Literature Review of Energy Storage Services
February 13, 2018

for the
NC Energy Storage Study
Stakeholder Input Meeting
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1 Existing Approaches for Defining Energy Storage Services

Several studies have catalogued and characterized the range of services that can be provided by energy storage systems (ESS). In this section, we present several figures and tables that outline these services and potential ways to group them. Many of these services can be stacked, but the viability of using multiple services depends on the location (behind-meter, distribution, transmission, etc.), technology type, regulatory hurdles, and the value of the service. It is important to note that some of these services are not explicitly procured or valued, but are needed for the reliable and safe operation of the grid.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Reliability Services</th>
<th>Non-Reliability Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer</td>
<td>None</td>
<td>TOU bill management; Demand charge management; Increased self-consumption of on-site generation; Back-up power; Supporting customer participation in DR programs</td>
</tr>
<tr>
<td>Distribution</td>
<td>Distribution capacity deferral; Reliability (back-tie) services; Voltage support; Resiliency/microgrid/islanding</td>
<td>None</td>
</tr>
<tr>
<td>Transmission</td>
<td>Transmission deferral; Inertia*; Primary frequency response*; Voltage support*; Black start</td>
<td>None</td>
</tr>
<tr>
<td>Wholesale Market</td>
<td>Frequency regulation; Spinning reserves; Non-spinning reserves; Flexible ramping product</td>
<td>Energy</td>
</tr>
<tr>
<td>Resource Adequacy</td>
<td>Local capacity; Flexible capacity; System capacity</td>
<td>None</td>
</tr>
</tbody>
</table>

*Voltage support, inertia, and primary frequency response have traditionally been obtained as inherent characteristics of conventional generators, and are not today procured as distinct services. We include them here as placeholders for services that could be defined and procured in the future by the CAISO.

Figure 1: Energy Storage Services as Categorized by Sandia National Labs

Source: (Akhil et al. 2013)
Table 1. Electric Grid Energy Storage Services Presented in This Handbook

<table>
<thead>
<tr>
<th>Bulk Energy Services</th>
<th>Transmission Infrastructure Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Energy Time-Shift (Arbitrage)</td>
<td>Transmission Upgrade Deferral</td>
</tr>
<tr>
<td>Electric Supply Capacity</td>
<td>Transmission Congestion Relief</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ancillary Services</th>
<th>Distribution Infrastructure Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulation</td>
<td>Distribution Upgrade Deferral</td>
</tr>
<tr>
<td>Spinning, Non-Spinning and Supplemental Reserves</td>
<td>Voltage Support</td>
</tr>
<tr>
<td>Voltage Support</td>
<td>Customer Energy Management Services</td>
</tr>
<tr>
<td>Black Start</td>
<td>Power Quality</td>
</tr>
<tr>
<td>Other Related Uses</td>
<td>Power Reliability</td>
</tr>
</tbody>
</table>

Figure 2 Energy Storage Services as presented by the Energy Storage Association

Source: (“Decision on Multiple-Use Application Issues (Proposed Decision Rev. 3)” 2018)
Figure 3. Energy Storage Services as presented by Rocky Mountain Institute

Source: (Fitzgerald et al. 2015)
2 End User Services

In this section, we provide a list of energy storage services and values that can directly benefit end-users.

2.1 Time-of-Use/Energy Management

ESS are able to shift the net load of customers to take advantage of time-of-use (TOU) pricing or other incentives for adjusting when they consume electricity from the grid.

2.2 Demand Charge Management

Shifting electricity consumption to reduce the customer’s highest peak consumption from the grid can reduce demand charges ($/kW). These are especially significant for industrial and commercial customers. This application can often be coupled with TOU rate reduction ($/kWh).

2.3 Backup Power

Aside from reducing electricity bills, ESS can provide emergency backup power in the event of outages. During power outages, ESS can provide power to an end user-user disconnected from the electrical grid.

2.4 Distributed Energy Resource Management

For residential, commercial, industrial, and even utility distributed energy resource (DER) sites, ESS can enable the management of energy consumption and injection into grid. Depending on the objective of ESS control, DER management may respond to economic incentives for end-users (e.g. selling power, self-consumption, and energy arbitrage) or manage variability of power injection to avoid reliability issues.

2.5 Power Quality Management

Particularly for industrial customers who require highly conditioned power, ESS allows management of facilities’ interaction with the grid to reduce reliance on and disturbance of the power quality including voltage fluctuation, voltage drop, and frequency.
3 Distribution Services

In this section, we provide a list of energy storage applications that provide distribution-level services.

3.1 Voltage Support and Control
ESS can provide voltage support and control to ensure the reliability of local distribution circuit. Storing energy can be used to smooth voltage flicker due to DER and load variability and maintain voltages within industry limits across distribution circuits. There is significant value to utilities to reduction of operation of voltage control devices (e.g., load tap changers (LTC), voltage regulators, capacitors). Reduction in operation reduces wear and tear on devices and increases useful lifeline of these capital intensive devices.

3.2 Microgrid/Islanding
Similar to backup power for end-use customers, ESS can be used to support microgrid islanding during power outages either as the main source of energy or to support operation of other DERs. Additionally, ESS can support microgrids with participation in economic dispatch or price responsive demand programs.

3.3 Circuit Upgrade or Capacity Deferral
ESS can reduce the need for circuit upgrades to meet peak demands for small number of hours of the year. ESS can be used to reduce the net peak load on circuits for periods which line sizing, transformer sizing, regulator placement, and capacitor placement are determined. Control through ESS can replace the need with peak demands higher than planned or high penetrations of DER.

4 Transmission Services

In this section, we provide a list of energy storage applications that provide transmission-level services.

4.1 Transmission Investment Deferral
ESS can reduce need for or defer transmission build out. The highest projected annual load drives transmission planning decisions. ESS can provide additional capacity in locations which might otherwise require additional transmission capacity to serve load a few hours per year. This use of ESS also reduces overloading of transmission lines and transformers which increases equipment lifetime.

4.2 Transmission Congestion Relief
ESS located at the transmission level can relieve congestion for constrained periods of the year and allow more economic generators or variable generators to produce energy. Relieving congesting allows for more economic (i.e., less expensive) generators to be used more frequently and avoids variable generator curtailment.
4.3 Black Start Capacity
In the event of bulk system blackouts, ESSs which can store energy for long periods of time can be used as black start units. These units or parts of their capacity are set aside as part of a plan for restarting the grid in the case of a system-wide black out. Primarily, pumped-hydro plants are used for this purpose because of the ease of storing water in reservoirs for long periods of time and starting the generators without minimal external electricity.

5 Generation/Resource Adequacy Services
In this section, we provide a list of energy storage applications that provide generation/resource adequacy services.

5.1 Synthetic Inertia
While energy storage devices have no physical inertia, control systems on ESS can be used to provide fast responses which mimic inertia responses of generators. Inertia provided by conventional thermal generator reduces the rate frequency fluctuates due to mismatch in produced and demanded real power. Higher penetrations of renewable energy lead to lower system inertia and may require additional sources of inertia. This is often overlooked as a service to electricity grids because thermal generators, especially coal, provided these services by default.

5.2 Peak Capacity Deferral
Peak generation capacity requirements can be decreased by utilizing ESS during peak demand periods. Energy produced at lower demand periods can be stored and injected at higher demand periods to avoid generation capacity expansion and peaker plant operation. The firm capacity that energy storage can provide is related closely to the energy to power ratio of the storage device. Additionally, ESS can be used to increase the capacity value of variable generation resources to meet these needs.

5.3 Reserves (Spinning/Non-Spinning)
ESS can be used as spinning and non-spinning reserves to respond to contingency events and correct for large imbalances between electricity supply and demand. The rapid start-up time and ramp rate of ESS makes them eligible for spinning reserves which can respond to sudden contingencies and give non-spinning reserves time to come online over longer time frames. ESS can provide reserves required to hedge uncertainty in load and variable generator forecasts.

5.4 Frequency Regulation
Primary and secondary frequency regulation and emergency frequency response can be provided by ESS. Especially for ESS technologies with quick ramp rates, ESS can follow a real-time signal or the area control error (ACE) for primary frequency regulation or the longer timeframe scheduling (minutes) of secondary frequency regulation. ESS’s ramping ability also allows emergency frequency response to reduce the initial frequency drop in contingency scenarios and support return to 60hz operating point. ESS providing these services avoids wear and tear on thermal generators and lower efficiencies associated with ramping output.
5.5 Flexible Ramping
While not a conventional product in electricity operation, ESS provides the ability to reduce the need for thermal generators to ramp as quickly in response to diurnal demand profiles and variable generation from solar and wind power. Reducing the ramp rate needed for thermal generators allows for the capacity needed to reach peak demand to come on earlier and ramp more slowly to meet the peak demand. Slower ramping allows for more efficient generation and generators with longer minimum startup and shutdown times to participate.

6 References


“Decision on Multiple-Use Application Issues (Proposed Decision Rev. 3).” 2018. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M204/K478/204478235.pdf.