Energy Storage and Microgrids

Presented by
Ben Schenkman

March 12, 2019
Outline

• Sandia Energy Storage Program Overview
• Microgrid Resiliency Sandia
• Energy Storage Microgrid Application
• Energy Storage Evaluation
• Demonstrations and Lessons Learned
Energy Storage is a Major Crosscut

Wide ranging R&D covering energy storage technologies with applications in the grid, transportation, and stationary storage.
Major R&D Thrust Areas

- **Materials Research** – Advancing new battery chemistries through technology development and commercialization.

- **Power Electronics** – Optimization at the interface between power electronics and electrochemistry. Power electronics including high voltage devices (SiC, GaN), high voltage passives and magnetics.


- **Energy Storage Analytics and Controls** – Analytics and controls for integration of utility class storage systems. Software tools for optimal use of energy storage across the electricity infrastructure. Standards development.

- **Energy Storage Project Development** – Support for demonstration projects.

- **Industry Outreach** – Outreach to utilities, regulators, and the industry.
What We Do and Why

- Work with Utility, Industrial, Commercial, Private, State and International entities to:
  - Provide *third party independent analysis* for cells and systems
  - Support the development and implementation of *grid-tied ES* projects
    - Application/Economic analysis
    - RFI/RFPs
    - Design and Procurement Support
    - Commissioning Plan Development
  - Monitor and analyze operational ES Projects
    - Differing applications
    - Optimization
    - Operational performance
  - Develop public information programs

- Goal
  - Inform the Public and encourage investment.
Outline

• Sandia Energy Storage Program Overview
• Microgrid Resiliency Sandia
• Energy Storage Microgrid Application
• Energy Storage Evaluation
• Demonstrations and Lessons Learned
# Energy Surety Microgrid Efforts

## Conceptual Designs/Assessments
- Creech AFB – FY12 DoD
- Soto Cano – FY12 DoD
- West Point FY12, DoD/DOE
- Osan AFB, FY 12, DoD
- Philadelphia Navy Yard – FY11, DOE OE/PIDC
- Camp Smith – FY10, DOE FEMP
- Indian Head NWC – FY09, DOE OE/DoD
- Ft. Sill – FY08, Sandia LDRD
- Ft. Bliss – FY10, DOE FEMP
- Ft. Carson – FY10, DOE FEMP
- Ft. Devens (99th ANG) – FY09, DOE OE/DoD
- Ft. Belvoir – FY09 DOE OE/FEMP
- Cannon AFB – FY11, DOE OE/DoD
- Vandenberg AFB – FY11, DOE FEMP
- Kirtland AFB – FY10, DOE OE/DoD
- Maxwell AFB – FY09, DoD
- Ft. Sill – FY09, DoD w/ SNL serving as advisor
- Ft. Sill – FY09, DoD
- Cannon AFB – FY09, DOE OE/DoD
- Maxwell AFB – FY09, DoD/DOE
- Alaska Villages– FY12, DOE
- Bagram – FY13, DoD
- Kuwait – FY15, DoD
- 29 Palms – FY14, DoD
- Korea Naval Academy – FY16, DoD
- Kauai – FY15, DOE
- Northhampton, MA – FY14, DOE
- New Orleans – FY17, DOE
- UPS in KY – FY17, DOE
- Puerto Rico – FY19, DOE

## Small Scale Microgrid Demos
- Maxwell AFB – FY09, DoD
- Ft. Sill – FY09, DoD w/ SNL serving as advisor

## Large Scale Microgrid Demos
- SPIDERS JCTD – FY11, DOE/DoD
  - Camp Smith
  - Ft Carson
  - Hickam AFB
  - Cordova – FY19, DOE

## Operational Prototypes

---

*Map showing various locations where microgrid efforts have been undertaken.*
Resilience Definition

**Presidential Policy Directive (PPD) 21**

“the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruption. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents.”

-PPD-21: *Critical Infrastructure Security and Resilience*

- Resilience is defined in context of multiple hazards and not to be confused with sustainability and efficiency which are also important
The grid is the keystone infrastructure – central to the web of interconnected systems that support life as we know it.
Resilient Community Design Framework

1. Determination of Resilience Drivers
   - Determine Resilience Metrics and Threats
   - Threat and Impact Forecasting

2. Community Resilience Analysis
   - Multi-Infrastructure Performance Analysis
   - Consequence Estimation

3. Resilience Alternatives Specification
   - Resilience Technology Screening
   - Regulatory Framework Screening
   - Resilience Service Screening

4. Evaluation of Resilience Alternatives
   - Translation to Stakeholder KPI’s
   - Calculate Co-benefits (Reliability, Cost of Service, etc)
   - Multi-Stakeholder Cost-Benefit
   - Multi-Criteria Portfolio Evaluation

Stakeholders Engaged:
- Local Government
- Electric Utilities
- State/Local Regulators
- Community Groups
- Infrastructure Owners

Evaluating alternative regulatory decisions in the same manner that we evaluate investments.
1. **DETERMINATION OF RESILIENCE DRIVERS**

Deciding what we want to be resilient to, which infrastructure systems matter the most, and how we will determine consequence to our communities.

**Measure Classification**

<table>
<thead>
<tr>
<th>Measure Classification</th>
<th>Common Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community Measures</td>
<td>Number of People Without Necessary Services</td>
</tr>
<tr>
<td></td>
<td>Lives at Risk</td>
</tr>
<tr>
<td>Economic Measures</td>
<td>Societal Burden to Acquire Services</td>
</tr>
<tr>
<td></td>
<td>Gross Municipal Product Loss</td>
</tr>
<tr>
<td></td>
<td>Change in Capital Wealth</td>
</tr>
<tr>
<td></td>
<td>Business Interruption Costs</td>
</tr>
</tbody>
</table>
Understanding the current community risk – in units of consequence – to extreme events over a planning horizon
3. SPECIFICATION OF RESILIENCE ALTERNATIVES

- Alternative investments
  - Utility, city, or third party
- Alternative regulatory approaches
  - Performance-based
  - Incentives-based
  - Cost causation
- Alternative utility business models
  - Resilience as a service
  - Increased integration with insurance products

Proposing alternatives requires design capabilities inclusive of consequence-based resilience metrics
4. Evaluation of Resilience Alternatives

- Evaluation based on resilience performance in addition to:
  - Blue sky cost benefit
  - Sustainability metrics
  - Other?

Evaluation depends on the evaluator and the specific planning process.
Metrics to Evaluate Microgrid Portfolio (Puerto Rico)

Goal is to:
- Assess microgrid impact resilience
- Choose optimal portfolio of all the potential options

Sandia uses two primary metrics to evaluate resiliency of portfolio of microgrids:
- Percent of Services Covered (taking into account design basis threat such as floods)
- Burden to the community to acquire services

The cost for each microgrid in the portfolio is evaluated

**Effort (Distance)**
Overall time necessary to acquire service

**Ability (Speed)**
Median household income for census block

\[ B_C = \sum_{inf} \sum_{pop} \frac{E_{inf, pop}}{A_{pop}} \]
Services Covered by Microgrid (Puerto Rico)

66 Microgrid Identified

Resilience Node Contributions to Each Service - 100 Year Flood
Evaluating Burden for Microgrid Portfolios

Recognize complementary nature of certain microgrids

Goal is to design a system of microgrids to decrease overall burden
The random portfolios shown here have on average 33 microgrids and range of 16-50.

A large decrease in burden can be achieved for relatively low cost compared to all 66 microgrids.

Can obtain similar level of reduced burden for much less than cost of investing in total portfolio.
Outline

- Sandia Energy Storage Program Overview
- Microgrid Resiliency Sandia
- Energy Storage Microgrid Application
- Energy Storage Evaluation
- Demonstrations and Lessons Learned
Energy Storage Interconnection Points

- Substation Microgrid
- Full Feeder Microgrid
- Single Customer Microgrid
- Partial Feeder Microgrid
Energy Storage Connection

- Seamless Transition is Possible
- Does not require external signal to trigger Voltage source mode

Series

- Less Equipment = Lower Capital Cost
- Easily Expandable
- Simple Controls

Parallel

Microgrid Load
Energy Storage Technology

Image Credited to DOE/EPRI 2013 Electricity Storage Handbook
Topology Evaluation

- Central (Big) vs Distributed (Multi-Small)
Grid Tied Applications

- Energy Storage in Microgrid Application While Grid Tied
  - Peak Shaving
  - Frequency Regulation
  - Renewable Smoothing/Firming
  - Voltage Support
  - Power Quality
  - Demand Response
  - Distribution/Transmission Upgrade Deferral
  - Transmission Congestion Relief
  - Spinning Reserve
  - Arbitrage
  - Generation Fuel Deferral
  - Load Following (Ramp Rate Mitigation)
  - Uninterruptible Power Supply
Energy Storage Duty Cycle in Microgrid

- Peak Shaving
- VAR Support
- Power Quality

Add Renewables

- Add Frequency Regulation
- Remove VAR Support and Power Quality
Outline

- Sandia Energy Storage Program Overview
- Microgrid Resiliency Sandia
- Energy Storage Microgrid Application
- Energy Storage Evaluation
- Demonstrations and Lessons Learned
Energy Storage Before Economic Analytics

- Network Transmission Integration Customer
- 500kW/1MWh Lithium Ion Installed
- Integrated with Rooftop PV (Approximately 50kW)
- Designed to backup power for an emergency shelter and demand management

Behind the Meter Peak Shaving

$6,000 Cost Avoidance
Energy Storage Before Economic Analytics

- In Front of Meter
- Energy Arbitrage and Peak Demand Reduction
- Performed at Full Charge and Discharge Profile
- Approximately $20,000 annual Cost Avoidance
- \( \text{NPV}_{12} @ 5\% \text{discount} \approx -1.322 \text{M} \)
- Simple Payback is 75 years
Energy Storage Analytics

Estimating the value of energy storage

- Production cost modeling
  - Stochastic unit commitment/planning studies
  - Linear Programming Optimization
  - Control strategies for distributed storage
- Wide area control
- Control and architectures for kWh-GWh

Energy Storage Systems

T&D simulation with energy storage (PSLF, OpenDSS, MATLAB)

Supporting Public policy: identifying and mitigating barriers

Standards development and DOE Protocols

Project evaluation

- Technical performance
- Financial performance
Energy Management and Dispatch Controls

- Optimized economic dispatch algorithm development for grid tied and islanded systems
- Resilient and Stacked application development
- Validation through real time power hardware-in-the-loop and field validation
Energy Storage Software Suite

https://energy.sandia.gov/quest-optimizing-energy-storage/

• Open source, Python-based energy storage analysis software application suite.

• Developed as a graphical user interface for optimization and analysis capabilities of SNL’s energy storage group.

• Initial development driven by Pyomo models for energy storage valuation in market areas.
  • Behind the Meter and Market Areas

• Now publicly available on GitHub
  • https://github.com/rconcep/snl-quest
Outline

- Sandia Energy Storage Program Overview
- Microgrid Resiliency Sandia
- Energy Storage Microgrid Application
- Energy Storage Evaluation
- Demonstrations and Lessons Learned
SANDIA/DOE ES Projects

International Projects:
- Canada - WEICAN
- Singapore - EMA

FY18 Projects
- California Energy Commission (CEC)
- Eugene Water and Electric Board (EWEB)
- Alaskan Center for Energy and Power (ACEP)
- Cordova Electric Co Op
- Green Mountain Power (GMP)
- Electric Power Board Of Chattanooga (EPB)
- Helix
- Burlington Airport
- New York State Energy Research and Development Authority (NYSERDA)
- Connecticut (DEEP)
- Sterling - Cape and Vineyard - Holyoke
Sterling Municipal Light Department

Installed a 2 MW/3MWh battery storage system in Sterling Massachusetts

The system can isolate from the grid in the event of an outage

Along with the existing PV array, it can provide 12 days of backup power to the Sterling police station

Saves the town ratepayers $400,000 per year by decreasing the costs associated with capacity and transmission charges
**SMLD Issues and Lessons Learned**

**Issue**
- Lack of knowledge and experience regarding procurement of a combined system lead to a difficult and arduous process for vendors

**Lessons Learned**
- For successful integration of storage, it can be helpful to have 1 project combining PV and Storage done by 1 company rather than 2 separate projects done by 2 companies
- There is a growing need for companies who can do both
Green Mountain Power

Installed in Rutland, Vermont
4MW/3.4MWh of a combined lead-acid and li-ion system
Integrated with 2.5 MW of PV
Helps with ancillary services, backup power for an emergency shelter, and demand management
Saved approximately $300,000 by reducing annual and monthly peak
GMP Issues and Lessons Learned

Issues
- Project built with 4 - 500KW multi input (DC) inverters
- 500KW ea. of LA and Li-ion, plus ~500KW of PV per inverter
- Inverters limit output
  - Reduced demand reduction capability

Lessons Learned
- Not designing for flexibility of applications limited DR value
Contact Information

Benjamin Schenkman  
blschen@sandia.gov  
(505) 284-5883

Tu Nguyen  
tunguy@sandia.gov  
(505) 844-1722

Dan Borneo  
drborne@sandia.gov  
(505) 284-9880

David Copp  
dcopp@sandia.gov  
(505) 284-2284

Frank Currie  
fmcurri@sandia.gov  
(505) 844-8852