Performance Evaluation of Distributed Energy Resource Management via Advanced Hardware-in-the-Loop Simulation

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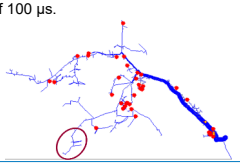
Abstract

This paper evaluates voltage regulation coordinated across advanced distribution management systems (ADMS), distributed energy resources (DERs), and distributed energy resource management systems (DERMS) using an advanced hardware-in-the-loop (HIL) platform. The HIL platform provides a realistic laboratory testing environment, enabling accurate dynamic modeling of a real-world distribution system from a utility partner, with real controller (ADMS and DERMS) and power hardware (DER) and standard communications protocols. The test results show proper performance of the voltage regulation by coordinated control systems and confirm correct functioning of the HIL platform. This HIL testing capability will help mitigate risks of potential issues (e.g., instability) during field deployment.

Cosimulation of HCE Feeder

The cosimulation of the real-world distribution feeder from Holy Cross Energy (HCE) includes both a quasi-steady-state time-series (QSTS) simulation in OpenDSS with a simulation time step of 1 s and an electromagnetic transient (EMT) real-time simulation in OPAL-RT with a simulation time step of 100 μs.

Topology of HCE distribution feeder

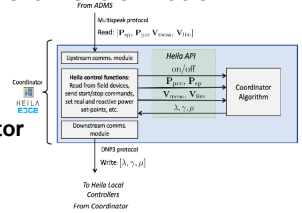


Survalent ADMS

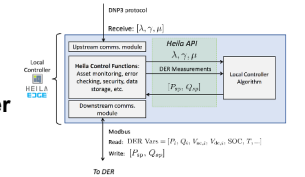
- Receive AMI data from the cosimulation via DNP3 protocol
- Send all measurements to DERMS coordinator and control commands/set points via Multispeak protocol
- Situational awareness and SCADA system.

Heila Control Platform

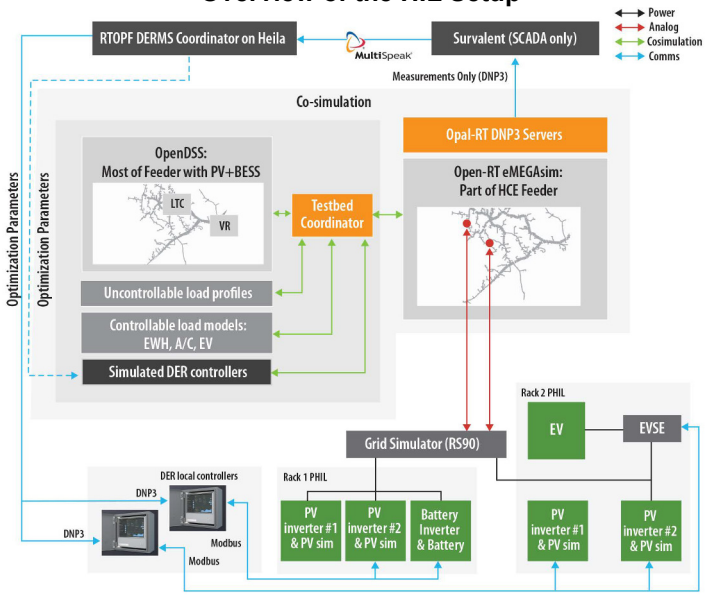
RT-OPF DERMS Coordinator



RT-OPF DERMS Local Controller



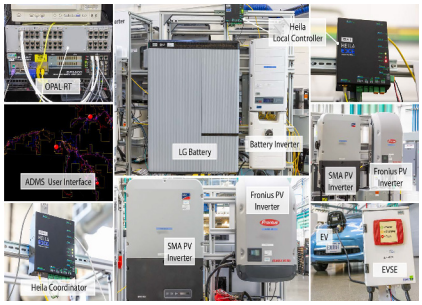
Overview of the HIL Setup



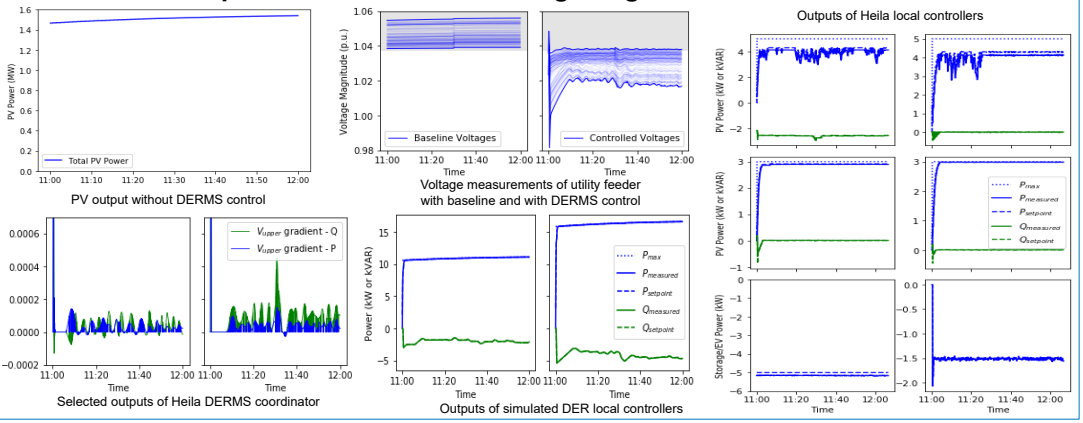
PHIL Testing of Behind-the-Meter DER Inverters

Rack Components	Description
Rack 1 (PCC#1): • 3-kW SMA PV inverter • 5-kW Fronius PV inverter • 8-kW SolarEdge battery inverter	• Both photovoltaic (PV) inverters produce active and reactive power, and the battery inverter produces only active power. • The PCC voltage and current are fed back to OPAL-RT. • The DC side of the PV inverters is powered by PV emulators, and the battery inverter is powered by a LG battery.
Rack 2 (PCC#2): • 3-kW SMA PV inverter • 5-kW Fronius PV inverter • 6.6-kW/22-kWh Nissan Leaf EV	• Rack 2 has the same PV units as Rack 1. • The electric vehicle (EV) is connected through an EVSE and can only draw active power from 0 to rated power.

Photo of Experimental Setup of the HIL Platform



Experimental Results of Voltage Regulation via DERMS



Conclusions

This paper evaluates the performance of voltage regulation algorithms coordinated across ADMS, DERMS, and DERs using an advanced HIL platform with a simulated real-world utility feeder. The HIL platform includes a cosimulation of the distribution system model, real controller (ADMS and DERMS) and power hardware (DER) and standard communications protocols. The structure and implementation of the HIL platform is described with details on each component's hardware, integration, and communications. An experimental test with large PV penetration is performed, and the test results demonstrate the effectiveness of the voltage regulation algorithms.

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