Evaluating the Impacts of Battery Energy Storage System Functionalities on Distribution Systems Using Power Hardware-in-the-Loop Simulation

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Abstract

A battery energy storage system (BESS) can provide various grid support services, including voltage regulation, peak shaving, and photovoltaic (PV) smoothing. This paper presents results from a power hardware-in-the-loop (PHIL) simulation that was performed to test and demonstrate the impacts of BESS functionalities on a distribution feeder. The PHIL platform includes a simulated distribution grid in a real-time digital simulator (RTDS), AC and DC power amplifiers, and a battery inverter as the device under test. Guidelines on how to set up a PHIL platform to evaluate the impact of grid integrated systems are provided. Accelerated time-series PHIL simulations of peak shaving and volt-watt functionalities were performed using a 540-kVA BESS. These experimental results illustrate how PHIL simulations can be used to evaluate the impact of BESS functionalities on the distribution grid prior to installation in the field.

Distribution Grid with BESS

We based our evaluation on a San Diego Gas & Electric Company (SDG&E) feeder in which a lithium-ion-based BESS has been installed. Our research was encouraged by SDG&E in light of their need to comply with the California Public Utilities Commission’s requirement to meet a target of 165 MW of cost-effective grid storage by year 2020. The simulated distribution feeder is a reduced-order representation of the full network. The full SDG&E 2,174-node feeder model was reduced to an equivalent 7-bus model. It is a 12-kV feeder with a peak load of 7.5 MW. The loads are modeled as dynamic loads. Two capacitor banks, both rated at 1.2 MVar, are used to regulate the voltage. A 1.2-MW PV system is connected at the end of the feeder, and a 1-MW/3-MWh BESS is connected upstream of the PV system. The loads are modeled as dynamic power sinks, and they are controlled by multiplying a per-unit load profile by a fixed load.

Conclusion

Two functionalities—peak shaving and volt-watt—are simulated, and the experimental results are presented. These results demonstrate how a PHIL simulation platform can provide a valuable evaluation prior to field installation. Information from the PHIL simulations can be used by utility operators to determine how to operate their utility assets most effectively under different scenarios in the field presented.