
Jing Wang, Senior Research Engineer
National Renewable Energy Laboratory
Jing.Wang@nrel.gov

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Background

• **Challenges**: integrate distributed energy resources (DERs) like rooftop PV into the grid while balancing that generation with traditional utility generation.
• **Needs**: develop software and hardware solutions for utility distribution system control and operations that integrate sensing, communication, and data analytics.
• **Requirements**: field-tested by utilities to demonstrate their performance and value in real-world operating environments.

Need to test those solutions prior to field commissioning in a realistic lab environment.
Generic Platform

• Objective: develop an easy configure and plug-in-play platform to provide realistic laboratory testing

• Integrated hardware-in-the-loop (HIL) platform
  – Co-simulation
  – Software HIL
  – Controller HIL
  – Power HIL
  – HELICS
Project I: ECO-IDEA

- Address the challenges of distribution systems especially associated with high penetrations of distributed PV, such as voltage stability

*Voltage variability at the grid edge measured by 1,005 AMI meters collected over 14 months*
Project I: ECO-IDEA

• Address the challenges of distribution systems especially associated with high penetrations of distributed PV, such as voltage stability
  – State-of-the-art grid operation: ADMS controls the legacy devices, limited control and visibility of PVs and grid-edge devices
  – Develop a unique and innovative Data-Enhanced Hierarchical Control (DEHC) architecture
  – Real-time operation and control for distribution systems
    • ADMS — legacy devices
    • ADMS — grid-edge synergy
    • Real-time optimal power flow (DERMS)
Proposed a Hardware-in-the-Loop (HIL) platform\(^1\) – Co-simulation, SHIL, CHIL and PHIL with standard communications protocols

- Accurate real-time modeling of distribution system from a utility partner
- Real controller (ADMS and grid-edge server), software controller DERMS
- Hardware grid-edge devices

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Experimental Results

Selected PV profile—high-voltage scenario

4-hour run (10:00 – 14:00)

Voltage measurements

DERMS and PV

PHIL: Grid-edge devices

Legacy devices
Project II: GO-Solar

• Objective: Validate the control and optimization solution\(^2\) in a realistic testing environment
  – Four major elements of the HIL platform:
    • Co-simulation
    • Grid Optimization algorithm
    • PHIL with 5 PV inverters (each 3-5 kVA)
    • ModBus communication interface
  – Software controller interacts with the real-time simulation model and hardware inverters as if the controller were interacting with a real-world system

Experimental Results – Voltage Regulation

– Distribution feeder from Hawaiian Electric Company
  • Over 2,000 nodes
  • 245 loads and 245 PVs (242 simulated and 3 PCCs with hardware PV inverters)
  • 50% PV penetration

– Testing details
  • Simulation time 10:00-12:00 2-hour run at high solar irradiance
  • Voltage regulation target: 0.95 – 1.03 p.u.
Results from real-time simulation

4.2% curtailment

Results from PHIL – 3 DER racks

1.6% curtailment
Project III: SolarExpert

- Need to evaluate DERMS Technology\(^3\) in a more realistic environment
- **Requirements:** real-time simulation of large network, software controller runs in fixed time-step, interact with hardware inverters with standard communication protocols.
- Integrated hardware-in-the-loop platform by using HELICS

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Implementation

- HELICS Architecture and Hardware Setup
Experimental Results

- **Setup configuration**
  - 11,000 node distribution feeder (IEEE 8,500 node test feeder and a modified EPRI Ctk7 test feeder)
  - 532 simulated PV in OpenDSS
  - 6 PCCs in OPAL-RT with PHIL testing of 6 DER Racks (90 DER hardware inverters)
  - 2-h from 11:00-13:00
  - Voltage regulation performance

**Baseline and Controlled voltages**

- CHIL and PHIL testing
- Total PV Active and Reactive Power
- 6.55% curtailment
Experimental Results

PHIL results: DER Rack #1-4

PHIL results: DER Rack #5-6

Results of two selected simulated PV
Conclusions

• This panel presented the performance evaluation of various grid solutions for DER integration using an advanced HIL platform with realistic testing environment.

• HELICS is the key tool to integrate all the software pieces and hardware devices together.

• The experimental tests demonstrate that the grid solutions function well to maintain system voltages within the target limits.