PJM Energy Storage Participation Model: Energy Market

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MIC: Special Session ESR cost offers
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1. Can sell* energy, **Capacity**, and A/S (incl. Black Start etc.) if the resource is technically capable of providing

2. Dispatched and sets price as seller and buyer

3. Bid parameters that account for ESR characteristics

4. Min market threshold is 100 kW ✔️ = already in compliance

5. Stored MWh are billed at LMP as wholesale

* “Eligible to provide…”
Electric Storage Resource Definition

- Electric Storage Resource (ESR) = “a resource capable of receiving electric energy from the grid and storing it for later injection of electric energy back to the grid.”
- Connected at: transmission, distribution, or behind a customer meter.
  - PJM has ESR at both T and D today, none behind a meter that inject.
- Excludes demand response.
- Includes pumped hydro

Over 5,300 MW of Electric Storage Resources currently in PJM

- Pumped Hydro: 96%
- Other Storage: 4%

**Data taken from Generation Queue and EIA 860**
ESR Participation Model Overview

- ESRs will be modeled as one continuous resource
- PJM will not make commitment decisions in the ESR model
  - Start-up and no load cost will not be considered
- PJM will not manage state of charge
  - Resource owners use mode of operation, offers, and parameters
- 3 modes of operation:
  - Continuous, Charge & Discharge
- Parameters
  - Max/Min charge/discharge, etc
  - Ramp rate considered infinite only in continuous 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 for telemetered resources
• Questions: esr@pjm.com
• Issue Tracking: Electric Storage Participation - FERC Order 841
Appendix: February MIC Presentation on Cost Offers
Energy Storage Resources (ESR) Cost Offer Development

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• Commitment
• Cost Development
• Opportunity Cost
• PJM does not plan to optimize an ESR’s State of Charge

• In **Day-ahead Market (DAM)**, the market participant will:
  – Enter a profile of hourly-differentiated economic minimum and maximum limits for the market day
    • Each hour reflects the capability to produce or consume energy for the entire hour (in MW-h)
  – The unit will be considered “self-scheduled” / “running for company”; startup costs and no-load costs will be zero.
If there is a spread between min and max limits, then the unit will be economically dispatched on a participant-provided incremental offer curve.

<table>
<thead>
<tr>
<th>Operating Mode</th>
<th>Economic Min</th>
<th>Economic Max</th>
<th>If LMP &lt; PRICE @ Min</th>
<th>If LMP &gt; PRICE @ Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge (Injecting)</td>
<td>0 MW</td>
<td>Max MW &gt; 0</td>
<td>No DA Commitment (0 MW)</td>
<td>Committed for Max MW</td>
</tr>
<tr>
<td>Continuous</td>
<td>Min MW &lt; 0</td>
<td>Max MW &gt; 0</td>
<td>Committed for Min MW</td>
<td>Committed for Max MW</td>
</tr>
<tr>
<td>Charge (Withdraw)</td>
<td>Min MW &lt; 0</td>
<td>0 MW</td>
<td>Committed for Min MW</td>
<td>No DA Commitment (0 MW)</td>
</tr>
</tbody>
</table>
Why is this important?

- ESR are allowed to “self-schedule” to meet RPM must-offer req.
- Self-scheduled in DAM is considered “committed”
- Any unit can hourly-differentiate offers & limits in the DAM
- Only IDO-enabled units can update offers after Rebid up to 65 minutes before an interval, and are not committed for Day-ahead

- A unit that offered into DAM, with no committed MW (0 MW) should not be considered committed in RT so that it can update with IDO
• DAM Commitment is not a RT “operating plan”
  – The participant is required to provide the DAM committed MW for the given hour, else they may be exposed to Deviation charges
  – The market participant is responsible for managing the real-time SOC to honor any DAM commitment

• The resource can modify the economic min and max limits to signal availability to charge/discharge in a given interval
  – If there is a spread between min/max, then the unit is potentially dispatchable, and eligible to set price with its energy offer
Why is this important?

• RTSCED solves a ramp-limited security-constrained economic dispatch for a *single interval* in “opportunistic” fashion
  – It does not optimize total energy (MWh) over future periods
  – The cheapest short run marginal cost unit will be dispatched first
  – At full injection, the battery may be depleted well before a peak

• Participants can modify economic max and min limits to represent their charge and discharge abilities in a given interval
• PJM has a “fixed gen” flag where the resource self-schedules in real-time, injects whatever MW the unit wants, & is price-taker
  – Typically used for energy-only, intermittent, or renewables who don’t control output, but just want to be paid LMP for generation

• Otherwise, the unit is “economic”, and PJM follows the offer curve as bid-in. The participant determines the value of energy
• But what about mitigation?
Cost-based Offers

• There are situations where a participant may have *market power* when providing *reliability services*
  – Transmission Constraints, Reactive control, Black Start, etc.
  – During commitment, PJM executes the Three Pivotal Supplier (TPS) test to scan for market power in constraint relief

• The resource is switched to the cheapest of the available cost-based or price-based offers (cheapest schedule)
  – Cost-based schedule is typically short run marginal costs + adders
Types of Opportunity Costs

• Ancillary Service Opportunity Cost
  – A resource providing SR or REG “loses” the opportunity to provide its full range of energy *in the current interval*
  – This “product substitution” LOC is used in ancillary market pricing

• Operationally Limited Opportunity Cost
  – A unit has emission limitations that, if the unit runs *today*, it may not be available to run *later in the year* (e.g. at summer peak)
  – The Opportunity Cost Calculator (OPC) generates an cost-based adder that “optimizes” potential run hours; *evaluated daily*
Types of Opportunity Costs

• Limited Energy Opportunity Cost
  – A unit has charge limitations that, if the unit runs in this interval, it may not be available to run later in the market day

• Inter-temporal Opportunity Cost to Dispatch
  – If I discharge now, then the marginal cost is the inventory cost
  – If I discharge now, and I have an opportunity to charge later, then the replacement cost is important for the future discharge interval
  – I never know for certain what the future LMP will be