Hawai‘i Natural Energy Institute Research Highlights

Grid Integration & Renewable Power Generation

Solar Power Forecasting

OBJECTIVE AND SIGNIFICANCE: This project's objective is to develop advanced forecasting methods and technologies to predict solar photovoltaic (PV) power generation from minutes to days ahead. Knowledge of PV system future output will allow grid operators and grid management systems to proactively address the inherent variability of solar power. Day ahead (DA) forecasts support unit planning and scheduling, while hour ahead (HA) forecasts support unit dispatch and operational reserve management, and minute ahead (MA) forecasts predict the timing and magnitude of significant PV ramp events. Solar forecasts also provide visibility and situational awareness for distributed behind the meter solar systems, helping to minimize reliability issues and disruptive events and manage the cost of grid operations with increasing levels of PV interconnected to the electric grid.

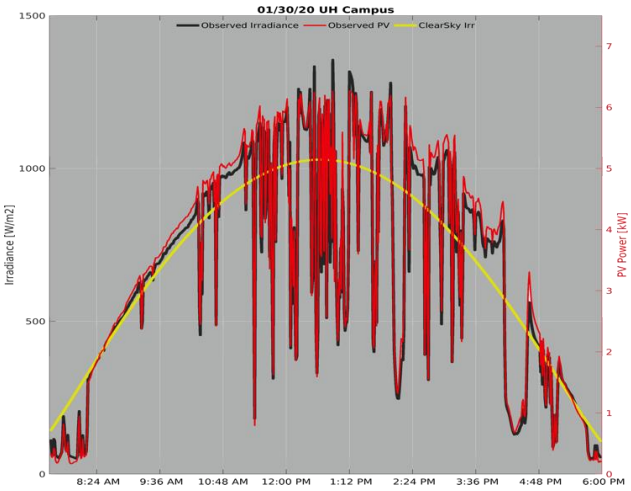

Figure 1. Irradiance observations and PV power measurements from the UH FROG Building on January 30, 2020.

BACKGROUND: Power output from PV systems is directly related to the power of the sunlight striking the panel, measured as irradiance. Solar irradiance at the top of the atmosphere varies slowly and predictably, modulated by Sun-Earth geometry and solar variability. Solar irradiance at ground-level varies quickly and erratically, modulated by the absorption and scattering of sunlight by clouds, fog and haze, as well as other particulates, such as dust, ash, and smog. The state of these particles is controlled by complex, nonlinear, and dynamic atmospheric processes, which make PV power output in most cases highly variable and difficult to predict. A sample day of irradiance observations and measurements of PV output from the UH FROG Building are shown in Figure 1.

HNEI has developed a multi-scale, solar forecasting system capable of monitoring irradiance in near real-time and generating PV power forecasts from minutes to days ahead. This system is fully automated, generating predictions without human intervention.

For DA forecasts (longer than 6 hours ahead), numerical weather prediction (NWP) models are required to account for turbulent atmospheric processes. DA forecasts are generated from a specific configuration and augmentation of the Weather Research and Forecasting (WRF) system designed for solar energy applications.

Geostationary satellite images provide consistent monitoring of regional atmospheric conditions, while ground-based sky camera images monitor local conditions at high resolution (Figure 2). From these images we determine the position, velocity, and optical properties of cloud formations. This information is used to drive cloud dynamics models that estimate future cloud conditions and irradiance at HA and MA time scales.

Using ensemble methods, DA, HA, and MA irradiance predictions are combined to generate probabilistic irradiance forecasts. These probabilistic forecasts are used to drive PV simulation tools to predict PV power.

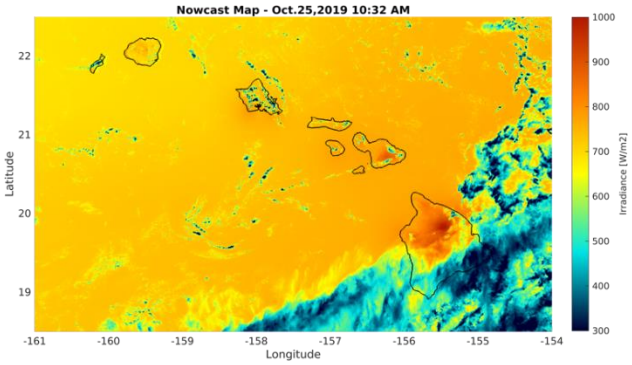

Figure 2. Sample irradiance map from GOES-17 images.

Hawai‘i Natural Energy Institute | School of Ocean & Earth Science & Technology
University of Hawai‘i at Mānoa, 1680 East-West Road, POST 109 • Honolulu, HI 96822
Phone: (808) 956-8890 • Fax: (808) 956-2336 • www.hnei.hawaii.edu

PROJECT STATUS/RESULTS: HNEI continues development of an irradiance mapping and prediction instrument for high-resolution irradiance nowcasting and MA forecasting. The instrument is designed for low production cost, wireless operation, and self-monitoring. The latest version of the instrument incorporates more robust electronics and increased computational power to allow for edge computing functionality. A prototype instrument is currently deployed on the UH campus, a sample image can be seen in Figure 3.

Figure 3. Sky image taken from the UH Mānoa campus on October 25, 2020.

The HNEI solar forecasting system is actively generating operational probabilistic forecasts for the Hawaiian Islands.

Each night, a regional 24-hour ahead forecast is generated from NWP. During daylight hours, a regional 6-hour ahead forecast is generated from NWP and GOES-West images. This forecast is updated every 10 minutes to include information the most recent satellite images.

Tools for forecast data distribution and web-based visualization have been added to the system. The prototype visualization system focuses on the Natural Energy Laboratory of Hawai‘i Authority (NELHA) site (on the island of Hawai‘i), where the National Renewable Energy Laboratory (NREL) maintains instrumentation that provide realtime irradiance observations. NELHA site forecasts and realtime observations can be viewed at: **http://128.171.156.27:5100/hawaii/**. Figure 4 shows sample output from the visualization system for September 25, 2020 at 12:22 PM HST.

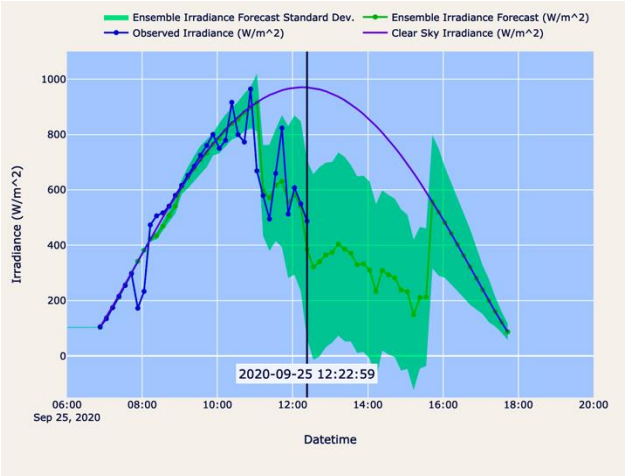

Figure 4. Sample output from the forecasting visualization system for the NELHA site. The probabilistic forecast and ensemble distribution are shown in green, while realtime irradiance observations are shown in blue. The black solid line indicates the current time.

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Contact: Dax Matthews, daxm@hawaii.edu

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