Hawaiʻi Natural Energy Institute Research Highlights

Grid Integration & Renewable Power Generation

Solar Power Forecasting

<u>OBJECTIVE AND SIGNIFICANCE</u>: This project's objective is to develop advanced forecasting systems, including new methods and technologies, to predict solar photovoltaic (PV) power generation from minutes to days ahead. Knowledge of upcoming PV power production allows grid operators and grid management systems to proactively address the inherent variability of solar power. These systems also provide visibility and situational awareness for distributed behind-the-meter solar systems, helping to minimize the impact of reliability issues and disruptive events and manage the cost of grid operations, as the levels of PV interconnected to the electric grid increase.

<u>BACKGROUND</u>: Power output from PV systems is directly related to the power of the sunlight striking the panel, measured as irradiance. Irradiance variability at the top of the atmosphere (TOA) is driven by sun-earth geometry and fluctuations in solar output that occur on nearly periodic 11 year solar cycle. TOA irradiance varies predictably at diurnal, seasonal, and interannual time-scales. As solar radiation passes through the atmosphere, it is attenuated through a complex series of reflections, absorptions, and re-emissions due to interactions with clouds, fog, and haze, as well as other particulates, such as dust, ash, and smog. Ground-level irradiance varies erratically across a range of time-scales. A sample day of irradiance observations and measurements of PV output from the University of Hawaiʻi (UH) FROG Building is shown in Figure 1.

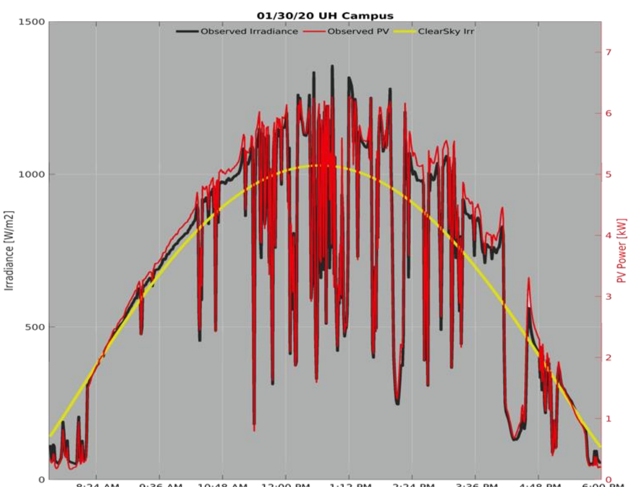

Figure 1. Irradiance observations and PV power measurements from the UH FROG Building on January 30, 2020.

HNEI developed a multi-scale, probabilistic solar forecasting system that monitors current regional irradiance conditions in near real-time and predicts upcoming irradiance conditions and resulting PV power production, from minutes up to 4-days ahead. This system is fully automated, generating predictions without human intervention.

Probabilistic irradiance predictions are generated using ensemble methods that combine individual, overlapping forecasts from three components. Each component focuses on, and is more accurate at, a different forecasting horizon. The ensemble methodology increases forecasting accuracy and allows for spatial and temporal flexibility in PV production forecasts.

Minute-ahead (MA) forecasts, from 1 to 30 minutes ahead, are provided by the Affordable High-Resolution Irradiance Prediction System (AHRIPS), a novel solar forecasting instrument developed by HNEI's Grid***START*** team. MA forecasts contain valuable information on the timing and magnitude of upcoming PV ramp events. A sample AHRIPS sky-image is shown in Figure 2.

Figure 2. AHRIPS sky image taken from the UH Mānoa campus on October 25, 2020.

Hour-ahead (HA) forecasts, from 10 minutes to 6 hours ahead, are derived from geostationary satellite images, which provide consistent monitoring of

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regional atmospheric conditions. HA forecasts provide information to support unit dispatch and operational reserve management. A sample irradiance “nowcast” map from GOES-17 is shown in Figure 3.

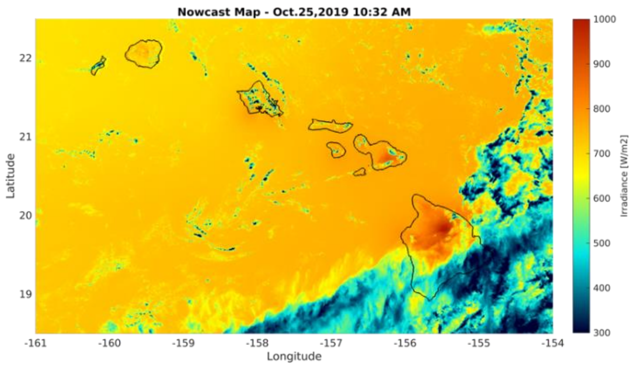

Figure 3. Sample irradiance nowcast map derived from GOES-17 imagery.

Day-ahead (DA) forecasts, longer than 6 hours ahead, are generated using a specific configuration and augmentation of the Weather Research and Forecasting (WRF) system designed for solar energy applications. WRF is a next-generation mesoscale numerical weather prediction system provided by the National Center for Atmospheric Research (NCAR). DA forecasts provide information to support utility generation unit planning and scheduling.

PROJECT STATUS/RESULTS: The HNEI solar forecasting system was originally developed for the Hawaiian Islands, but its design incorporates a flexible platform that allows for component updates and regional flexibility. Other applications have included: a South Korea domain, for operational forecasting of PV systems at the Korea Electrotechnology Research Institute campus in Changwon, South Korea; a Thailand domain, for a feasability study that focused on northern Thailand; a SE United States domain, for a feasability study that focused on the state of Georgia; and a Puerto Rico Domain, for a feasability study that focused on the island of Puerto.

The system is currently generating operational forecasts for a Hawaiian Island domain that includes all of the main islands of the Hawaiian archipelago. Multiple probibalistic irradiance and PV power forecasts are generated from ensembles composed of 4-day ahead WRF forecasts, generated nightly, and 6-hour ahead GOES forecasts, generated from the latest satellite images, every 5-10 minutes.

Realtime forecasts are shown along with realtime observations at: http://128.171.156.27:5100/uhfrog/ and http://128.171.156.27:5100/hawaii/. Figure 4 shows a sample probabilistic forecast from September 25, 2020 at 12:22 PM HST for the Natural Energy Laboratory of Hawaiʻi Authority (NELHA) technology park on the Island of Hawaiʻi.

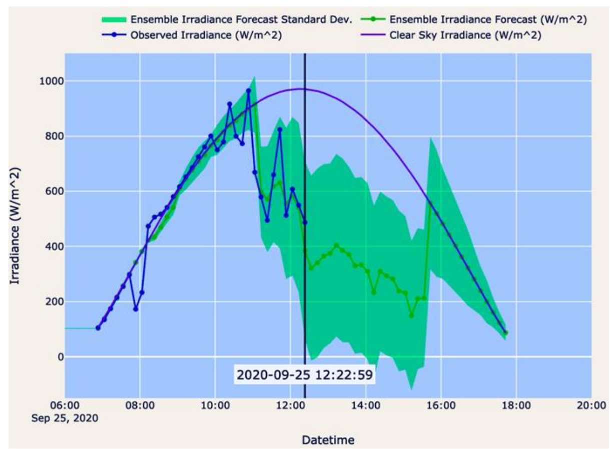

Figure 4. Sample output from the forecasting system. The probabilistic forecast (green), while realtime observations (blue). The black solid line indicates the current time.

In April, 2021 a patent for the AHRIPS hardware and software was approved by the U.S. Patent & Trademark Office: Matthews, Dax Kristopher, 2021, Ground-based sky imaging and irradiance prediction system, U.S. Patent 10989839, filed August 29, 2018, and issued April 27, 2021.

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