Energy Storage Systems Program Project Highlights

John D. Boyes
ESS Program Manager
Sandia National Laboratories

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Systems Integration

Large Systems

Field Tests

Hybrid Systems

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Vernon BESS

GNB Industrial Power

- Lead Smelter: Battery Recycling
- Near Los Angeles, CA
- California Air Resources Board
- 5 MW, 3.5 MWH VRLA Battery
- 1996 Commissioning

1. Critical Load Backup
2. Energy Management

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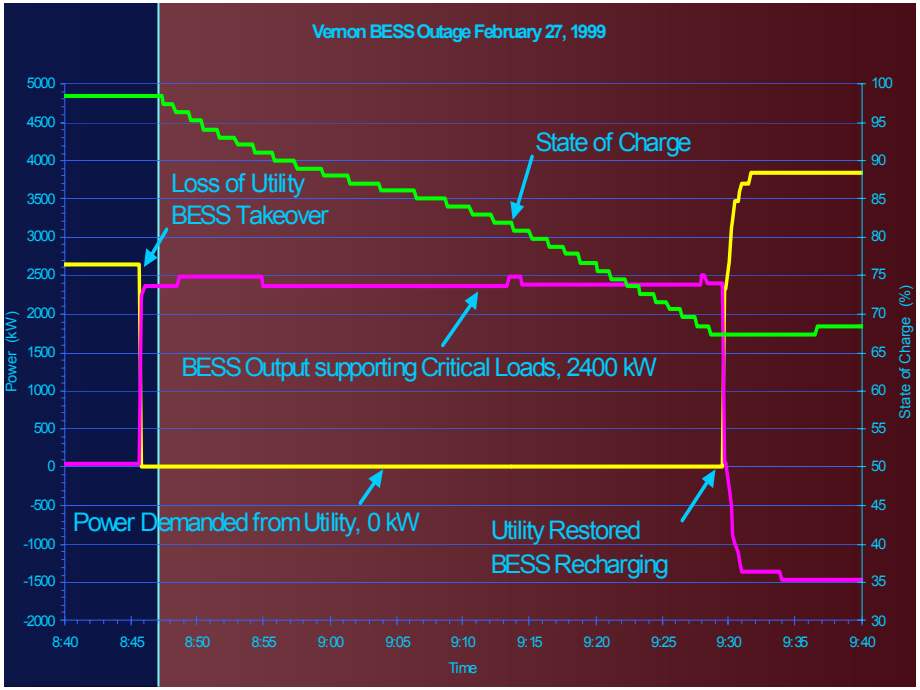
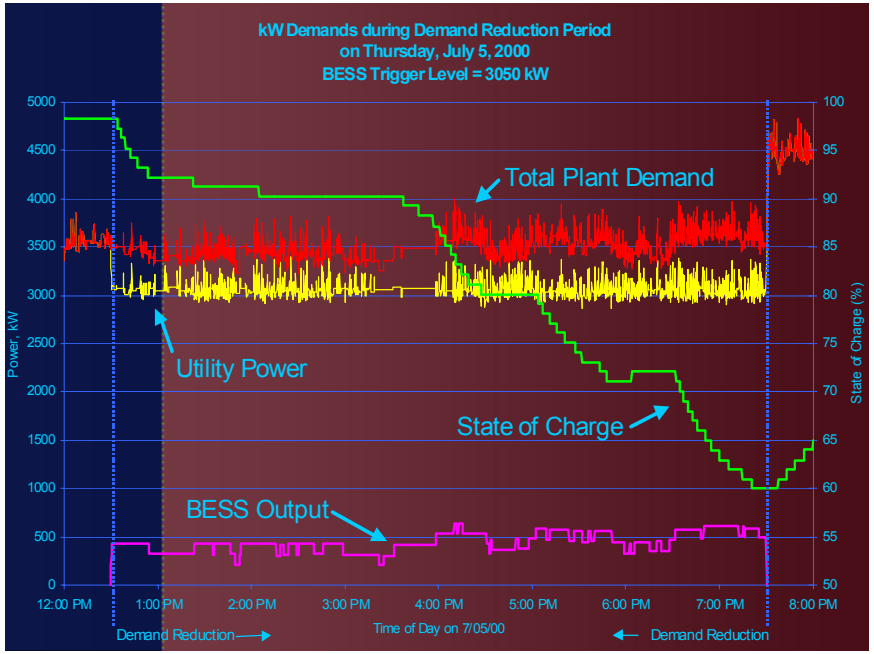
Vernon BESS Performance



Power Quality
45 Minute Utility Outage

Energy Management
500-600 kW
Peak Shaving



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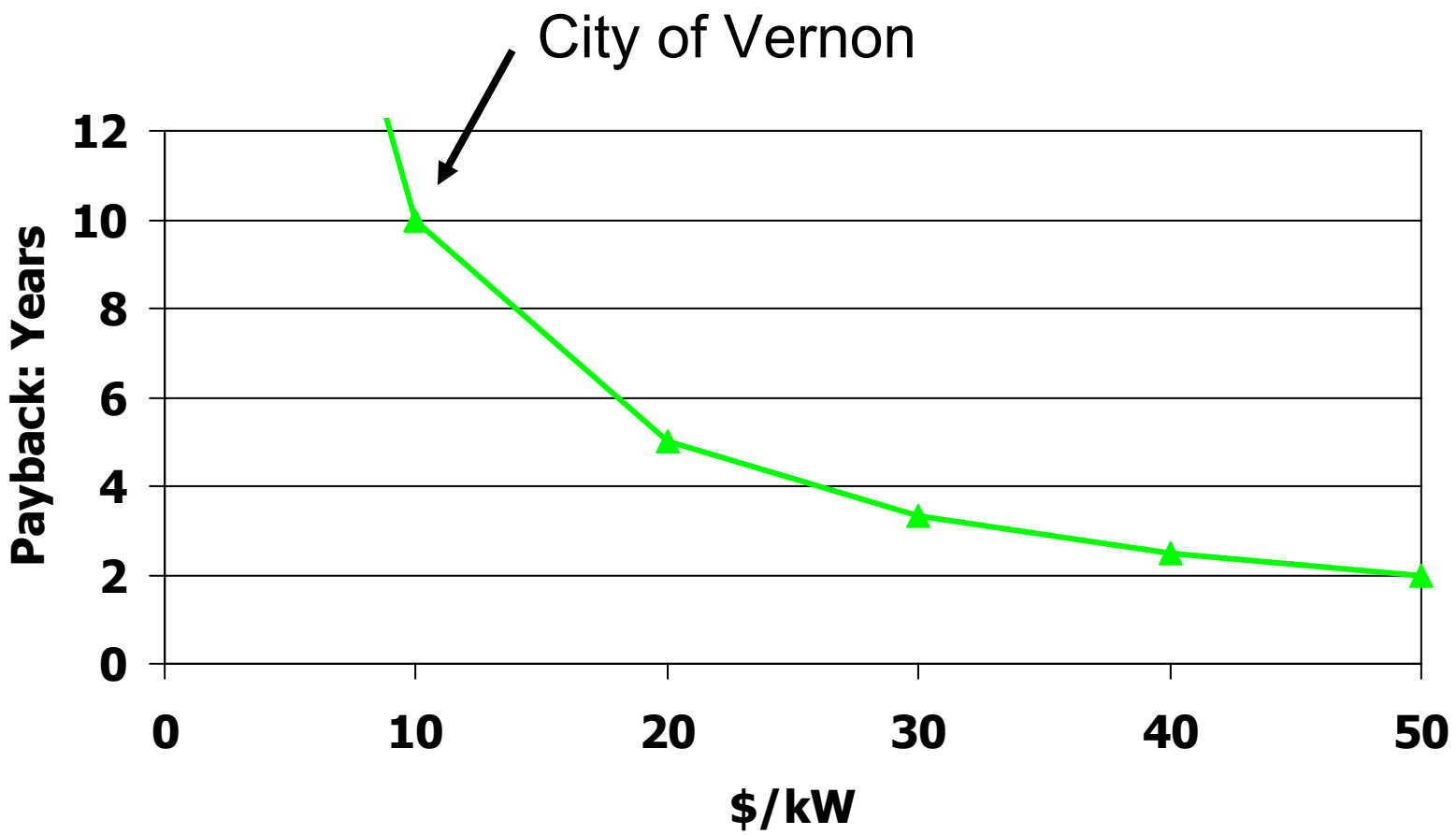
Effect of Rate Structure on Payback Period



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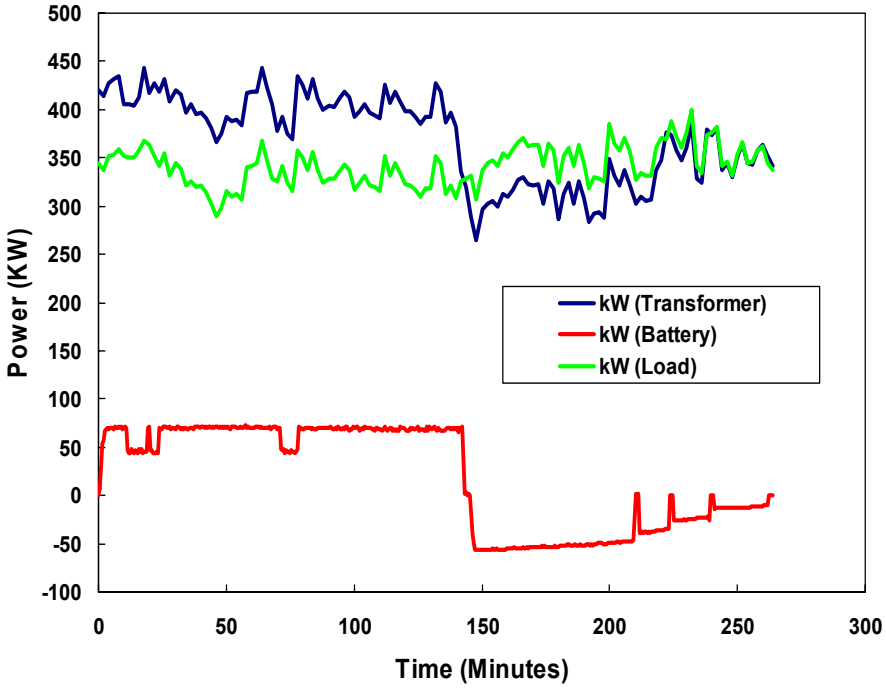
400 kWh Zinc Bromine BESS

ZBB Inc.

Detroit Edison

400 kWh ZBB System at Lum Site



- **Demonstrated Interconnection to utility**
- **Demonstrated ability on automatically control in peak shaving**
- **Invited back next summer**

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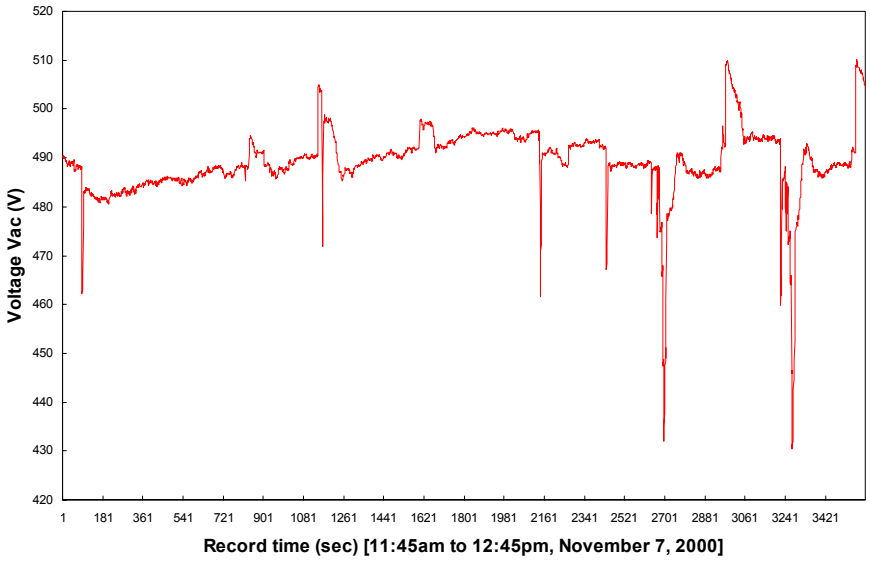
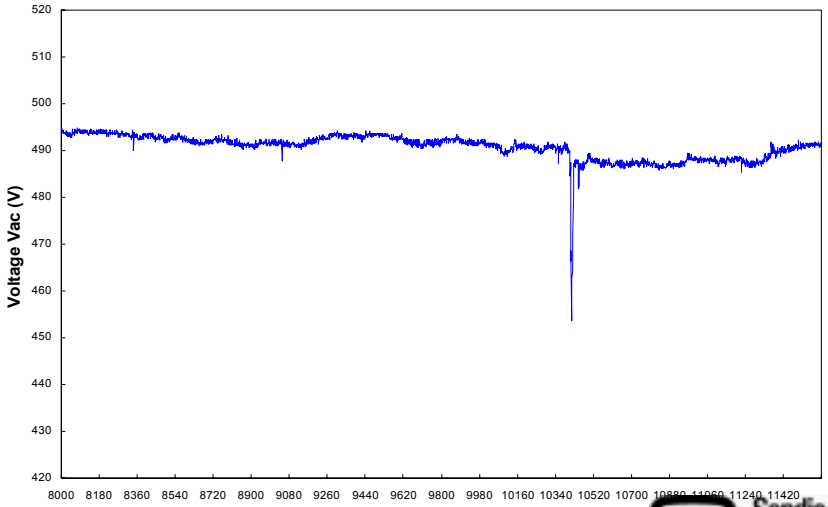
ZBB Power Quality Application



Akron MI, Grain Dryer Site



- **Reduced voltage drop due to 75 hp motor starts**
- **Eliminated spikes as dryer turns off**

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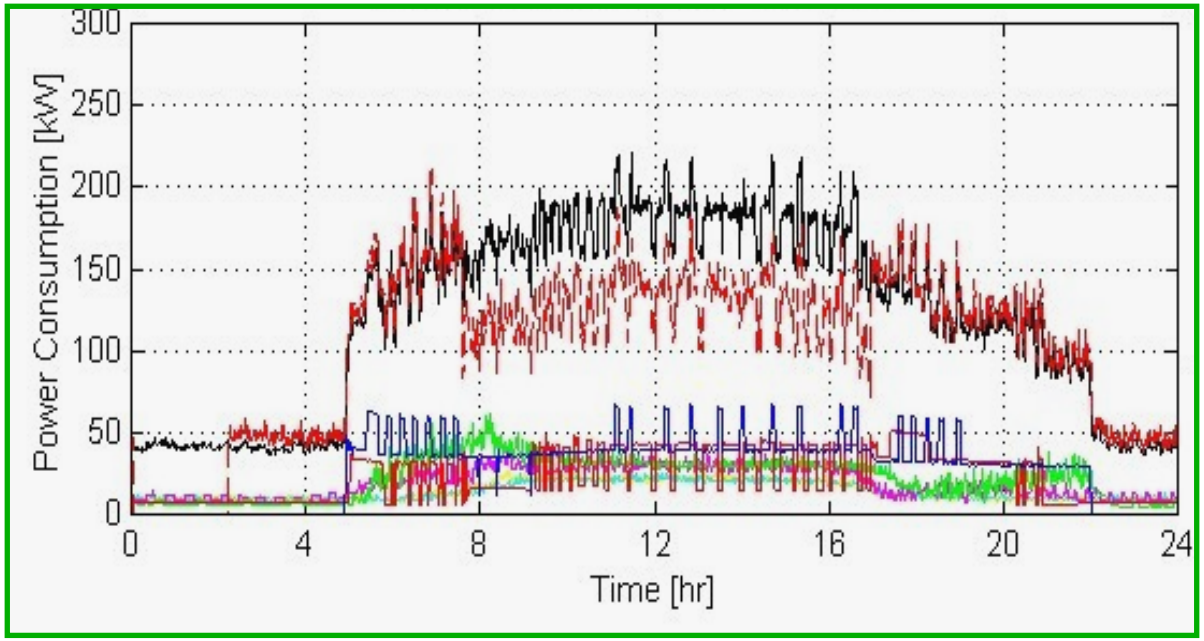
Energy Storage/Distributed Resource Options at the University of Maryland

Energetics Inc

Evaluate the net benefit of electricity storage at University of Maryland (UM) Chesapeake Building



Chesapeake Building Load Profile with Microturbine BCHP

- **Flooded Lead-Acid Battery**
- **Valve-Regulated-Lead-Acid Battery**
- **Zinc Bromine Battery**
- **Power Quality Battery**
- **Diesel Generator**
- **Microturbine**
- **Phosphoric Acid Fuel Cell**

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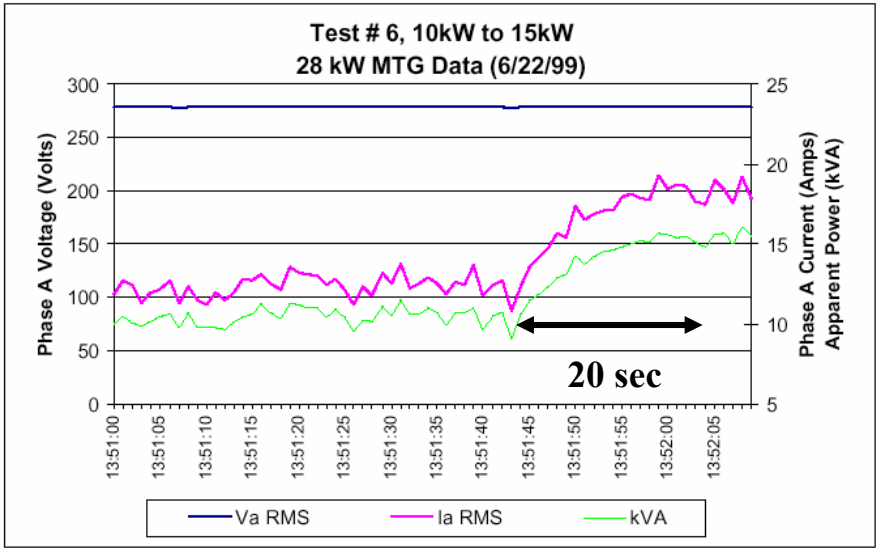
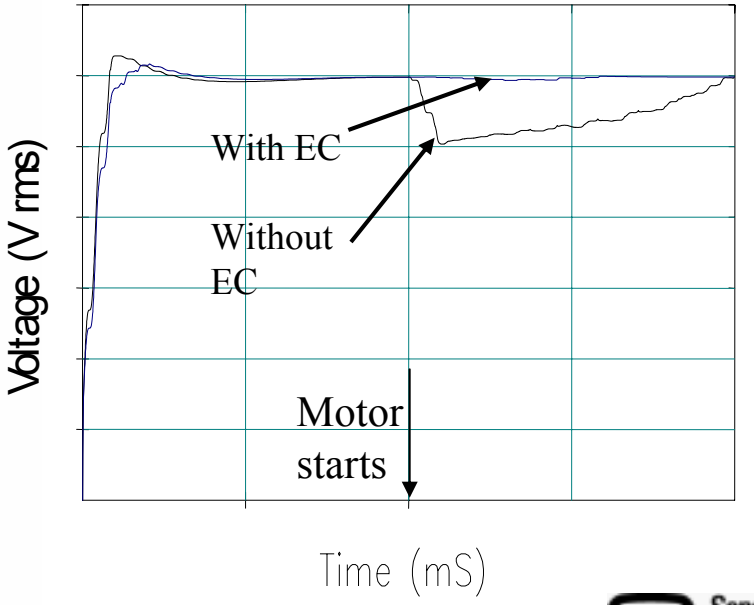
Extending DER Transient Response Using Super Capacitors

Dr. Satish Ranade, New Mexico State University
EPRI PEAC, Sandia National Laboratories

Distributed Energy Resources (DER) suffer lags in responding to transient loads.
Energy Storage could assist DER in transient conditions.





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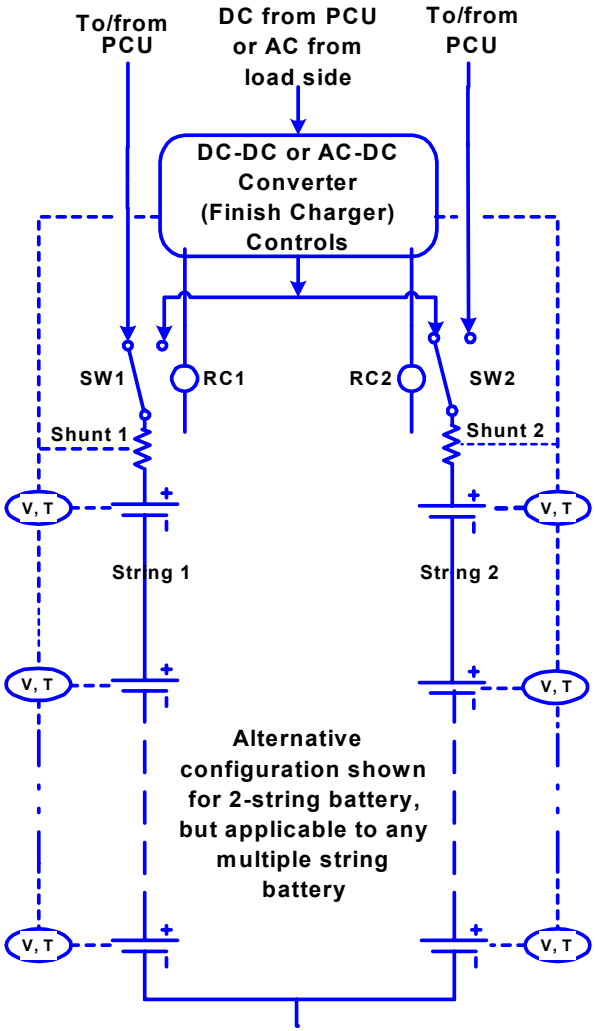
Alternative Configurations to Optimize Lead-Acid Batteries for Renewable Generation and Storage (RGS)

Dr. Philip Symons, EECI
Sandia National Laboratories

- **Battery finishing charge & generator "de-coupled"**
- **Can utilize PV for and while finish charging**
- **Easily made smart relative to expected load & solar**
- **Module volts and temp's to control finish charging**
- **Opportunity to maximize battery and system life, performance, and to minimize life-cycle-cost**



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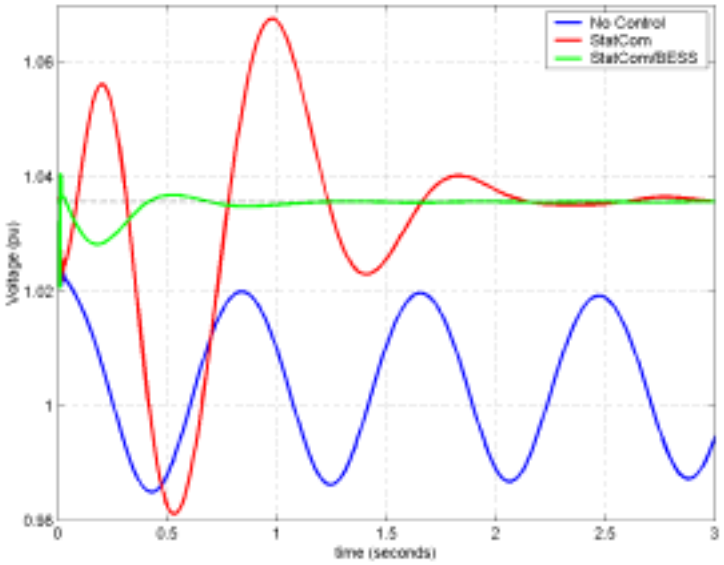
Integration of FACTS and Battery Energy Storage

Dr. M. L. Crow
University of Missouri-Rolla, Rolla, MO

StatCom Front Panel



Performance Comparison
StatCom vs. StatCom/BESS

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PV-Hybrid System Field-Test Monitoring At STAR

Bob Hammond, Arizona State University
Arizona Public Service Co.

- Partner With a Progressive Electric Utility with Mutual Interests [i.e. APS]
- Develop a Renewable Generator & Storage (RGS) Operational Strategy To Improve Battery Life Cycle Costs for Off-Grid Hybrid Systems
- Support the Development of a New Technique to Equalize Individual Strings of a Battery Bank

Fully test systems with <u>all</u> components before installing in the field. Especially SN 001

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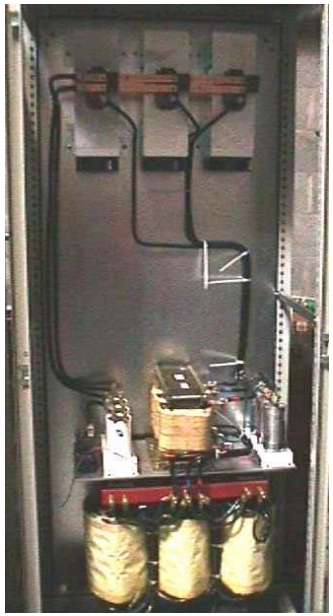
Renewable Energy Systems for Peruvian Amazon Region

ILZRO, Orion Energy Corp.

PV/Battery/Diesel Hybrid Systems

- Project led by ILZRO
- ESS funding data acquisition
- Multiple International partners



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Subsystem Development

Flywheel

Advanced Batteries

Power Electronics

Controls

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Superconducting Flywheel Development

Boeing Phantom Works

Joint Project with Superconducting Project Initiative

Advantages of Superconducting Bearings

Much lower frictional losses No electronic bearing controls required

Simple bearing design

Passive control for greater reliability and life

Lower weight, cost, and maintenance

ESS Project Goals

- Develop low-cost rotor/bearing
- Determine & enhance system reliability

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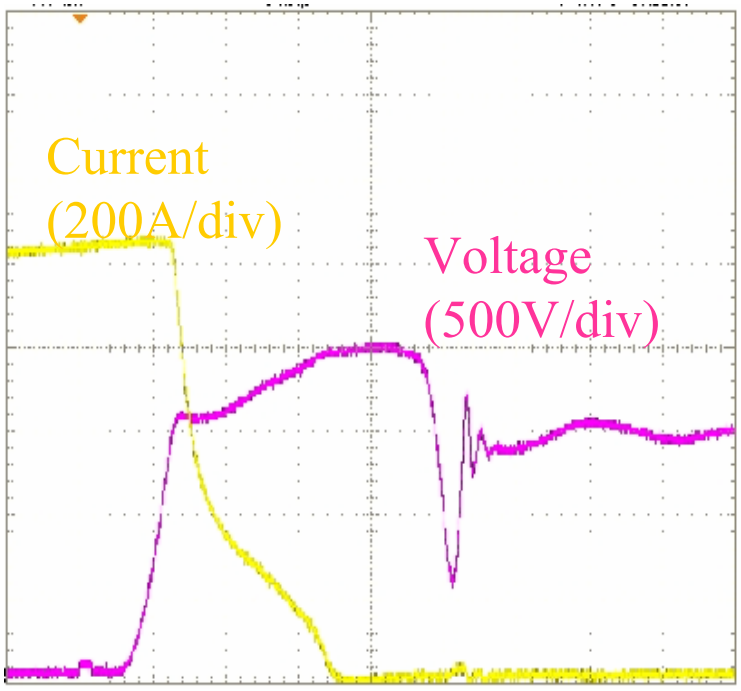
Emitter Turn-off (ETO) Thyristor Development

Dr. Alex Q. Huang
Center for Power Electronics Systems, Virginia Tech



Gen-3 ETO Prototype (OCT. 2001)

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An Optically Isolated HV-IGBT Based Mega-Watt Cascade Inverter Building Block for DER Applications

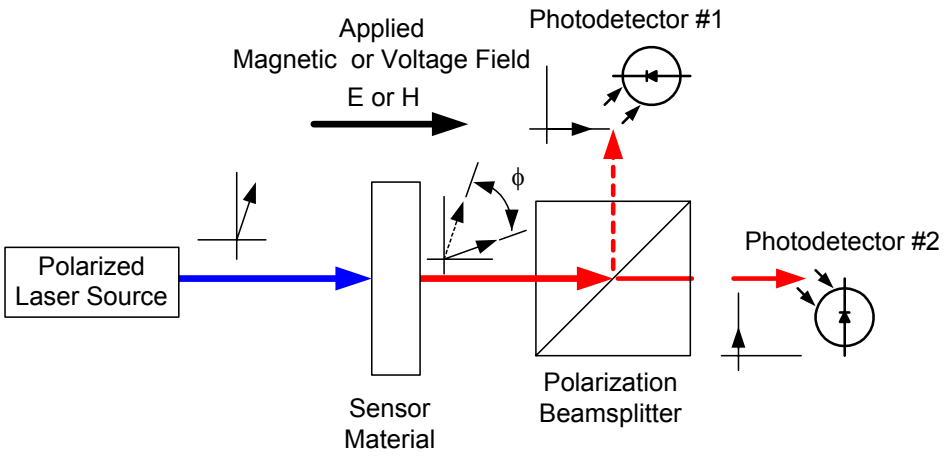
Airak Inc., Dr. Jason Lai CPES Virginia Tech Univ.

SBIR Contract Managed by the ESS Program

Develop 3 phase, IGBT based, MW inverter with optical current, voltage and temperature sensing and command/control interfacing

Why Optical Sensors

- **Intrinsic Safety**
- **Intrinsic Isolation**
- **Increased Reliability**
- **Higher Response**
- **Greater Dynamic Range**
- **Small Size and Weight**



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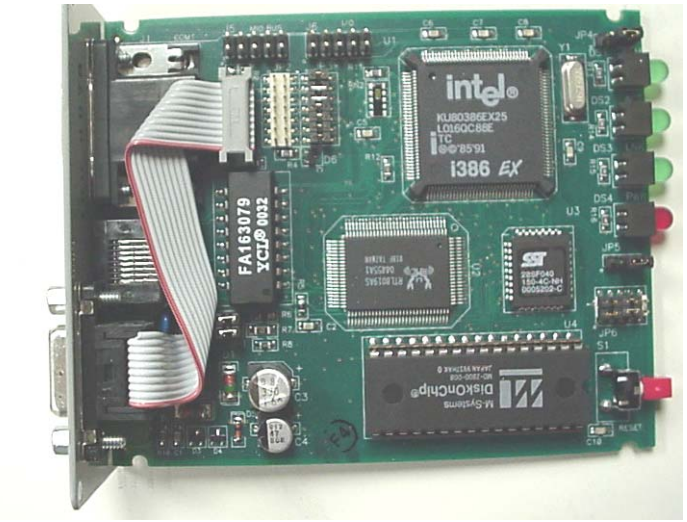
Advanced Hybrid Controller

Advanced Energy Inc.

Improve hybrid & minigrid power system performance

- **Simplifying Integration**
- **Increasing Reliability**
- **Reducing Cost**
- **Increasing Flexibility**

- **Separation of Inverter and Controller**
- **Standard Component Communications Protocol**
- **Droop mode control for paralleling multiple units**
- **Heuristic optimization of single-unit systems**



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Strategic Research

Analysis

Standards

Reporting

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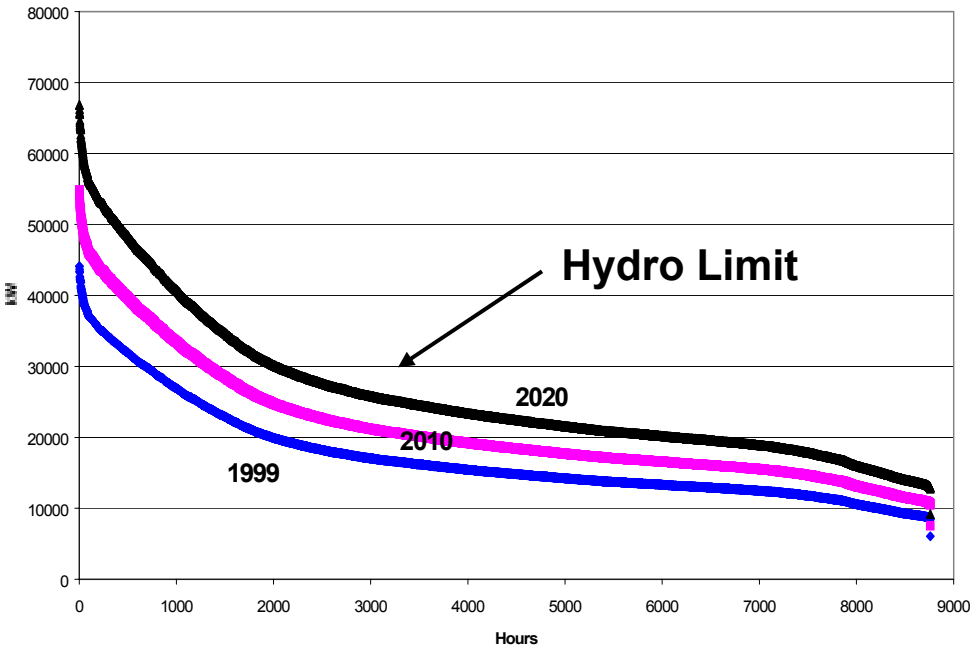
Boulder City Battery Energy Storage Pre-Conceptual Design Study

Black and Veatch
Gridwise Engineering



Load Duration Curve

2.5 MW, 10 MWh System

Sodium Sulfur,
Vanadium Redox,
Zinc Bromine Technologies

- **are technically viable**
- **have sufficient project experience**
- **are compact enough to fit in available land**
- **can be constructed in the anticipated timeframe**

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Battery/Diesel Hybrid Systems

Sentech, Inc., Alaska Energy Authority, USAID

Diesel generators are inefficient when operated at light loads

- Identified two operating regimes:
  - –Peak Shaving – reduce diesel size, meet peaks with battery
  - –Cycle Charging – run diesel at more efficient full loading

Diesel Size (kW)	60 (retrofit)	55	50	45
Battery Size (kWh)	13.2	15.8	19.2	20.4
Fuel Savings (over 85 kW diesel)	10.6%	12.7%	14.6%	16.3%
Projected Battery Life (yr)	7.0	5.9	2.2	1.0
Net Annual Savings ($/yr)	$4,407	$2,505	$1,532	$1,549
Payback of Net Hybrid Investment (yr)	Immediate	0.75	2.2	1.4

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Development of Design Practices for PV/Battery Remote Area Power Supplies (RAPS)

Energetics Inc.
Sandia National Laboratories

- **Support development and facilitate coordination of standards and recommended practices for RAPS, concentrating on the storage system**
- **IEEE Standards Coordinating Committee 21 (SCC21)- Energy Storage Working Group**

- **Published four Recommended Practices involving the sizing, installation, and maintenance of lead-acid and nickel/cadmium batteries in PV applications**
- **Developing two Guides for the use of lead-acid batteries**
  - **Hybrid RAPS Systems (PAR 1561)**
  - **Stand-Alone PV Systems (PAR 1361)**
- **Coordinating activities with IEEE SCC29 (Batteries) and Power Engineering Society**

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Value of Storage for Restructured Utilities

Joe Iannucci, Distributed Utility Associates

Characterize Innovative Storage Market Opportunities

"High T&D Value & High Power Price Volatility"
(five hours of storage capacity is required)

1. **Power/Output Capacity Potential Over 10 Years = 10% of load growth of 240 GW = 24 GW**
2. **Storage Capacity Potential For 10 Years = 120 GWh**
3. **Storage value = value of T&D equipment deferral ($90/kW-yr) + spot price swings (20¢/kWh) = $218/kWh**
4. **Total benefit = 120 GWh*$218/kWh = $26 Billion**

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