Electric Storage Resources & Wholesale Electricity Markets

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MYPSYCON
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Agenda

- PJM Overview
- Energy storage market activity today
- FERC Order 841
- What’s next?
- Q&A
### Key Statistics

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member companies</td>
<td>1,040+</td>
</tr>
<tr>
<td>Millions of people served</td>
<td>65</td>
</tr>
<tr>
<td>Peak load in megawatts</td>
<td>165,492</td>
</tr>
<tr>
<td>MW of generating capacity</td>
<td>178,563</td>
</tr>
<tr>
<td>Miles of transmission lines</td>
<td>84,042</td>
</tr>
<tr>
<td>2017 GWh of annual energy</td>
<td>773,522</td>
</tr>
<tr>
<td>Generation sources</td>
<td>1,379</td>
</tr>
<tr>
<td>Square miles of territory</td>
<td>243,417</td>
</tr>
<tr>
<td>States served</td>
<td>13 + DC</td>
</tr>
</tbody>
</table>

- 28% of load in Eastern Interconnection
- 20% of transmission assets in Eastern Interconnection

As of 2/2018

21% of U.S. GDP produced in PJM
Unprecedented number of changes in the power industry

- Storage technologies
- Distributed energy resources
- Intermittent renewables
- Electrification
- Fuel Swap
- Changes in customer expectations
Over 5,300 MW of ESR currently in PJM

“Other Storage” is about ~300 MW of mostly batteries.

50% of batteries connected on the distribution system.

50% connected to the Bulk Electric System.

Pumped Hydro currently participates in capacity, energy, regulation and reserves.

** Data taken from Generation Queue and EIA 860
FERC Order 755 – Performance-based Regulation

Battery Energy Storage

Steam Unit
Measuring and Paying for Performance

(MW) * ($/MW) * (Performance Score) = Revenue

Simple Example

Accuracy, 95%
Precision, 74%
Delay, 66%
Score, 78%
Regulation Market – Clearing Prices and ESR Revenue

2017
$38.9M – battery revenue
46.5% of total market

*Data up to 10/1
FERC Order 841
Directive:
Establish a participation model for Electric Storage Resources

1. Eligible to provide all Energy, Capacity, and Ancillary Services
2. Dispatched and sets price as seller and buyer
3. Bid parameters that account for ESR characteristics
4. Minimum market threshold no larger than 100 kW
5. Stored MWh that are resold to the market are wholesale (LMP)
10 MWh energy storage resource

Available Capacity

10 hour duration requirement, with ability to de-rate

= 1 MWh
• ESRs will be modeled as one continuous resource
• PJM will not make commitment decisions in the ESR model and will not manage state of charge
• 3 modes of operation:
  – Continuous, Charge, and Discharge
• Parameters
  – Updated through Markets Gateway tool
    - Max/Min charge/discharge, Ramp rate, etc.

<table>
<thead>
<tr>
<th>Price</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10.00</td>
<td>20</td>
</tr>
<tr>
<td>$ 9.00</td>
<td>15</td>
</tr>
<tr>
<td>$ 8.00</td>
<td>10</td>
</tr>
<tr>
<td>$ 7.00</td>
<td>5</td>
</tr>
<tr>
<td>$ 6.00</td>
<td>0</td>
</tr>
<tr>
<td>$ 5.00</td>
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<tr>
<td>$ 4.00</td>
<td>0</td>
</tr>
<tr>
<td>$ 3.00</td>
<td>-5</td>
</tr>
<tr>
<td>$ 2.00</td>
<td>-10</td>
</tr>
<tr>
<td>$ 1.00</td>
<td>-15</td>
</tr>
</tbody>
</table>
Continuous operation mode - ESRs can update their max charge and discharge limits hourly in day-ahead and more frequently in real-time.

** State of charge telemetry will be requested, but not used for dispatch / optimization
Charge & Discharge mode will be available to ESR resources in DA and RT.
ESR resources can manage their own state of charge through the different modes and updates to limits, as well as hourly price offers in DA.

Self-schedule will also be available for ESRs.
Some ESR can directly serve retail load

Plain old “front of meter” ESR

“Resilience” ESR

“Behind the customer meter” ESR

N.C. = normally closed switch. N.O. = normally open switch.
Two categories of charging energy

Charging stored for later wholesale sale = “Direct Charging Energy”

Charging stored for later retail sale = “Load Serving Charging Energy”
What’s next for storage?
Generator ‘Hybridization’ with Storage

Breaks the conventional ‘one generator, one market ID’ construct. New market rules needed?

| Project Code | Location     | State     | Status  | Utility | Capacity | Market ID | CE | Rate
|--------------|--------------|-----------|---------|---------|----------|-----------|----|-------
| AB2-132      | Haumesser Road | Illinois | Active  | ComEd   | 240      | 2.5       | 2.2| GI    
| AD1-020      | Hunterstown-Lincoln 115 kV | Pennsylvania | Active | ME      | 100      | 100  | 53.6 | GI    
| AD1-143      | Hauto-Siegfried 69 kV | Pennsylvania | Active | PPL     | 90       | 90   | 11.84| GI    
| AD2-165      | South River II 230kV | New Jersey | Active | JCPL    | 590      | 110  | 40   | GI    

Project examples in PJM interconnection queue
Arizona Public Service and Fluence deploy 2 MW, 8 MWh batteries in a community northeast of Phoenix to defer investment on a 20-mile, radial distribution line.
PJM Control Room - 2025
Let’s Talk . . .

PJM’s Emerging Technology Initiatives

pilots.pjm.com