Applications and Requirements for Grid-Scale Energy Storage

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The Electric Power Research Institute (EPRI)

- Independent, non-profit, **collaborative** research institute, with full spectrum industry coverage
  
  - Nuclear
  - Generation
  - Power Delivery & Utilization
  - Environment
  - Technology Innovation

- Major offices in Palo Alto, CA; Charlotte, NC; and Knoxville, TN
Our Members…

• 450+ participants in more than 40 countries
• EPRI members generate more than 90% of the electricity in the United States
• International funding of more than 18% of EPRI’s research, development and demonstrations
• Programs funded by more than 1,000 energy organizations
Help Move Technologies to the Commercialization Stage…

Our Role…

Technology Accelerator!
Grid Energy Storage: Taking electricity into the fourth dimension!

- Storage moves electricity in time, just as transmission moves it through distance

- Storage enhances the flexibility of the bulk grid, accommodating more variable renewable energy

- Storage increases reliability and asset utilization of the power delivery system
How the Electricity Grid Works Today

Power flows in one direction

Generation and load must always be balanced

Central Plant

Industrial Loads

Transmission Substation

Step-Up Transformer

Residential Loads

Distribution Substation

Industrial Loads

Commercial Loads
How the Grid is Changing

Smart Grid Infrastructure

Renewables

Expanding Load

PV

PHEV
The Role of Storage

Distributed Storage

Ancillary Services

Residential Storage

V2G

Bulk Storage

Commercial Storage
Storage Applications

Power Rating (MW)

- System stability
- VAR Support
- Power quality
- Temporary Power Interruptions
- Spinning Reserve
- Freq Regul.
- Load Following, for DR, go to lower MW level
- Load Leveling Ramping Energy
- Renewables (eg., Wind)
- For Solar we may need 10’s of hours of storage
- Peak Shaving and T&D Deferral; Transmission Congestion Management

Energy Discharge Time
(Axis not to Scale)

- "Village Power" Remote "Islands"
- Black Start needs 1 to 10 MW for a duration of 1 to 2 hr.
Overlapping applications

<table>
<thead>
<tr>
<th>Benefit Type</th>
<th>Time</th>
<th>End User</th>
<th>Distribution</th>
<th>Transmission</th>
<th>Utility System</th>
<th>ISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy ($/kWh)</td>
<td>Hours</td>
<td>Energy Management</td>
<td>T&amp;D Investment Deferral</td>
<td>Renewable Integration</td>
<td>Energy Arbitrage</td>
<td>System Capacity</td>
</tr>
<tr>
<td>Reliability ($/kW)</td>
<td>Minutes</td>
<td>Reliability</td>
<td>Renewable Smoothing</td>
<td>Ancillary Services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power ($/kW)</td>
<td>Seconds</td>
<td>DESS</td>
<td>T&amp;D System Support</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operations ($/kVAR &amp; $/kW)</td>
<td></td>
<td></td>
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</tbody>
</table>

Size of Application:
- 10s kW
- 100s kW
- 10s MW
- 100s MW
Enabling Grid-Ready Storage

Technology Capabilities

Grid-Ready Storage Solutions

Grid-Ready Storage
Safe and Reliable
Cost-effective
Ready for Integration
Established Track Record

Industry Requirements
Critical Parameters for Grid-Ready Storage

Technical Specifications
- Power rating
- Energy rating (duration)
- Operating Voltage
- Temperature Range
- Footprint
- Reliability
- Efficiency
- Lifetime
- Required Maintenance

Economic Considerations
- Initial Cost
- Lifetime Cost
- Operating Costs
- Maintenance Costs
- Disposal Costs
- Costs of Alternatives
- Possibility of Multiple Value Streams

Other Factors
- Safety
- Environmental Effects
- Recyclability
- Regulatory Status
- Public Perception

The customer must know what he is getting!
Storage must interface with all aspects of grid

- Grid Operations
  - Regulatory Framework
  - Market Framework
  - Operational algorithms

- Energy Storage
  - Protection schemes
  - Understanding capacity implications

- Smart Grid
  - Communications and control protocols
  - Object Models
  - Cybersecurity

- Distribution Infrastructure
  - Islanding
  - Interface with public and local agencies
Energy Storage at EPRI

Near Term: Enable Grid-Ready Storage Solutions by 2015
Near-term Focus: Grid-Ready Storage Solutions

• EPRI goal: Reliable, cost-effective storage solutions in three areas:
  – Large-scale bulk storage as a balancing resource for renewables (> 50 MW for several hours)
  – Substation storage for transmission and distribution asset upgrade deferral (1 – 10 MW for 2 – 6 hours)
  – Distributed energy storage systems at neighborhood level (15 – 25 kW for 2 – 4 hours)
Project Goals
The overarching goal of the project is to develop functional requirements for energy storage systems connected to the electric grid to be used in specific ways (use cases/operational modes). From such functional requirements, vendors will be able to develop energy storage system products that meet utility needs.

Project Management and Staff

**EPRI**
- Bill Steeley | Project Manager
- Ben Norris | Technical Content

**TTC**
- Jeff Serfass | Facilitation of collaboration
- Emanuel Wagner | Project Coordinator

Project Timeframe
- April 1st – Commencement of Project
- May - August – Webinar Reviews
- August 31st – Draft Report
- September 30th – Project Completion
1. Executive Summary
   – Project description and goals, Methodology and participants, Results, Conclusions

2. Introduction
   – Need for Energy Storage, Defining functional requirements, This project

3. Substation Grid Support Functional Requirements - Eva Gardow
   – storage at the substation or distribution feeder

4. Distributed Energy Storage System (DESS) Functional Requirements - Tom Walker
   – storage at the transformer serving several customers

5. Energy Storage to Support Renewable Energy Integration Functional Requirements for
   A. Wind Smoothing (Ramping) in Power System Operations – Dale Bradshaw
   B. PV Transient Support in Power System Operations - Mike Grant
   C. Load Shifting to Integrate Wind and Solar in Power System Operations - George Gurlaskie

6. Recommendations for Future Work

7. Appendices - List of Organizations that Participated and other Resource Materials
### Functional Requirements

#### Substation Grid Support
- 1 – 20 MW
- 2 – 6 hours
  - Minutes only for frequency regulation
- Includes
  - Stationary
  - Transportable
  - Modular

#### Distributed Energy Storage System (DESS)
- 25 – 1000 kW
- 1 – 4 hours

### Use Cases / Operation Modes

#### Substation Grid Support
- Peak load management
- Frequency regulation
- Capacity market (RTO/ISO)
- Reactive Support
- Support for critical loads during outage (Islanding)

#### Distributed Energy Storage System (DESS)
- Peak load management
- Increase customer reliability (backup power)
- Voltage regulation

### Interconnection

#### Substation Grid Support
- Distribution voltage
- Substation or feeder

#### Distributed Energy Storage System (DESS)
- Secondary voltage
- Utility side of meter
- Can operate as island

### Notes

- Use cases are listed in order of priority
- Products do not need to meet all use cases
- Peak load management is controlled based on substation/feeder real time loads
- Frequency regulation based on signals from ISO
- Capacity market based on control from ISO
- System may be modular

- No frequency regulation support
- Peak load management is controlled based on substation/feeder real time loads
- Reactive power support based on local voltage
- No DC ports (as in AEP doc)
- Dampens PV variability
## Energy Storage to Integrate Renewables

### Use Cases/Operating Modes

- **A. PV Transient Support**
  - Power up to several MVA (TBD by utility site)
  - 1 second to 20 min (TBD by utility)
  - Eliminate rapid voltage and power swings (flicker) on distribution systems where high-penetration levels of PV systems are found

- **B. Wind Smoothing (Ramping)**
  - 1 – 100 MW
  - 2 – 15 minutes
  - Ensure windfarm ramp-rates (MW/min) are kept to within design limits;
  - Maintain local transmission and sub-transmission voltage

- **C. Load Shifting**
  - Power defined by size of renewable resource; kW to hundreds of MW
  - Up to 10 hours
  - Shift renewable generation to peak times
  - Utility demand response resource
  - Participate in capacity markets as a dispatchable resource
  - Energy arbitrage
  - Ancillary services

### Inter-connection

- **A.** Distribution voltage (4kV - 34kV)
- **B.** Medium or transmission voltage
- **C.** May be directly coupled and sized to local renewable resource or sized and operated independently

### Notes

- **A.** Better manage the intermittency of solar real power output due to cloud cover (act like an electric shock absorber).
- **B.** May also serve to smooth windfarm output and/or dampen PV transients.
- **C.** Typically windfarm owned and operated.
P94.002 Energy Storage and Distributed Generation Options for Grid Support and Reliability

Chapter Outline for Each Functional Requirement

Description of Application
- Block Diagram
- Scope

Use Cases/Operating Modes

Performance Ratings
- System Definition
- Auxiliary Loads
- System Ratings

System Effectiveness
- System Efficiency
- Performance Curve

Physical Characteristics
- Size
- Transportation Standards
- Harnessing
- Status Lights and Alarms
- Environmental Conditions

Electrical Interface
- Standards
- Disconnect Breaker
- Contactor

Communications, Control and Data Management
- Communications Method
- Communications Protocol
- Integrated Interface
- Operational Data
- Event-triggered Data
- Data Access

Installation and Maintenance
- Installation
- Operation and Maintenance
- DC Maintenance

Safety
Sample Block Diagram for Load Shifting

- Utility
- Renewable Resource (Optional)
- Transformer (As Required)
- Disconnect
- Aux. Loads (Optional)
- Contactor
- Energy Storage and Power Conditioning
• Plans and Next Steps
  – Currently obtaining input from stakeholders to incorporate into the next version of draft report
  – Working Groups will then review and revise as necessary
• Schedule
  – Finish draft report
  – Complete Project in 4th QTR
Together...Shaping the Future of Electricity