Power Systems Engineering Research Center

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Executive Summary

This project is motivated by the growing integration of distributed energy storage resources (DERs) in the electric power systems. The massive DER integration brings significant voltage stability challenges to the transmission and distribution systems, as well as wholesale market challenges and opportunities to the independent system operators (ISOs) and DER aggregators. This research focuses on three core areas: 1) mitigating fault induced delayed voltage recovery (FIDVR) by using DERs and variable frequency drive (VFD) driven air conditioners; 2) coordinating transmission and distribution operations for massive DER integration in the wholesale electricity markets; and 3) DER coordination for frequency regulation service provision. The research is presented in five chapters (Chapters 2-6).

Chapters 2-3 propose FIDVR mitigation techniques by using DERs and VFD driven air conditioners. By properly modeling the VFD driven air conditioners, which is a relatively new technology in residential air conditioning, in the composite dynamic load models, these chapters investigate the impact of increasing VFD driven air conditioner penetration and DER penetration within a large-scale power system on reducing the severity of FIDVR events.

Chapters 4-5 propose transmission and distribution coordination frameworks which enables the wholesale market participation of massive DERs while ensuring secure operation of the distribution grids. A non-profit distribution system operator (DSO) is adopted as the coordinator between the wholesale market operation and the distribution grid operation. A parametric programming approach and a two-stage stochastic programming approach are proposed for the DSO to coordinate the wholesale market participation of aggregated DERs while satisfying the distribution grid operating constraints.

Chapter 6 presents and implements the centralized and distributed methodologies which enable the microgrids to coordinate multiple DERs in order to provide frequency regulation services to the bulk power systems. Details on the controller hardware-in-the-loop (CHIL) testbed that is used to test the centralized and distributed DER coordination approaches are presented in this chapter.

Project Publications

- [1] Mohammad Mousavi and Meng Wu, “A Two-stage Stochastic Programming DSO Framework for Comprehensive Market Participation of DER Aggregators under Uncertainty”, *52nd North American Power Symposium (NAPS)*, Virtual Conference, 2021.

- [2] Adriana Cisco Sullberg, Meng Wu, Vijay Vittal, Bo Gong and Philip Augustin, "Examination of Composite Load and Variable Frequency Drive Air Conditioning Modeling on FIDVR," in *IEEE Open Access Journal of Power and Energy*, vol. 8, pp. 147-156, 2021.
- [3] Mohammad Mousavi and Meng Wu, "A DSO Framework for Comprehensive Market Participation of DER Aggregators in Unbalanced Distribution Networks", in *IEEE Transactions on Power Systems*, vol. 37, no. 3, pp. 2247-2258, May 2022.
- [4] Mohammad Mousavi and Meng Wu, "ISO and DSO Coordination: A Parametric Programming Approach", *2022 IEEE Power & Energy Society General Meeting (PESGM)*, Denver, Colorado, July 2022.

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