# FINAL TECHNICAL REPORT

## Executive Summary

# Development and Demonstration of Smart Grid Inverters for High-Penetration PV Applications

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**By the**

**Hawaii Natural Energy Institute**
**School of Ocean and Earth Science and Technology**
**University of Hawaii**
**Principal Investigator: Leon R. Roose**

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## Executive Summary:

The focus of this project is to implement, on operating utility distribution feeders with "very high" penetration of rooftop PV, enhanced capability smart inverters to achieve improved operational performance, control and visibility via standards based communications technology. This will be accomplished by creating, deploying, and evaluating new smart inverters using integrated inverter management control software (IMCS) and standards-based communications systems. In addition, detailed distribution modeling (modeled to the home meter) will be employed to aid in development of inverter control algorithms/settings and the model will be validated using high resolution field data monitoring to capture inverter field performance. The project will test these different inverter control strategies in two project deployment locations – Maui, Hawai'i and Maryland/Washington D.C.

Focus areas of demonstration will include:

- Standards based cost effective communications and control architecture extending from utility head-end to field deployed "smart " inverters for rooftop PV
- Coordinated control algorithms for multiple inverters on same feeder
- Interoperability of smart inverters supplied by multiple manufacturers operating under a common control platform
- Collection of high resolution (1 second time step), time synchronized field performance data across entire feeder
- Develop high fidelity distribution feeder model; validate model, test inverter control algorithms, and iterate with operational performance data
- Enhanced distribution feeder level control interface for utility grid operators
- Through improved control and visibility, improve feeder operational performance and reduce the scope, time and cost of interconnection requirement studies
- Enhanced visibility of energy use and on-site production for utility customers

To date the research that has been done on advanced inverter functions has focused on large utility scale PV systems, theoretical model based analysis or lab tests on a single residential PV inverter operating in isolation. In contrast, this project will not only consider advanced residential inverters in a modeling environment, but it will also deploy multiple advanced inverters operating in a coordinated manner on an actual residential feeder with high penetration of PV systems to test their actual response and impact on improved grid performance.

The UH-HNEI led consortium, which includes Silver Spring Networks (SSN), Fronius, Hitachi, Maui Electric Company (MECO), Hawaiian Electric Company (HECO), Pepco Holdings, Inc. (PHI), Oklahoma Gas and Electric (OG&E), Standard Solar, and Rising Sun Solar & Electric (Rising Sun), will demonstrate smart grid inverters from three industry leading manufacturers, Fronius, Hitachi and SMA, at two different utility sites. The inverters and communications protocols were initially tested in a newly constructed inverter laboratory at OG&E to test smart inverter control capabilities in various programmed scenarios. The project has also completed end-to-end testing of the control

system, field communications systems, and inverters using a pre-deployment installation at Maui Electric.

The team will install new and retrofit PV inverters to test the feasibility of using inverters to mitigate voltage fluctuations caused by the intermittency of PV systems, and control PV system output with the curtailment capability. At a second site on the PHI grid, the project team will install new residential PV systems in two locations. The first deployment area at PHI will use the curtailment function of the inverters to study their ability to prevent back feeding in an underground secondary network grid. In the second location, a single inverter has been deployed in Maryland at the Watershed demonstration center to provide an opportunity for public demonstration and outreach showcasing this new technology. The project will leverage smart grid infrastructure previously installed at each site and knowledge and experience gained. PHI has deployed a SSN Smart Grid network and MECO/UH-HNEI has deployed a SSN demonstration network as part of their DOE RDSI Smart Grid Project (Maui Smart Grid). This project will further leverage the Japan New Energy and Industrial Technology Development Organization (NEDO) demonstration project on Maui by utilizing a smart inverter developed for that project by Hitachi, thereby demonstrating in this project the interoperability of multiple inverters from multiple manufacturers.

The project has developed a detailed model of the Maui Meadows deployment area using EDD's DEW power system modeling application. The project team has also deployed high resolution (1 second interval) power monitors in the Maui and PHI project sites to monitor the output of the smart grid inverters and the distribution system to understand their effect on the power system. The project team will use the DEW model to simulate the smart inverters and their impact on the grid to develop control strategies for the inverters. These strategies will then be implemented in the field and their actual impact to the grid measured by the power system monitors. This measured data will then be used to validate and update the results from the model. This iterative process will be used to fine tune the inverter control strategies.

The development and demonstration of the technology aims to reduce the integration and interconnection costs of future distributed PV systems. By assembling a world class team with significant expertise, experience, sizable share of the PV inverter market, PV sales and installation experience, and smart grid solutions expertise, the team is well positioned to commercialize the proposed solution.

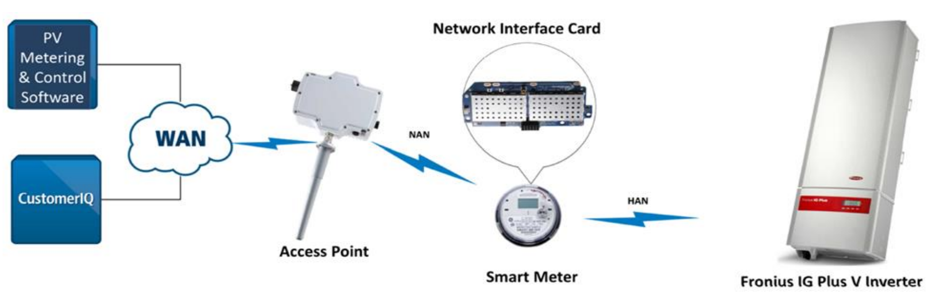


**Figure 1: Smart Grid Inverter solution primary components.**