Perspectives on Grid Transformation and the Market for Storage

Landis Kannberg
October 23, 2014
Major Trends Affecting Grid & Grid Storage

- **Deployment of renewable generation** –
  - Faster than load growth – displacing conventional generation
  - Variable – creating need for flexibility
  - Flexibility -
    - Acquired via markets – double edged sword for storage
      - Creates revenue stream for storage
      - Enables alternatives (e.g. Demand Response)

- **Smart Grid** –
  - Enables new sources of flexibility
  - Enables multiple functions for distributed storage

- **Reliability/Resiliency**
  - High reliability zones
  - Microgrids – Storage a vital component
U.S. PV Costs and Deployment

Figure 2.1  U.S. PV Installations and Average System Price, 2000-2013

U.S. Wind Generation

~4% of U.S. Gen

U.S. Annual and Cumulative Wind Power Capacity Growth (Utility-Scale Wind)
Global Power Generation Forecast

GLOBAL POWER GENERATION CAPACITY ADDITIONS
2010 – 2030 (GW)

FOSSIL FUEL AND NUCLEAR

- Nuclear
- Oil
- Gas
- Coal

RENEWABLES, EXCL. HYDRO

- Other
- Biomass & waste
- Hydro
- Solar
- Wind

Source: Bloomberg New Energy Finance

Proudly Operated by Battelle Since 1965
Forecast of German Generation Profile

GERMAN HOURLY GENERATION PROFILE, (GW)

JULY 2012

Source: Bloomberg New Energy Finance

Proudly Operated by Battelle Since 1965
Grid Operations & Stochastic Generation

BPA Aggregated Wind (March 12-18, 2014)
Up to 500 MW Forecast error, 1 GW per hour ramp

Intermittent supply of PV for California ISO

BPA Balancing Area
• >5 GW Wind
• ~6 GW Avg. Load
• ~10 GW Peak Load

Over-generation
• Congestion
• Markets for transmission rights
• Frequency ride-through capability
• Impacts on dynamics and stability
• Reactive power generation/voltage
• Coordinating System Protection Schemes,
• System balancing, reserve requirements, and frequency control;
• Dispatch of the remaining conventional units (e.g. more starts and cycling), and
• Transmission cost recovery and allocation
Rapid PV penetration increasingly displaces mid-day loads over time

Challenges presented by PV penetration become barriers under business-as-usual operations

- Ramp rate (load change) at end of day expected to double
  - Rapid swings complicate dispatch – a challenge for reliability
  - Increased costs for more reserve power plants

- Rapid distribution system voltage swings from fluctuations in output (intermittently cloudy days) must be managed
  - Disruptive to electronics; when outside ANSI standard range can damage customer equipment
  - Voltage management gear will wear out – designed for ~10 operations/day now will see 100s
  - Who will pay for the upgrades or storage needed? Regular customers? PV owners?

Change in CA-ISO Net Load as a Result of PV Penetration, 2012-2020
Coordination is Important

There are 37 BAs within the Western Interconnection, as wind and solar penetration in each BA increases, it becomes more challenging to operate individually.

<table>
<thead>
<tr>
<th></th>
<th>11% Case</th>
<th></th>
<th>33% Case</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Up</td>
<td>Down</td>
<td>Up</td>
<td>Down</td>
</tr>
<tr>
<td>Regulation Capacity, GW</td>
<td>Individual BAs</td>
<td>1.76</td>
<td>-1.82</td>
<td>3.65</td>
</tr>
<tr>
<td></td>
<td>CBA</td>
<td>0.74</td>
<td>-0.75</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>Savings in %</td>
<td>58%</td>
<td>59%</td>
<td>71%</td>
</tr>
<tr>
<td>Regulation Ramp Rate, MW/min</td>
<td>Individual BAs</td>
<td>566</td>
<td>-597</td>
<td>962</td>
</tr>
<tr>
<td></td>
<td>CBA</td>
<td>138</td>
<td>-143</td>
<td>222</td>
</tr>
<tr>
<td></td>
<td>Savings in %</td>
<td>75%</td>
<td>76%</td>
<td>76%</td>
</tr>
<tr>
<td>Load Following Capacity, GW</td>
<td>Individual BAs</td>
<td>12</td>
<td>-11</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>CBA</td>
<td>4.1</td>
<td>-3.9</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>Savings in %</td>
<td>64%</td>
<td>66%</td>
<td>70%</td>
</tr>
<tr>
<td>Load Following Ramp Rate, MW/min</td>
<td>Individual BAs</td>
<td>356</td>
<td>-357</td>
<td>708</td>
</tr>
<tr>
<td></td>
<td>CBA</td>
<td>186</td>
<td>-190</td>
<td>245</td>
</tr>
<tr>
<td></td>
<td>Savings in %</td>
<td>48%</td>
<td>47%</td>
<td>65%</td>
</tr>
</tbody>
</table>

Consolidation saves over $600M/yr
Simply going to 10 minute scheduling will save over $750M/yr
Intra-Hour Balancing
2020 Grid with 20% Renewable Portfolio Stds. (Wind)

18.6GW, 8.6 GWh of Energy Storage needed to meet intra-hour balancing capacity

$170/kWh is the price-point at which widespread energy storage becomes cost effective

Grid Scale Energy Storage

- Smart Grid
- Resiliency
- Reliability
- Asset Utilization
- Renewable Integration
- EV deployment
Grid Energy Storage Diverse Markets Encourage Bundling and Cost Reduction

- Many Applications/Services
- Cost Reduction = More Market
- Applications Require, Diverse Storage Attributes
- Evolving Grid = Changing Market and Value
- Bundling of Applications Desirable
Bainbridge Island Storage Analysis

Bainbridge Setup:
- 3 Substations
- 2 radial substations supply power for most of the island
- Substations are capacity constrained
- Reliability issues with radial transmission AND distribution

Proposed Solution:
- Add new substation to the island
  - Community opposition
Bundling Services: how to do it optimally?

Energy price ($/MWh)

Arbitrage only
Bundling Services: how to do it optimally?

Energy price ($/MWh)

Arbitrage only

Arbitrage + Balancing
Bundling Services: how to do it optimally?

Energy price ($/MWh)

- Arbitrage only
- Arbitrage+Balancing
- Arbitrage+Balancing+T&D deferral

Unloading distribution system transformer
Total Value of Bundled Values

Energy Storage at Distribution System Substation

Only when 5 value streams are captured storage can be cost-effective requires: optimized control strategies to avoid double counting of resources.
Grid Scale Energy Storage Challenges

- Cost competitive energy storage technologies
- Validated reliability & safety
- Equitable regulatory environment
- Industry acceptance

- Smart Grid
- Resiliency
- Reliability
-Installed Cost
- Performance
- Safety
-Lifetime, M&O
-Asset Utilization
-Renewable Integration

Challenges:
- Competitive storage technologies
- Validated reliability & safety
- Regulatory environment
- Industry acceptance

EV deployment

Pacific Northwest National Laboratory
Proudly Operated by Battelle Since 1965
Codes, Standards and Regulations

Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems
October 2012
Kathy Bray, Ph.D.,
David Conover, Ph.D.
Michael Ketzer-Meyer, Ph.D.
Vishnuraj Venkataraman, Ph.D.

Overview of Development and Deployment of Codes, Standards and Regulations Affecting Energy Storage System Safety in the United States
August 2014

Inventory of Safety-related Codes and Standards for Energy Storage Systems
with some Experiences related to Approval and Acceptance
September 2014

Proudly Operated by Battelle Since 1965
Deployment of renewables generation increase the need for storage (and other sources of grid flexibility)

Institutional and markets adapting to provide more flexibility – creating opportunity and challenge for storage

Market projections for storage are dramatically up

High storage system costs encourage realization of multiple storage benefits/revenue streams

A number of challenges face widespread deployment of grid energy storage

Storage industry and governments are responding to the challenge – new technologies, new incentives, maturing deployment