U.S. DEPARTMENT OF ENERGY

Energy Storage Systems

Research Program

(DOE / ESS)

Sandia National Laboratories

Quarterly Progress Report

January 2009 — March 2009

(Fiscal Year 2009 / 2nd Quarter)

Produced By:

DOE Energy Storage Systems Research Program

Sandia National Laboratories

Albuquerque NM

(SNL / ESS)

PROJECTS

An Advanced Power Converter System Using High Temperature, High Power Density, SiC Devices

Date Project Began:	November 06, 2006
Dates for this Project Report:	January – March 2009
Sandia Project Manager (PM):	Stan Atcitty
Contractor:	Aegis Technology, Inc., Santa Ana CA
Partner(s):	Univ. of Tennessee, Knoxville TN

Project Description:

In this DOE-STTR project, Aegis Technology is to design and demonstrate a SiC-based inverter system, addressing related technical issues and illustrating the system's benefits. The resultant SiC inverter will be capable of working at high power densities, high temperatures, and high frequencies, and thus achieving the advantages of high efficiency, small size, and light weight.

During Phase I research, Aegis succesfully carried out the feasibility study of the proposed SiC inverter, including design, modeling and prototyping. The modeling on one SiC inverter design for energy storage applications has shown dramatic reducitons in power loss (2-3 times) and heatsink size (5-10 times), compared with a Si-based inverter. A six-packed SiC power module (1200 V, 14 A), an AlN high-temperature package, a graphite foam heatsink, and a gate drive based on IXYS-chip were demonstrated.

Currently, during Phase II research, Aegis will demonstate, model, and characterize a scaled-up SiC inverter. The research work covers: (1) Circuit design and modeling to evaluate the effects of SiC devices on the inverter system at both the device-level (e.g. junction temepratures) and the system-level (e.g. energy efficiency, size); (2) Development of high temperature packaging, gate drive and other ancillary devices; (3) Construction and characterization of a SiC inverter; and (4) Technical/economical analsyis of this system and technology transfer for commercial applications.

Key Project Events:

1. DC-AC inverter design.
2. Power module design and prototype.
3. Packaging and thermal management.
4. Gate drive/control design and prototype.
5. Modeling and characterization.
6. Inverter prototype and testing.
7. Commercialization.

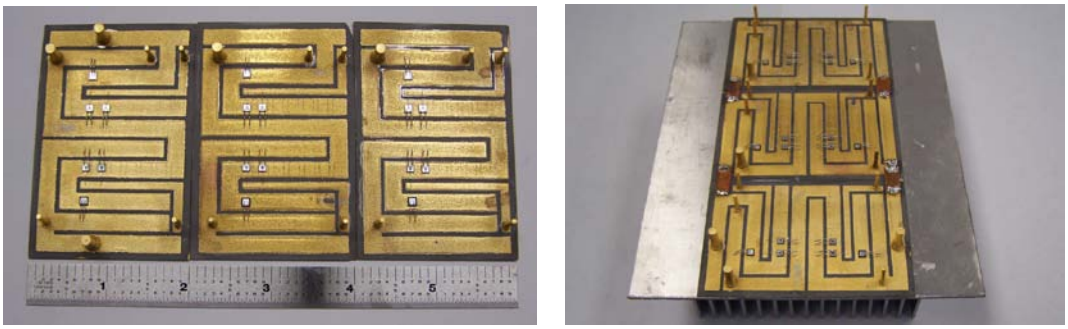
Project Status:

So far, in this ongoing project, we have accomplished the following tasks:

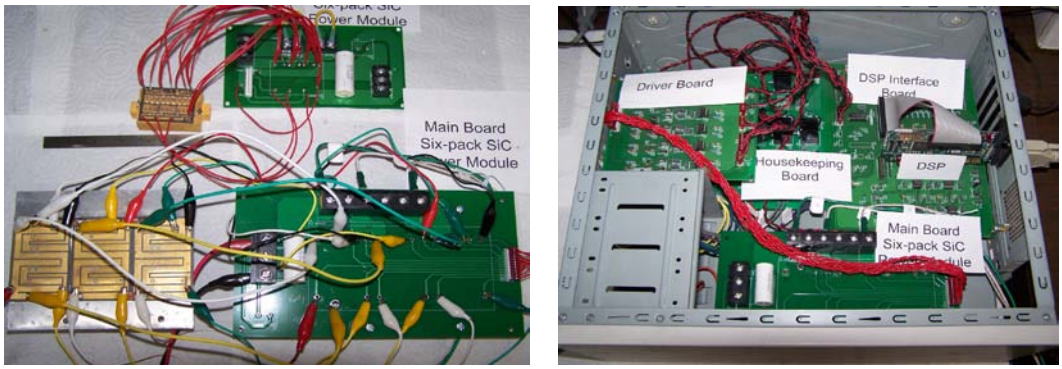
1. DC-AC inverter design.
2. Power module design/prototype.

3. Packaging/thermal management.
4. Gate design/prototype.
5. Modeling/characterization.
6. Preliminary inverter prototype/testing.
7. Testing and characterization of a 5kVA DC-AC inverter in a motor drive system.
8. Fabrication and characterization of a scaled-up 25 kVA SiC inverter.
9. Preliminary commercialization.

Pictures / Tables / Graphs:



The new, scaled-up inverter power module. (Left: a set of power module consisting of three AlN substrates; Right: the power module joined with heat sink)



(a) *(b)*

(a) A new design of Main Board (connected with the power module), contrasted with the old; (b) The scaled-up system in a metal case (Note: the power module is under the Main Board).

Advanced High Temperature Packaging Scheme with Non-wire Bond Interconnection for SiC Power Switches

Date Project Began:	June 30, 2008
Dates for this Project Report:	January – March 2009
Sandia Project Manager (PM):	Stan Atcitty
Contractor:	Aegis Technology Inc., Santa Ana CA

Project Description:

The goal of this project is to develop a robust electrical interconnection technique based on parallel-plate direct area bonding (PPDAB), which can be used in high-temperature packages for SiC power devices. The PPDAB will provide a better interconnection to replace the traditional wire bonding, overcoming the limitations associated with the wire bonding and thereby offering improved mechanical, electrical, and thermal performance of the packages. The technical objective in this Phase I work is to demonstrate the feasibility of the proposed PPDAB scheme, including design, processing, modeling, prototyping and testing.

A detailed investigation on the interconnection realization (structure design and material processing) such as pads metallization, chip bonding and other related technical issues will be conducted for a better structure/process control and future optimization. In addition, a finite-element analysis (FEA) model will be created to conduct the stress analysis (e.g. the residual stress magnitude and distribution) in the bonding structure using this new interconnect approach and the associated packages, and the stress analysis of the conventional wire bonding interconnects in the same power module, in order to illustrate the advantages of our proposed PPDAB (being carried out throughout both Phase I and II). In the end of Phase I, several pieces of packaging prototypes will be fabricated, and the related mechanical, thermal and electrical characterizations will be carried out to verify our design concepts.

Key Project Events:

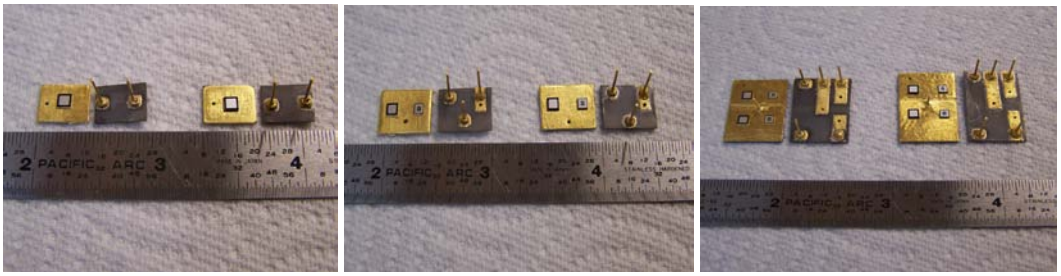
8. **Concept demonstration with Printed Circuit Board (PCB) substrate**
   a. Single SiC JFET and single switch unit consisting of a Silicon Carbide (SiC) junction gate field-effect transistor (JFET) and a Schottky diode; Single phase power module consisting of two switch units.
9. **Concept demonstration with aluminum nitride (AlN) ceramic substrate**
10. Designs, processing and assembly
11. **Prototyping, testing and characterization**
    a. Prototyping; Electrical/mechanical/thermal tests.
12. **FEA modeling**

Project Status:

So far, in this ongoing project, we have accomplished the following:

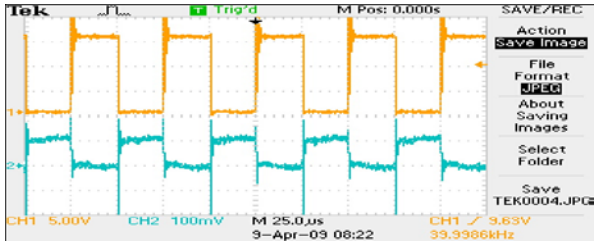
a. **Concept demonstration with PCB substrates -** Single SiC JFET and single switch unit consisting of a SiC JFET and a Schottky diode; single phase power module consisting of two switch units; electrical characterization.
b. **Concept demonstration with AlN ceramic substrates -** Designs, processing and assembly; characterization (ongoing).
c. **FEA modeling -** Model building and parameters sett up.

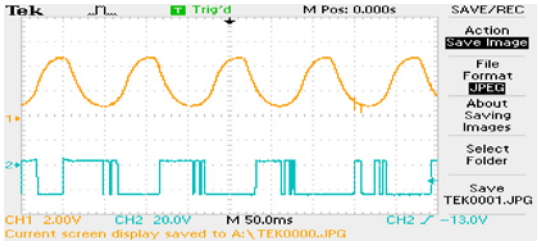
Pictures / Tables / Graphs:



(a) (b) (c)

Concept demonstration with AlN substrates and SiC power device: (a) for a single SiC diode; (b) for a single switch unit; (c) for a single-phase, half-bridge SiC inverter module.

(a) 

(b) 

Electrical characterization of PPDAB prototypes: (a) turn-on/off behavior of single switch unit; (b) wave form of a single phase power module.

Large Area Silicon Carbide GTO Thyristor Development

Date Project Began: June 20, 2007

Dates for this Project Report: January – March 2009

Sandia Project Manager (PM): Stan Atcitty

Contractor: GeneSiC Semiconductor Inc.

Partner(s): Princeton Power Systems, Dow Corning Corporation

Project Description:

The goal at the end of Phase II of this program is to achieve the following from a Silicon Carbide (SiC)- based, gate turn-off (GTO) Thyristor:

- Blocking Voltage > 10-16 kV
- Packaged device on-state Current > 100 A
- Switching frequency > 20 kHz
- Cost effective solution that can be deployed on a large scale

Key Project Events:

- Completed fabrication of 1st batch of GTO Thyristors
- Conducted in-depth, on-state and blocking characterization of the first batch of GTO Thyristors
- Blocking voltages in excess of 7000 V were measured on this batch of devices
- Reverse Leakage currents were as low as 10 μA at 7000 V
- On-state voltage drops as low as 3.4 V were measured at a forward current of 1 A.

Project Status:

The fabrication of the first batch of 7 kV GTO Thyristors has been completed. This first batch of GTO Thyristors have been thoroughly characterized to yield blocking voltages in excess of 7000 V and on-state voltage drops as low as 3.4 V at 1 A.

Pictures / Tables / Graphs: none

High Temperature, Fully Programmable Power Controller for High Density Power Electronics

Date Project Began:	May 30, 2008
Dates for this Project Report:	January – March 2009
Sandia Project Manager (PM):	Stan Atcitty
Contractor:	SJT Micropower
Partner(s):	PermaWorks, Honeywell SSEC, SemiSouth Conductors

Project Description:

Phase I is focusing on design and development of a high temperature controller that interfaces the High-Temperature Silicon-On-Insulator (HT SOI)-based controller to Silicon-Carbide (SiC) power switches. This high temperature controller creates the basic building block for power converters, motor controllers, and a host of industrial control applications using American developed technology. Sandia will work with Honeywell and other US component manufacturers to design basic power controller interfacing HT SOI electronics with SiC power devices that will reliability operate in an environment of 240ºC,with junction temperatures of the power devices operating up to 300 ºC. These new systems will be more reliable, more energy efficient and >30% smaller than existing silicon solutions.

At the end of Phase I, a prototype microcontroller-based HT power controller will be demonstrated. The HT controller will have the capability of monitoring the temperature at several key areas throughout the system (for diagnostic purposes) and have two basic functions: 1) as an inverter that provides the ability of interfacing with an inductive load, and 2) providing a software-controlled current limit. These functions demonstrate two key attributes needed in a controller, managing an inductive load and demonstrating the capability of an "active" circuit breaker).

Key Project Events:

- Basic Metal Semiconductor Field Effect Transistor (MESFET)/SiC driver demonstrated at 230°C.
- Field Programmable Gate Array (FPGA)-based H-bridge gate control complete.
- Low temperature board designed and fabricated.
- Design validated using low temperature counterparts to the HT devices.
- HT board on order and will arrive 4/13/09.
- Initial HT testing scheduled for 4/21/09.

Project Status:

The full bridge inverter design is complete and a low temperature board has been fabricated and tested using low temperature counter parts for the SOI and SiC devices. Figure 2 shows the inverter in operation. The supply voltage was 48 volts DC and the output AC voltage was 38 volts (up to 1 amp). The inductive load for this test

was a drill motor. Tests were performed at ambient, 50, 100 and 125°C with satisfactory results. While the design is not optimized, it does demonstrate the concept.

The high temperature board design is complete and is being fabricated. The boards should arrive the week of April 13 and will be assembled and tested by the end of April. The HT boards will enable us to evaluate the developed circuits up to 240°C.

The basic block diagram is shown in figure 3. The proposed, highly integrated module is also shown in the block diagram.

Pictures / Tables / Graphs:

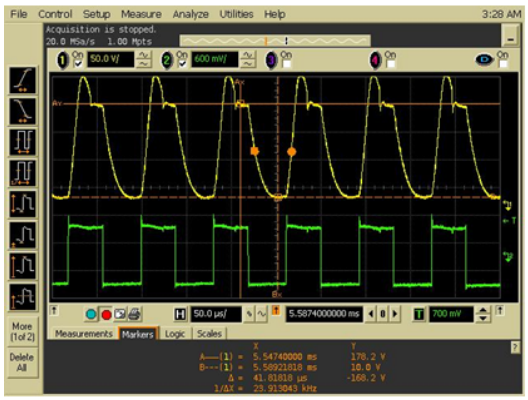


Figure 1 shows the resulting waveform using a timer IC to drive the gate of the MESFET. The bottom (green) trace is the waveform on the gate of the MESFET and the top (yellow) trace is the resulting waveform on the drain of the JFET.

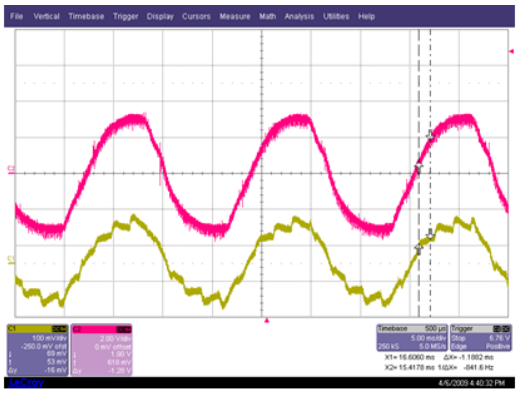


Figure 2 shows the resulting waveform using the FPGA-based H-bridge gate control circuit. The bottom (yellow) trace is the load current waveform and the top (red) trace is the resultant 60 Hz waveform using a differential amplifier across the inductive load (drill motor operating at 38 VAC and .7 amps).

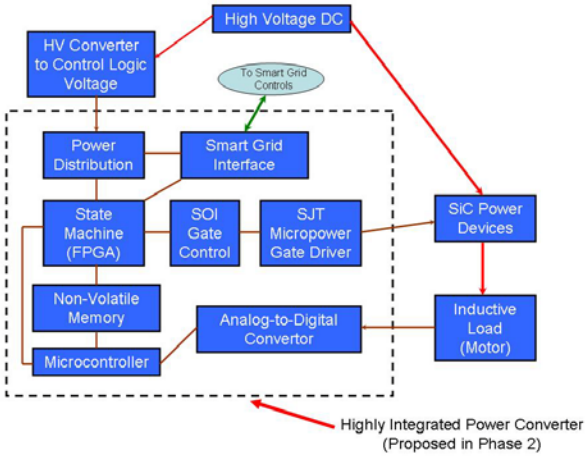


Figure3. Block Diagram of HT Power Controller

Development and Validation of Advanced Energy Management Control Algorithms for Short- or Long-term Energy Storage

Date Project Began:	July 28, 2008
Dates for this Project Report:	January – March 2009
Sandia Project Manager (PM):	Stan Atcitty
Contractor:	Missouri Univ. of Science & Technology
Partner(s):	No. Carolina State Univ.

Project Description:

From previous support, the Missouri University of Science & Technology (MST) has developed a hardware-in-the-loop (HIL) test-bed that mimics the electric power grid. This laboratory shall be used as a basis to develop the basis for a plug-and-play microgrid.

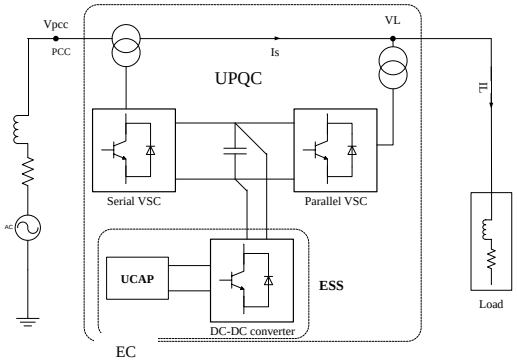
The current project focuses on characterizing different load types, resources, and configuration of a mid-sized distribution system, development of computer models of a power-electronics-based microgrid, development of formal security models, superimposing the control nodes on a microgrid, developing theories and interface models for cooperating power electronics devices, and development and testing of distributed energy management strategies. In addition, a new ETO Light converter-based series compensating Distributed Power Flow Controller (DPFC) was proposed.

Key Project Events:

- With the EC connected through the DC/DC converter, the UPQC was shown to provide satisfactory performance even with up to 50% voltage variations (Figs 1-2)
- A new multi-input buck converter (topology 2 in Fig. 4) was developed that has improved performance over existing multi-input buck converters.
- A new, decoupled, synchronous reference frame, phase-locked-loop method was developed that has better dynamic response during unbalanced harmonics, good adaptability to grid frequency variation, and a simple structure
- The level of observability of a power system was modeled using a combined graph theoretic and matrix approach to quantify uncertainty as a function of the number of observers (Fig 5)
- The ETO-based DPFC was shown to provide good performance under unsymmetrical current compensation (Fig. 6), current limit after disturbance (Fig 7) and a fault tolerant design (Fig 8).

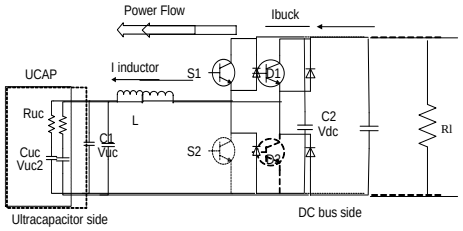
Project Status: ongoing

Pictures / Tables / Graphs:

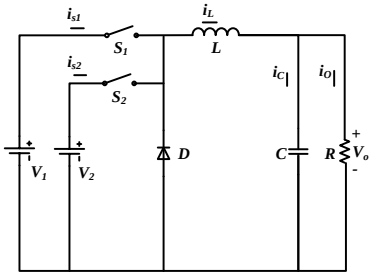


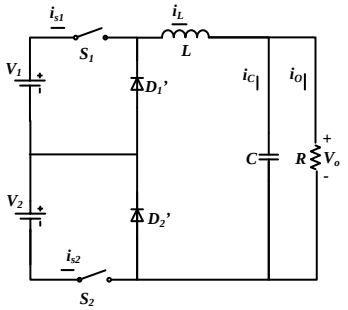
harmonic load

UPQC topology with EC based ESS.



DC/DC converter during buck mode (charging)



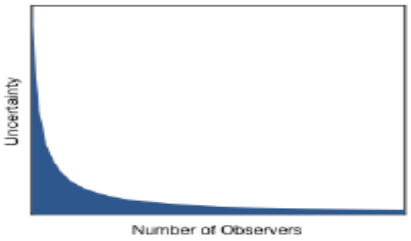


MODE	S1	S2	VL	VD
I	ON	OFF	V1-VO	V1
II	OFF	ON	V2-VO	V2
III	OFF	OFF	-VO	0
IV	ON	ON	NOT POSSIBLE	

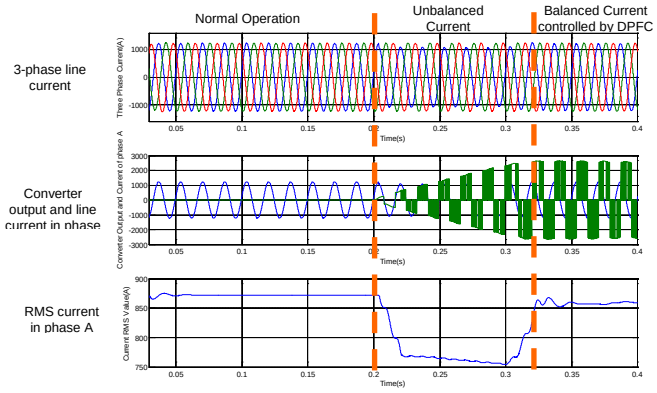
Topology 1 of double-input buck converter

MODE	S1	S2	VL	VD1	VD2
I	ON	OFF	V1-VO	V1	0
II	OFF	ON	V2-VO	0	V2
III	OFF	OFF	-VO	0	0
IV	ON	ON	V1+V2-VO	V1	V2

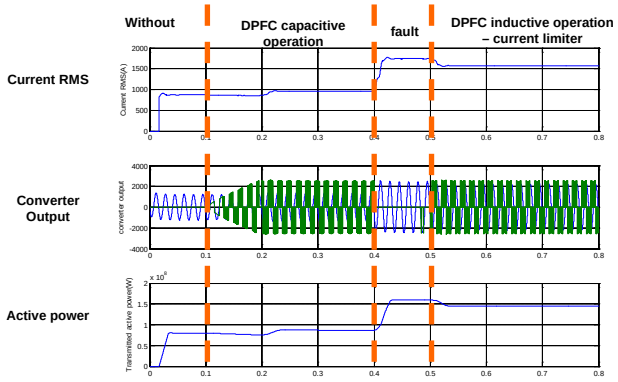
Topology 2 of double-input buck converter



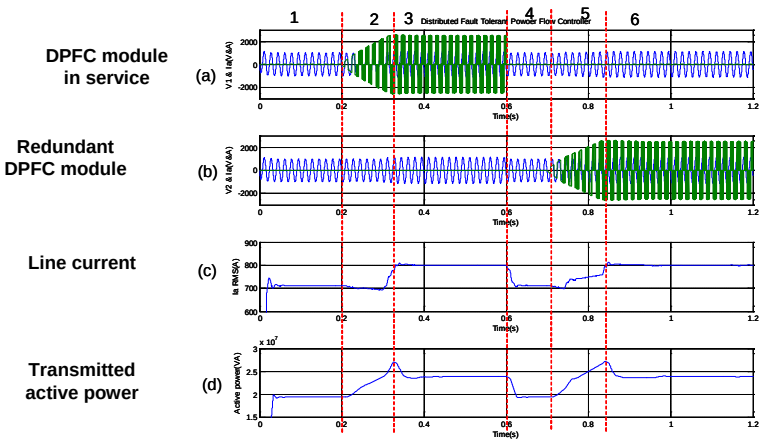
Uncertainty versus number of observers



The unsymmetrical current compensation



The current limit after disturbance



DPFC fault tolerant design

Date Project Began: July 14, 2008

Dates for this Project Report: January – March 2009

Sandia Project Manager (PM): Stan Atcitty

Contractor: No. Carolina St. Univ.

Project Description:

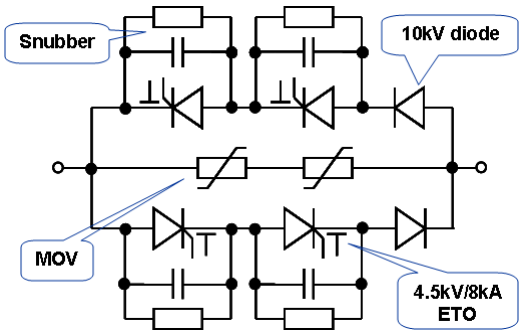
Under the support of DOE's Energy Storage Program, the Gen-4 Emitter Turn Off Thyrsitor (ETO) (Light Triggered ETO) has been developed. Its application in DC application such as a Voltage Source Converter (VSC) has been studied in the previous quarters. ETO is also an excellent switch for AC applications, an example of this is the solid state circuit breaker (SSCB). FY07 4th quarter and future FY08 project support focus on SSCB application of the ETO. SSCB is also the key component used in solid state fault current limiter (SSFCL)

Key Project Events:

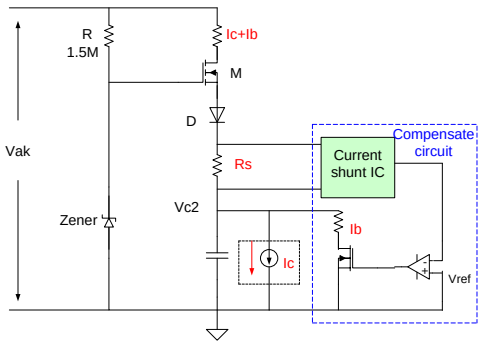
The startup and unbalance issues in series ETOs have been solved. Two ETOs in series have been set up in pulse test bench to check the dynamic voltage balance during turn-on and turn-off period.

Project Status: On-going in FY08

Pictures / Tables / Graphs:



Proposed 9kV SSCB module



Compensate circuit configuration

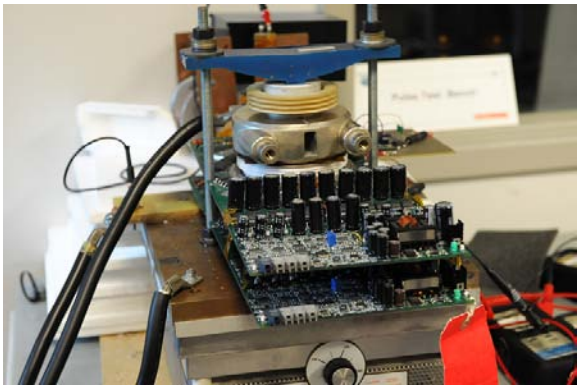
In last report, a solution shown in Fig.2 was proposed to improve all ETOs control circuit current to a fixed value which minimizes the difference between them. The experiment result is shown in Table 1.

Experimental result in two series ETOs with compensate circuit

Vbus (V)	Vak1 (V)	Vak2 (V)	Vak1-Vak2 (V)
400	191	216	-25
1000	489	528	-39
1500	737	786	-49
1900	936	995	-59
2500	1238	1306	-68
3100	1536	1620	-84
3700	1828	1930	-102
4160	2055	2170	-115

The leakage current variation of high voltage probe has impact on experiment result. To reduce probe leakage current effect, a 200k resistor is parallel with each ETO. In the table, the maximum voltage difference between two ETOs is 115V which is acceptable in real application. The maximum power loss on resistor is 21.6W which can be dissipated by nature air.

Two ETOs in series have been set on pulse test bench. In the following quarter, two ETOs will be operated as it does in proposed solid state circuit break module. The dynamic voltage balance between two ETOs which is concerned mostly will be checked.



Two ETOs in series on pulse test bench

Due to gate drive delay and GTO storage time dispersion, the dynamic voltage unbalance between switching devices exits in most case. Compared with GTO, the storage time spread of ETO is greatly reduced which benefits voltage sharing during turn-on and turn-off period. The experimental result on this aspect will be shown in next quarter report.

Senior Design Project

Date Project Began: June 9, 2008

Dates for this Project Report: January – March 2009

Sandia Project Manager (PM): Stan Atcitty

Contractor: New Mexico State University

Project Description:

Technology development and deployment requires a simultaneous investment in the education for sustainability. The goal of this project is to offer Senior Design Project classes in the areas of Energy Storage and Renewable Energy to undergraduate students in the Klipsch School of Engineering and the College of Engineering at New Mexico State University. The funding is applied towards purchasing parts needed to prototype and demonstrate Energy Storage System concepts.

In consultation with the DOE and Sandia National Laboratories, we have developed six design project classes, each lasting an academic year, with thirty students completing these classes.

The FY09 classes deal with developing a Photovoltaic system with storage that can operate in a grid-tied or stand-alone mode. In addition, based on an energy price signal from the electric utility, the system manages energy storage and energy sale/purchase.

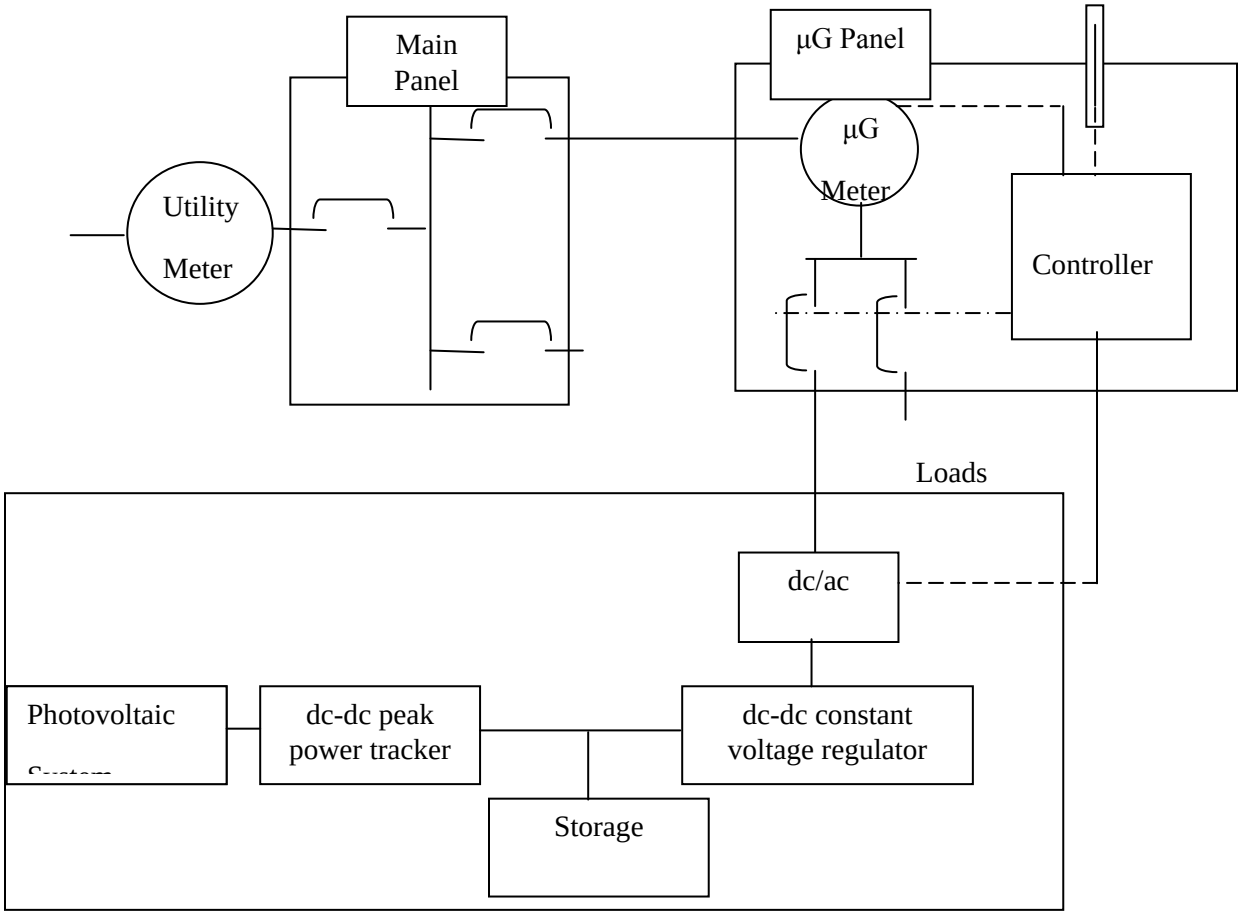
This project provides significant visibility for the energy storage area and DOE programs among the undergraduate and graduate student body at NMSU. It introduces a group of students to this important area and trains them in the technologies that they will use in their future careers.

Key Project Events:

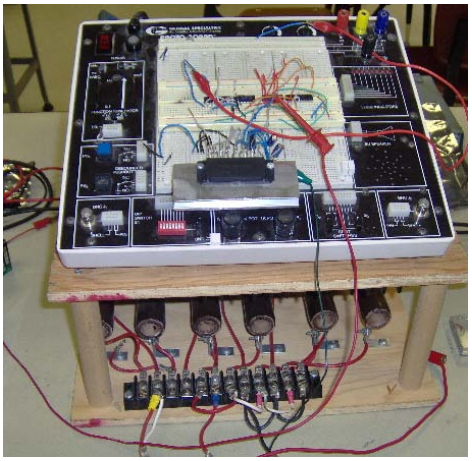
- The student team for Fall 2008 completed their project, but did not meet the goal of system level integration. A final presentation was made to Sandia.
- A bench top, square-wave, three-phase inverter was fabricated; and a printed circuit board and packaging for a prototype are being developed for completion in May 2009

Project Status: Project progress is consistent with schedule and budget. It is a 'high visibility' project in our undergraduate curriculum. A new design class has been designed and is being offered.

Pictures / Tables / Graphs:



System Solution Developed by Design Class (µG symbolizes "microgrid)



Benchtop Prototype with Resistive Load

Scale Model Demonstration of Storage in Customer-driven Microgrids

Date Project Began:	June 17, 2008
Dates for this Project Report:	January – March 2009
Sandia Project Manager (PM):	Stan Atcitty
Contractor:	New Mexico State University

Project Description:

It has become abundantly clear that large-scale penetration of renewable-based distributed resources is impossible without attendant application of centralized and distributed storage. Therefore, it is important to examine the nature and application of small storage systems in so-called customer-driven microgrids. The customer-driven paradigm suggests that distribution microgrids with substantial penetration will evolve from the customer side. Small residential and commercial customers, who constitute as much as 35-50% of load, will invest in energy sources. The distribution utility services would include network service, aggregation service for economic benefit, and reliability management through islanding for disturbances.

The El Paso Electric Power Laboratory at NMSU is an ideal environment to demonstrate the integration of storage-based or storage-supported distributed generation in distribution systems. The goals of this project are to:

1. Interconnect sources to a distribution system and steady state impact.
2. Study the responses of sources during disturbances
3. Explain the role of storage in steady state feeder management during disturbances and in supporting islanded operation

Key Project Events:

Project Status:

The design of systems for allowing the implementation of a microgrid has continued. The hardware modifications have been prototyped and implementation has begun. Hardware development includes power electronic inverters for interfacing renewable sources and storage systems, as well as providing frequency/voltage regulation services for distributed generation. Preliminary, agent-based control algorithms have been developed and are being studied through simulation. The simulation studies indicate that completely decentralized agent-based systems can solve some key problems in microgrid management.

The power electronics interfaces play a special role in agent-based control of microgrids because they inherently include measurements, control capability, and computation/communication. This synergism will be exploited to explore agent implementation.

The project budget is on track, although implementation is behind schedule. It is expected that this will be rectified in the next quarter.

Pictures / Tables / Graphs: none

Power Electronics Reliability

Date Project Began: June 19, 2008

Dates for this Project Report: January – March 2009

Sandia Project Manager (PM): Stan Atcitty

Partner(s): Silicon Power Corporation

Project Description:

Sandia National Laboratories has initiated a reliability project to better understand the current and future reliability of power electronics. While anecdotal evidence of major contributors to reliability is available, solid data upon which to base decisions is scarce. Sandia's project will provide the Department of Energy and the Power Electronics industry a process for creating a reliability baseline for a power electronics system.

In addition to creating the modeling and analysis process, Sandia will use the process to create a reliability model for a selected application (Silicon Power Corporation's Solid State Current Limiter) using a systems view of the selected equipment. Then, opportunities for Prognostics and Health Management will be explored, first focusing on those opportunities with the highest reliability return on investment.

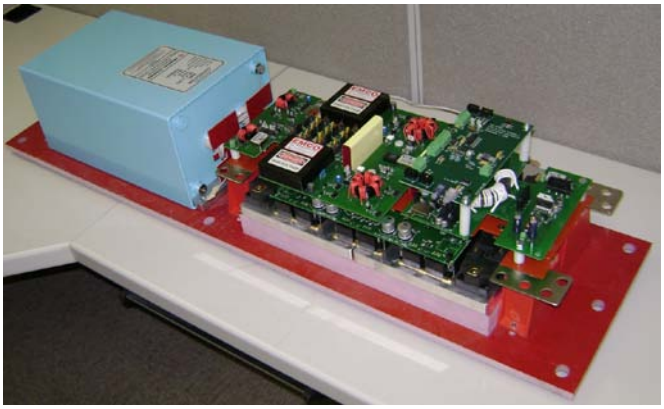
Key Project Events:

- March 2009 – Completed the first milestone/deliverable (a report detailing data collection recommendations for Silicon Power Corporation).

Project Status:

To date, information regarding reliability performance expectations and consequences has been obtained from Silicon Power, and initial failure modes and fault trees are being created. Work is also underway on analyzing the fault trees and creating a report of findings for Silicon Power Corporation. The next step is presenting the findings to Silicon Power Corporation. Subsequent steps will include documenting lessons learned in the form of a general data collection and analysis process for DOE, demonstrating reliability optimization for Silicon Power, and comparing the Silicon Power analysis results with their actual testing outcomes (as data availability permits).

Project Pictures / Graphs / Tables:



Silicon Power's Standard Building Block for the Solid State Current Limiter

Electrochemical Solution Growth of Gallium Nitride for Substrates for Power Electronics

Date Project Began:	June 6, 2008
Dates for this Project Report:	January – March 2009
Sandia Project Manager (PM):	Stan Atcitty
Contractor:	Karen Waldrip (Sandia National Laboratories, Org. 2546)
Partner(s):	David F. Smith, GNOEM Systems, Inc,

Project Description:

Demonstrate seeded growth of gallium nitride by the novel Electrochemical Solution Growth (ESG) technique, which has the potential to grow large volume, high quality, bulk gallium nitride for large-area substrates for high temperature, high power, and very reliable electronics for utility grid applications. Substrates are the key to large area growth and have been met with little to no success over decades of investment. The ESG technique has the potential to overcome many difficulties encountered in traditional growth approaches.

Key Project Events:

- Performed several experiments related to electrochemical parameters and seed rotation speed.
- Developed key analytical and characterization methods with academic partners.

Project Status:

Project is on track; successful demonstration of seeded growth will take many experiments to understand the influence that temperature, rotation speed, salt purity, seed crystal orientation and preparation conditions, and super saturation conditions (dictated by electrochemical parameters) have on the ability to begin to grow on the seed. Several growth experiments have been performed and characterized; however, seeded growth has not yet been achieved. We continue to learn much with each experiment and believe we are closing in on our goal of seeded growth.

Design, Development, Testing, and Demonstration of a 10-MVA ETO-based StatCom

Date Project Began:	Nov. 2008
Dates for this Project Report:	January – March 2009
Sandia Project Manager (PM):	Stan Atcitty
Contractor:	TBD
Partner(s):	TBD

Project Description:

The DOE Energy Storage Program, through Sandia National Laboratories (SNL) and in collaboration with the Bonneville Power Administration (BPA), the Electric Power Research Institute (EPRI), the Tennessee Valley Authority (TVA), and North Carolina State University (NCSU), has developed a semiconductor switch known as the *emitter turn-off thyristor* (ETO), plus the preliminary design for an ETO-based static synchronous compensator (StatCom) and controls. The ETO is a novel semiconductor switch that is suitable for high-power and high-frequency applications. The ETO has several advantages over IGBT or GTO technology, including low gate drive power, high-frequency operation, snubberless operation, a large and safe operating area, and high current and voltage ratings.

Through SNL, DOE is seeking proposals from qualified system integrators to complete the design, construction, factory testing, installation, and field demonstration of a full-scale, 10-MVA, ETO-based StatCom for installation at a location in the BPA power system. Originally specified to be located adjacent to the AES Seawest Condon Wind Farm, the ETO StatCom is currently expected to be located at the BPA DeMoss Substation. The BPA DeMoss Substation, at which the StatCom will be connected to the 69-kV bus, is located approximately 120 miles east of Portland, Oregon, near the town of Wasco. BPA will provide a transformer to connect the 4160-V ETO StatCom to the 69-kV bus. Final site selection might be different if BPA Network Planning determines otherwise.

Key Project Events:

The Request for Proposal was issued during this quarter, and a Memorandum of Understanding (MOU) between DOE and BPA is being drafted.

Project Status: Awaiting proposals from bidders and final draft of the MOU.

East Coast Distributed Grid

Date Project Began: November 2007

Date of This Project Report: Jan – Mar 2009

Sandia Project Manager (PM): Dan Borneo

Contractor: James Madison University

Partner(s): Sandia National Laboratories

Project Description:

James Madison University, Sandia National Laboratories and other partners are interested in building a distributed energy grid (DG) on the east coast.

Key Project Events:

- DOE/SNL contacted by Castlebridge, FY07Qu4
- DOE/Sandia attended a meeting with Chesapeake in January 2008.
- Follow on meeting held May 2008

Project Status:

Currently, we have submitted an application to EERE for funding to complete a study and conceptual design of a wind power and storage system on Tangier Island, located in the Chesapeake Bay. System might include:

1. One or two 1-1.5 MW wind turbines.
2. Solar PV.
3. Energy storage (size and type TBD).

Project Pictures / Graphs / Tables: none

Emerson Network Power Fuel Cell Implementation

Date Project Began: June 2007

Date of This Project Report: Jan – Mar 2009

Sandia Project Manager: Dan Borneo

Contractor: Emerson

Partner(s): DOE

Project Description:

This project will develop and test a fuel cell that can be utilized as the backup power source for an outdoor, remote telecom cabinet. The fuel cell is anticipated to be a rack-mounted unit that would be integrated with the telecom equipment cabinet.

Key Project Events:

- Scope submitted to Sandia Contracts Division in January 2008
- Sandia contract in place as of Fy09Qu1

Project Status:

Contract in place as of Fy09Qu1. Emerson not yet engaged in project scope. Working with them to see if they want to continue with this project or start another.

Project Pictures / Graphs / Tables:

none

Emerson/Sprint Race to Failure Thermal Management

Date Project Began: January 2008

Date of This Project Report: January – March 2009

Sandia Project Manager: Dan Borneo

Contractor: Sprint

Partner(s): DOE

Project Description:

This project will design, manufacture and install a backup chiller system in a remote telecom equipment shelter. The shelter houses an Integrated Digital Enhanced Network (IDEN) as well as Code Division Multiple Access (CDMA) equipment. Anticipated heat load of the shelters will range from 10 kW - 20 kW.

Key Project Events:

Contract Placed FY08Qu1

Project Status:

Project is complete. Cooling system designed by Schrofftech. The system performed well under adverse conditions. Final report is being produced.

Project Pictures / Graphs / Tables:

Pre-fabricated concrete wall construction, wall insulation R12, roof insulation R10.

Interior dimensions: 9 ft H x 19 ft D x 10.5 ft W

Equipped with:

- 2 5-ton Bard air conditioners, with economizer capability, Model WA602-A05EP.
- 15 inch diameter DC Vent Fan for emergency fresh air cooling, with dampers normally closed by gravity. The fan was disabled during these tests and the opening blocked with a sheet of cardboard.

Oldcastle outdoor telecom hut, Sprint model RCS 11520-38U5-95 .

1 door-mounted Schrofftech fan/filter unit.

Distributed Energy Systems 450 kW Ultracapacitor (EnergyBridge™) Demonstration at Palmdale CA Water Plant

Date Project Began:	2004
Date of This Project Report:	January – March 2009
Sandia Project Manager:	Dan Borneo
Contractor:	Palmdale (Calif) Water District; Distributed Energy Systems (DES: formerly Northern Power)
Partner(s):	California Energy Commission (CEC) / Palmdale Water District / DOE

Project Description:

In support of distributed energy resources, this project demonstrates the use of a 450 kW, 30-second duration, electro-chemical capacitor, energy storage module that could potentially be configured as an electric microgrid. The energy resources include a 950 kW wind turbine, a 200 kW natural gas generator, a 250 kW water turbine generator, and an 800 kW diesel generator.

Key Project Events:

- Commissioning completed September 2007
- Unit shipped and installed at Palmdale, December 2007
- Initial operational acceptance testing completed January 2008.
- Functional acceptance testing completed May 2008

Project Status:

The 450 kW *EnergyBridge* electro-chemical capacitor is installed at the Palmdale site and the functional acceptance testing has been completed. The system is currently off line and no data is being collected. CEC is working the issue.

Project Pictures / Graphs / Tables:

EnergyBridge System Installed at Palmdale (May 2008)

EPRI and DUA Data Collection and Economic Analysis

Date Project Began:

Date of This Project Report: January – March 2009

Sandia Project Manager: Dan Borneo

Contractor: EPRI (Electric Power Research Institute) / DUA (Distributed Utility Associates)

Partner(s): DOE

Project Description:

This project collects electrical data from demonstration electrical storage systems and analyzes the data to ensure that the technology is reliable and viable. The project also performs an economic analysis of the technologies to determine their cost effectiveness. The information is used to determine if the technology would be viable in the marketplace and to identify areas for improvement and possible deployment.

Key Project Events:

- New contract with EPRI placed FY08Qu1
- New contract with DUA placed FY08Qu2
- Palmdale data collection initiated FY08Qu3

Project Status:

Presently, EPRI and DUA are not performing any field work relating to DSOE projects. DUA, however, is updating the various SAND reports that they have issued in the past. Reports include:

- "Energy Storage for Electricity grid: Benefits and Market Potential."
- "Comparing T&D capacity Options, including Stationary and Transportable DER, on a risk-adjusted Basis."
- "Electric Utility Transmission and Distribution Upgrade Deferral Benefits for Modular Electricity Storage."

Project Pictures / Graphs / Tables:

none

20 MW FESS Facility Construction

Date Project Began: 2007

Date of This Project Report: January – March 2009

Sandia Project Manager: Dan Borneo

Contractor: Beacon Power Corp.

Partner(s): DOE

Project Description: Build a 20 MW flywheel facility

Key Project Events:

- Design Closeout meeting conducted February 6, 2008.
- Tyngsboro. NY selected as first 20 MW FESS site.
- FESS under construction at Beacon's Tyngsboro manufacturing facility. Work began FY08Qu2

Project Status:

A 1 MW FESS has been constructed at Beacon's Tingsboro, MA plant. Another 1 MW facility is in construction. Beacon is planning to participate in a Massachusetts non-generation-based pilot program. They are continuing the permitting process to build a 20MW FESS in Stephentown, New York. Permitting includes construction and grid connection, and operation as a non-generation supplier.

Project Pictures / Graphs / Tables: none

Pacific Gas & Electric (PGE) Sodium Sulfur Battery - Substation Upgrade Deferment

Date Project Began:	January 2008
Date of This Project Report:	January – March 2009
Sandia Project Manager:	Dan Borneo
Contractor:	California Energy Commission (CEC)
Partner(s):	CEC, PG&E (Pacific Gas & Electric), DOE

Project Description:

This project is to demonstrate a NaS battery being utilized to defer upgrades of an overloaded transmission line. The system will be located near the load and provide peak shaving capability.

Key Project Events:

DOE's economic analyst performed preliminary evaluation of cost benefits FY08Qu1.

Project Status:

Project is on hold.

Project Pictures / Graphs / Tables:

none

SMUD/RT Trackside – Ultracapacitor Energy Storage

Date Project Began: 2005

Date of This Project Report: January – March 2009

Sandia Project Manager: Dan Borneo

Contractor: Sacramento Municipal Utility District (SMUD)

Partner(s):

- Sacramento Regional Transit District (RT)
- Sacramento Municipal Utility District (SMUD)
- California Energy Commission (CEC)
- Siemens Transportation Systems (STS)
- U.S. Department of Energy (Sandia National Laboratories)

Project Description:

This project is to demonstrate a 1 MW, 20-second duration, static energy storage system (SES) on the Sacramento Rapid Transit (RT) light rail system. Utilizing Siemens electro-chemical capacitors, the SES will provide a voltage boost to the rail distribution lines. This boost will allow faster acceleration out of the stations and the use of more locomotives. It will also help stabilize the rail power during peak demand periods, which will decrease the need for additional substations. Preliminary investigations revealed that, at peak times, the operating voltage of the rail is less than the minimum operating voltage (600VDC). Calculations indicate that installation of the SES will increase the rail voltage above the minimum 600VDC level and shave 50kW of demand during peak hours of operation.

Key Project Events:

- Phase I: Study/Simulation began in 2005 and completed in 2007;
- Phase 2: SES Demonstration Project began June 2007;
- Contract between CEC and SMUD was in place by January 2008;
- System estimated to be on line during third quarter of FY09

Project Status:

The project is on hold pending the new contract between SMUD and Siemens. DOE and Sandia have been working with SMUD to identify monitoring needs in order to be ready for testing when required, and to obtain preliminary “as is” data on the system.

Project Pictures / Graphs / Tables none

SMUD/Sprint 20 kW Vanadium Redox Battery (VRB)

Date Project Began: June 2007

Date of This Project Report: January – March 2009

Sandia Project Manager: Dan Borneo

Contractor: Sacramento Municipal Utility District (SMUD)

Partner(s):

- CEC (Calif. Energy Comm.)
- SMUD, Sprint
- VRB (VRB Power Systems)
- DOE

Project Description:

This project is to demonstrate a 20kW, 180 kWh, VRB battery system. The VRB battery will be designed to supply the required electrical energy at the Sprint transmission equipment site located in Sacramento CA. The system will be used in a peak shaving mode and as a battery backup. The load on the system will be limited to a maximum of 20 kW, and the battery system will be designed to support up to six hours of operational run time in the peak shaving mode. Additionally, the system will be required to have an additional three hours of backup run-time to provide battery backup capability. VRB will design and install the system. Once the system is commissioned and operational, DOE/ and Sandia will collect the electrical data and perform a technical and economic analysis of the system.

Key Project Events:

- SMUD contract with VRB signed December 2007.
- VRB battery being manufactured FY08Qu3
- Kickoff meeting held January 2008.

Project Status:

Project is on hold pending a new contract.

Project Pictures / Graphs / Tables

none

Zinc Bromine Battery (ZBB) 1 MWh Energy Storage Demonstration

Date Project Began: 2006

Date of This Project Report: January – March 2009

Sandia Project Manager: Dan Borneo

Contractor: ZBB (ZBB Energy Corp.)

Partner(s):

- Calif. Energy Comm. (CEC)
- Electric Power Research Institute (EPRI)
- Distributed Utility Associates (DUA)
- DOE

Project Description:

This demonstration project utilizes a zinc bromine battery storage system installed at an electric utility test facility that is designed to reduce overloads during peak demand periods. The zinc bromine battery is discharged when the substation circuits exceed a predefined threshold. The objective is to defer a substation transformer upgrade until all associated planning and permitting can be accomplished. The initial design was for a 2 MWh system; but was subsequently reduced to a 500 kWh demonstration.

Key Project Events:

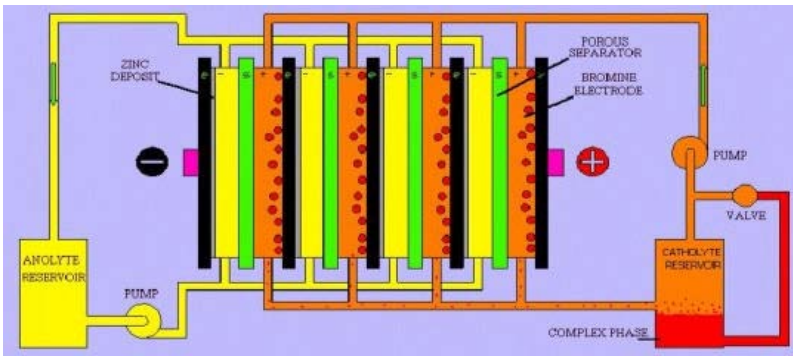
40-day test of a 500 kWh system completed October 2007.

Project Status:

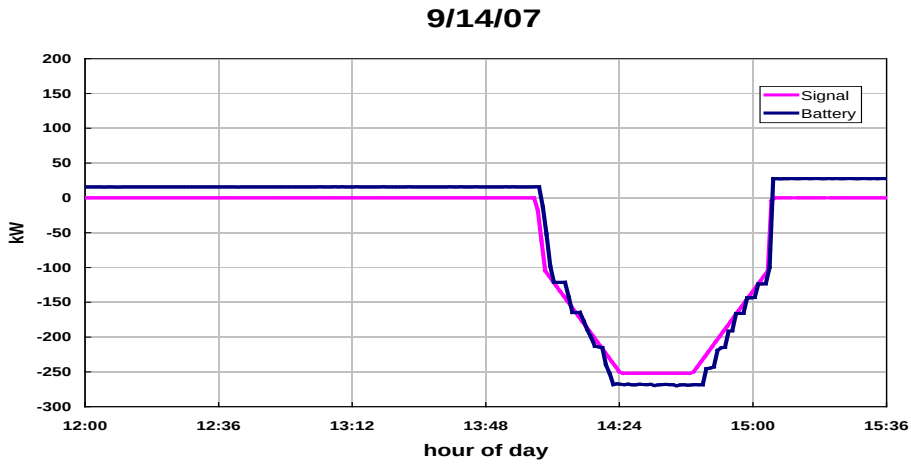
New contract pending that will allow ZBB to continue the demonstration of a 1 MWh system. The team is working with PG&E to identify a location to install the system once the new contract is in place. ZBB has one 500 kWh unit in California and is ready to ship the secondt. Once the new contract is in place, which is estimated by FY09Qu3-Qu4, DOE and Sandia will provide electrical monitoring and perform an analysis to determine if this system is cost effective as a means for energy storage.

Project Pictures / Graphs / Tables:

500Kw battery system on DUIT site, San Ramon Ca. 5/2007



The Flowing Electrolyte System 2/2005



Load Following Discharge 9/14/0

Carbon-Enhanced Lead-Acid Battery and EC Testing

Date Project Began: December 2005

Date of This Project Report: January – March 2009

Sandia Project Manager: Tom Hund

Contractor: (SNL In-house Project)

Partner(s): none

Project Description: In a cooperative effort with Mead-Westvaco, NorthStar Battery, and Battery Energy, the ESS Program was working to enhance the high-power cycle performance of valve-regulated, lead-acid (VRLA) batteries for utility cycling applications. The goal of this work was to evaluate the effect of different carbon formulations when used in the negative electrode of the battery. The carbon additions can significantly improve battery performance in high-power, partial-SOC cycling and prevent hard sulfation in the negative electrode, which can lead to capacity loss and premature battery failure. NorthStar Battery, Battery Energy, CSIRO/Furukawa, and East Penn Battery have produced a number of VRLA batteries containing carbon additives. All of the above batteries were, or are, under test at SNL.

The goal of the current testing on the second series of carbon-enhanced VRLA batteries is to identify a carbon formulation and/or manufacturer that can build a battery for utility applications that will maintain a low gassing current, while providing the high-power, intermediate-SOC cycle performance with a long cycle-life.

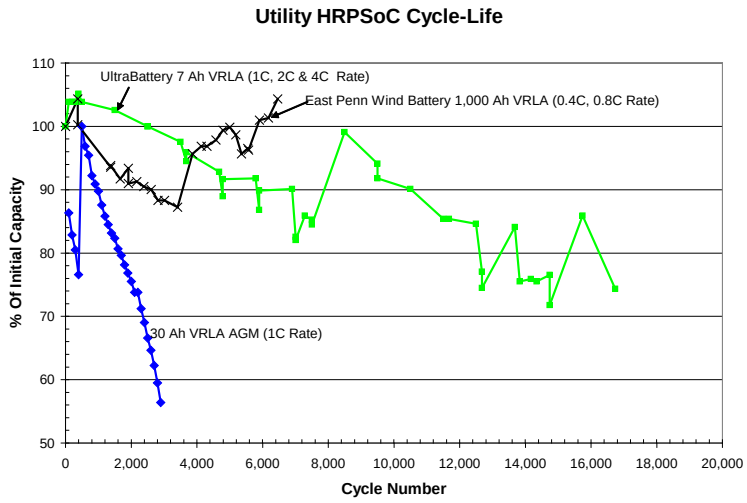
Key Project Events:

- MeadWestvaco and NorthStar Battery team to evaluate carbon formulations in the negative electrode of NorthStar VRLA batteries for utility applications. Two series of MeadWestvaco carbon formulations have been evaluated to date. This battery is designed for telecommunications systems.
- MeadWestvaco includes Battery Energy SunGels in their carbon formulation testing. This battery is designed for motive power and remote area power supplies.
- CSIRO/Furukawa provides Sandia with an Ultrabattery for utility cycle testing. This battery is designed for hybrid electric vehicles (HEVs).
- Sandia purchased an East Penn carbon enhances large format VRLA battery for testing. This battery is designed for utility cycling and wind farm power smoothing.
- The CSIRO/Furukawa Ultrabattery test results are published at the *18th International Seminar on Double Layer Capacitors and Hybrid Energy Storage Devices 12/08.* The results show a high rate partial state of charge cycle performance increase of at least 13 to 1 over conventional VRLA batteries.
- Sandia purchased 24 ea 1,000 Ah Ultrabattery cells in January of 2009 from Furukawa Battery for high-rate-partial-state-of-charge testing and for photovoltaic energy storage applications.

Project Status: Testing for FY09Qu2 is currently focusing on the new East Penn, carbon-enhanced, VRLA wind farm energy smoothing battery. The large format (1,000 Ah) Ultrabattery, with an asymmetric electrochemical supercap, manufactured by Furukawa in Japan and East Penn in the US, is now being purchased by Sandia for high-rate-partial-state-of-charge (HRPSoC) cycle testing.

The testing on the East Penn large format, carbon-enhanced, VRLA for wind power smoothing is progressing well and is showing a significant improvement in HRPSoC cycle-life over conventional VRLA batteries. This is the first large format, VRLA battery designed for partial state of charge cycling. If successful, the East Penn VRLA battery could be used directly in multi-megawatt energy storage systems, such as wind farm energy smoothing and/or utility voltage support and frequency stabilization.

Project Pictures / Graphs / Tables:



UltraBattery manufactured by Furukawa (Japan) and designed by CSIRO (Australia).

Designed for hybrid electric vehicles (HEVs). East Penn wind farm smoothing battery carbon enhanced VRLA for HRPSoC cycling.

U.S. Coast Guard National Distress System — Electric Power System Optimization Study

Date Project Began: FY2003

Date of This Project Report: January – March 2009

Sandia Project Manager (PM): Ben Schenkman

Contractor: Sandia National Laboratories (SNL)

Project Description: Sandia National Laboratories (SNL) is working closely with the US Coast Guard (USCG) to assist in the improvement of battery systems management in the electric power systems currently used at remote sites in the National Distress System (NDS). The battery management system is based on the results of a successful field test using the SNL-patented Symons Advanced Battery Management System (ABMAS) at SNL's Distributed Energy Technology Laboratory (DETL).

Key Project Events:

- Initial successful field test (2006) in which ABMAS improved battery state-of-health over the first several months of operation and the start/stop sequencing of the on-site propane generators resulted in shorter run times for the generators, which indicated the effectiveness of the advanced controller.
- Based on the successful initial test, the USCG expanded ABMAS to include other NDS sites

Project Status: Fire, Wind, and Rain delivered the upgraded version of the ABMAS late January 2009 and it is currently undergoing "burn-in." Due to the lengthy intervals between tests, SNL equipment such as the Mechron generators and battery strings must be continually evaluated for malfunctions because they are not being periodically exercised. This issue is to be resolved early April 2009. In early March, schematics of the installation at Bay Point, California were submitted to the USCG for approval. Once USCG has approved the schematic and "burn-in" testing is complete, SNL plans to install the unit, scheduled for late April 2009.

Manuals for the system are being completed by SNL technical writers. The installation manual is approximately 95% complete; the operation and maintenance manual is approximately 85% complete.

Pictures / Tables / Graphs: