Evaluating the Impact of Price-Responsive Load on Power Systems Using Integrated T&D Simulation

Himanshu Jain, Bryan Palmintier, Dheepak Krishnamurthy, Ibrahim Krad, and Elaine Hale
National Renewable Energy Laboratory (NREL)

Abstract

This paper explores the differences between simulating price-responsive load (PRL) interactions with power systems using integrated transmission and distribution (T&D) models and transmission-only (T-only) models. This analysis uses the Integrated Grid Modeling System (IGMS) software to capture "ISO-to-appliance" simulations using a synthetic T&D model built on the PJM 5-bus transmission network with multiple full-scale taxonomy feeders that include physics-based models of thousands of customers and PRLs. The results show important differences in the impacts of PRLs between integrated T&D and T-only models.

Modeling Approach

- **Integrated T&D simulations:**
  - ✓ **Method**: IGMS [1] co-simulates GridLAB-D, MATPOWER, and FESTIV to perform quasi-steady-state simulations.
  - ✓ **Load model**: Load profiles are generated automatically during the co-simulation.
  - ✓ **PRL model**: Only HVACs were modeled as PRLs using GridLAB-D's passive controller [2].
- **T-only simulations:**
  - ✓ **Method**: IGMS co-simulates MATPOWER and FESTIV to perform quasi-steady-state simulations.
  - ✓ **Load model**: Aggregated, constant power loads at the transmission buses with precalculated load profiles are used.
  - ✓ **PRL model**: Own-price elasticity is used to model the price-responsive behavior of aggregated transmission loads.
- **Price input:**

  Real-time locational marginal price (LMP) of the transmission bus calculated by FESTIV every 5 minutes.

Model Used in Simulations

- Transmission topology: PJM 5-bus system [3]
- Distribution topology: 11 taxonomy feeders [4]
- More than 70,000 T&D components modeled [5].

Simulation Results

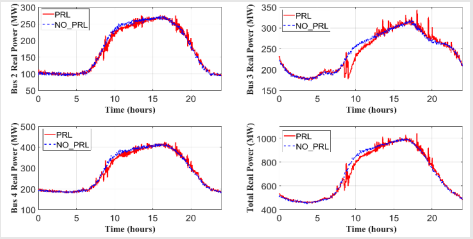

Figure 1. Real power demand at the transmission buses in integrated T&D simulations

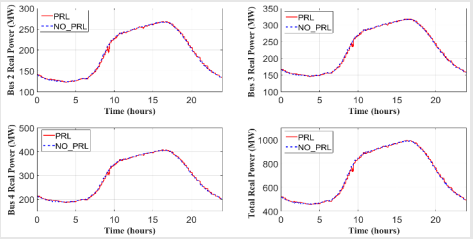

Figure 2. Real power demand at the transmission buses in T-only simulations

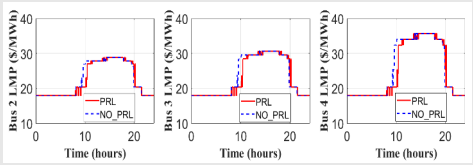

Figure 3. LMPs at Bus 2, Bus 3, and Bus 4 in integrated T&D simulations

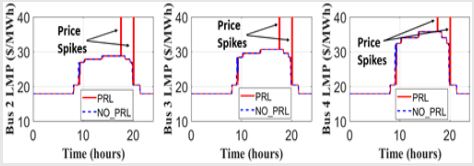

Figure 4. LMPs at Bus 2, Bus 3, and Bus 4 in T-only simulations

Key Observations

- Real power demand profiles and LMPs are very similar between integrated T&D and T-only simulations in the absence of PRLs.
- Significant differences in real power demand profiles and LMPs can be observed between integrated T&D and T-only simulations when PRLs are present.
- Few LMP spikes occur in the T-only simulations; no such spikes occur in the integrated T&D simulations.
  - ✓ Price spikes occurred because price elasticity caused loads to increase in response to reduced real-time LMPs, and a small amount of load was shed (4 MW at 5:30 p.m.) and reserves were deployed (at 8:00 p.m.) to meet the increased demand.

Conclusions

Using high-resolution integrated T&D models that include detailed models of end-use appliances and PRLs, the impact of PRLs on individual customers, distribution feeders, and the bulk power system can be calculated in one simulation. Such detailed analysis cannot be performed with T-only models where load is aggregated at the transmission load buses.

References

[1] B. Palmintier et al. 2017. "IGMS: An Integrated ISO-to-Appliance Scale Grid Modeling System." *IEEE Trans. Smart Grid* 8, no. 3 (May): 1,525–1,534.

[2] "Transactive Controls—GridLAB-D Wiki." [Online]. http://gridlab-d.shoutwiki.com/wiki/Transactive_controls. Accessed September 14, 2017.

[3] F. Li and R. Bo. 2010. "Small Test Systems for Power System Economic Studies." *2010 IEEE PES General Meeting Proceedings*: 1–4.

[4] K.P. Schneider, Y. Chen, D.P. Chassin, R. Pratt, D. Engel, and S. Thompson. 2008. *Modern Grid Initiative Distribution Taxonomy Final Report* (PNNL-18035). Richland, WA: Pacific Northwest National Laboratory.

[5] H. Jain, B. Palmintier, I. Krad, and D. Krishnamurthy. "Studying the Impact of Distributed Solar PV on Power Systems Using Integrated Transmission and Distribution Models." *2018 IEEE PES T&D Conference and Exposition Proceedings*.

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office and Grid Modernization Laboratory Consortium. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes. Authors: Please replace the funding statement with the new required notice. This can replace both statements currently included on the bottom of the poster.

IEEE ISGT 2019
Washington, D.C.
February 17–20, 2019
NREL/PO-5D00-73296