GO solar CALIFORNIA

CSI RD&D PROGRAM

Grid Integration

Grantee:
University of California, San Diego

Phase I Partners:
Vertum Partners, San Diego Gas and Electric

Phase II Partners:
San Diego Gas and Electric

CSI RD&D Funding:
Phase I $868,522
Phase II $99,673

Match Funding:
Phase I $1,214,850
Phase II $35,000

Project Timeframe:
Phase I 2014-2016
Phase II 2014-2016

RD&D Project Portal:
Phase I
calsolarresearch.ca.gov/csi/112
Phase II
calsolarresearch.ca.gov/csi/122

Itron | CSI RD&D PROGRAM MANAGER

Comprehensive Grid Integration of Solar Power for San Diego Gas and Electric

OVERVIEW AND OBJECTIVES

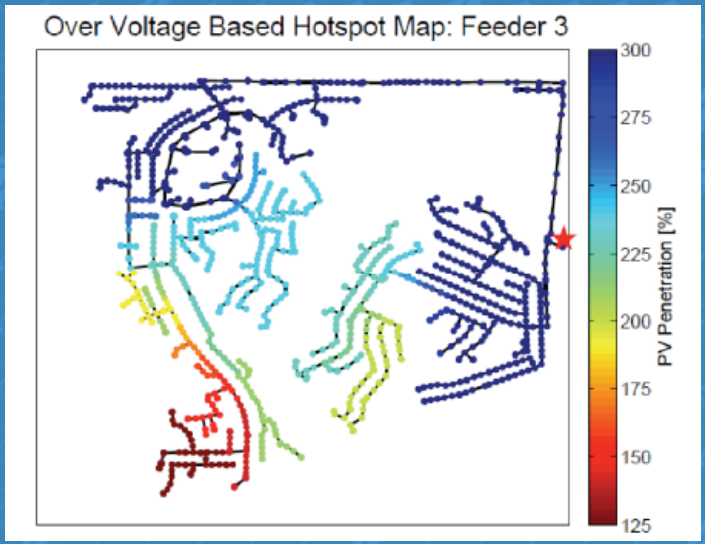
Solar forecasting is an important tool for effectively managing the electricity grid. Distributed solar power represents a negative load, and knowledge and information about net load supports more efficient distribution system operation in terms of scheduling repairs, feeder switching, and emergency operations.

Phase I: The University of California, San Diego (UCSD) team sought to advance solar and load forecast modeling in San Diego Gas and Electric (SDG&E) territory by improving and implementing previously developed forecasting tools at high temporal and spatial resolution. The objectives of this project were to build an operational solar and net load forecasting system and to develop and demonstrate energy storage siting and dispatch for solar power optimization. Using solar and net load forecasting, SDG&E identified feeder issue hot spots and prioritized feeder upgrades and energy storage sites. The team developed a tool that integrates solar forecasting with planning and simulation software to determine the best locations for energy storage based on system performance and expected solar performance. Additionally, a control algorithm was developed to interface with existing utility software and solar forecasting to maximize energy storage, photovoltaic (PV) performance, and PV integration.

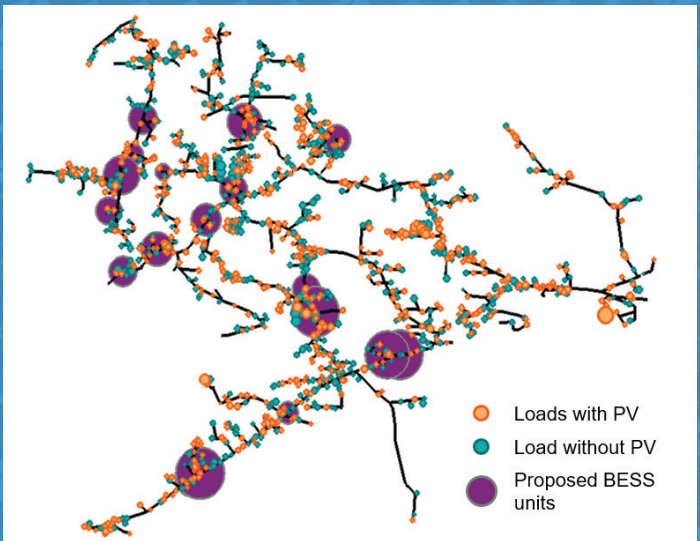
Phase II: A primary application of energy storage is mitigating fluctuations in net load, aiding the integration of intermittent renewable energy resources. For the second phase of the project, the UCSD team investigated whether battery energy storage system (BESS) controls for ramp mitigation would achieve the same benefits while reducing storage capacity requirements. Coupling power prediction solar forecasting to a feed-forward battery controller allows for the adjustment of battery charge state in advance of sharp changes in solar energy production. More intelligent and efficient utilization of battery capacity will reduce required battery size and frequency of deep discharges, thus extending battery life and reducing system lifecycle costs.

This document provides a brief project description. For more detail on the project and the California Solar Initiative's (CSI) Research Development, Demonstration & Deployment (RD&D) Program, please visit calsolarresearch.ca.gov

The CSI RD&D Program is managed by Itron on behalf of the California Public Utilities Commission (CPUC).



The star indicates the distribution substation, and the color bar indicates PV penetration levels that correspond to a thermal over-load and/or voltage exceedance.



Optimal BESS Solution on top of the One-Line Diagram of the IEEE8500 Feeder. Purple dots indicate proposed BESS units; orange dots, loads with PV; and turquoise dots, loads without PV.

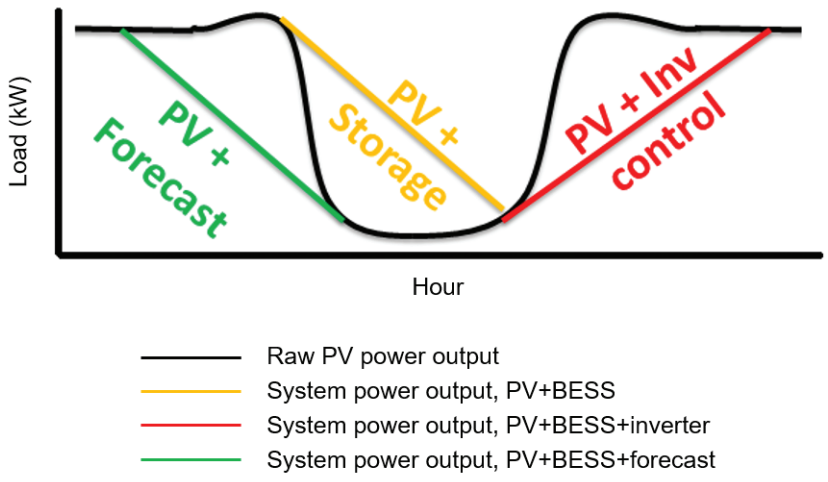
PHASE I: METHODOLOGY

The UCSD team began by developing a tool that integrates solar forecasting with planning simulation software to determine the best locations for energy storage deployment based on actual and expected system performance. The team then improved real time operations by developing a control algorithm to interface with existing utility control and data acquisition software and solar forecasting, with the goal of maximizing the performance of energy storage with PV through coordinated control. The team conducted power flow simulations for 14 representative SDG&E feeders with high PV penetration to quantify the impact of solar power variablility on voltage variations, overvoltage conditions, and load tap changer operations. Feeder voltage profiles and electrical conductor thermal ratings informed the algorithm that identified feeder hotspots arising from both solar variability and feeder stress. These improvements were then demonstrated on the SDG&E system, which is a unique testbed for forecasting and storage technology integration due to its large variations in PV penetration, meteorology, and voltage regulation equipment.

PHASE I: RESULTS AND OUTCOMES

Operational solar and net load forecasting systems were demonstrated for 68 SDG&E substations and validated for forecast horizons ranging from ten minutes to four days. A numerical weather prediction atmospheric modeling system for coastal Southern California was implemented to improve forecast accuracy. The solar forecast system has been operational since May 2015 at high reliability and is expected to remain operational past the end of this grant project.

The results highlighted that significant increases in PV penetration levels across all 14 feeders are feasible without network augmentation. Battery energy storage can further increase high PV penetration, but the ideal siting of storage is a practical challenge. A methodology was developed and demonstrated for optimal allocation of energy storage to maximize support for the integration of high penetration PV in residential distribution networks and minimize cost. This was demonstrated on a feeder in the SDG&E territory, and the algorithm is available for use by other researchers and industry.



A conceptual schematic shows the operation of the control algorithm. The "system" consists of a PV array, BESS, inverter, and solar forecasting. Without BESS and inverter control, ramp violations are frequent (black). The addition of a BESS and inverter provides reactive ramp smoothing (yellow, red). The further addition of forecasting provides proactive ramp smoothing (green); the response is proactive because the BESS charges prior to the ramp violation.

PHASE II: METHODOLOGY

The UCSD team developed an optimization routine that uses solar forecasting to control BESS and a PV inverter to mitigate ramp rates in PV power output. The efficacy of ramp rate control was evaluated for a summer and winter period using real irradiance data and real sky imager solar forecasts. A cloud base height algorithm was developed to improve solar forecast accuracy.

PHASE II: RESULTS AND OUTCOMES

A ramp rate control algorithm for BESS and inverter control to mitigate ramp rates in power output from a PV system was developed. The control algorithm uses image-based solar forecasts to predict future ramps in PV output and schedules optimal control of a BESS and inverter. The BESS provides and absorbs power in concert with fluctuating power output from the PV system to mitigate up- and down-ramps; the inverter curtails energy by adjusting the efficiency of the PV system to mitigate up-ramps. For the majority of battery configurations, the use of sky imager forecasts reduces ramp violations compared to the same method without forecasting. However, this requires greater battery energy dispatch and energy curtailment via the inverter.

PUBLIC BENEFITS

This research on improving the accuracy of solar forecasting is a common good that is unlikely to be funded by the private sector. These findings assist California utilities as they deal with meteorological issues such as the marine layer clouds specific to the coastal region.

The integration of short-term solar forecasting using sky imagery, control algorithms, and relatively small energy storage systems presents a unique synthesis of technologies with high potential in firming solar generation.

Solar forecasting combined with energy storage can reduce or mitigate the need to dispatch fossil fuel generators and reduce operating costs.