University of California – San Diego - Microgrid and Energy Storage Projects

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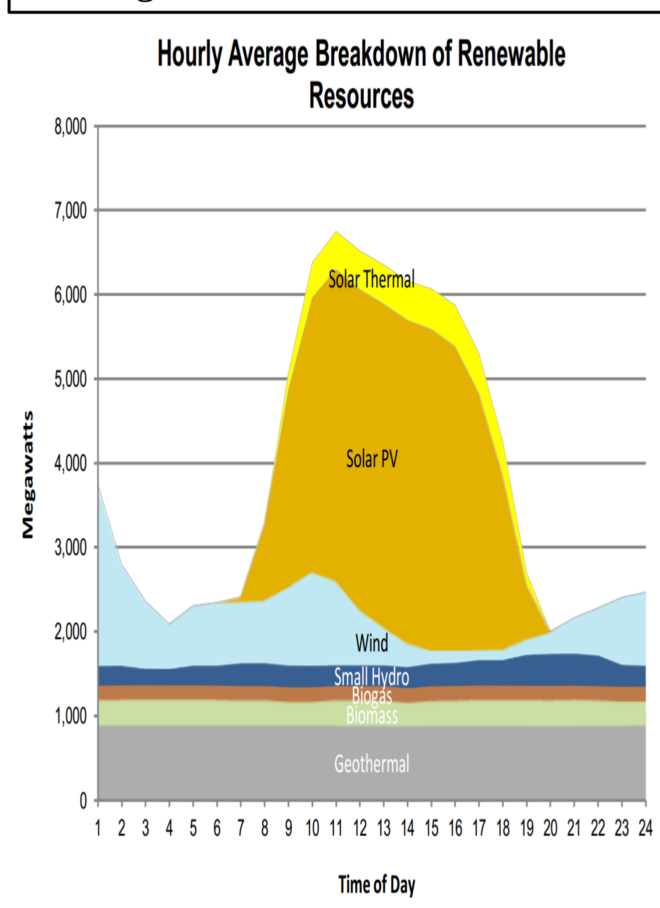
Increasing Renewables in California and Need for Energy Storage

Solar energy will become a main source of energy in the future.

- Germany has 36GW of installed PV (>50% of power demand).
- In California, PV production is contributing to 15% of peak demand.
- U.S. Solar Industry is a $11.5 Billion market with the growth of 34% in 2012.



Peak Demand: 28GW

Peak PV Production: 3.9 GW (14%)

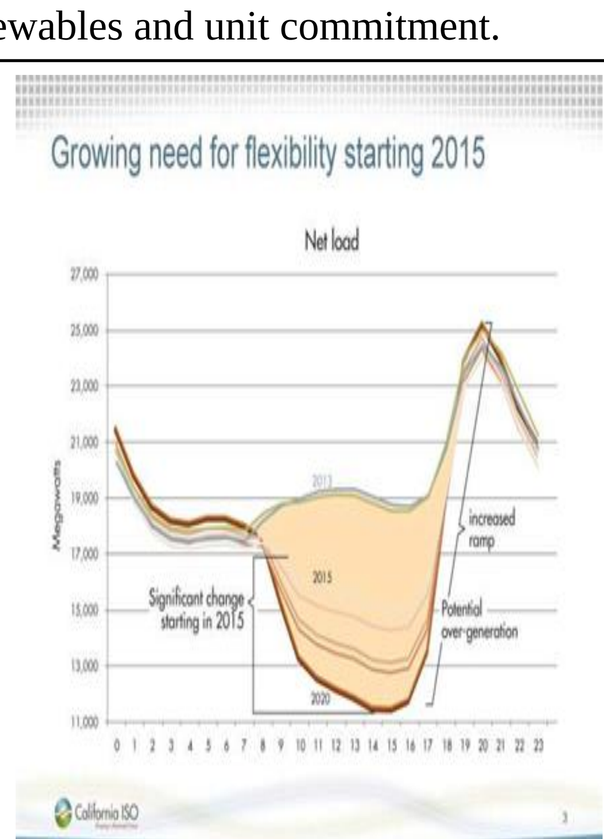
Courtesy: CAISO

California Renewable Energy Breakdown on April 14, 2014

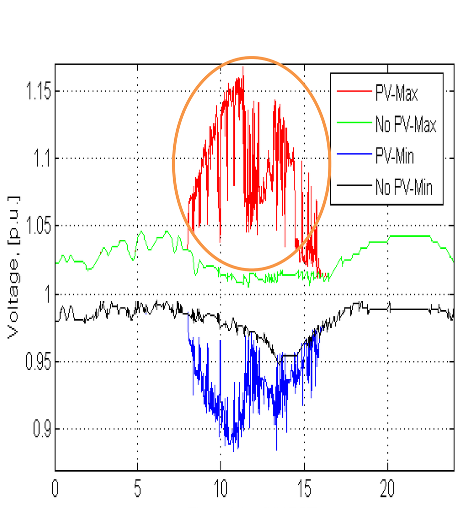
Forecasted Impact of Renewables on California Load Curve

High PV penetration and Wind generation is expected to drastically alter the net load and resources curve in California in the future :

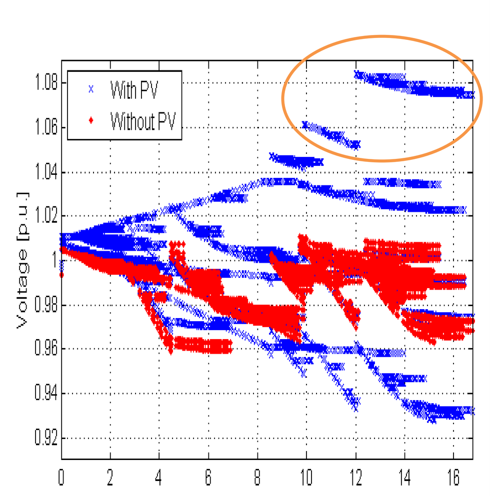
- Energy storage is needed to ensure resource adequacy due to the variability and uncertainly of dispatch
- Capture of PV solar mid-day can be used to reduce the evening peak and increase overall efficiency and flatten the "duck" curve.
- Energy Storage coupled with solar forecasting can be used to improve dispatch-ability of renewables and unit commitment.



Impact of Solar and Wind Generation on California Load and Need for Energy Storage



Voltage Fluctuation due to PV on Dec 14, 2012



Overvoltage due to PV along the feeder at 1pm

Summary of Energy Storage Research at UCSD

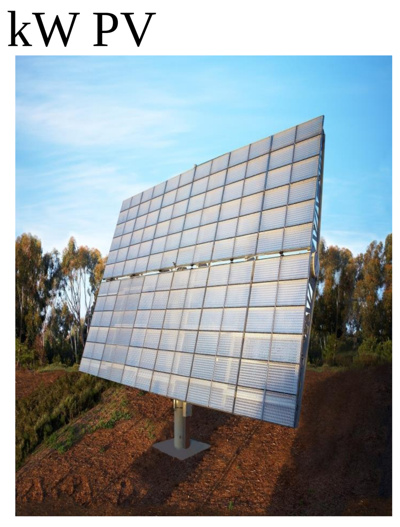
Goal: To test and demonstrate various types of energy storage to support integration of high penetration of renewable generation for microgrid operations.

- 30 kw, 30 kWh Sanyo/Panasonic Li-Ion battery energy storage system, integrated with 30 kW PV
- 35 kW, 35 kWh MCV Energy, Community Energy Storage
- 10 kW, 25 kWh Flywheel, Amber Kinetics, CEC
- 108 kW, 180 kWh BMW, demonstration of application of 2 nd use EV batteries, coupling to PV, and EV charging
- 2.5 MW, 5 Mwhr, SGIP Advanced Energy Storage, design underway
- 730 kW, 1460 kwhr SGIP PV Integrated, five off campus sites
- 30 kW, Maxwell Labs, Ultracapacitors, CPV smoothing of intermittency, coupled with solar forecasting
- 3.8 Million Gallon Thermal Energy Storage

30 kW// 30 kWh Li-io Integrated with 30 kW PV

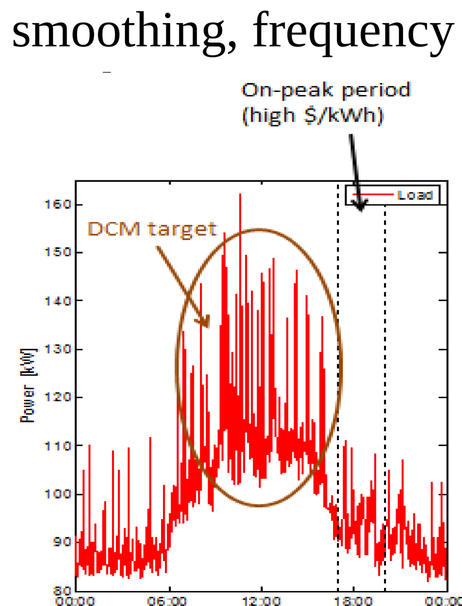
35 kW Community Energy Storage - MCV

2.5 MW / 5 MWh Li-ion Energy Storage

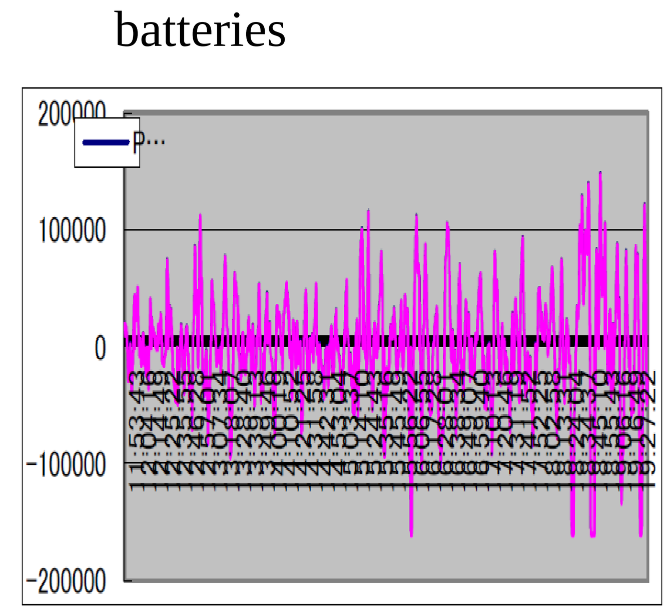


25 kW/ - 5 min energy storage CPV intermittency smoothing, frequency

100 kW / 160 kWh Li-ion Repurposed BMW EV batteries



Demand Charge Management Example Using UCSD Building Load

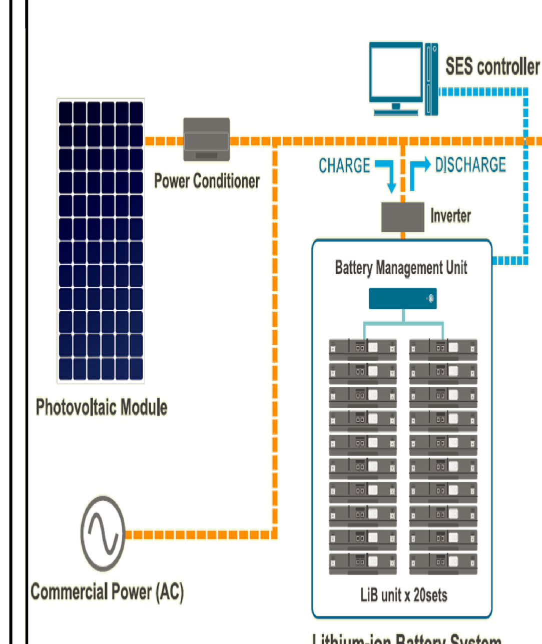


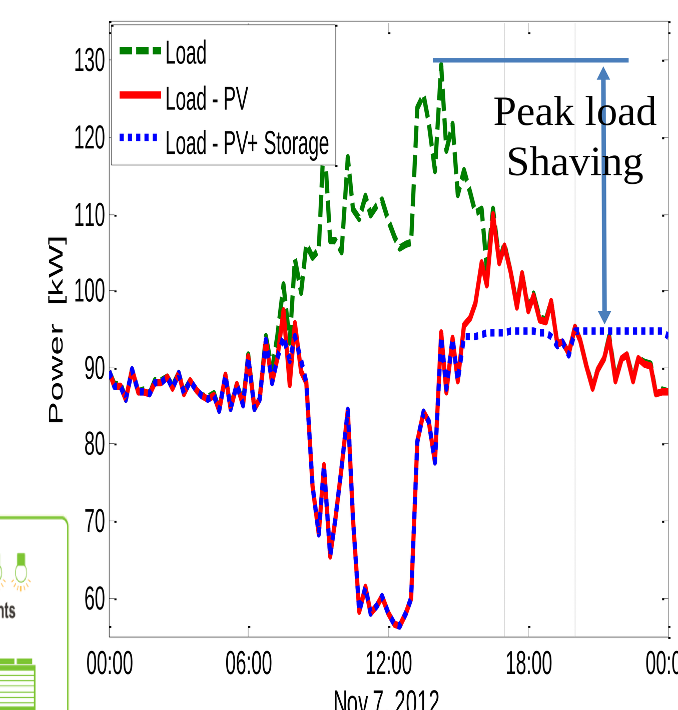
Frequency Regulation Energy Storage Power Output

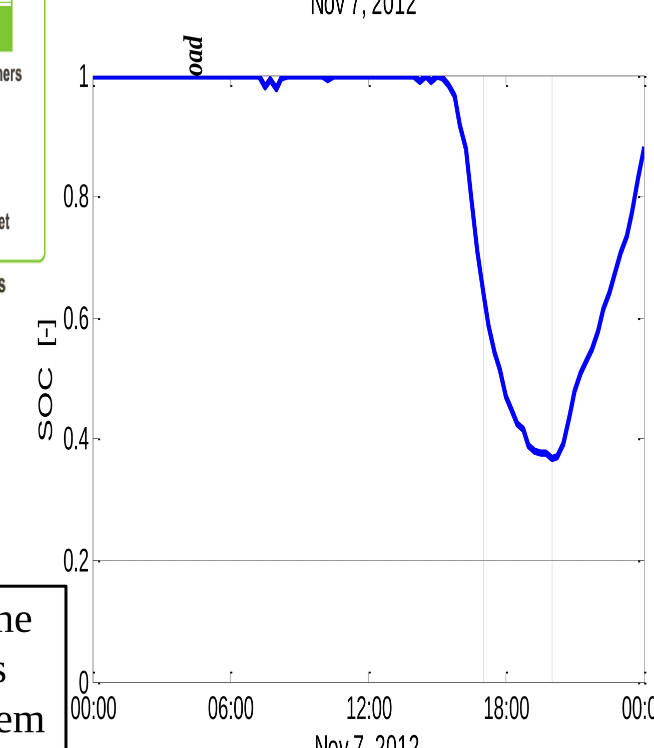
Peak load shaving control with Short-term Solar Forecast for Storage System

Control with Sky Imager Solar Forecast was developed for a 31kW PV tied to a 31 kWh Li-ion at Hopkins parking structure at UCSD, CA. The solar forecasts was used to optimize the charge/discharge cycling for peak load shaving and battery life longevity. The strategy for peak load shaving is "Time-of-use Energy Cost Management Plus Demand Charge Management" (Eyer and Corey, 2010).

UCSD Hopkins Building's local control connection schematic







Control operation on Nov 7, 2012

Results in table below shows that the incorporation of forecast data was shown to dramatically increase system lifetime (6 years extra) and its lifetime profit (360% increase on a 31 kWh storage system).

	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

Central Microgrid Control of Energy Storage Dispatch Test and Developed at UCSD

Coordinated Control and Dispatch of Distributed Energy Storage Resources To Maximize System Efficiency