SMUD-NEO IRRADIANCE (SNI) NETWORK OPEN ACCESS DATABASE

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ABSTRACT

In June of 2011 Sacramento Municipal Utility District (SMUD) the country's 6th largest utility, and NEO Virtus Engineering (NEO), a solar engineering, consulting and monitoring service provider, developed and deployed a network of 71 irradiance monitoring stations covering most of SMUD's 2330 square kilometer service territory. The network, dubbed the SMUD-NEO Irradiance Network (SNI Network), was built to validate forecasts generated from the NOAA National Digital Forecast Database (NDFD), with one station deployed near the centroid of each 5km by 5km grid-cell. Data is collected at 1-minute resolution once per day, and is available for public purposes, in addition to the current research objectives. Additional research being done using the SNI network includes: validation of four commercially available solar forecasts; evaluation of solar resource variability; validation of satellite based solar resource assessment; and evaluation of appropriate densities of solar monitoring/forecasting for informing utility operations in a cost-effective manner.

1. INTRODUCTION

SMUD has initiated a number of projects related to integrating high penetrations of solar PV. SMUD's motivation was and is a concern for the reliable, efficient and safe management of the electrical power system (EPS) from both an operational and an energy trading perspective in the face of ever increasing penetration of PV. Fueling recent rapid growth and the increasing urgency for improved forecasts is SMUD's feed in tariff (FIT) which saw nearly 100 MW of new capacity come online between late 2011 and the end of 2012.

By the end of 2012, SMUD had connected to its system approximately 150 MW of distributed and utility scale PV, which is approximately 250 watts per customer and by nameplate is close to 5% of peak demand or nearly 15% of daytime minimum loads. Solar is expected to continue to grow in Sacramento, and with it, the need to improve our ability to forecast its output accurately. Previous studies have indicated forecast errors with RMSE for individual sites of 100 – 150 watts/m^2. However, translating this error to a utility service territory has not yet been done. Understanding how forecast error might be mitigated across a region is important for determining the adequacy of current forecasting techniques and the level of improvement necessary as installations increase [1, 2].

To address these issues, and as part of a research grant from the California Public Utility Commission (CPUC), SMUD engaged NEO Virtus Engineering to design and build a monitoring system to measure global horizontal irradiance (GHI) on a 5km grid and direct normal and diffuse horizontal irradiance (DNI and DHI) at selected locations covering their service territory (figure 1).

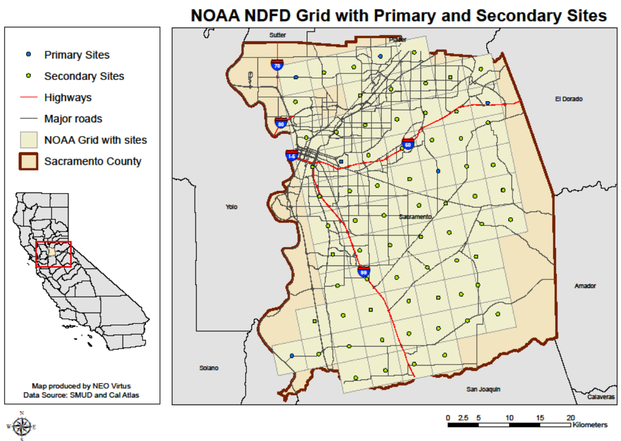

Fig. 1: SMUD-NEO Irradiance network

This paper will describe in detail the data set specifications for the irradiance measurements (GHI, DNI, DHI), the spatial resolution (the lat/long of each site), the hardware devices with which the measurements were made and their calibrations, the temporal resolution of the measurements and records, the daily data retrieval schedule, and the data quality control measures which were put in place.

SMUD's R&D department is using the SNI data to research the impacts of variable irradiance, and thus variable PV production levels, within their service territory as they impact their energy trading needs in the day-ahead market. Beyond day-ahead forecasts, SMUD is also studying forecasting short-term hour-ahead PV output, as well as likely variability around that output to be able to plan for appropriate regulating and load following resources. While knowing the absolute forecast is helpful for scheduling resources, understanding the variability around the absolute, in terms of ramp-rates and maximum and minimum values, will be necessary for ensuring the right resources are scheduled. To this end SMUD has engaged several early entrants in the solar forecasting services business to participate in a solar forecasting benchmarking activity. For this benchmarking effort the SNI database serves as the ground truth reference along with the SCADA record of the power production of several of the SMUD FIT megawatt scale PV plants. SMUD is also collaborating with Sandia National Laboratories on the analysis of the data set and has used the data to create visualizations of minute by minute irradiance variability over a large geographic area.

2. DATA ACQUISITION HARDWARE

The instrumentation which makes up the SNI network consists of a combination of 5 primary and 66 secondary data acquisition systems (DAS). The primary sites each employ an Irradiance Inc. Rotating Shadowband Radiometer (RSR2). The RSR2 devices measure and report direct normal, diffuse horizontal and global horizontal irradiance, as well as ambient temperature in one minute records. Four of the RSR2 devices also possess Eppley Precision Spectral Pyranometers (PSP) which also report one minute records and are used as reference devices. NEO designed and built the 66 global horizontal measuring secondary DAS that SMUD then deployed. By mounting these devices on utility poles the overall system is able to achieve a high degree of spatial uniformity across SMUD’s full service territory.

The RSR2 (figure 2) uses a Licor 200SZ silicon pyronometer as its primary irradiance sensor and a Campbell Scientific 107 thermister probe for temperature measurements. The data logger is a Campbell Scientific CR1000. Though data is collected nightly via cellular modem, data memory is sufficient for approximately one month between collections. The data logger clock is synchronized at each nightly collection to the NEO server clock. Four of the five RSR2s are located in substations and are also connected to SMUD local SCADA system via spread spectrum modems. The RSR2s are powered by individual PV systems for autonomous operation.

Fig. 2: NEO Primary DAS, Rotating Shadowband Radiometer (RSR2) with Eppley Precision Spectral Pyranometer.

The 66 secondary sites are custom data logger based monitoring systems developed for this project which are designed for installation on utility poles (figures 3 and 4). These secondary sites monitor global horizontal irradiance and ambient temperature and report one minute average records. The secondary DAS use a Licor 200SZ silicon pyronometer in a global horizontal orientation as their irradiance sensors and a thermister probe for temperature measurements. Irradiance and temperature readings are taken every two seconds and averaged to one minute records that are stored in logger memory. The data logger is a Campbell Scientific CR200 with data memory sufficient for approximately one month between collections. The data logger clock is synchronized at each nightly collection to the NEO server clock. The secondary DAS have cellular modems with PV power systems for continuous autonomous operation.

Fig. 3: NEO Secondary DAS installation.

Fig. 4: NEO Secondary DAS, exploded view.

3. DATA COLLECTION & QUALITY ASSURANCE

At present the full network has been in place and collecting data for one and a half years and is over 98% complete (approximately 2% data gaps).

3.1 NEO Data Collection Method

Data is collected by connecting to the dedicated IP address assigned to each station's Sierra Wireless Raven XT cellular modem. The cellular modems are programmed to power on for one hour during the night to conserve battery power. During this nightly hourly window, Campbell Scientific Loggernet Admin software is scheduled to call each station, attempt connection, and if cellular connection can be made, collect data. The collection window was set up for the middle of the night, because cellular traffic is lower during this period, so the chance of connection will be greater. Should the connection fail, a second window during the day was also set up to attempt a second automatic collection. Manual collections can also be attempted during this period. Loggernet Status Monitor is viewed on a daily basis to confirm the status of each automatic nightly collection. Additionally, data download is verified within Loggernet Database Manager.

Upon successful data collection, the raw data files are saved on a dedicated RAID server and are automatically pushed into a MySQL database using Loggernet Database software. NEO also maintains a redundant computer running Loggernet which connects and collects data as a backup. Data is transmitted to SMUD via daily ftp upload. Campbell Baler software is used to parse the large raw data files into 24 hour chunks which are automatically uploaded to the SMUD ftp site using WinSCP software.

Plots of station global horizontal irradiance and battery voltage are checked daily within Loggernet RTMC viewer. Visual displays have been set up in RTMC viewer to give an obvious indicator of battery voltage outside expected range. In addition to Loggernet Status Monitor, complete data buffer collection is verified using Loggernet LNDB Manager. The LNDB Manager has the added benefit that it displays the last date of data collected rather than simply the last date of successful collection in order to detect the event of memory failure.

Some stations have exhibited signs of soiling, as a sensor cleaning regime is impractical with the stations located on telephone poles. We have observed that after significant rainfall, some soiled sensors readings return to normal. With the issue of soiling in mind, a global calibration method has been developed to calibrate secondary station sensors against four PSP sensors which are periodically cleaned.

When problems arise with the DAS units SMUD trouble shooters go out and inspect the units. The normal issues that we see are soiling, Licor sensors being misaligned, or equipment malfunctioning. Most issues can be dealt with by cleaning the Licor sensor or adjusting the arm on the DAS unit. When issues can't be dealt with in the field, the units are replaced with a new unit.

The primary RSR units are cleaned every 3 to 4 weeks. When issues arise with the RSR units, technicians address the issue. Most issues are with the telecommunications with the RTU. Most problems are fixed on site. Data is downloaded directly from the data logger when telecommunications is lost.

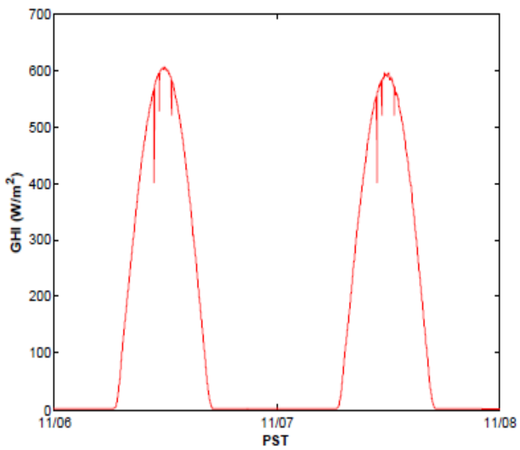

Fig. 5: Anomalies on clear days (11/6 & 11/7)

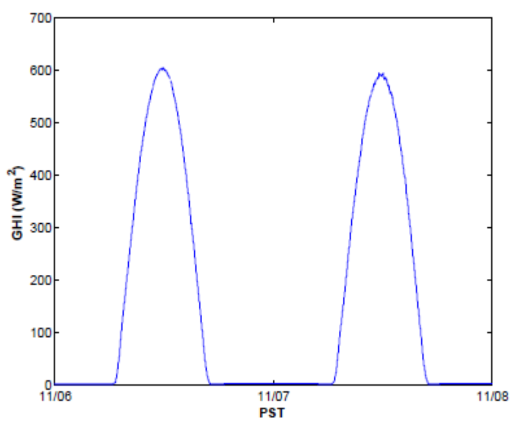

Fig. 6: Anomalies removed and interpolated on clear days (11/6 & 11/7)

3.2 SMUD/Sandia Data Post Processing

During the data collection process overhead power lines and pole cross arms cause occasional, momentary shading which diminishes the accuracy and value of the data record (figure 5). SMUD, working with researchers at Sandia National Labs, developed an algorithm and program to filter the data and provide two "cleaned" versions of the data set [3]. One version replaces known shading periods with a value of "NAN" (not a number). The second version interpolates between data points known to be valid which are on either side of (before and after) a data gap (figure 6). For SMUD's research purposes the data is filtered on a nightly basis.

4. DATABASE ORGANIZATION AND ACCESS

The database is organized in MySQL, and contains irradiance, temperature, and battery status data. The public can download the latest back-up file for the database via the SMUD ftp site.

4.1 Database Organization

At NEO Virtus, data is organized in a MySQL database. The secondary stations each have three tables associated with them. Tables store data for one minute battery voltage, daily max and min battery voltage, and global horizontal irradiance and temperature. Data is managed in the database using the GUI tool MySQL Administrator. The tables are updated on a daily basis using Loggernet Database Manager to automatically push newly downloaded data into the database. In addition to the tables containing the station data, other tables have been created containing station information such as station and NDFD grid centroid latitudes and longitudes. The database exists on a server configured with a RAID mirror so that data is automatically mirrored on a duplicate hard drive. Data is additionally backed up remotely using Cobian Backup software.

4.2 How to Access the SNI Database

The SNI Database posted online is an updated copy of the NEO Virtus database with the addition of the filtered values and interpolated values.

To download a zip file of the database backup file use: ftp://ftp01.smud.org/pub/SNIData/ . This directory will contain the most up to date SNI database back up. This will be updated on a monthly basis until the end of the project.

5. CONCLUSION

The deployment of 71 irradiance sensors covering SMUD's service territory has been invaluable for improving

SMUD's understanding of the nature of solar resources in Sacramento, and preparing for increasing amounts of generation that will be coming from those resources. Forecast validations and variability assessments are being used to inform balancing resource planning studies for major investments the utility expects to make in the next decade. In addition, the SNI database provides a unique opportunity for the solar research community to access a rich database of high density irradiance measurements covering an electric utility service territory.

5.1 Future Work

SMUD anticipates continuing the network monitoring for at least an additional 1 – 2 years beyond the 2 year timeframe funded by the grant. In addition, deployment of additional sensors to provide information in real-time at higher densities to inform distribution system PV variability mitigation strategies is being explored.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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