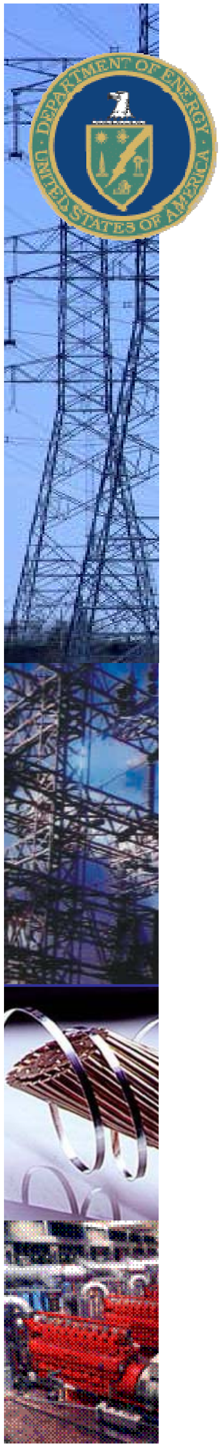
U.S. Department of Energy

Office of Electricity Delivery and Energy Reliability

Discussion of Data for Smart Grid Metrics and Benefits

Storage System Performance Supplement

November 12, 2010

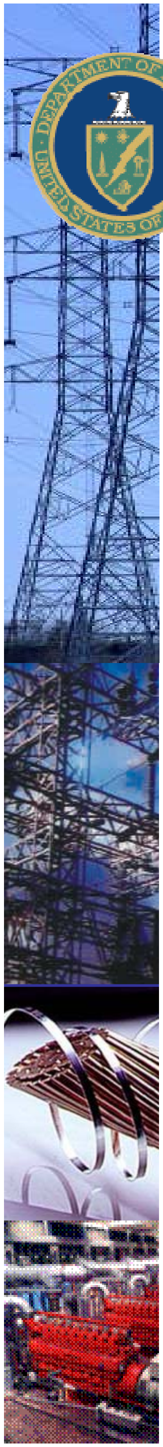


Storage System Performance Overview

Each project team should provide the following four types of storage system performance information via the interim and final Technology Performance Reports (TPRs):

1. **System Characteristics** – profiles of the prototype and field demonstration systems.
2. **Data Measurements** – required storage system measurements and recordings, including balance of plant status and external operating environment data over the course of the demonstration.
3. **System Performance Parameters** – technical, economic, and environmental health & safety (EHS) performance characteristics that will be measured or calculated over the course of the demonstration.
4. **Projected Performance Parameters** – performance characteristics that will require extrapolating or forecasting based on data collected during the demonstration. Examples include life cycle cost information and long term capacity degradation.

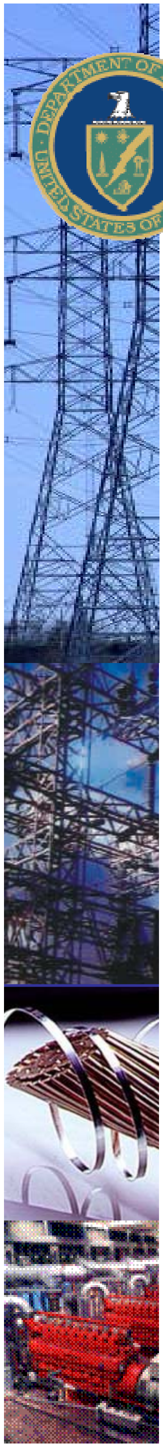
Performance information described on the following pages are broadly applicable to storage technologies. However, the DOE/NETL Data Analysis Team fully anticipates that they are not universally applicable to all projects involving storage technologies and that some projects will have other technology-specific performance characteristics that should be identified by the project team for inclusion in the technology performance reports.



System Characteristics

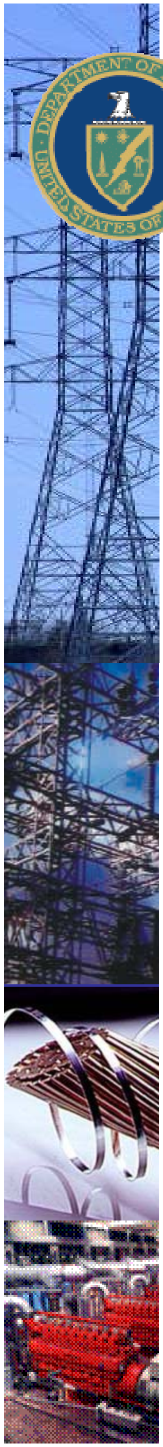
- Appropriate system characteristics should be identified and described in the MBRP.

Storage System Characteristics
• Location • Weight, footprint, and dimensions • Transportability • MW nameplate rating (including depth of discharge, operating conditions) • MWh nameplate capacity (including depth of discharge, operating conditions) • Energy density • Specific energy and power • System components (e.g., storage module, power conversion system, cooling system, balance of plant)



Data Acquisition System

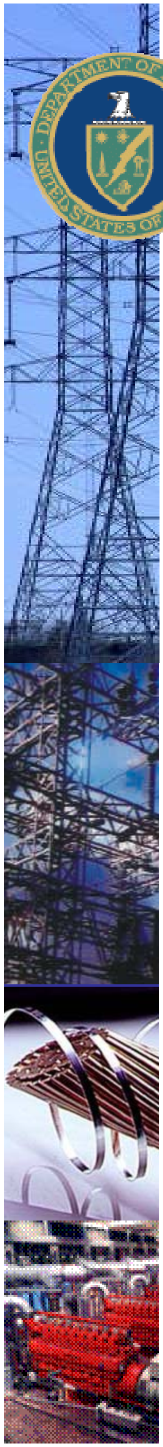
- Recipients are responsible for providing the equipment necessary to ensure the accurate capture and reporting of experimental and demonstration field data and results. Data should be reported to the TPO and the Data Analysis Team (DAT) on an agreed upon schedule. Recipients should retain and house all storage system performance information generated until the conclusion of the project and final reporting.
- Recipients should review and obtain approval from the TPO and the DAT of the following aspects of the Data Acquisition System (DAS) prior to equipment purchase and installation:
  1. 1-line schematic of DAS including:
     - Monitoring points and data to be monitored at each point
     - Type of monitoring equipment needed and number of units needed
     - Communications link between monitoring devices and data repository
     - Amount of on-site storage (back-up) needed
  2. Specifications for DAS components
- Once a prototype or field test system is ready for operation, the Recipient and Data Analysis Team will review the monitoring equipment installation and verify accurate data capture and storage.



Data Measurements

- A description of the Data Acquisition System (DAS) should be included in the MBRP.
- The MBRP should provide a list of all data to be captured by the DAS.
- Each data point should include a description and sampling rates.

Data Measurements
• Operational mode • Import energy signal • Export energy signal • kW input • kW output • Voltage • VAR • Amp • kWh • Frequency • Power factor • Battery system state of charge • Response time • Number of cycles • Harmonics • Hourly electricity price • Regulation price (regulation only) • Demand response revenue (load shifting only) • Congestion charges (load shifting only)



System Performance Parameters

Storage System Performance Parameters

Technical

- Scheduled maintenance down time
- Down time associated with State of Charge (SOC)
- Unscheduled down time
- Plant availability**
- Number and duration of failure incidents
- Energy dispatched on day-to-day and lifetime basis
- Round-trip efficiency (RTE)
- Ability to follow Automatic Generation Control (AGC) signal (regulation only)
- Ramp rate (charge/discharge)
- Capacity degradation

Economic

- Engineering and design costs
- Capital cost (i.e., equipment capital and installation) ($)*
- Capital cost ($/kWh & $/kW)*
- End of life disposal cost ($)**
- End of life value of plant and equipment**
- Operating cost (activity based, non-fuel, by application plus monitoring)
- Maintenance cost (by cost category)

Environmental Health & Safety (EHS)

- Operating temperature
- Flammability
- Material toxicity
- Recyclability
- Other

*To be reported at the start of operations
**To be reported only at the end of operations

Performance Parameter Definitions –Technical

STORAGE SYSTEM PERFORMANCE PARAMETERS: Technical		
Metric	**Value**	**Definition**
Scheduled maintenance down time	%	Ratio of the time that the energy storage system is down for scheduled maintenance divided by the total timeframe. Example: If the system was down for scheduled maintenance 50 hours out of 30 days (720 hours), then the “scheduled maintenance down time” would be 6.9% = (50/720*100).
Down time associated with State of Charge (SOC)	%	Ratio of time that the energy storage system has been charged/discharged to the limit and is unable to respond to a signal divided by the total timeframe minus scheduled maintenance down time. Example: If the energy storage system was at the SOC limit for 5 hours and the system was down for scheduled maintenance 50 hours out of 30 days (720 hours), then the “down time associated with SOC” would be 0.7% = (5/(720-50)*100) .
Unscheduled down time	%	Ratio of the unscheduled down time divided by the total timeframe minus scheduled maintenance down time. Example: If the system was down for 10 hours due to unscheduled incidents and down for 50 hours for scheduled maintenance out of 30 days (720 hours), then the “unscheduled down time” would be 1.5% = (10/(720-50)*100).
Plant availability**	%	Ratio of the total timeframe minus scheduled maintenance down time minus down time associated with SOC minus unscheduled down time divided by the total timeframe minus scheduled maintenance down time. Example: If the system was down for 50 hours due to scheduled maintenance, 5 hours due to down time associated with SOC and another 10 hours for unscheduled down time out of 30 days (720 hours), then the “plant availability” would be 97.8% = ((720-50-5-10)/(720-50)*100).

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Performance Parameter Definitions –Technical (cont’d)

<table>
<tr><th colspan="3">STORAGE SYSTEM PERFORMANCE PARAMETERS: Technical</th></tr>
<tr><th>Metric</th><th>Value</th><th>Definition</th></tr>
<tr><td>Number and duration of failure incidents</td><td># and hours</td><td>Date and time of the failure incidents including a description of the general cause and duration.

Example list:
1. August 1, 2010, 14:38, Inverter down – 49:38 hours
2. October 20, 2010, 07:45, Fault in system – 23:51 hours
3. January 15, 2011, 11:05, Communication board failure – 2:09 hours

Note: This is a summary list and the details of each of these failure incidents will be tracked and available for review.</td></tr>
<tr><td>Energy dispatched on day-to-day and lifetime basis</td><td>kWh</td><td>Energy dispatched on day-to-day basis accumulated for entire project.

Example table:
<table>
<tr><th colspan="3">ENERGY DISPATCHED</th></tr>
<tr><th>Date</th><th>kWh</th><th>Cumulative kWh</th></tr>
<tr><td>August 1, 2010</td><td>557</td><td>557</td></tr>
<tr><td>August 2, 2010</td><td>330</td><td>887</td></tr>
<tr><td>August 3, 2010</td><td>129</td><td>1,016</td></tr>
</table></td></tr>
<tr><td>Round-trip efficiency (RTE)</td><td>%</td><td>Ratio of total energy storage system output (discharge) divided by total energy input (charge) as measured at the interconnection point.

Example: If the total output was 5,000 kWh, but the total energy input was 6,500 kWh, then the “round-trip efficiency” would be 76.9% = (5,000/6,500*100). Note: supplemental loads and losses (e.g., cooling, heating, pumps, DC/AC and AC/DC conversions, control power, etc.) consumed the 1,500 kWh.</td></tr>
</table>

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Performance Parameter Definitions –Technical (cont'd)

STORAGE SYSTEM PERFORMANCE PARAMETERS: Technical		
Metric	**Value**	**Definition**
Ability to follow Automatic Generation Control (AGC) signal (load following only) and Area Control Error (ACE) signal (regulation only)	Minimum, Maximum, and Average Difference (%)	Ratio of the kWh provided by the energy storage system divided by the kWh required by the AGC or ACE at each 4 second interval. Example: If the AGC or ACE signal requires discharge of 100kWh but the energy storage system only provides 80kWh during that 4 second interval, the ability to follow the AGC or ACE signal would be 80% = (80kWh/100kWh *100) *Note: This is a summary number and the details of each of these incidents will be tracked and available.*
Capacity degradation	%	Ratio of energy capacity at the end of the time period divided by the capacity at the beginning. Example: If the total energy storage system capacity at the end of the project had a capacity of 4,000 kWh and at the start of the project was 5,000 kWh, then the "capacity degradation" would be 20% = ((5,000-4,000)/5,000*100). Note: for battery systems, this measurement is taken on the device DC bus. Otherwise it is at the interconnection point.

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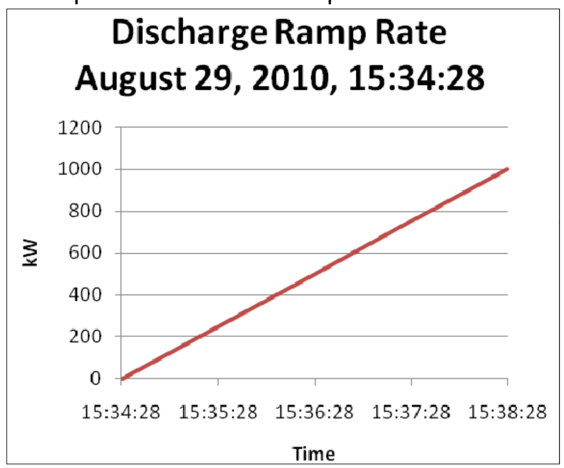
Performance Parameter Definitions –Technical (cont'd)

STORAGE SYSTEM PERFORMANCE PARAMETERS: Technical		
Metric	**Value**	**Definition**
Ramp rate (charge/discharge)	kW/sec Graph and Table	The change in power charged and discharged over time to meet the variations in power requirements. Graphically (with resolution of 100 ms) demonstrate the energy storage system's sustainable maximum ramp rate (kW/sec). List the number of times that the energy storage system did not meet the requested ramp rate on a daily basis. Example Details: August 29, 2010, 15:34:28, Maximum Discharge 0kW – 1,000kW achieved in 4 seconds.

Example of Associated Graph:



Example Table:

RAMP RATE NOT MET			
Date	**Ramp Rate**	**Charge**	**Discharge**
August 1, 2010; 10:45:37	500 kW/sec	X	
August 1, 2010; 16:30:04	750 kW/sec		X
August 3, 2010; 18:32:21	900 kW/sec		X

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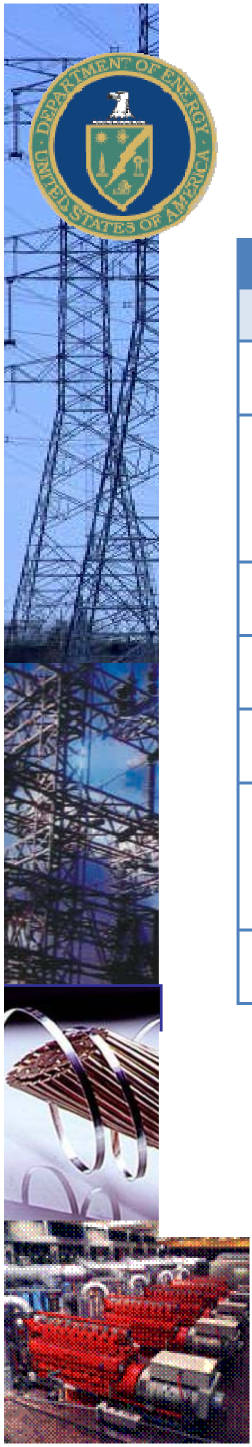

Performance Parameter Definitions – Economic

STORAGE SYSTEM PERFORMANCE PARAMETERS: Economic		
Metric	**Value**	**Definition**
Engineering and design costs	$	The cost associated with engineering and design for the demonstration project implementation.
Capital cost (i.e., equipment capital and installation)*	$	Total installed first cost of fielded system, breaking out major categories including equipment (i.e., major equipment components, related support equipment, and initial spare parts) and costs associated with shipping, site preparations, installation, and commissioning.
Capital cost*	$/kWh & $/kW	Total installed first cost of fielded system, normalized by energy storage capacity and peak power output.
End of life disposal cost**	$	Total cost of dismantling and removing the fielded system, including (if applicable) decontamination long-term waste storage, environmental restoration and related costs.
End of life value of plant and equipment**	$	Resale or salvage value of plant and all associated equipment.
Operating cost (activity based, non-fuel, by application plus monitoring)	$/kW-month	Activity based, average monthly total of all direct and indirect costs incurred in using the system, excluding the cost of purchased electricity and including third-party monitoring if applicable.
Maintenance cost (by cost category)	$/kW-month	Activity based, average monthly cost of maintaining the fielded system.

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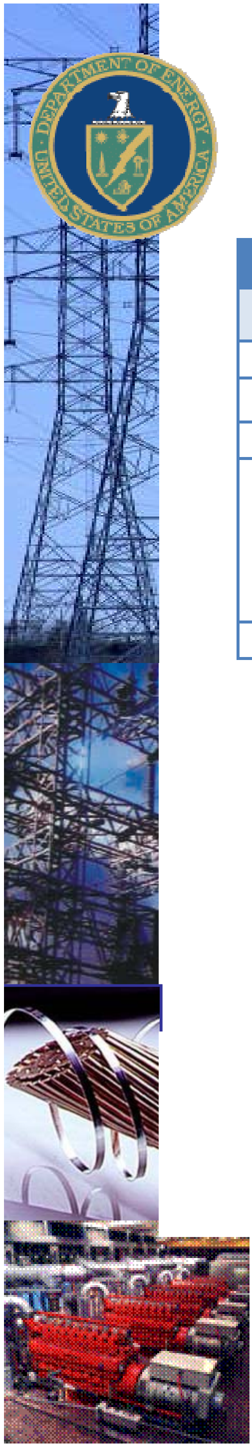

Performance Parameter Definitions – Environmental Health & Safety

STORAGE SYSTEM PERFORMANCE PARAMETERS: Environmental Health & Safety		
Metric	**Value**	**Definition**
Operating temperature	°F	Degrees Fahrenheit at which the energy system normally operates.
Flammability	°F	Material flammability ignition temperature and ignition energy.
Material toxicity	--	Qualitative discussion on materials toxicity.
Recyclability	%	Percent of the material from the energy storage system expected to be recyclable at the end of life. Example: If there are four tons of lead that can be recyclable from the original five tons installed, then the lead "recyclability" would be 80% = (4/5*100).
Other	TBD	List and describe any other EH&S issues.

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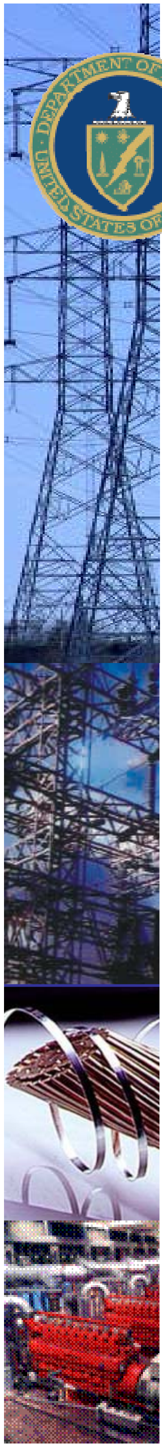

Projected Performance Parameters

- Projected Performance Parameters should reflect estimates based on results of testing and demonstration activities.
- The MBRP should include a discussion of these parameters and provide details of how each parameter is defined for the technology and the approach that will be used to provide estimates over the course of the project.

Projected Performance Parameters
• Cycle life (define basis for estimation, e.g. based on 80% capacity degradation, or other metrics) • Calendar life (define basis for estimation) • Total life cycle maintenance cost • Total life cycle operating cost • Capacity degradation • Capital cost ($/kWh over lifetime)