DOE(SNL)/CEC Energy Storage Program
FYO07 Projects

September 27, 2007
San Francisco, CA

Daniel R. Borneo, PE
Sandia National Laboratories
Presentation Outline

• DOE(SNL)/CEC Collaboration
  – Background of DOE(SNL)/CEC Collaboration
  – FY07 Project Review
    • Zinc Bromine Battery (ZBB) Demonstration
    • Palmdale Super capacitor Demonstration
    • Sacramento Municipal Utility District (SMUD) Regional Transit (RT) Super capacitor demonstration
    • Beacon Flywheel Energy Storage System (FESS)
Background of DOE(SNL)/CEC Collaboration

• Memorandum of Understanding Between CEC and DOE (SNL).
  – In Place since 2004
  – Provides support to CEC in the implementation of Electrical Energy Storage Projects.
    • Project development and coordination
    • Technology transfer
    • Data Acquisition System (DAS) management
      – Monitor and analyze system performance
      – Provide economic evaluation of technology
DOE(SNL)/CEC FY07 Projects
Zinc Bromine Battery (ZBB) Energy Storage Demonstration

• Overview
  – Peak shaving project initiated in 2004
    • 2 MW/2 MWhr Zinc Bromine Battery demonstration

• Objective
  – Allow for Substation deferral
    • Demonstrate that Zinc Bromine battery system can cost effectively provide peak shaving

• Technology
  – Presently testing 500-kWh Zinc Bromine battery system
    • Two strings of five 50-kWh battery modules
    • 500 kWh dc capacity
    • 250 kW ac continuous; 500 kW ac peak
DOE(SNL)/CEC FY07 Projects
Zinc Bromine Battery (ZBB) Energy Storage Demonstration

ZBB’s 50 kWh module (3 stacks in parallel)

ZBB’s 500 kWh system (10 - 50 kwh modules)
DOE(SNL)/CEC FY07 Projects
Zinc Bromine Battery (ZBB) Energy Storage Demonstration

• Status
  – ZBB finished field testing of initial system at the DUIT facility in 2006
  – ZBB installed upgraded 500 kWh system at DUIT summer 2007
  – Presently system is in 40 day reliability testing
  – Upon successful completion of 40 day test, determination will be made whether to install additional 500 kWh systems for further evaluation

• DOE/SNL Role
  – Collect electrical data during demonstration and provide performance analysis
  – Conduct economic evaluation of system
DOE(SNL)/CEC FY07 Projects
Palmdale UltraCapacitor Demonstration

• **Overview**
  – *System developed by Northern Power (Distributed Energy Systems) to provide voltage ride through and conditioning*
    • Energy storage
    • PF correction
    • Harmonics

• **Objective**
  – *Develop and demonstrate an ultracapacitor based Electrical Energy Storage System for power reliability and power quality applications*
    • Power outage ride-through capabilities
    • Power factor correction
    • Power conditioning
DOE(SNL)/CEC FY07 Projects
Palmdale UltraCapacitor Demonstration

• Technology
  – Ultracapacitor system provides 450 KW for 30 seconds

One-line diagram of EnergyBridge system
One of four ultracapacitor cabinets
DOE(SNL)/CEC FY07 Projects
Palmdale UltraCapacitor Demonstration

• Status
  – System is assembled at Barre Plant
  – Operation acceptance test and factory commissioning completed
  – Unit will be shipped to the Palmdale site where a functional acceptance test will take place in Q4 CY07

• DOE/SNL Role
  – Technical advisor for storage technology
  – Collect electrical data during demonstration and provide performance analysis
  – Conduct economic evaluation of system
  – Conducted Factory commissioning test
DOE(SNL)/CEC FY07 Projects
SMUD/RT SES demonstration

• Overview
  – Voltage stabilization project
    • New power configuration needed to accommodate heavier and more powerful train cars
      – Existing configuration - 1 MW SS located every 2 miles
      – New configuration - 2 MW SS every mile

• Objective
  – Avoid cost of new substation by incorporating Static Energy Storage (SES) into existing lines and new expansions
    • Provide Voltage stabilization
      – Estimated 65 VDC increase from 600 V to 665V on 750 VDC system
    • Reduce Energy consumption
      – Estimated 35 – 55kWh energy savings
        • 7-10% energy reduction
DOE(SNL)/CEC FY07 Projects
SMUD/RT SES demonstration

• Technology
  – 1MW Siemens Static Energy Storage System SITRAS® SES
  • BCAP 3000 Maxwell UltraCapacitor
  • 1MW for 20 second

Dresden-Hellerau (Container Version)
DOE(SNL)/CEC FY07 Projects
SMUD/RT SES demonstration

**Functionality SITRAS® SES**

Energy exchange between vehicles through energy storage unit

Energy storage unit absorbs energy

Time $t_1$: vehicle 1 brakes

The energy storage absorbs the braking energy of vehicles and the energy can be given off after a time lag to the system.

**Optimizing the system voltage**

Energy storage unit supplies energy; the system voltage decreasing. Normal operation is guaranteed.

Time $t_2$: both vehicles accelerate at the same time

The energy storage unit absorbs energy and supplies energy to the system, when the system voltage is below a defined level.
DOE(SNL)/CEC FY07 Projects
SMUD/RT SES demonstration

Static Energy Storage System SITRAS® SES
Design: Single-line diagram

Connection unit | Converter | Capacitor bank
--- | --- | ---

DC Traction System
DC 600/750 V

<table>
<thead>
<tr>
<th>S₀</th>
<th>Disconnector</th>
<th>L₁</th>
<th>Line reactor</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁</td>
<td>DC-Circuit breaker</td>
<td>C</td>
<td>DC-link capacitor</td>
</tr>
<tr>
<td>R₁</td>
<td>Pre-charging resistor</td>
<td>V₁</td>
<td>Step-up/step-down converter</td>
</tr>
<tr>
<td>K₁</td>
<td>Pre-charging contactor</td>
<td>L₂</td>
<td>Chopper reactor</td>
</tr>
<tr>
<td>V₂, R₂</td>
<td>Discharging unit</td>
<td>C_{Bank}</td>
<td>Capacitor bank</td>
</tr>
</tbody>
</table>
DOE(SNL)/CEC FY07 Projects
SMUD/RT SES demonstration

• Static Energy Storage System SITRAS® SES
  – Capacitor bank consist of 30 Watchdog modules
    • Each module consists of 7 function blocks supervising capacitors connected in parallel.
  – Technical data of the capacitor
    • Voltage 2.7 V; capacity 3,000 F
    • Double-layer capacitors
DOE(SNL)/CEC FY07 Projects
SMUD/RT SES demonstration

• Static Energy Storage System SITRAS® SES
  – Converter: IGBT converter module
DOE(SNL)/CEC FY07 Projects
SMUD/RT SES demonstration

• Status
  – Phase I started in 2005 and included:
    • RT light rail system model simulation by Siemens Transportation Systems started in 2006 that analyzes the potential benefit of SES at specific locations
      – Detailed data collection and analysis by RT for input to the Siemens model
      – Detailed billing study by SMUD for all 34 RT substations
  – Phase II started in 2007 and includes:
    • Additional Data collection and cost analysis
    • SES operational for summer/Fall 2008
    • 15 month demonstration of SES System on Sacramento RT Light Rail Folsom Line
DOE(SNL)/CEC FY07 Projects
SMUD/RT SES demonstration

• DOE/SNL Role
  – Technical advisor for storage technology
  – Collect electrical data during demonstration and provide performance analysis
  – Conduct economic evaluation of system
DOE(SNL)/CEC FY07 Projects
Beacon Flywheel Energy Storage System (FESS)

• Overview
  – 100 KW 15 minute Power unit successfully demonstrated over 18 month test period (2005/06)
    • 7 ea. 15 KW flywheel units

• Objective
  – Show efficacy of flywheel technology for grid-scale frequency regulation

• Technology
  – Kinetic Energy Flywheel
    • Fast response
      – Full “up” or “down” regulation < 4-seconds vs. 5-minutes for conventional technology
DOE(SNL)/CEC FY07 Projects
Beacon Flywheel Energy Storage System (FESS)
DOE(SNL)/CEC FY07 Projects
Beacon Flywheel Energy Storage System (FESS)

• Status
  – Demonstration of 100 KW system successfully completed Dec 2006
  – Final reports in progress

• DOE/SNL Role
  – Technical advisor for storage technology
  – Capture electrical data during testing, provide performance analysis
  – Economic benefit/cost evaluation of commercial-scale plant
  – Facilitate commercialization
DOE(SNL)/CEC FY07 Projects Summary

• DOE/SNL continues to provide support to new and ongoing energy storage businesses and technologies
  – Technical performance and economic feasibility analysis
  – Technical consulting and advisory role

• Upcoming Projects
  – NaS battery installation
    • CEC/PG&E collaboration
  – VRB Battery
    • CEC/SMUD/Sprint Collaboration