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Hawaiian Electric Company (HECO) Grid Optimization with Solar

Cooperative Research and Development Final Report

CRADA Number: CRD-17-00705

NREL Technical Contacts: Yingchen Zhang and Bryan Palmintier

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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-6A40-86408
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Cooperative Research and Development Final Report

Report Date: May 17, 2023

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the CRADA final report, including a list of subject inventions, to be forwarded to the DOE Office of Scientific and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Hawaiian Electric Company, Inc.

CRADA Number: CRD-17-00705

CRADA Title: Hawaiian Electric Company (HECO) Grid Optimization with Solar

Responsible Technical Contact at Alliance/ National Renewable Energy Laboratory (NREL):

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Sponsoring DOE Program Office(s):

Office of Energy Efficiency and Renewable Energy (EERE), Solar Energy Technologies Office (SETO)

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
Year 1 Year 2, Modification #1 Year 3, Modification #2	$667,505.00 $436,596.00 $487,501.00
TOTALS	$1,591,602.00

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Executive Summary of CRADA Work:

The purpose of this project is to provide a software platform that gives utility companies the capability to seamlessly dispatch legacy devices (at both the distribution and subtransmission levels) and distributed energy resources (DERs) to achieve system-wide performance and reliability targets–such as minimizing loss, reducing voltage violation, and corresponding imbalance–for extreme solar futures with well over 100% (capacity) penetrations. Figure 1 shows the architecture of Grid Optimization with Solar (GO-Solar) platform.

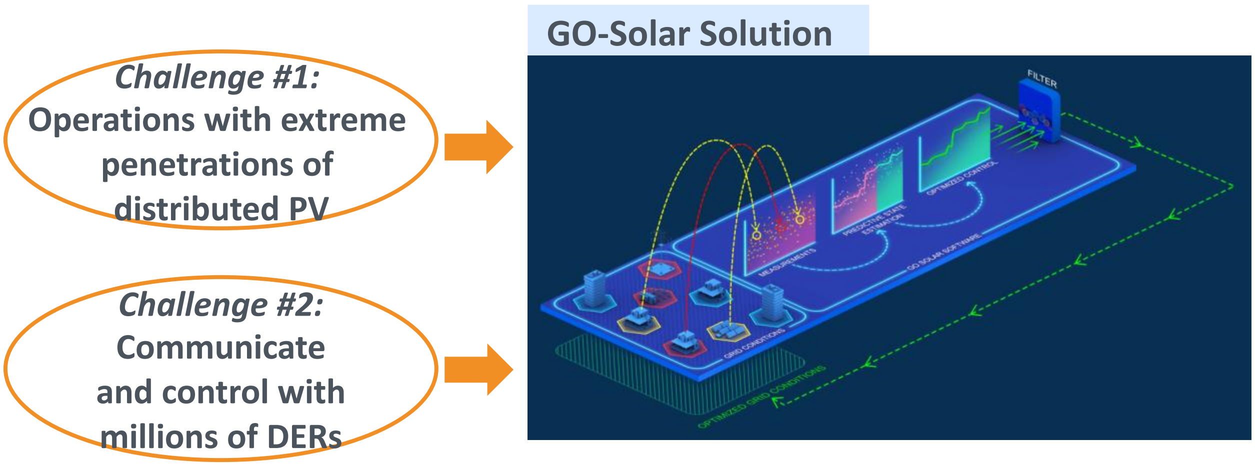

Figure 1. GO-Solar architecture.

Summary of Research Results:

Task 1: Data Collection

NREL team has directly engaged HECO to gather actual system models and data used for development, testing, demonstration, and validation of the GO-Solar platform.

Task 2: Technology Development

The team has developed a novel GO-Solar platform to proactively manage very large DER populations using only a few measurement points as inputs through predictive state estimation (PSE) [1]–[3] and only a few outputs through carefully selected control nodes identified and dispatched through online multi-objective optimization (OMOO) [4], [5]. The PSE takes heterogeneous measurements collected from limited locations in the system to first estimate the system voltages at the current time step using the matrix completion method and then forecasts the system voltages in the short-term future using a multi-kernel learning method. The forecasted system voltages are then fed into a slow-scale OMOO algorithm that determines the optimal set points of various controllable devices, including both the fast-responding DERs and legacy devices, in the short-term future by solving an OPF problem. The optimal set points for the short-term future are then communicated with each device. In real time, an online optimization is employed to follow the plan produced by the slow-scale optimizer and adjust the set points of DERs to cope with the fast variability of DERs and optimize the voltage profile in the system. Figure 2 shows the integrated GO-Solar platform.

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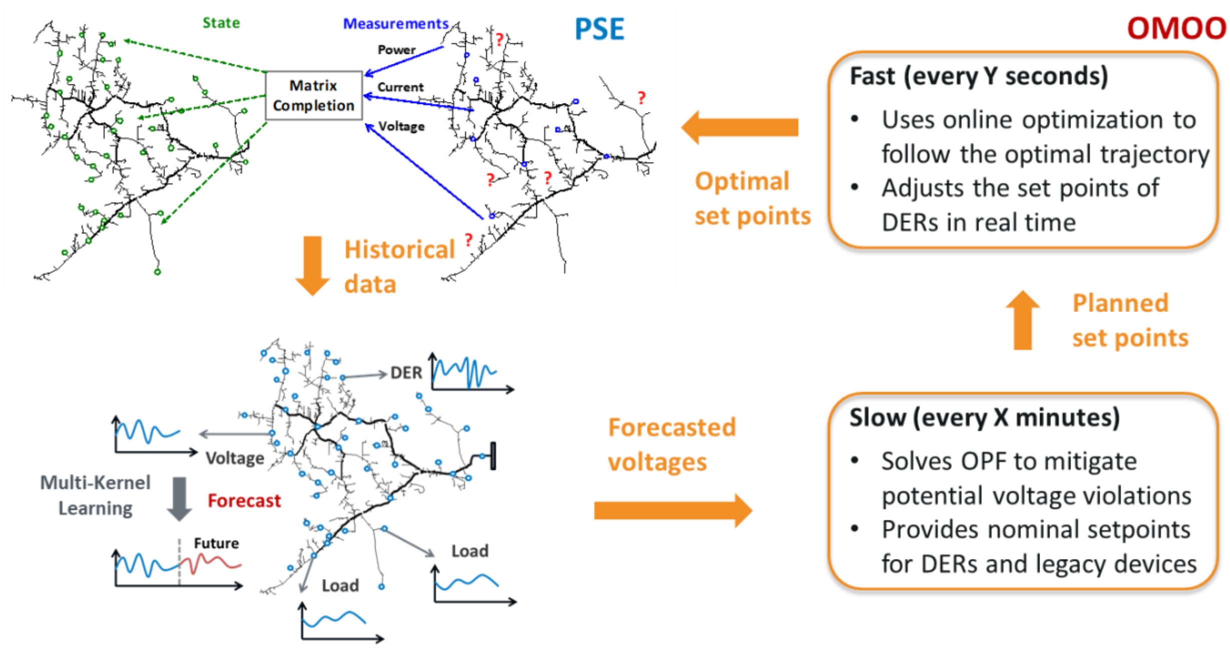

Figure 2. Integrated GO-Solar platform.

Task 3: Validation: Hardware-in-the-Loop (HIL) Testing

HIL testing that integrates 100 physical DER hardware was conducted at NREL's Energy Systems Integration Facility (ESIF) to assess the performance of the GO-Solar framework using real utility system data from HECO and commercial off-the-shelf inverters and other devices at power [6], [7]. The main elements of the HIL platform include a HELICS-based [8] co-simulation to capture larger system interactions with OpenDSS [9], the GO-Solar control platform, an Opal-RT-based power HIL (90 DER inverters, grid simulators, sensors, and PV emulators), and a ModBus communication interface to communicate to the devices using protocols commonly found in the field. Figure 3 shows the overall HIL setup for the GO-Solar platform. The team has tested the GO-Solar algorithms in 5 scenarios, including:

- A baseline scenario with PV operating as smart inverter volt-VAR function,
- Two cases of PHIL testing without battery hardware inverters, and
- Two cases of PHIL testing with battery hardware inverters.

The four no-baseline PHIL testing cases represented a full factorial combination of with/without battery inverters and level of PVs control: full control (100%) and only 30% PVs controlled. The HIL testing results show that while the GO-Solar platform controlling 100% PVs provides the best voltage regulation performance, voltage performance improvements are also seen with only 30% control [7].

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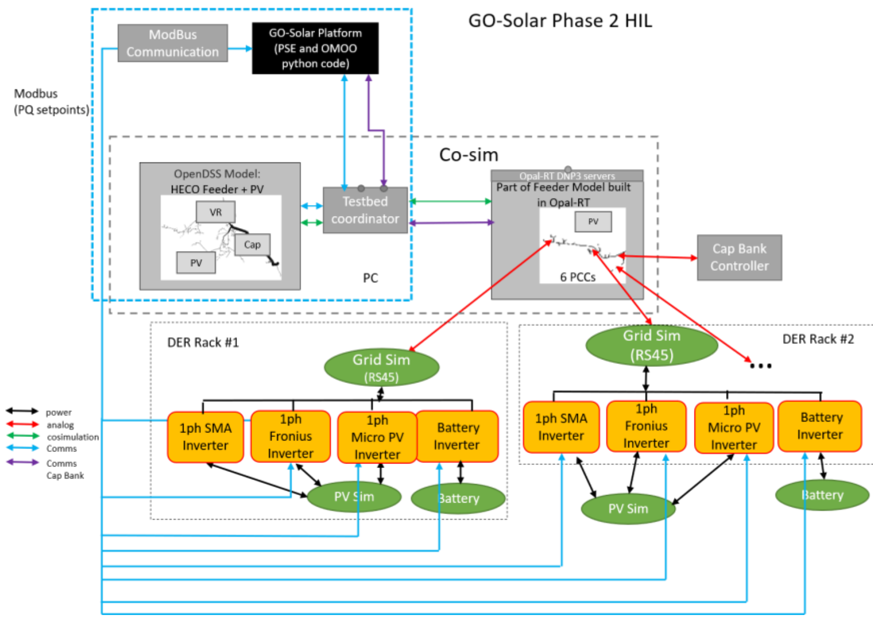

Figure 3. The HIL setup for the GO-Solar platform.

Task 4: Validation: Large-Scale Simulation

The team has conducted a full-scale integrated transmission-distribution simulation using NREL's Integrated Grid Modeling System (IGMS) co-simulation environment [10] with the Hierarchical Engine for Large-Scale Infrastructure Co-Simulation (HELICS) [8] at its core. Figure 4 shows the co-simulation framework used in this project. The team integrated the GO-Solar algorithms with the transmission-distribution co-simulation and validated the performance of GO-Solar algorithms [11]. The larger scale co-simulations show that GO-Solar algorithms can readily scale to hundreds of feeders and hundreds of thousands of electrical nodes using a hierarchical architecture with the GO-Solar algorithms running at each feeder or substation. These larger simulations also reveal that although standardized default algorithm settings provide good results for most feeders (approximately 80%), providing improved results for some will require additional tuning or adjustments.

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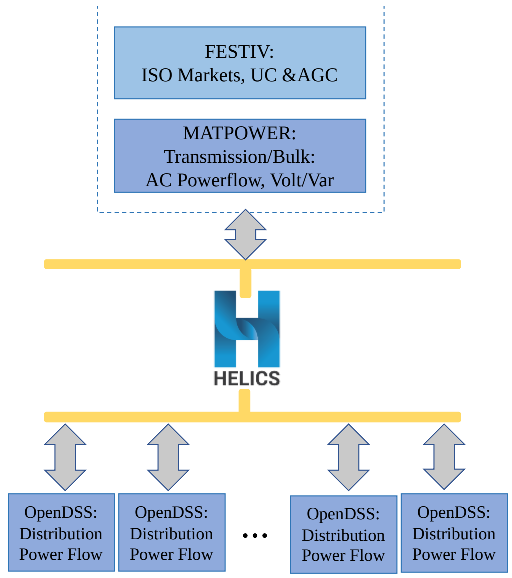

Figure 4. T&D co-simulation framework

Task 5: Value Analysis and Stakeholder Engagement

The team has also conducted an impact analysis for the GO-Solar platform. The analysis found benefits of the GO-Solar platform include increasing PV penetration for utilities, reducing voltage and thermal violations, reducing the possibility of reverse power flow for substations, and reducing the number of control actions of legacy devices.

The team also convened two stakeholder groups: 1) the Project Advisor Group (PAG) to provide a Hawaiian context with representatives from throughout HECO and key partners; and 2) a broader group of stakeholders, the Industry Advisory Panel (IAP), which focuses on nationwide applicability and brainstorming possible paths for commercialization of the GO-Solar approach. The team also organized 1 in-person and 2 virtual stakeholder workshops to get input, guidance, and feedback throughout the project.

Subject Inventions Listing:

Low-observability matrix completion, U.S. Patent No. 11,169,188 B2, Bernstein, Andrey, Zhang, Yingchen, Schmitt, Andreas

ROI #:

ROI 18-26 “Matrix completion for low-observability voltage estimation”

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