Regulation Market Overview

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Regulation Market Issues Sr. Task Force
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Regulation is a product in the Ancillary Services Market that provides market-based compensation to resources that have the ability to adjust output or consumption in response to an automated signal:

- Helps to maintain interconnection frequency
- Help to track moment-to-moment fluctuations in customer loads
- To correct the unintended fluctuations in generation
- Manage differences between actual and scheduled power flow between control areas
- Match generation to load within a control area

The Regulation service is a reliability product.
Reserves are additional generation capacity above the expected load. Scheduling excess capacity protects the power system against the uncertain occurrence of future operating events, including the loss of energy or load forecasting errors.

<table>
<thead>
<tr>
<th>Time Interval Following PJM Request</th>
<th>Day-Ahead Scheduling Reserve ($T \leq 30$ Min)</th>
<th>Contingency (Primary) Reserve ($T \leq 10$ Min)</th>
<th>Synchronized Reserve (Synchronized)</th>
<th>Secondary Reserve ($10$ Min $\leq T \leq 30$ Min)</th>
<th>Non-Synchronized Reserve (Off-Line)</th>
</tr>
</thead>
</table>

$T = \text{Time Interval Following PJM Request}$
• The main goal of this service is to recover the ACE back to its pre-contingency level within the allotted timeframe after a resource loss, large tie errors, and under frequency conditions.
  – Outside of regulation

• This service provides a quick boost of generation (or load reduction) to the system to recover low ACE
  – Synchronized reserves cannot control over-frequency
  – Manual deployment
Non-Synchronized Reserve is reserve capability that can be fully converted into energy within 10 minutes of the request from the PJM dispatcher and is provided by equipment not electrically synchronized to the system

- Why do we procure NSR?
  - Reliability reason: NSR provides a backfill in case SR does not adequately respond to a spin event
  - Market reason: a non-zero NSR market clearing price (NSRMCP) is a good indication that the system is getting tight on reserves
Day-Ahead Scheduling Reserves

- PJM schedules reserves on a Day-Ahead basis
  - Ensures the difference between forecasted load and forced generator outages does not negatively impact reliable operations
  - DASR considers variables that negatively impact system reliability, specifically Underforecasted Load Forecast Error (LFE) and Generator Forced Outage Rates (FOR)
  - DASR = Underforecasted LFE + FOR
  - Percentage is calculated annually
  - Currently set at 5.93%
- Unlike Synchronized Reserves, DASR is not maintained in Real-Time
- There are no DASR events for resources to respond to
Regulation Resource Requirements

- Resources must be located electrically within the PJM RTO
- Generation resources must have a governor capable of AGC control.
- Resources must be able to receive an AGC signal.
- Resources must demonstrate minimum performance standards (must maintain 40% historic performance score), as set forth in the PJM Manual
- New resources must pass an initial performance test (minimum of 75% compliance required). PJM will rely on owner's data for initial qualification.
  - Resources that pass are enabled in the markets databases by PJM personnel
- Resources MW output must be telemetered
## Qualified Regulation MW

<table>
<thead>
<tr>
<th>Resource Type</th>
<th>REGA MW</th>
<th>REGD MW</th>
<th>Dual Qualified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam</td>
<td>3103</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hydro</td>
<td>970</td>
<td>420</td>
<td>420</td>
</tr>
<tr>
<td>CT</td>
<td>1194</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>Energy Storage</td>
<td>0</td>
<td>176</td>
<td>0</td>
</tr>
<tr>
<td>DSR</td>
<td>4</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total MW</strong></td>
<td><strong>5271</strong></td>
<td><strong>684</strong></td>
<td><strong>442</strong></td>
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</table>
To qualify for the regulation market resources must pass three (3) consecutive regulation tests with a performance score of 75% or greater

- Resources MW output must be telemetered and activated before testing
- One self test is allowed (Signal data is available to participants on PJM.com)

Resources must continue to demonstrate minimum performance requirements once in the Regulation Market

- Historical performance score must be greater than 40% (100 hour rolling average)
- Individual hour performance must be greater than 25% to be compensated

Manual 12 – Section 4.5
PJM scores resources on 3 components:

**Accuracy**: the correlation or degree of relationship between control signal and response

**Delay**: the time delay between control signal and point of highest correlation

**Precision**: The instantaneous error between the control signal and the regulating unit’s response

A resource’s performance score is calculated as:

\[
\text{Perf\_Score} = \frac{1}{3} \times \text{Accuracy} + \frac{1}{3} \times \text{Delay} + \frac{1}{3} \times \text{Precision}
\]
REGULATION MARKET

Throughout the operating day PJM clears the Regulation Market hourly and makes intra-hour adjustments as necessary.

**12:00 p.m.**

Due a day ahead of the operating day by noon:
- Energy schedule for LOC calculation to qualify units

**6:00 p.m.**

Due a day ahead by 6:00 p.m.:
- Cost based offer (capped at actual cost + $12 adder) *Required for clearing*
- Price based offer (optional – capped at $100/MWh)
- All other regulation data can be revised up till 60 minutes before the operating hour

**12:00 a.m.**

Up to 1 hour prior to the operating hour:
- Regulating status (available, unavailable, SS)
- Regulating capability (MW above and below reg midpoint)
- Reg min and max
- Reg signal type (A or D)

Data submitted to eMKT
Performance Based Regulation Concepts

• Benefits Factor - translates a RegD MW into a RegA MW
  – All RegA resources have a BF = 1
  – Value ranges from 2.9 to 1 during excursion hours and 2.9 to 0 during non-excursion hours
    • Excursion hours: HE7, HE8, HE 18 – HE 21
    • Pending MRC endorsement from the RPI group
• Mileage - the absolute sum of movement of the regulation signal in a given time period. Resources following the dynamic signal (RegD) will likely move much more than those on the traditional signal (RegA)
• Performance Score – evaluation of how a regulating resource closely follows the regulation signal. Value ranges from 1 to 0.
  – Resources with an hourly performance score of <= .25 will not receive compensation
  – Resources with a historical performance score of <= .40 will be removed from the market
Effects of Performance Based Regulation

• Resource offers (capability and performance), and Lost Opportunity Cost are adjusted based on:
  – Resource specific Benefit Factor
  – Resource specific Historic Performance Score
  – System-wide Historic Mileage

• Good performing resources look less expensive and poor performing look more expensive to the Market Clearing Engine
  – Currently not true for self-scheduled resources.

\[ \text{Effective MW} = \text{RegMW} \times \text{Performance Score} \times \text{Benefits Factor} \]
Regulation Market Clearing Process

Participant Data of a Regulation Resource
- Capability Offer ($/MW)
- Performance Offer ($/MW)
- Regulation Offer (MW)

PJM Calculated Data (Resource Specific RTO Regulation Signal)
- Resource Specific Historical Performance Score (last 100 hrs. average)
- Resource Specific Market Interval Benefits Factor
- Historical Signal Type Mileage (rolling 30 days average)

PJM RTO Regulation Requirement

Joint Co-optimization of Energy, Reserve and Regulation

Total Incremental Cost of Regulation Marginal Resource

Resource Specific Lost Opportunity Cost (RegLOC)

Regulation Three Pivotal Supplier Test (RegTPS)

Performance Clearing Price (PCP)
- Highest Adjusted Performance Offer of Committed Resources

Capability Clearing Price (CCP)
- Residual of Total Incremental Cost of Marginal Resource

Regulation Market Clearing Price (RMCP)
• Regulation is cleared every hour for one hour look-ahead
  – Pricing is done every 5 minutes along with energy LMP in real-time
  – Co-optimized with energy

• Regulation is cleared to meet the established requirements
  – 525 Effective MW for Off-peak (0000 – 0500)
  – 700 Effective MW On-Peak (0500 – 0000)
  – Clear the most economic mix of RegA and RegD resources

• One RTO Regulation market and therefore one uniform clearing price (RMCP)
  – Clearing is based on merit (cost, performance, and benefits to the system)
  – Clearing price separates into capability and performance clearing prices (CCP and PCP)
  – No clearing price based on signal type (RegA, RegD)

• The Area Control Error (ACE) is not a factor in the clearing process
Clearing (ASO) vs. Pricing (LPC)

**ASO**
Ancillary Services Optimizer

Runs one hour in advance of operating hour to procure least cost set of resources

- Input:
  - Regulation Offers from eMKT
  - Historical Performance Score
  - Historical Mileage

- Output:
  - MW assignment
  - Forecasted LMP (for LOC calculation)
  - Rank Price (not financially binding)

**LPC**
Locational Pricing Calculator

Runs every 5 minutes in Real-Time to price assigned resources

- Input:
  - Assignment from ASO
  - Intra-hour commitments
  - Historical Performance Score
  - Actual Mileage

- Output:
  - Actual 5 minute LMP (for LOC calculation)
  - Regulation Market Clearing Price (comprised of the Regulation Market Capability Clearing Price and the Regulation Market Performance Clearing Price) used in Settlements
Rank = Adjusted Capability Offer Cost 
    + Adjusted Performance Offer Cost 
    + Adjusted Lost Opportunity Cost 

• Rank is used by ASO to stack resources in order to determine the least cost set of resources to meet the requirement
  – RegA and RegD resources are evaluated simultaneously
• Rank price is not financially binding
• The term “adjusted” means factoring in the PBR measures of Benefits Factor, Mileage, and Performance Score
Rank = Adjusted Capability Offer Cost + Adjusted Performance Offer Cost + Adjusted Lost Opportunity Cost

**Cost Based Offer is required for clearing**

Regulation Offers

- Regulation Three Pivotal Supplier (RegTPS) Test is used to mitigate market power
- If supplier PASSES, price based offer is used for remainder of clearing process

Clearing starts at:
Least of [(Capability Cost + Performance Cost), (Capability Price + Performance Price)]
Capability Offer Cost Example

Rank = \text{Adjusted Capability Offer Cost} + \text{Adjusted Performance Offer Cost} + \text{Adjusted Lost Opportunity Cost}

\[
\text{Adjusted Reg Capability Offer Cost (}$/\text{MWh}$) = \frac{\text{Capability offer (}$/\text{MWh}$)}{\text{Benefits Factor} \times \text{Historic Performance Score}}
\]

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Type</th>
<th>Signal Type</th>
<th>Capability</th>
<th>Performance</th>
<th>Benefits Factor</th>
<th>Performance Score</th>
<th>Adjusted Capability Offer</th>
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<tbody>
<tr>
<td>A</td>
<td>Self-Scheduled</td>
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<td>$0.50</td>
<td>1</td>
<td>0.5</td>
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<tr>
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<td>$1.00</td>
<td>1.8</td>
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<td>0.6</td>
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<td>0.8</td>
<td>$0.83</td>
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</table>
**Adjusted Reg Performance Offer Cost ($/MWh)**

\[
\text{Adjusted Reg Performance Offer Cost ($/MWh)} = \frac{\text{Performance offer ($/MWh)} \times \text{Historic Mileage}}{\text{Benefits Factor} \times \text{Historic Performance Score}}
\]

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<tr>
<th>Resource</th>
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<td>$5.00</td>
<td>$0.50</td>
<td>1</td>
<td>0.75</td>
<td>5</td>
<td>((0.5 \times 5)/(1 \times 0.75) = $0.67)</td>
</tr>
<tr>
<td>F</td>
<td>Economic</td>
<td>D</td>
<td>$1.00</td>
<td>$0.25</td>
<td>1.5</td>
<td>0.8</td>
<td>15</td>
<td>((2 \times 15)/(1.5 \times 0.8) = $3.13)</td>
</tr>
</tbody>
</table>

Historic mileage is used for clearing, actual mileage is used for pricing.
RegLOC – is the foregone revenue or increase in costs relative to the energy market for providing regulation.

- Calculated only for pool scheduled generators
- Is $0 for DSR and self-scheduled generators
- RegLOC is calculated relative to the cheaper of available priced-based energy schedule or the most expensive cost-based energy schedule

$$\text{RegLOC Schedule} = \text{Least} \begin{cases} \text{available priced-based energy schedule,} \\ \text{greatest(available cost-based energy schedule)} \end{cases}$$
In the clearing process – RegLOC is calculated as the difference between forecasted LMP and price at the Reg base-point on RegLOC schedule.

In the pricing – RegLOC is calculated as the difference between Real-Time LMP and price at the Reg base-point on RegLOC schedule.
Effects of Zero Offers on LOC

- Resource types determine the eligibility for LOC
  - Storage and DSR
    - Not eligible for LOC
    - Rank is zero
  - Generation Resources
    - Participate in Real-Time market
    - LOC component may be non-zero
    - Rank may be non-zero
- Self Scheduled Offers
  - Price taker
  - Not eligible for LOC
  - Rank is zero
**Adjusted Lost Opportunity Cost Example**

\[ \text{Adjusted RegLOC} = \left[ \frac{\text{LM} \times \text{MC}}{\text{Resource BFactor} \times \text{Resource Historical Performance Score}} \right] \]

*where MC is the price of Reg set point on the RegLOC schedule*

<table>
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<th>Mileage</th>
<th>Adjusted Capability Offer</th>
<th>Adjusted Performance Offer</th>
<th>Adjusted LOC</th>
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</table>
Rank Example

Rank = Adjusted Capability Offer Cost + Adjusted Performance Offer Cost + Adjusted Lost Opportunity Cost

Example requirement = 90 MW

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Type</th>
<th>Signal Type</th>
<th>Adjusted Capability Offer</th>
<th>Adjusted Performance Offer</th>
<th>Adjusted LOC</th>
<th>Rank</th>
<th>Effective Offer MW</th>
<th>Cleared MW</th>
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<tr>
<td>C</td>
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</table>
• Calculating the Rank in ASO and the RMCP in LPC
  – The same steps are performed except Reg TPS Test (only done in ASO)

• Real-Time conditions affect regulation pricing
  – System conditions change
    • Resources needed for constraint control
    • Impacts to LOC
  – Forecasted LMP vs. 5 minute LMP
  – Historical mileage vs. actual mileage
Regulation Market Clearing Price = Regulation Market Capability Clearing Price + Regulation Market Performance Clearing Price
RMCP = RMCCP + RMPCP

<table>
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<tr>
<th>Resource</th>
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<th>Signal Type</th>
<th>Adjusted Capability Offer</th>
<th>Adjusted Performance Offer</th>
<th>Adjusted LOC</th>
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- Regulation Market Clearing Price (RMCP) = highest rank of cleared resources = $27.34
- Regulation Market Performance Clearing Price (RMPCP) = highest adjusted performance offer from cleared resources = $3.13
- Regulation Market Capability Clearing Price (RMCCP) = RMCP – RMPCP = $24.21
Regulation Settlements

- **Capability Credit** = Hourly-integrated Raw Regulation MW * Hourly Performance Score * Regulation Market Capability Clearing Price (RMCCP)
- **Performance Credit** = Hourly-integrated Raw Regulation MW * Hourly Performance Score * Mileage Ratio * Regulation Market Performance Clearing Price (RMPCP)

- 5 minute RMCCP and RMPCP are hourly integrated
- Hourly performance score must be above 0.25 to receive compensation
- Manual 28 Section 4