Improved Modeling Tools Development for High Penetration Solar

University of California, San Diego; Power Analytics

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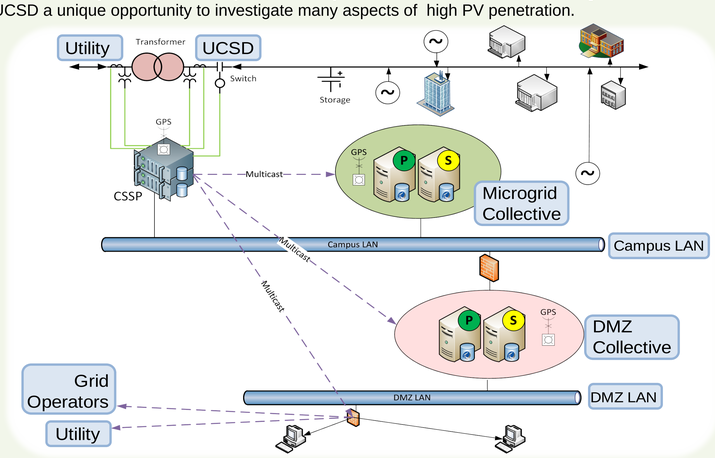
SYSTEMS INTEGRATION

UCSD Microgrid

UCSD's Microgrid has been converted to a smart microgrid with the development of a sophisticated monitoring network and integrated control software. UCSD personnel have access to 84,000 measurement streams across campus of building energy as well as power production data from both the combine cycle cogeneration plan, PV arrays other renewable sources. This gives researchers at UCSD a unique opportunity to investigate many aspects of high PV penetration.



Current Infrastructure

- Generation:
  - 42 MW peak load
  - 30 MW natural gas CCHP plant generates 80% of annual demand at 61% efficiency
  - 2.0 MW of PV
  - 2.8 MW fuel cell using methane gas
  - 40,000 ton hr thermal energy storage
  - Second Life Battery
- Distribution
  - Own 69 kV substation
  - 96 x 12 kV underground feeder circuits and 4 x 12 kV distribution substations
  - Meters 50,000 energy datapoints

The Future

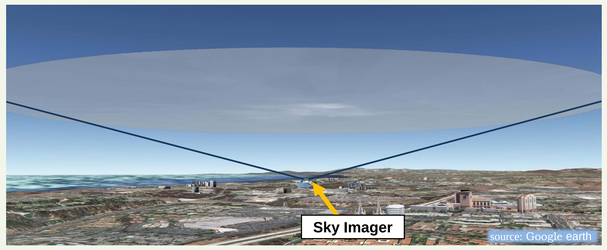
- Committed to:
  - Power Analytics / Viridity Scheduler / Optimizer
  - 1.8 MW / 11.2 MWh electric energy storage
  - 2.0 MW / 8 MWh of PV integrated storage with CA SGIP incentives
  - $250M/yr building expansion and $72M 3 Yr Energy Efficiency Program

Summary

The goal of this project is to develop modeling tools for high penetration PV on a distribution feeder. Steady-state, short circuit, and dynamic models of PV systems were developed, validated, and incorporated into Power Analytics advanced modeling software. Open-source inverter simulation files can be used by power system designers and planners to assess maximum loading of solar PV on a distribution feeder. UCSD derived historical probabilistic ramp rate model from 1sec GHI data and incorporated this information into a modeling tool for geographic smoothing. Frequency and magnitude of the extreme ramp rates on individual solar panels were considered to model the geographic dispersion effects on variability through a fleet of PV systems. Solar forecasting is conducted with total sky imagery to control charge and discharge of energy storage systems.

Sky Imager Solar Forecasting

The sky imager cloud map is projected into the sky. Knowing the location of the cloud in the sky and the topography on the ground, the shadows of the clouds can be computed. The sky cloud map, it is advected with the cloud velocity determined from the cloud motion processing at the desired forecast intervals.



Projection of clouds into the sky above the UCSD campus.

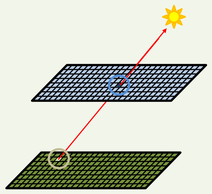


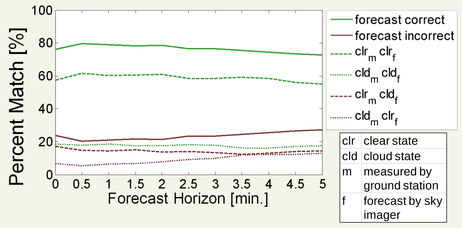
Illustration showing the shadow-mapping procedure. Topography of ground surface is not shown.

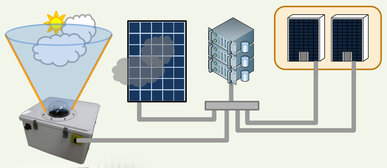
Solar Forecasting and the Microgrid

The procedure to integrate solar forecasting into microgrid operation:

1. Generate real time forecast and publish forecast to microgrid database.
2. Optimization package collects current grid state and forecasts for load, power generation, and market pricing and generates a control schedule.
3. Control schedule is assessed by simulation package for power quality and other power system constraints.
4. Microgrid controller makes adjustments based on recommendations of optimization package if the simulation results show no potentially harmful power issues.

The sky imager forecasting technique was validated for four days in 2009 and 2010 (8,000 images) for a 5 minute forecast using 6 meteorological stations across campus. UCSD is actively working to both improve the imaging hardware, processing techniques and to extend the validation.





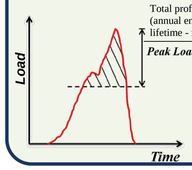
UCSD Sky Imager

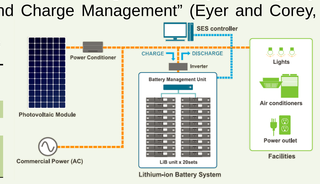
Total Sky Imager

Storage Optimization using Solar Forecasting

Sky Imager and numerical weather forecasts are applied to control a 31 kWh Li-ion battery connected to 30kW of PV. The solar forecasts will be used to optimize the charge/discharge cycling for peak load shaving and battery life longevity following the strategy of "Time-of-use Energy Cost Management Plus Demand Charge Management" (Eyer and Corey, 2010).

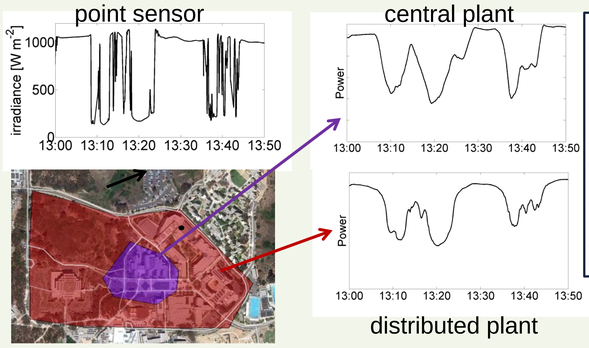
	Optimization with PV Power Output and Load Forecast	Off-Peak/On-Peak without PV Power Output and Load Forecast
Annual energy bill cost reduction [$]	33,200	30,500
Number of cycles at 80% DoD [cyc/yr]	212	365
Battery Lifetime [yrs]	14.2	8.2
Fixed cost simple payback time [yrs]	5.7	6.2
Total profit at end of battery lifetime (annual energy bill savings x battery lifetime - fixed costs) [$]	281,000	60,000





An industrial customer with onsite PV-storage system and storage placed "behind the meter" was modeled (Table). While the energy bill is comparable, the incorporation of forecast data was shown to dramatically increase battery lifetime.

Modeling Solar Variability

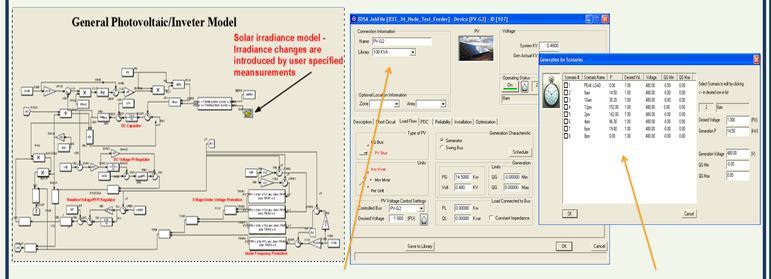


Impact of geographic diversity on any configuration / fleet of PV systems can be modeled. Validated wavelet variability model has demonstrated that variability of PV is dramatically reduced when aggregated over a large plant or a fleet of systems.

Power Modeling & Interoperability

Power modeling is essential to establish a base line and validate power network assumptions:

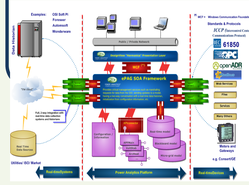
1. Where, how and what. Static and dynamic modeling determines allowable power circuit penetration levels, performance constraints and cost.
2. Specific inverter designs are implemented as hardware options. These inverter modeling capabilities are essential to power system modeling and analysis.
3. Generic inverter attributes are also defined facilitating broad based modeling and analysis.



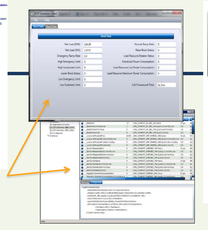
Time series irradiance is modeled based on maximum variability scenarios from one year of global horizontal irradiance measurements in San Diego.

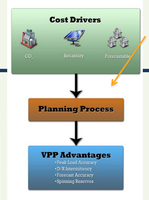
Secure Bi-Directional Communications

Service Oriented Architecture (SOA) is the interoperability layer for command and communications . Maximizes resources and economic benefit as a virtual power plant (VPP).



ICCP or IEC 60870-6/TASE.2 is an international standard that supports bi-directional generation





The ICCP stack integrated into Power Analytics architecture turns the PV and Microgrid into a market optimized VPP.

SunShot U.S. Department of Energy