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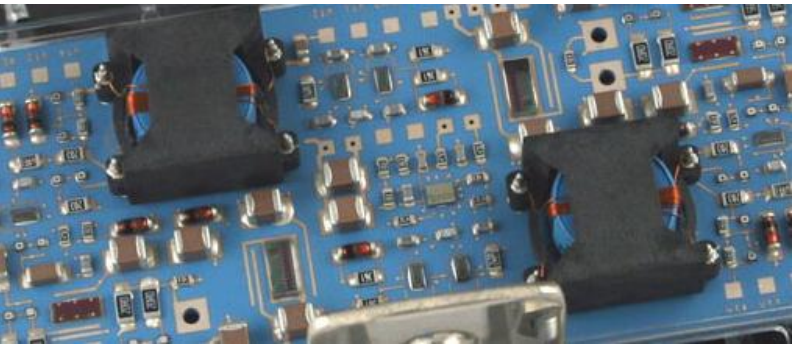

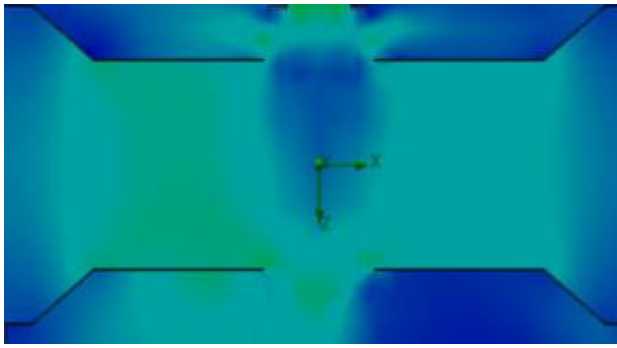

Energy Storage System/Power Electronics Overview

Stanley Atcitty (Stan), Ph.D.
Wind Energy Technologies Dept.

EPRI Workshop on Power Electronics for the Grid
November 17-18, 2011

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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DOE Energy Storage Program

Program Manager: Dr. Imre Gyuk

- Mission:
  - Develop, in partnership with industry, advanced electricity storage and power conversion system technologies, for modernizing and expanding the electric supply to improve the quality, reliability, flexibility, and cost effectiveness of the existing system.

- The Program is led by Sandia National Laboratories.

Energy Storage Systems Program Goals

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- Develop and evaluate integrated energy storage systems
- Develop batteries, SMES, flywheels, electrochemical capacitors and other advanced energy storage devices
- *Improve multi-use power conversion system, controls, and communications components*
- Analyze and compare technologies and application requirements
- Encourage program participation by industry, academia, research organizations, and regulatory agencies

In short, develop a broad portfolio of demonstrated storage technologies for a wide spectrum of applications.

Benefits of Electricity Storage

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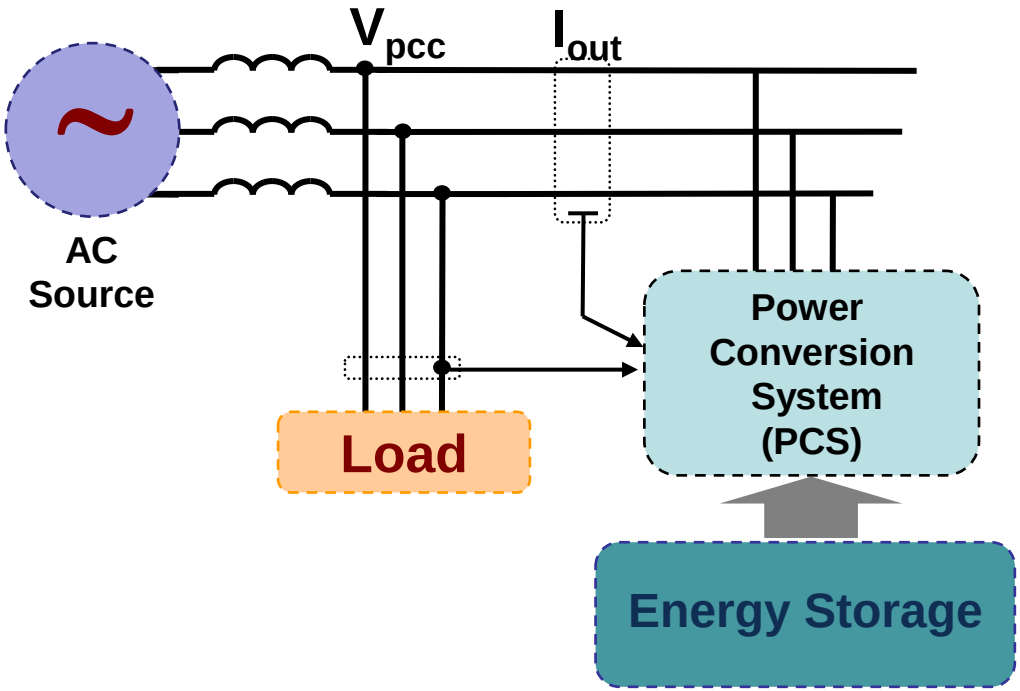
- Maintain quality power and reliability
- Provide customer services — cost control, flexibility and convenience
- Improve T&D stability
- Enhance asset utilization and defer upgrades
- Increase the value of intermittent renewable generation

Why is DOE/Sandia interested in power electronics?

- Needs:
  - Reduce install cost/kW
  - Decrease size & weight especially for transportable systems
  - Improve integration control
  - Increase reliability
  - Increase efficiency



The PCS is a key component of the energy storage system—it can represent 20-60% of the total system cost.

PCS Applications (5-kW to 10s-of-MW)

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	Power		Energy
Load	PQ, Digital Reliability	DER Support for Load Following	Peak Shaving to Avoid Demand Charges
Grid	Voltage Support, Transients	Dispatch ability for Renewables, Village Power	Mitigation of Transmission Congestion, Arbitrage
	Seconds	*Minutes*	*Hours*

Summary of System Costs (US $)

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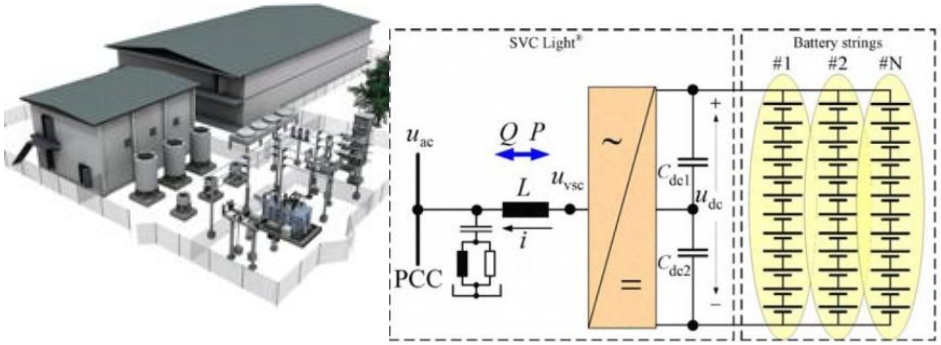
System Identification	System Description	Total Cost $/KW	Storage Cost	PCS Cost	Balance of System Cost
Puerto Rico	20-MW/14-MWh BES	1,102	22%	27%	51%
Chino	10-MW/40-MWh BES	1,823	44%	14%	42%
Vernon	3-MW/4.5-MWh BES	1,416	32%	19%	49%
Hawaii Electric - HELCO	10-MW/15-MWh BES	1,166	34.5%	18.5%	47%
Cresent	500-kW/500-kWh BES	1,272	41%	40%	19%
SDG&E	200-kW/400-kW BES	8,150	16%	23%	61%
PM250	250-kW/167-kWh BES	1,500	20%	50%	30%
Anchorage Municipal L&P	30-MVA/375-kWh SMES	1,467	45%	45%	10%

Ref: Akhil, A, Swaminathan, S, Sen, R, "Cost Analysis of Energy Storage Systems for Electric Utility Applications", SAND97-0443, February 1997

Examples of Large Energy Storage Demonstrations



- Golden Valley Electric Authority (GVEA), Fairbanks, Alaska
  - Ni-Cd Battery (5kV, 3.68kAh)
  - 46 MW for 5 minutes
  - ABB power electronics
- SVC light pilot system near Norfolk, England
  - Li-ion (5.8kV, 200kWh)
  - 600kW for 15 minutes
  - ABB power electronics

Transportable Systems

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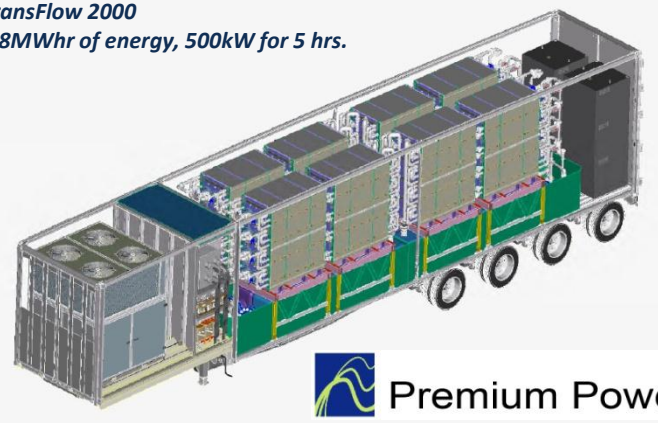
Peak Shaving, Demand Response, T&D Deferral, etc.

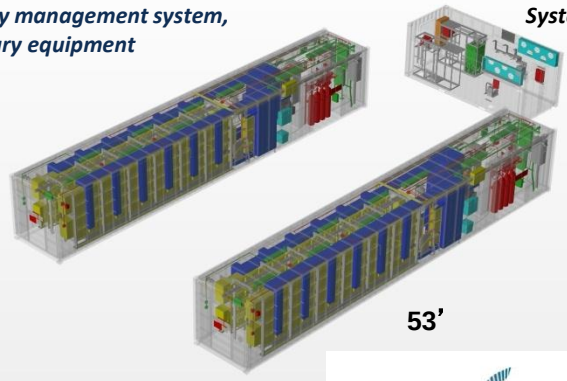
TransFlow 2000
2.8MWhr of energy, 500kW for 5 hrs.



Grid Stabilization/Renewable Integration

1MW battery stack, battery management system, auxiliary equipment

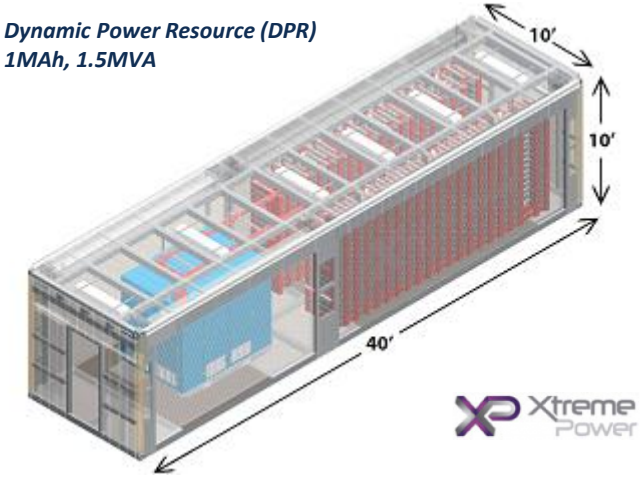
Power Control System Module



ALTAIR NANO
charging the energy revolution

Renewable integration, ancillary services, end-use

Dynamic Power Resource (DPR)
1MAh, 1.5MVA



Benefits

- Lower Installation Cost
- Less Time from Installation to Operation
- Use at Multiple Sites Optimizes Overall System Use

Emerging and Future Improvements

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- Transportable energy storage systems are becoming more attractive necessitating smaller, lighter, more reliable PCS designs.
  - Transformer-less, grid-tied PCS designs (e.g., multilevel converter topologies) are emerging.
  - New PCS topologies are being developed to reduce the size of the magnetics; to reduce electrolytic capacitor use; and in some cases to eliminate the use of DC-link capacitors.
  - Semiconductors continue to improve—3- and 2-terminal post-silicon semiconductors (e.g., SiC and GaN) are becoming available. These devices will increase inverter performance by requiring less thermal management and fewer passive components; increasing efficiency; providing high-voltage blocking; and using higher switching speeds.
  - Advancements in magnetic materials have resulted in higher ratings for operating flux densities (lower copper losses) and temperatures.
  - Wire bondless semiconductor switches are emerging and starting to show improvement in switch reliability.

Emerging and Future Improvements

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- High-level controls for multiple DER and storage components are being developed.
  - Inverter manufacturers are adding more value-added Smart Grid features (e.g., voltage support).
  - Inverter controls are being refined for new energy management schemes with proper energy storage or DER integration and grid support.
  - A multi-use PCS for energy storage or DER integration are being developed.
- Many improvements are making inverters more commercially attractive and easier to use.
  - PCS packaging is improving—they are more reliable and easier to service in the field.
  - Better sensor technology combined with improved diagnostic and prognostic health management systems (firmware and software) are reducing downtime.
  - Remote control and communication capabilities are becoming more common and reliable.
  - Long-term PCS reliability is improving, particularly for automotive applications. Currently a 10-year warranty (5 years with a 5-year option) is standard for PV inverters. Near-term targets are 15 or 20 years. Ideally users would prefer a 30-year lifespan.
  - Manufacturability is improving.

PCS Needs

- Lower installed cost/kW
- Increased round-trip efficiency
- Increased reliability
- Reduced size and weight, especially for transportable systems
- Multi-use PCS for a variety of DER/energy storage technologies and applications
- Improved controls and adaptability
- Improved manufacturability (to increase manufacturing volume)

Power Electronics

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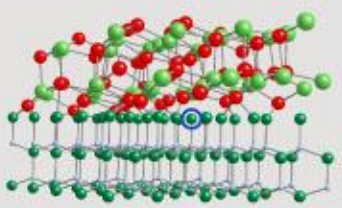
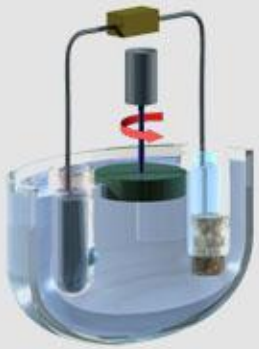
Materials R&D

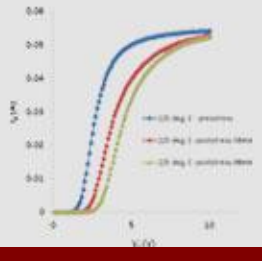


- Gate Oxide R&D
- Bulk GaN



Semiconductor devices

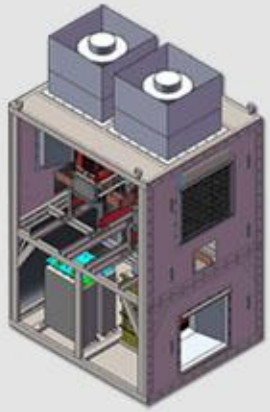
- Post Si Characterization & Reliability
- SiC Thyristors
- ETO



Power Modules

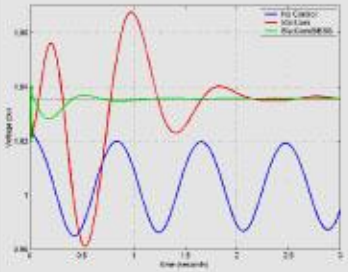
- High Temp/density Power Module

Power Conversion System

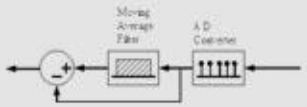


- Dstatcom plus energy storage for wind energy
- Optically isolated MW Inverter
- High density inverter with integrated thermal management
- High temp power inverter

Applications



- Power smoothing and control for renewables
- FACTS and Energy Storage



Key Issues

- Demand for DER and/or energy storage systems will not drive PCS or silicon technology improvements.
- Increased sales volume, better packaging, and better manufacturing techniques can reduce cost and increase reliability.
- Standardization is possible for a core unit, but custom design flexibility must be maintained.
- Focused cross technology R&D can be a win-win for technology and inverter manufacturers.

For Additional Information Contact

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