Energy Storage Research At UC San Diego

CER Seminar

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With a daily population of over 45,000, UC San Diego is the size and complexity of a small city.

As a research and medical institution, we have **TWO** times the energy density of commercial buildings.

12 million sq. ft. of buildings, $200M/yr of building growth

**Self generate 92% of annual demand**
- 30 MW natural gas Cogen plant
- 2.8 MW of Fuel Cells installed
- 2.2 MW of Solar PV installed, with another 0.8 MW planned in 2013
UCSD Energy Storage Research Program

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Objectives

- **Accommodate Higher Levels of Renewable Generation:** Mitigate impacts and accommodate higher levels of renewable generation
- **Improve Operational Capability of Energy Storage:** Develop and test new control algorithms and integrate solar forecasting
- **Grid Integration of Energy Storage:** Identify energy storage integration issues and develop cost effective solutions (i.e. smart inverters, advanced controls, etc.)
- **Advance Energy Storage Technology:** Test new energy storage technologies and battery chemistries to improve cost effectiveness and performance
- **Promote Commercial Development:** Provide a test bed for energy storage companies to test their technology, Energy Research Park development capable of grid connected testing of multiple energy storage systems
- **Optimize Resources, Microgrid Operations:** UCSD’s energy storage projects are also designed and controlled to optimize generation resource utilization and reduce microgrid operational costs and greenhouse gas emissions.
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**Operational (2014)**
- 10 kW, Sunverge, Scripps Institute of Oceanography
- 108 kW, 180 kWh BMW, demonstration of application of 2nd use EV batteries, coupling to 330 kW PV, and Fast EV Level 2
- 3.8 Million Gallon Thermal Energy Storage Tank

**In Design (To be operational 2015)**
- 2.5 MW, 5 Mwhr, SGIP Advanced Energy Storage, Lithium-ion from BYD
- 25 kW / 40 kWh Amber Kinetics, Flywheel energy storage
- 28 kW, Maxwell Labs, Ultracapacitors, CPV smoothing of intermittency, coupled with solar forecasting
- MCV 35 kW, 35 kWh Compact Li-Ion energy storage system
- NRG 100 kWh Li-ion, PV integrated energy storage with EV DC Fast Charging

**Future Planned**
- 730 kW, 1460 kwhr SGIP PV Integrated, five off campus sites

**De-commissioned**
- 30 kw, 30 kWh, 30 kW PV integrated, Li-Ion battery
- ZBB 100 kW/ 300 kWh kW Flow Battery
Establish major third party battery testing facility on West Coast
Both lab testing and grid connected testing capability
Tests protocols will represent real world grid scale applications
Up to 100 kva batteries, capability to test 10 battery packs simultaneously
Lab cell diagnostics and performance evaluation
Economic valuation and commercial viability assessment
Higher Levels of Renewables Driving Energy Storage

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[Graph showing the impact of PV penetration on energy generation and storage]
Variability and Intermittency Impact Mitigation

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![Graph showing variability and intermittency impact mitigation over daylight time.](image)
Installation of Solar PV Is Rapidly Increasing

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U.S. Solar Capacity (MW)

Year

MW capacity

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013*

16 39 84 142 221 326 486 784 1219 2067 3954 7777 12077
San Diego Zoo Solar to EV Project
PV Smoothing and Peak Shifting from Battery

Battery Discharge During Evening Peak to Offset Drop in PV Production

PV Smoothing

Battery Charging Off Peak

Time of Day (5/5/2014)
## California Energy Storage Procurement Targets

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<table>
<thead>
<tr>
<th>Sample Uses or Services</th>
<th>Procurement Targets (Total: 1325 MW)</th>
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<tbody>
<tr>
<td>Bulk Storage (Stand-Alone and Co-located)</td>
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<tr>
<td>Ancillary Services</td>
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<tr>
<td>Voltage Support</td>
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<td>Substation Energy Storage</td>
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<tr>
<td>DG Storage</td>
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<tr>
<td>Load Shifting</td>
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<tr>
<td>Vehicle Charging</td>
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<tr>
<td><strong>Total</strong></td>
<td>200 MW 270 MW 365 MW 490 MW</td>
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</tbody>
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NEDO/DOE 2010 Li Ion Cost Projections
Energy Storage Applications

Electric Energy Time-shift
Electric Supply Capacity
Load Following
Area Regulation
Electric Supply Reserve Capacity
Voltage Support
Transmission Support
Transmission Congestion Relief
T&D Upgrade Deferral
Substation On-site Power
Time-of-use Energy Cost Management
Demand Charge Management
Electric Service Reliability
Electric Service Power Quality
Renewables Energy Time-shift
Renewables Capacity Firming
Wind Generation Grid Integration

Important Metrics per Duty Cycle

1) Annual operational days/hours
2) Number of cycles per given time period
3) Average DOD per cycle
4) Energy throughput per kWh of available capacity
5) Financial value per kWh
6) Value per kWh of available energy capacity and C-rate
Panasonic/Sanyo PV Integration Storage

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Storage configured in 20 cassettes, 1.5 kW each
Panasonic/Sanyo fully integrated 30 kW PV and 30 kWh electric energy storage

- Solar Forecasting System coupled to energy storage controls to mitigate intermittency
- Peak shaving to reduce the energy use/cost.
- Provide stable and efficient energy.
- Ancillary Function (emergency power back up for communication etc)
Example: Minimize grid power purchasing

**Case 3: Using Lithium-ion Batteries with PV**

- **Reduction of peak**
  - Power Purchase
  - Reduce the amount of peak rate power used
  - Power Generation of PV
  - Discharge of LiB
  - Stabilize power supply using energy stored in the Lithium-ion battery array

With lithium-ion batteries used together with the PV system, the power “gaps” can be filled with the energy stored in the batteries to reduce the amount of peak hour power purchases. This will require a lot of power to be discharged from the batteries, however.

**Case 4: PV + Lithium-ion batteries + Solar Forecasting**

- **Minimize investment**
  - Power Purchase
  - Reduce the amount of peak hour power purchases and the amount of discharge from the Lithium-Ion batteries.
  - Power Generation of PV
  - Discharge of LiB
  - Weather changes

Solar Forecasting can be used to predict the amount of PV power generation with weather changes. With this information, the lithium-ion batteries can be used more efficiently. This will result in a reduction of not only peak power purchased but battery capacity.
- ZBB EnerStore V3 - 25 kW / 50 kWh
- DC Efficiency up to 76%
- Six units with 300 kWh total capacity
- Directly coupled with 60 kW of roof top PV
- Control system designed to reduce peak load demand requirements at East Campus Chiller Plant
- 120 kW/ 60 kWh of total energy storage capacity
- Test stand linked to Microgrid control system and remotely controlled.
- Plug-in vehicle batteries degraded to 70-80% of original power or energy capacity are insufficient for automotive use
- May provide a low cost source for stationary energy storage applications
Objective:
Demonstrate the feasibility of integrating and controlling multiple 2nd life repurposed MINI E battery systems, with additional integration of PV solar array and the UCSD micro grid for a three year period.

Research possibilities and value:
• Investigate test applications and load profiles.
• Results will lead to better understanding of different use cases and possible B2U scenarios
• Identify control issues related to managing multiple repurposed EV batteries with a different state of charge.
• First full scale energy storage system with repurposed EV batteries.
UCSD SGIP Bulk Energy Storage Project

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- 2.5 MW, 5 MWhr, bulk energy storage
- Reduce Peak Campus demand energy cost production
- Integrated with PV and fuel cell and campus cooling load
**Key Design Parameters**

- Phase I: 28 kW, 5 minute energy storage
- Phase II: 250 kW, 5 minute energy storage
- PV solar smoothing and firming, improve PV ramping
- Coupled with 28 kW Concentrated PV
- Control Strategies to be tested
- Solar predictive forecasting coupled with control systems
- Schedule: June, 2013 – Nov. 2015
Control and Dispatch of Distributed Energy Storage

UCSD Campus Load and Generation Requirements

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Master Microgrid Controller

2.5/5 Mwhr Energy Storage System

Sanyo 30 kW/30 kWh Energy Storage System

ZBB 125 kW/300 kWh Flow

2nd Life EV Battery Test Stand

BMW B2U 108 kW/180 kWh

Maxwell 28 kW Ultra Caps

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Summary of UCSD’s Energy Storage Program

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- Large diversified energy storage projects in university setting
- Planning to grow collaboration with DOE/SNL on energy storage
- Centralized and Distributed intelligence to control energy storage fleet dispatch
- Living laboratory for testing and determining the benefits for various energy storage technologies
- Lab To Market proven capability
- Valuable research to aid integration of increasing levels of renewables
- Opportunity to realize benefits in a true microgrid operational setting
Thank You!