Comparing Current and Future Storage Technologies and Their Applications

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John L. Del Monaco, P.E.
Manager-Emerging Technology and Transfer
PSEG Services Corp.

Public Service Enterprise Group

- PSEG Power LLC – 2009 Operating Revenues: $7.1 Billion
- PSE&G – 2009 Operating Revenues: $8.2 Billion

- Nuclear – 53%
- Coal – 24%
- Oil/Natural Gas – 23%
Discussion Points

- Assessing Infrastructure Integration
- Overcoming Economic and Policy Challenges
- Drivers for Energy Storage
- Storage Options
- Technology Comparisons
- PSEG Storage Projects

Assessing Infrastructure Integration

- **Converts variable renewable resources** (wind and solar) into firm, dispatchable resources available when customers need power
- **Enhances grid reliability**, which will become increasingly important as variable renewable resources become a larger part of the supply equation
- **Optimizes the utilization of transmission**, minimizing new required construction
- **Increases the value of renewable resources** by shifting production from low-demand, low-price periods (wind generation is greatest at night) to high-demand, high-price periods (reducing the overall price of power to customers)
Overcoming Economic and Policy Challenges

- Capital Cost of Storage
- Lack of incentives for development and commercialization
- Uncertain federal and state regulatory terrain
- Depressed energy markets and tight credit markets

Interest in MWH Scale Electric Energy Storage

- Managing Increased Wind Penetration
- Ancillary Services – Avoiding the cycling of thermal power plants
- Managing Grid Peaks and Outage Mitigation
Need to Shift Some Wind Energy Production from Off-Peak to On-Peak

January 6, 2005 California Wind Generation

Source: California ISO

Grid Frequency Regulation Opportunities for Fast Storage Systems

Current method to balance constantly shifting load fluctuation is to periodically adjust generation in response to an ISO signal.
PJM: Issues Arising with Intermittency of Wind Power Integration

- Difficult to schedule or predict, spawning the need for wind forecasting
- May require holding extra reserves or committing CTs to ensure drop in wind can be covered
- May require backing down baseload units when wind picks up even during shoulder or peak hours
- Has already experienced negative prices with 4 GW of wind generation (40 GW is planned).

Interest in kWh Scale Electric Energy Storage

- Electric Transportation
- Managing Grid Peaks and Outage Mitigation
- Provide Customer Load Control
- Improved Integration of Small Scale PV (Facilitate Zero Energy Home)
Storage Options

- Pumped Storage
- CAES
- Batteries
- Flywheels

The Yards Creek Generating Station is a 400 MW pumped-storage hydro plant located five miles northeast of the Delaware Water Gap in Warren County, NJ. PSEG has a 50% ownership with First Energy, who operates the facility.
Compressed Air Energy Storage (CAES)

- First US CAES Plant: Alabama Electric Cooperative McIntosh Plant (110MW – 26 Hr)
- Started commercial operation: midnight May 31, 1991

Advanced CAES Plant
Sodium Sulfur Batteries - NaS

1 MW / 7.2 MWh  NYPA – End-User Peak Shaving

Advanced (Dry Cell) Lead Acid Type Batteries

1.5 MW / 1 MWh unit tested for Wind Farm Application

- Technology assessment & evaluation
- Evaluate field units in wind application
- Plan future utility-scale demonstration
- Assess potential as bulk storage applications
Flow Batteries – Zn / Br
Gaining Utility Consideration for Grid Support Applications

Vanadium Redox Flow Battery Applications
New Products and Systems being Developed by Prudent Energy

-250 kW, 2 MWh unit at Castle Valley, Utah (PacifiCorp)
2 MW Lithium Ion System for Frequency Regulation

Early Field Trials by:
- Altarnano
- A123

Flywheel Energy Storage

Artist rendering of a 20 MW flywheel facility. 200 high-energy (25 kWh/100 kW) flywheels and associated electronics, will be able to provide 20 megawatts of "up and down" regulation—equal to a 40-megawatt swing. Photo Courtesy Beacon Power.
### Energy Storage Options

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#### System Power Ratings

- 100 kW
- 1 MW
- 10 MW
- 100 MW
- 1 GW

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### Performance Comparison of Storage Devices

#### Relative Performance of Various Electrochemical Energy Storage Devices

- **Battery Metrics**
  - Energy Density
  - Power Density
  - Cost
  - Cycle Life
  - Calendar Life
  - Safety

Source: LBNL
Market Application for Energy Storage

Market Application for Energy Storage (Without Niche Applications)
Current PSEG Program Focus

- Leverage EPRI research
- Two technologies have most promise based on cost and performance characteristics*
- CAES for >10 hrs energy storage
- Li –ion for < 4 hrs of storage


CAES2 Process Cycle

- 172 MW Total Power @ 3771 BTU/kWh
- Input MWhr
- Output MWhr

Modern CAES – CAES2
- 2MW to 450MW for 10+ hours @ 3750 BTU/kWh
- Two DOE stimulus grant winners (NYSEG + PG&E = $55M) based on ~$850/kW for 8 hours => $100/kWh
- Only fuel burned in Gas turbine block using OEM Dry Low NOx combustors
- Energy ratio = .71 (energy in/energy out)
Lithium-Ion Battery

- Utility applications: frequency regulation, VAR support, distribution grid infrastructure support (especially for large PV arrays)
- Customer applications: peak shaving, residential storage coupled with dynamic rates
- Expected low cost – currently $1,400/kWh - but projections as low as $250-350/kWh

50 kW BYD System under Factory Acceptance Testing by EPRI

Renewable Integration Issues & Role of Energy Storage

- Need to reduce electric sector GHG emissions
- Increased wind penetration is a potential solution
  - But variable wind generation and electric system integration is a big issue
  - Impacts of wind penetration in backing off base load coal generation
  - Most experts believe energy storage can be part of the solution for wind integration; but
- How much storage is needed for to improve wind penetration
- Best location for storage
- Cost effectiveness of storage vs. other options
- Trade-offs and assessments on transmission planning
- Impacts of policy changes