Regulation Redesign Phase 1
Clearing & Pricing Update

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Real-Time Market Operations

Market Implementation Committee

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Overview

The Regulation Redesign project stems from an approved solution developed with stakeholders during the Regulation Market Design Senior Task Force (RMDSTF).

The projected overall benefits of the FERC-approved Regulation Market updates are to create efficiencies in procurement and price formation for regulation service while meeting the challenges presented by the changing resource mix (increase in renewable resource types) over the next few years.

PJM and the IMM have been closely following the clearing and pricing since go-live, Oct. 1, 2025.

There are areas functioning well, and there may be opportunities for improvement.

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Phase 1 Summary of Changes

#	Design Components	Summary Description
1	**Signals and Products**	Change from ***two*** signals (RegA and RegD) bidirectional to ***one*** signal bidirectional that all resources that are assigned Regulation in a given market interval will follow.
2	**Requirement MW**	Changes to better reflect operational needs with consideration both to historic and future system conditions
3	**Performance Scoring**	Change from accuracy, delay and precision to precision only.
4	**Offer and Clearing Timing**	Eliminate "cost increase in VOM" except for Reg-only resources; change from hour clearing and commitment to 30-minute clearing and commitment.
5	**Opportunity Cost Calculation Reform**	1. Use the schedule the resource is running for energy or else the cheaper of available schedule for offline. 2. Use tracking desired megawatt at LMP ramp-rate limited. 3. Use the area between LMP and the energy schedule the resource is running on.
6	**Settlement**	For the eligible resources, settlement will calculate the shoulder interval opportunity cost for two five-minute ramp-in intervals before the resource Regulation operation and two five-minute ramp-out intervals following the resource Regulation operation (currently, three intervals ramp-in and three intervals ramp-out). Also, settlement will update the calculation for the regulation mileage credit (currently performance credit) such that the mileage ratio is equal to real-time regulation mileage/historic regulation mileage.

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What Is Working Well

Regulation Operation

- Regulation utilization and reduced pegging
- 30-minute commitment framework supports operational reliability

Reduced Uplift (from 14% to less than 2%)
Improved Cost Allocation

- Costs are now more transparently embedded in the market clearing prices
- Enhanced market efficiency and fairness

Performance Score Simplification

- Focus on precision improves clarity
- Better align pricing and compensation with the actual performance of the resource

Improved Opportunity Cost Representation (LOC)

- Incorporates ramp rate limitations and the energy schedule the unit is running on
- Better captures the true cost of holding capacity for regulation vs. energy

Pre-ramping Value Added

- Eligible resources are positioned ahead of need (10-minute pre-ramp)
- Improves deliverability and control performance

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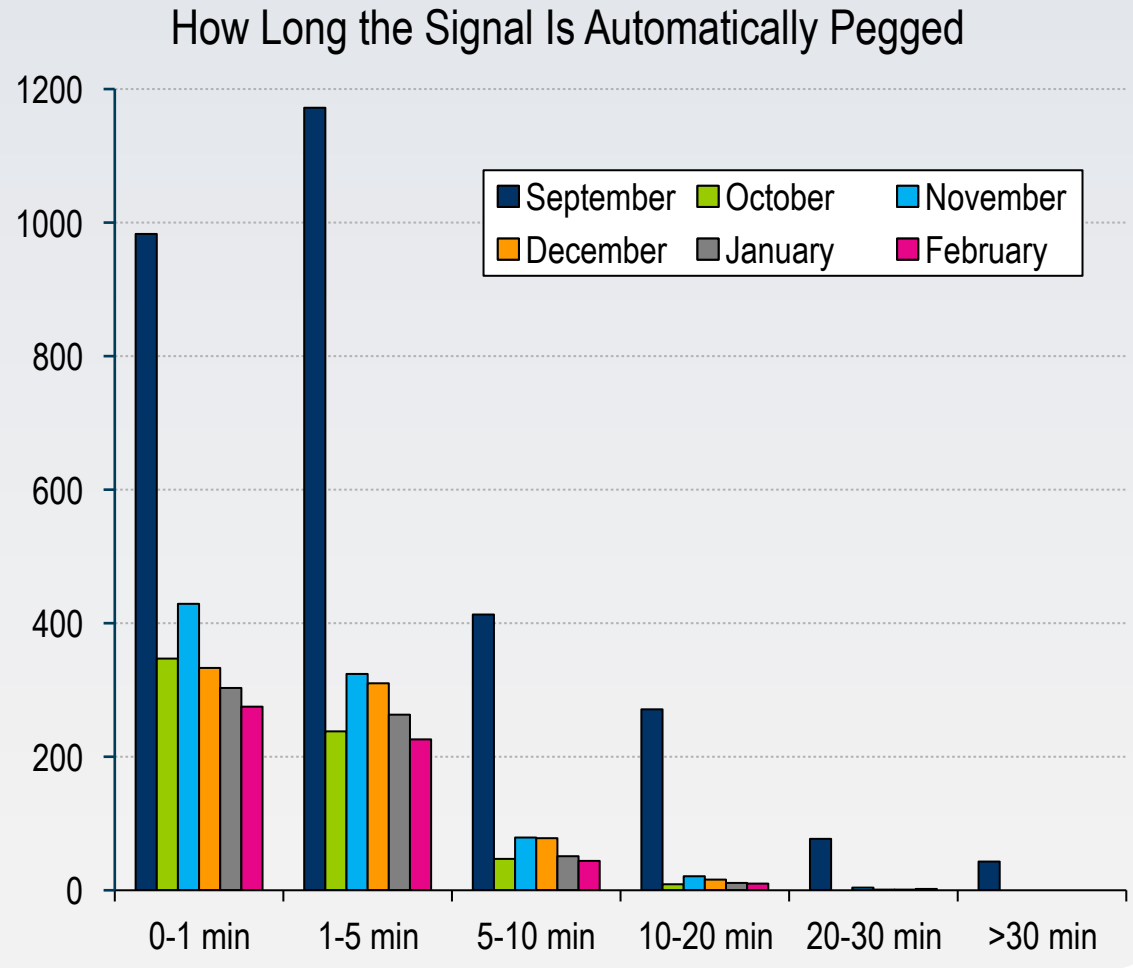
Regulation Operations

Regulation Requirement Effective Megawatts

Season	Dates	Hours Ending	Requirement MW
Winter	Nov. 1–Feb. 28	HE 5 – 10, HE 17 – 24	750
		HE 1, HE 11	650
		HE 2 – 4, HE 12 - 16	550
Spring	March 1–April 30	HE 19 – 1, HE 6 – 9	750
		HE 2, HE 10	650
		HE 3 – 5, HE 11 – 18	550
Summer	May 1–Sept. 15	HE 5 – 1	750
		HE 2	650
		HE 3 – 4	550
Fall	Sept. 15–Oct. 31	HE 6 – 9, HE 18 – 24	750
		HE 1, HE 10	650
		HE 2 – 5, HE 11 – 17	550

Key Takeaway:

The requirement megawatts changes have improved Regulation utilization.



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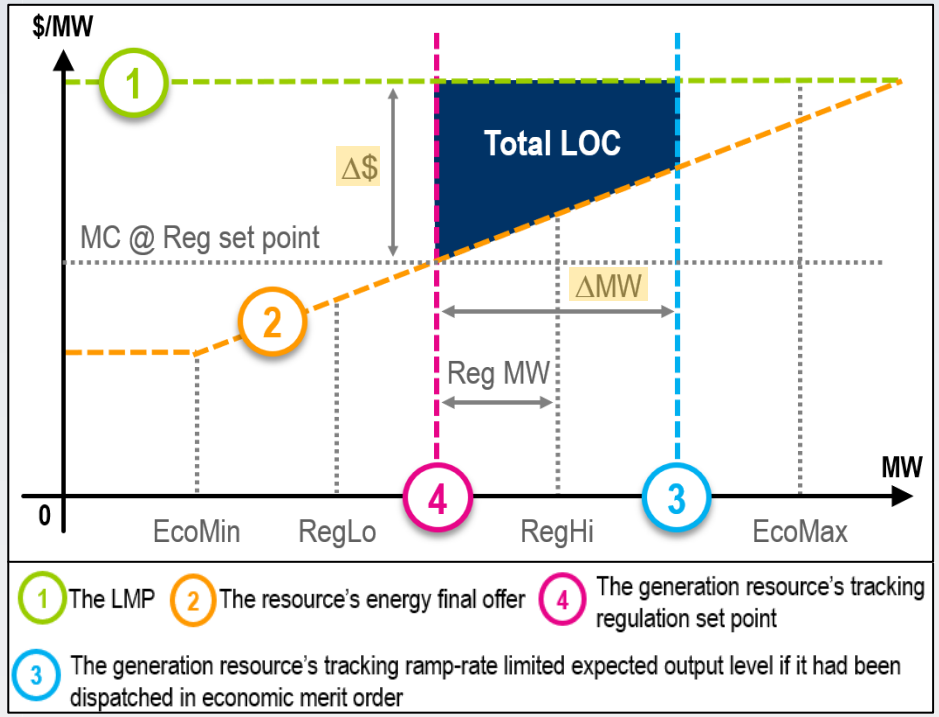
Driver for Regulation Prices

Regulation prices are result of market design, interacting system conditions and operational constraints.

- Real-time LMP: higher LMP → higher LOC → higher MCP
  - Load ramps
  - Congestion pattern
- Units with little or no residual ramp to move the regulation setpoint can widen LOC MW.
- Units with wide separation between eco-limits and reg-limits can widen LOC MW.
- Large Unit with small regulation assigned megawatt can bloat LOC.
- Small historic performance score can bloat LOC.



$$\text{LOC (\$/MW)} = \frac{TotalLOC}{PS * RegMW} = \frac{\Delta\$ * \Delta MW}{PS * RegMW}$$

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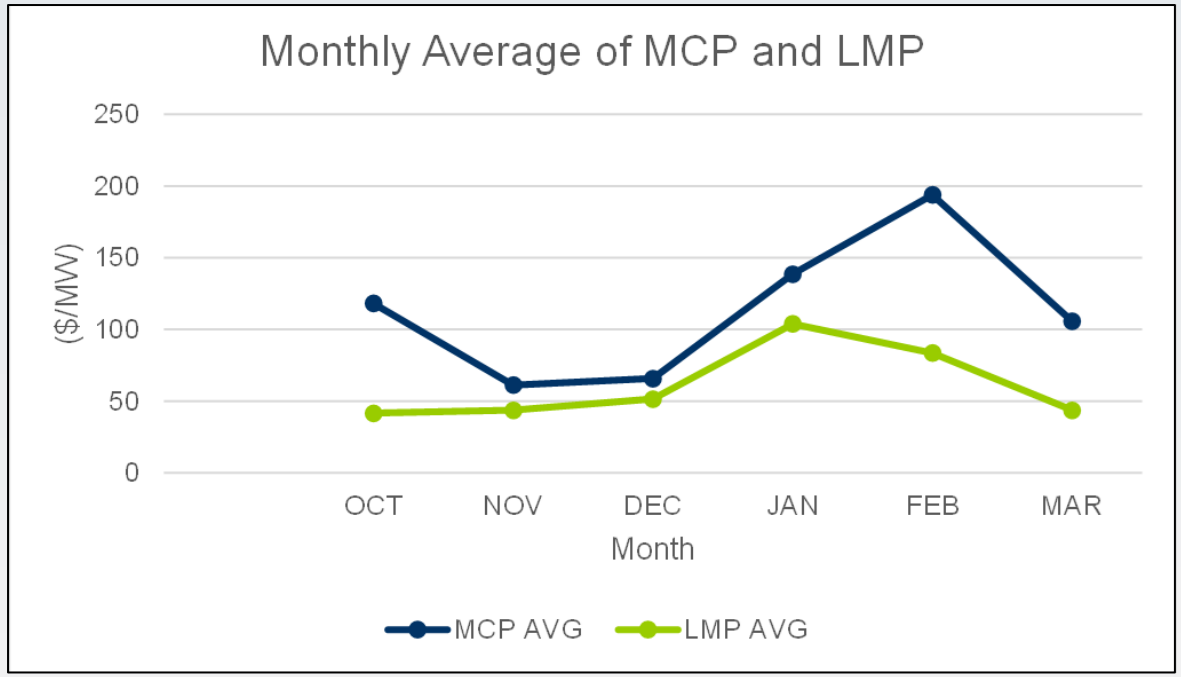
Average Energy LMP vs. Regulation MCP

Regulation Requirement Effective Megawatts

Month	Avg MCP	Avg LMP
Oct. 2025	118.23	41.75
Nov. 2025	61.40	43.80
Dec. 2025	65.90	51.58
Jan. 2026	138.69	103.97
Feb. 2026	193.86	83.64
Mar. 2026	105.82	43.78



Key Takeaway:

Real-time LMP and Regulation MCP may correlate. February saw high MCP.

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Areas of Focus

Regulation Phase 1 was implemented in full compliance with FERC-approved Tariff/OA changes:

PJM staff continues to evaluate Market results.

Improvements to optimization need to comply with existing Tariff/OA provisions.

Evaluate regulation clearing in ASO:

ASO needs to / and is clearing the “least cost set” of resources.

Consistent with the message above, any changes introduced must comply with existing FERC-approved Tariff/OA language.

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Drivers for Regulation Prices – Resources Attributes

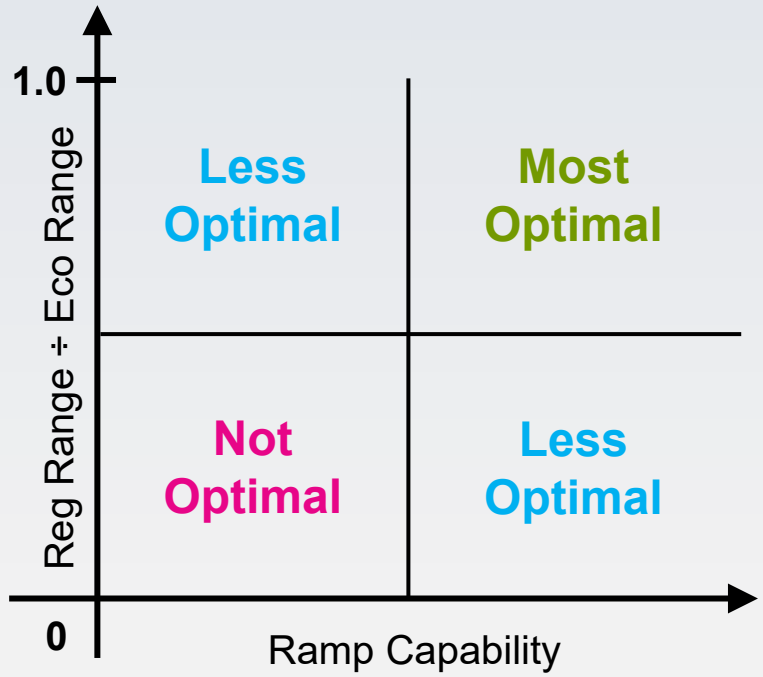
Regulation range and Economic range define the dispatchable limits of a resource for Regulation and Energy respectively.

- The closer $\frac{Reg\ Range}{Eco\ Range} \rightarrow 1$, the more flexible and better a resource is for Regulation.

Ramp capability of a resource is the rate of change of its output in megawatts per minute.

- The higher the up-ramp and down-ramp, the more flexible and better a resource is for Regulation.

RegMin, RegMax, EcoMin, EcoMax and Ramp values are all bid-in parameters of a resource by the Market Participants.



Key Takeaway:

The Regulation clearing engine can be enhanced to better account for resource's attributes through estimated LOC in its commitment decision.

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Resource Attributes That Increase or Reduce LOC

	Increase LOC	Reduce LOC
1	Low ramp	High ramp
2	Wide eco/reg gap	Narrow or no eco/reg gap
3	Small reg megawatt	Large reg megawatt
4	Low historic performance score	High historic performance score

See examples in the appendix section

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Summary of the Examples

1 Resources with residual ramp combine with equal economic and regulation ranges are most desirable for regulation.

- Mitigate LOC and MCP.
- Minimize the overall system production cost.

2 LOC is directly proportional to LMP.

3 Larger RegMW can mitigate LOC.

- Reduce effect of separate economic and regulation ranges.
- Reduce effect of LMP spike on magnitude of LOC.

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Key Takeaways

1	2	3
• Regulation prices are correct and are result of market design, interacting system conditions and regulating resources attributes. • There is no error in the clearing or pricing as it pertains to PJM's governing document language.	• Improved Opportunity Cost calculation that incorporates ramp rate limitations better captures the true cost of holding capacity for regulation vs. energy. • Regulation costs are more transparently embedded in the market clearing prices. • Reduced Settlement LOC from 14% to less than 2%.	• ASO needs to produce the "least cost set" of resources, that will withstand price volatility in real time. • PJM is constantly monitoring the optimization engine results with our software vendor and the IMM for potential improvements.

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Appendix

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Example - Little or No Residual Ramp To Move Reg Setpoint

Ramp rate constraint widen lost opportunity megawatt (ΔMW) for the continuous period LMP is higher than energy offer price.

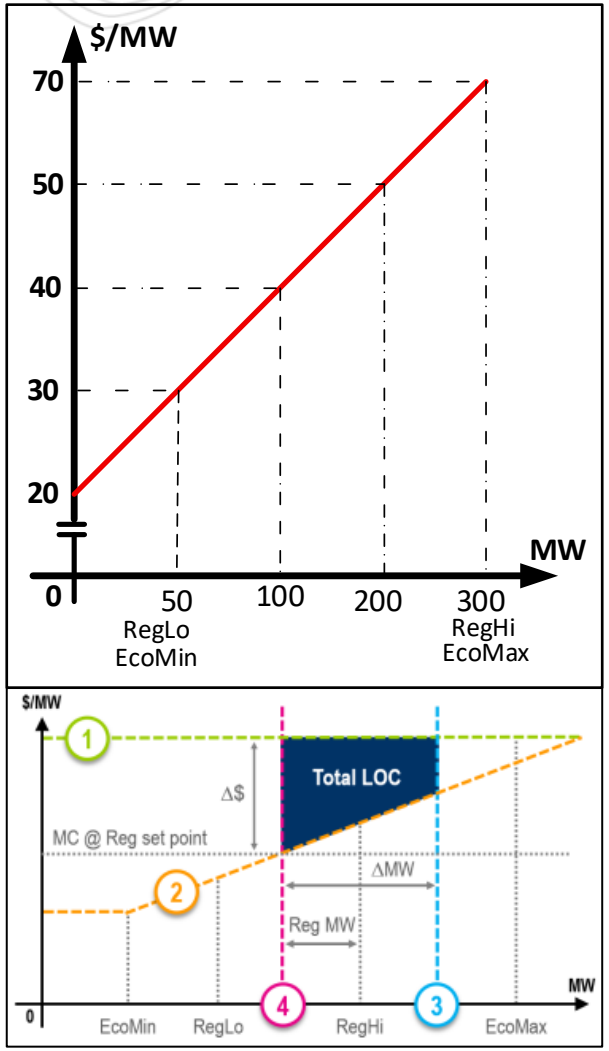
$$Residual\ Ramp\ Rate = max\left[0, Economic\ Ramp\ Rate - \frac{RegMW}{5}\right]$$

$$LOC = \frac{Total\ LOC}{PS * RegMW} = \frac{\Delta\$ * \Delta MW}{PS * RegMW}$$

Reg MW = 10 | **Ramp Rate = 2 MW/Min** | Historic Performance Score = 1.0

Interval	LMP, 1	Marginal Cost @ Reg Setpoint	MW @ Reg Setpoint, 4	Tracking Ramp Limited Desired (TRLD) MW, 3	LOC	Delta MW
12:05	50	32	60	60	0	0
12:15	300	32	60	80	536	20
12:25	74	32	60	100	168	40
12:35	74	32	60	120	252	60
12:45	74	32	60	140	336	80
12:55	74	32	60	160	420	100

The bigger the separation between points 3 and 4, the higher the LOC, hence MCP desirable for residual ramp rate > 0.



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Example – Unconstrained Residual Ramp To Move Reg Setpoint

Unconstrained residual ramp moves the Reg setpoint along with the TRLD and thereby mitigates delta MW, LOC, and consequently MCP.

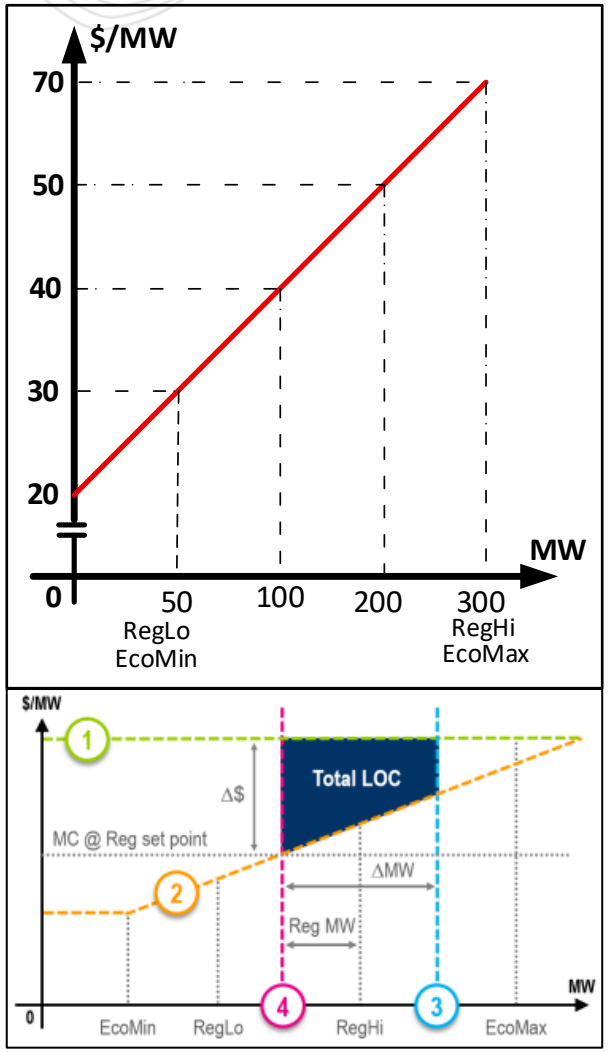
$$Residual\ Ramp\ Rate = max\left[0, Economic\ Ramp\ Rate - \frac{RegMW}{5}\right]$$

$$LOC = \frac{Total\ LOC}{PS * RegMW} = \frac{\Delta\$ * \Delta MW}{PS * RegMW}$$

Reg MW = 10 | **Ramp Rate = 10 MW/Min** | Historic Performance Score = 1.0

Interval	LMP, 1	Marginal Cost @ Reg Setpoint	MW @ Reg Setpoint, 4	Tracking Ramp Limited Desired (TRLD) MW, 3	LOC	Delta MW
12:05	50	40	100	100	0	0
12:15	300	48	180	200	504	20
12:25	74	62	260	300	48	40
12:35	74	68	290	300	6	10
12:45	74	68	290	300	6	10
12:55	74	68	290	300	6	10

The higher the residual ramp rate, the better for regulation and overall system.



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Example – Separate Eco-Limits and Reg-Limits, and Ramp Constrained

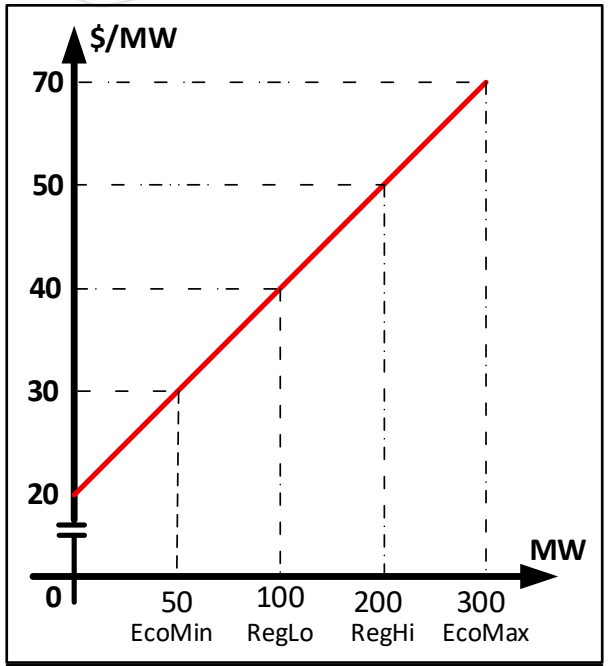
Ramp constrained and separate economic and regulation ranges can exacerbate LOC, and consequently MCP.

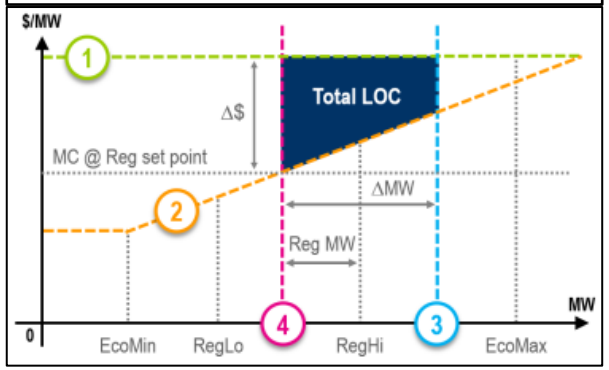
$$Residual\ Ramp\ Rate = max\left[0, Economic\ Ramp\ Rate - \frac{RegMW}{5}\right]$$

$$LOC = \frac{Total\ LOC}{PS * RegMW} = \frac{\Delta\$ * \Delta MW}{PS * RegMW}$$

Reg MW = 10 | **Ramp Rate = 2 MW/Min** | Historic Performance Score = 1.0

Interval	LMP, 1	Marginal Cost @ Reg Setpoint	MW @ Reg Setpoint, 4	Tracking Ramp Limited Desired (TRLD) MW, 3	LOC	Delta MW
12:05	50	49	190	190	0	0
12:15	300	49	190	210	502	20
12:25	74	49	190	230	100	40
12:35	74	49	190	250	150	60
12:45	74	49	190	270	200	80
12:55	74	49	190	290	250	100





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Example – Unconstrained Residual Ramp, Separate Eco-Limits and Reg-Limits

Unconstrained residual ramp mitigates delta MW and LOC but only to the extent of RegHi, then has no positive impact.

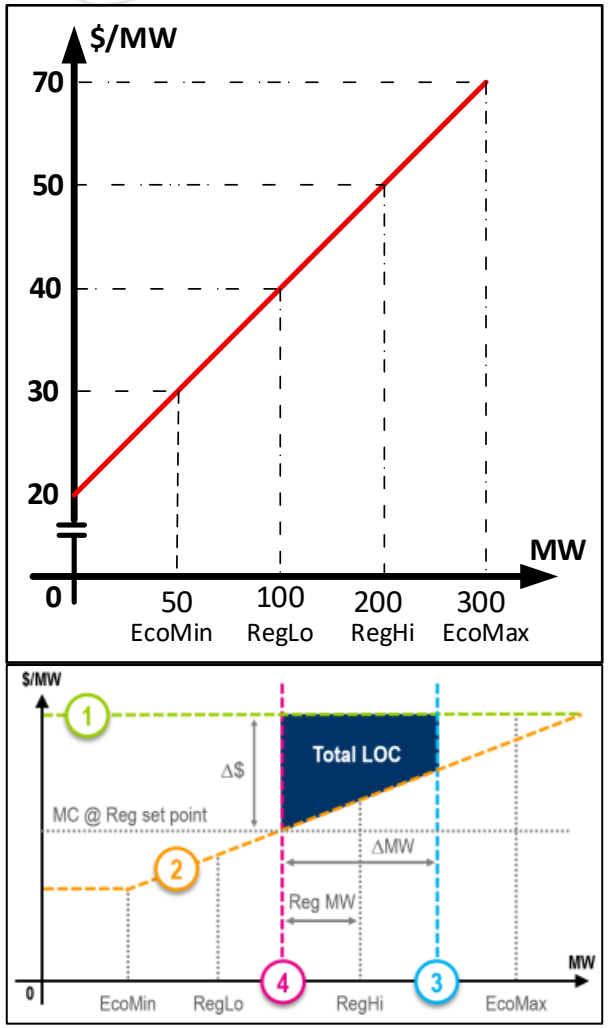
$$Residual\ Ramp\ Rate = max\left[0, Economic\ Ramp\ Rate - \frac{RegMW}{5}\right]$$

$$LOC = \frac{Total\ LOC}{PS * RegMW} = \frac{\Delta\$ * \Delta MW}{PS * RegMW}$$

Reg MW = 10 | **Ramp Rate = 10 MW/Min** | Historic Performance Score = 1.0

Interval	LMP, 1	Marginal Cost @ Reg Setpoint	MW @ Reg Setpoint, 4	Tracking Ramp Limited Desired (TRLD) MW, 3	LOC	Delta MW
12:05	50	49	190	190	0	0
12:15	300	49	190	290	2510	100
12:25	74	49	190	300	275	110
12:35	74	49	190	300	275	110
12:45	74	49	190	300	275	110
12:55	74	49	190	300	275	110

Unconstrained ramp with separate economic and regulation ranges are not desirable.



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Acronyms

Acronym	Term & Definition PJM Glossary
ASO	**Ancillary Service Optimizer** performs the joint optimization function of Energy, Reserves and Regulation in the dispatch run. The main functions of ASO are the clearing and commitment of all Regulation resources for a half-hour time period and inflexible Reserve resources for a one-hour time period.
MCP	**Market Clearing Price** – The price that is paid by all load and paid to all suppliers for the service received or provided
LOC	**Lost Opportunity Cost** – In general, the foregone revenues resulting from following PJM's dispatch instructions to provide some type of ancillary service. Lost opportunity costs are calculated for generating units participating in many PJM markets.
MW	**Megawatt** – A unit of power equaling one million watts (1 MW = 1,000,000 watts) or one thousand kilowatts (1 MW = 1,000 kW). To put it in perspective, under non-severe weather conditions, one MW could power roughly 800 to 1,000 average-sized American homes.
LMP	**Locational Marginal Price** is defined as the marginal price for energy at the location where the energy is delivered or received. For accounting purposes, LMP is expressed in dollars per megawatt-hour ($/MWh). LMP is a pricing approach that addresses Transmission System congestion and loss costs, as well as energy costs.
TRLD	**Tracking Ramp Limited Desired megawatt at LMP** – Reflects consecutive market conditions to form the real-time dispatch profile based on ramp rates, unit schedule and nodal LMP – independent of initial MW .

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