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High Penetration PV Initiative: 5km Irradiance Monitoring Network

Consultant Report

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SMUD™

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DISCLAIMER:

This project is receiving funding under the California Solar Initiative (CSI) Research, Development, Demonstration and Deployment (RD&D) Program. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the CPUC, Itron, Inc. or the CSI RD&D Program.

BACKGROUND

The Sacramento Municipal Utility District (SMUD), in partnership with the Hawaiian Electric Company (HECO), is implementing a research and development project which targets testing and development of hardware and software for high-penetration PV. This effort is intended to address key grid integration and operational barriers that hinder larger-scale PV adoption into mainstream operations and onto the distribution grid. As two utilities managing grid integration of high-penetration PV, SMUD and HECO are coordinating research efforts at specific locations in California and Hawaii. These sites will serve as case studies for assessing solar forecasting needs and PV grid integration and visualization tools. This project received funding from the California Solar Initiative Research, Development, Demonstration and Deployment (CSI RD&D) Program's first grant solicitation. The CSI RD&D Program is administered by Itron, on behalf of the California Public Utilities Commission (CPUC).

SMUD and HECO are partners in this project. Both utilities share synergistic problems on the distribution system based on high penetration and the explosion of DG PV deployment to meet Renewable Portfolio Standard (RPS) and Energy Efficiency targets. Hawaii and CA both have aggressive RPS and solar/Distributed Generation (DG) goals (in CA 3000 MW of Solar PV, in Hawaii 4300GWh of distributed resources for energy efficiency). SMUD and HECO also share common issues:

- Lack of visibility on the system down to the distribution level, and
- Lack of reliable forecasting capability for solar and DG resources for effective operations especially during variable weather days and peak loads.

In addition, SMUD and the Hawaii utility share similar planning and operations tools for control of DG systems. Both systems have high penetration of variable renewable generation. Hawaii is already "seeing" the high penetration level of DG on the system where as many mainland grids are just now concerned about potential impacts

This project has five tasks:

1. Project Management, Technology Transfer and Outreach
2. System Modeling
3. Field Monitoring and Analysis
4. System Integration and Visualization Tools Development
5. PV Production Forecasting

This report pertains to Task 5: PV Production and Forecasting, focusing on the 5 km irradiance monitoring network.

5km Irradiance Monitoring Network

Design, Manufacture, Deployment

This effort consisted of a range of technical and logistical subtasks required to design, manufacture and deploy a monitoring network of five primary and sixty six lower cost secondary irradiance monitoring stations. The network was deployed on a five kilometer grid using autonomous PV/battery powered data loggers installed on SMUD utility poles and in substations. Irradiance measurements are made using Rotating Shadowband Radiometers (5 primary RSR stations) and independent data loggers with global horizontal pyranometers (66 secondary monitoring stations).

The primary RSR stations required almost no modification because the Rotating Shadowband Radiometer is an existing commercial product. The secondary stations, however, were designed “from scratch” for this project due to the unique requirement for mounting on utility poles. The exterior enclosure design includes a PV module and bracket, an adjustable pyranometer arm and support bracket for easy pole mount. The internal enclosure design houses a battery, data logger and cellular modem. The enclosure and the internal mounting armature are entirely non-metallic allowing the modem antenna to be mounted internally.

Sheet metal and non-metallic parts were machined locally and the secondary units were assembled, programmed and tested at NEO Virtus. The calibration of each pyranometer was checked by comparing its output with that of the others in sets of 25 under identical irradiance conditions. Bulk rate cellular data plans were negotiated based upon data transmission bit calculations. Two prototype units were deployed, one pole mount and one on SMUD’s headquarters roof, to assure cellular connectivity and to collect sample data sets. Each of the secondary station production units was bench tested and then field tested on NEO’s roof in its final assembled form before shipping. Units were shipped in batches of 16 to SMUD’s Sacramento warehouse.

SMUD’s GIS department overlaid a map of available assets (locations for mounting primary and secondary monitoring stations such as utility poles, buildings, and secure land) on to the National Digital Forecast Database (NDFD) forecast 5km grid. The approximate "centroid" of each NDFD grid cell was targeted. SMUD staff surveyed the candidate sites and coordinated with SMUD’s line crews for approval of final locations. Installation of secondary monitoring stations started in early April and was completed in late June. After each installation, prior to the line crew leaving the site, the foreman called in the completed installation to NEO for confirmation of connectivity. All 66 of the secondary stations were mounted on utility poles. Four of the primary stations were installed on tripods in SMUD substations and one was installed on the roof of Sacramento State University less than a mile from SMUD’s headquarters. Due to the height of the substation walls, some of which were cement block, two of the RSR tripods had to have extensions to raise the measurement device above shading obstructions.

Data Collection

The units are polled to collect each unit's data via cell modem automatically each night. The data are captured at NEO using Campbell Scientific's Loggernet Admin software, and stored as a .dat files on a dedicated RAID server (three files per unit). Once a week, our software engineer uses Loggernet Database software to convert these .dat files into MySQL tables. By the end of June, NEO was automatically collecting and storing data from all five primary and sixty six secondary units. NEO has already transmitted preliminary sets of raw data to SMUD.

Lessons Learned

Data is collected from all 71 sites automatically using two separate computers (for redundancy) at NEO each night. Some nights all of the systems collect on both computers. Some nights one to five systems will not collect automatically on one or the other computer. We are always able to collect the absent systems the following day using manual log-in. The lesson is that cellular linkage is not 100% reliable all of the time. The majority of the units appear to be performing exactly as expected. The two of the five primary stations still need final adjustment of their orientation. About 3% of the secondary stations are exhibiting peculiar irradiance patterns under clear sky conditions (clear sky conditions are the only circumstances under which we can validate monitoring system performance). These systems are under review.

Summary and Next Steps

This project commenced formally in October of 2010. Since then, NEO designed and built the required 66 secondary stations, assembled the five primary stations (RSRs), and shipped all 71 units to Sacramento, where over the course of several weeks, they were all installed by SMUD linemen. As of July 1, 2011, we were collecting irradiance and temperature data from all 66 secondary units and most of the primary units. We should have a complete 12 month dataset by the end of June 2012. In the months ahead, besides continually monitoring data collection and maintaining the network of stations, NEO will be working with our solar and software consultants on NEO's proprietary PV production forecasting models. We will use the data collected by the deployed units in the models to forecast the energy production of several PV power plants in SMUD's area, and then compare this prediction to the plants' actual production. Numerous iterations to the models will be made in order to increase their accuracy. The project is scheduled for completion in the summer of 2012.

The photos below provide a visual narrative, starting with secondary station prototype development through data collection.

Figure 1: Prototype secondary monitoring units S/N 00 and S/N 01.

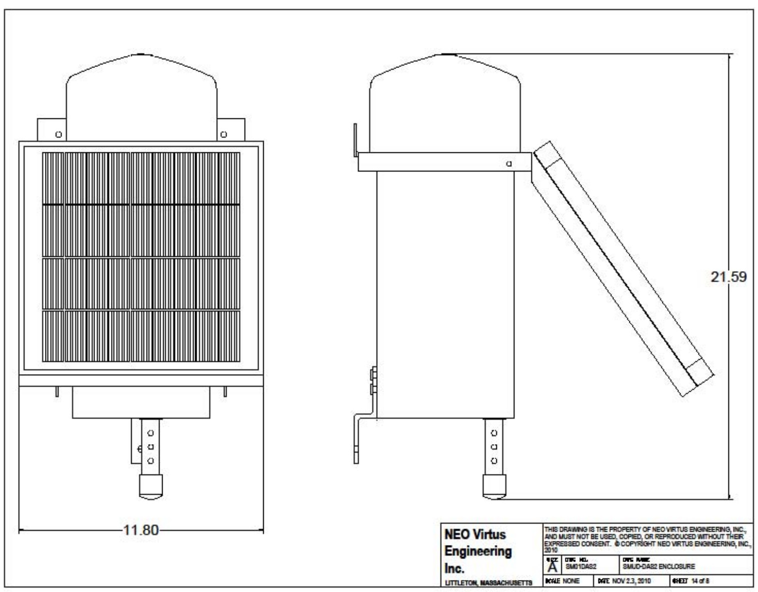

Figure 2: Secondary monitoring station assembly design.

Figure 3: Secondary monitoring station production.

Figure 4: Sixteen secondary monitoring stations being burned in (foreground). Pyranometer calibration coefficients being validated (background).

Figure 5: Secondary monitoring units being installed on SMUD poles.

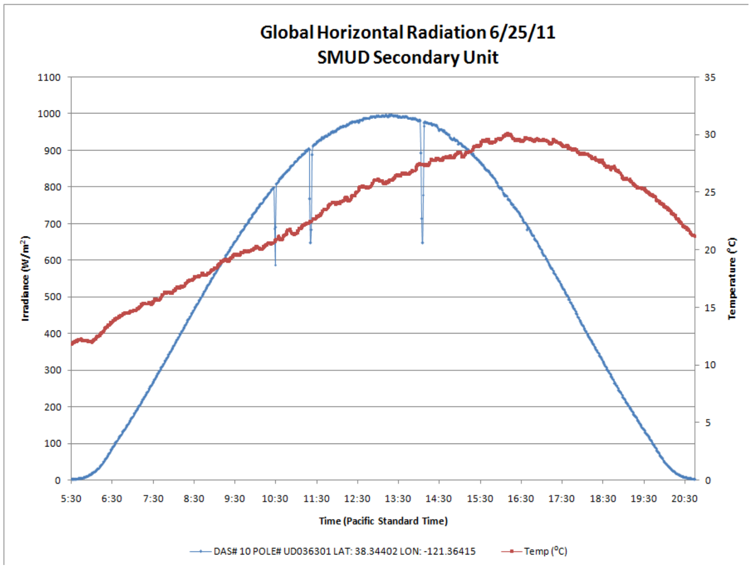

Figure 6: Sample of data collected from secondary stations.

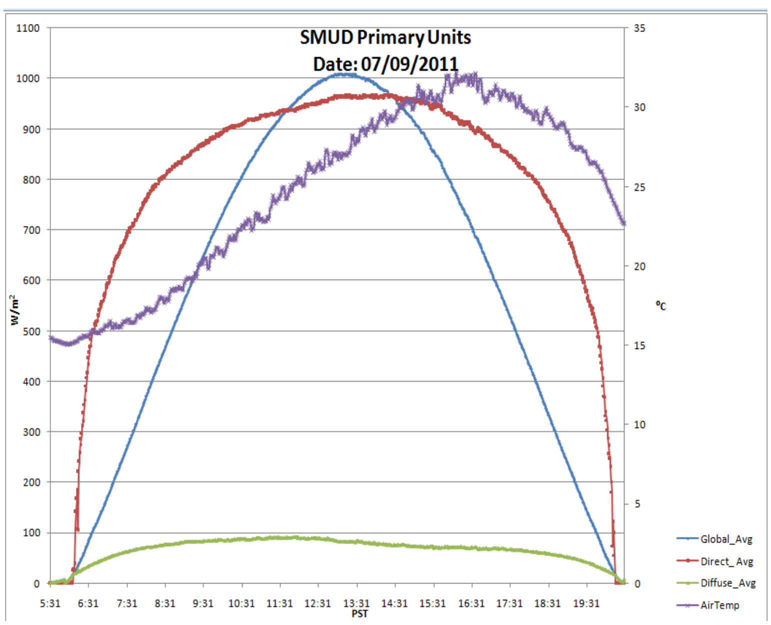

Figure 7: Sample of data collected from primary stations (Sacramento State location).