PJM Regulation Lost Opportunity Cost Overview

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Agenda

- Regulation Opportunity Cost Overview
- Current formulation of RegLOC
  - RegLOC components (shoulder hour before/after and regulation hour)
  - Impact of using the different energy schedule
  - Desired MW at LMP vs Desired MW at Ramp Rate Limit
- Impact of Look-Ahead Forecasted RegLOC and Hour-Ahead Commitment

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Regulation Lost Opportunity Cost (RegLOC)

RegLOC – The difference in net compensation from the Energy Market between what a resource receives when providing Regulation service and what it would have received for providing energy only.

- Calculated only for resources providing energy along with regulation service
- Calculated only for pool scheduled regulation resources
- Is $0 for DSR, and self-schedule and Non-Energy Regulation resources
- Can only be positive, else zero
- Calculated only within Eco limit range
  - ➢ Economic Minimum to Economic Maximum range
- RegLOC is a component of the Regulation Market Clearing Price

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Simplified RegLOC formula

$$|LMP - MC| * GENOFF$$

Where:

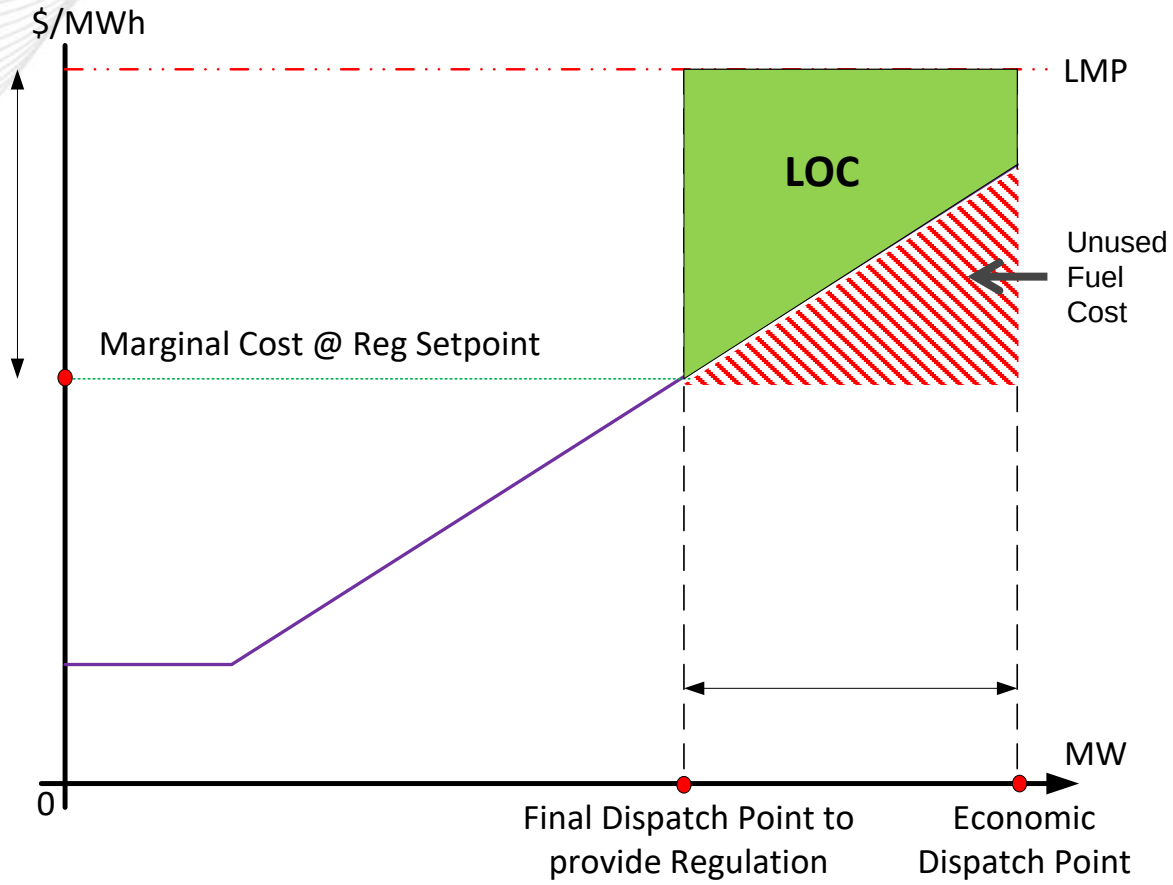
LMP – is the LMP at the resource bus;

MC – is the resource cost at the regulation set point;

GENOFF – is the MW deviation from the economic dispatch and the regulation set point

Note:

- In the clearing process, forecasted LMP is used
- In the pricing, Real-Time LMP is used
- RegLOC is further adjusted by:
  - Resource Historical Performance Score and
  - Resource Benefit Factor



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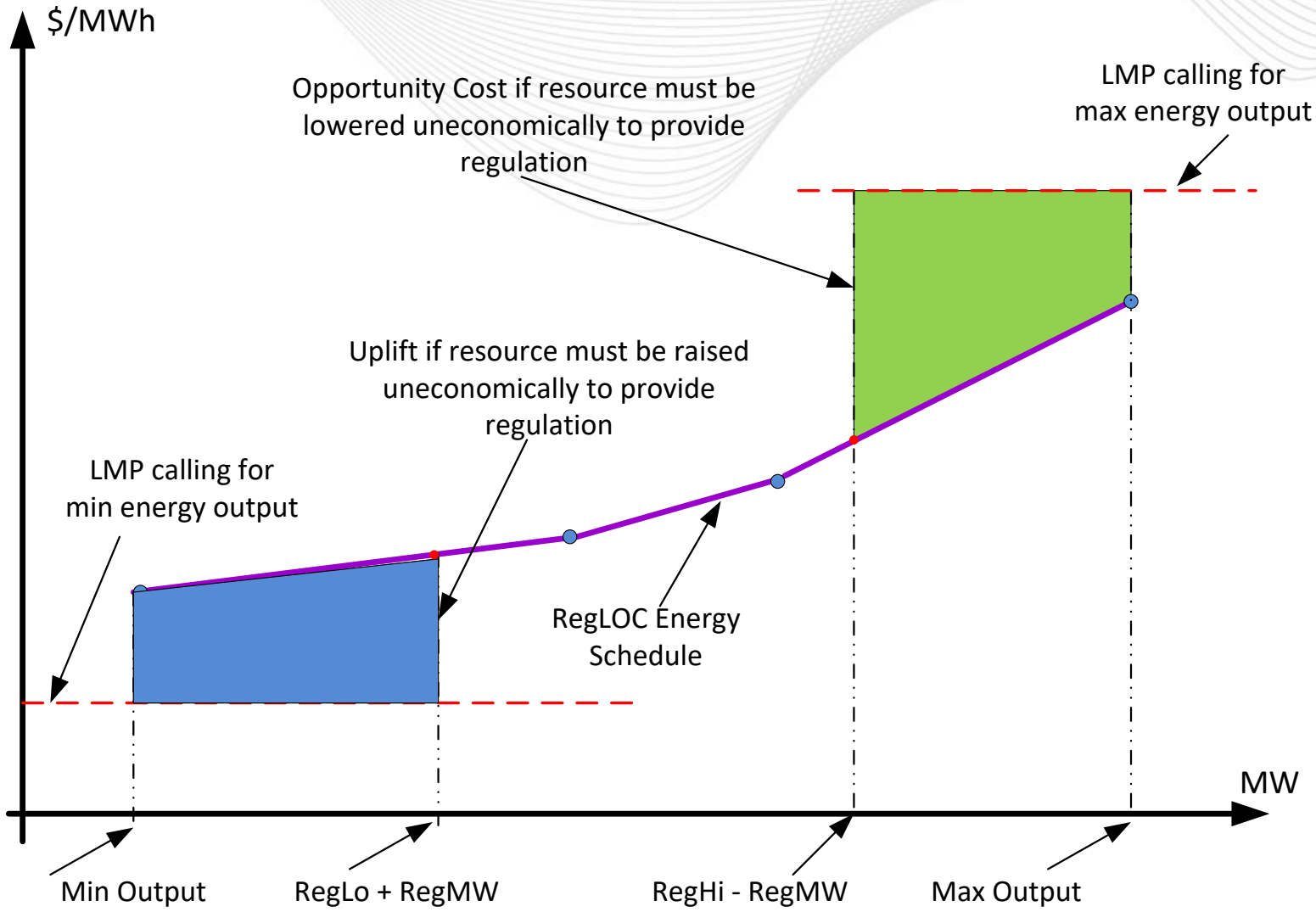
Regulation Uplift and LOC



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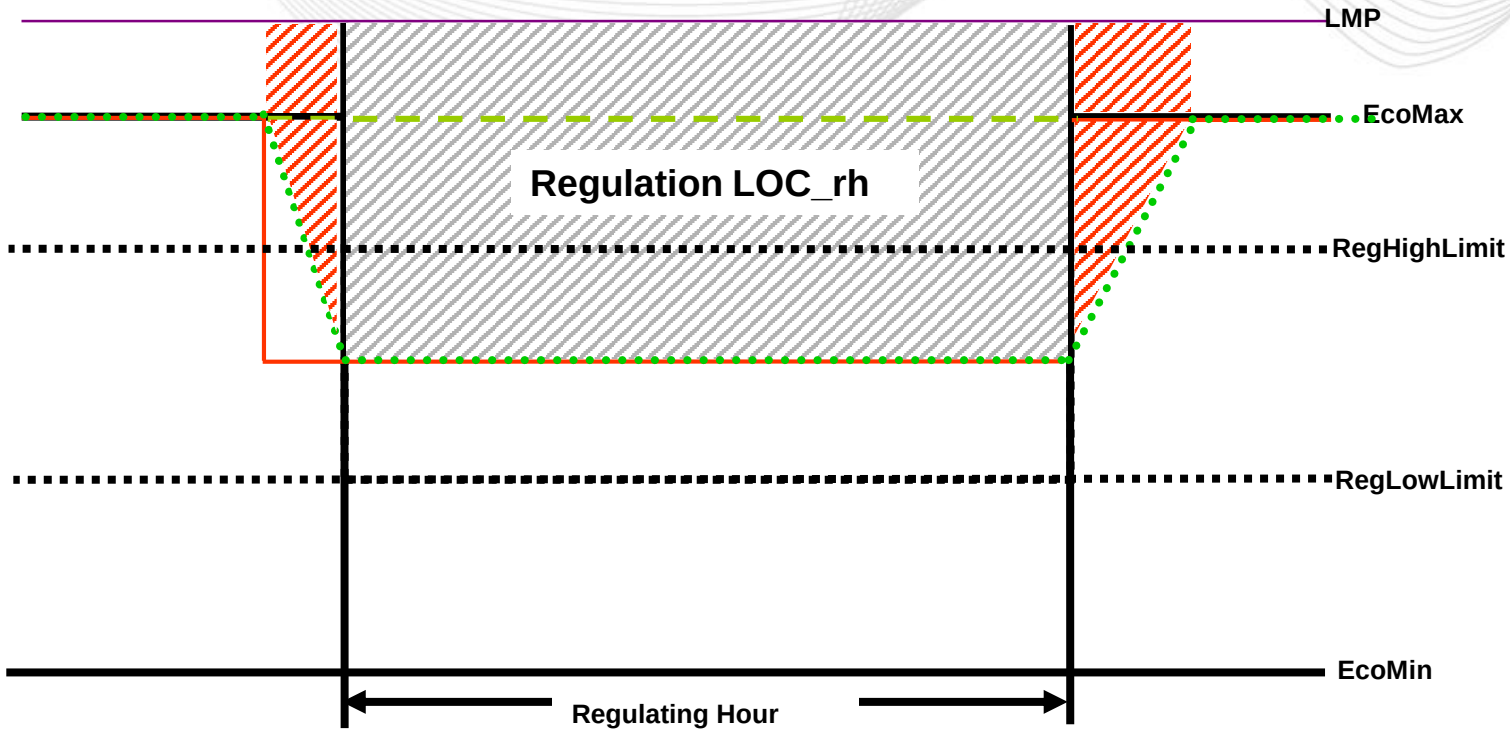
Shoulder Hours RegLOC



RegLOC = RegLOC_shb + RegLOC_rh + RegLOC_sha*

* - RegLOC_sha is calculated in Settlement

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RegLOC Schedule – Scenario 1 (LOC)

$$RegLOC\ Schedule = Least \left\{ \begin{matrix} available\ price\_based\ energy\ schedule, \\ greatest\ (available\ cost\_based\ energy\ schedule \end{matrix} \right\}$$

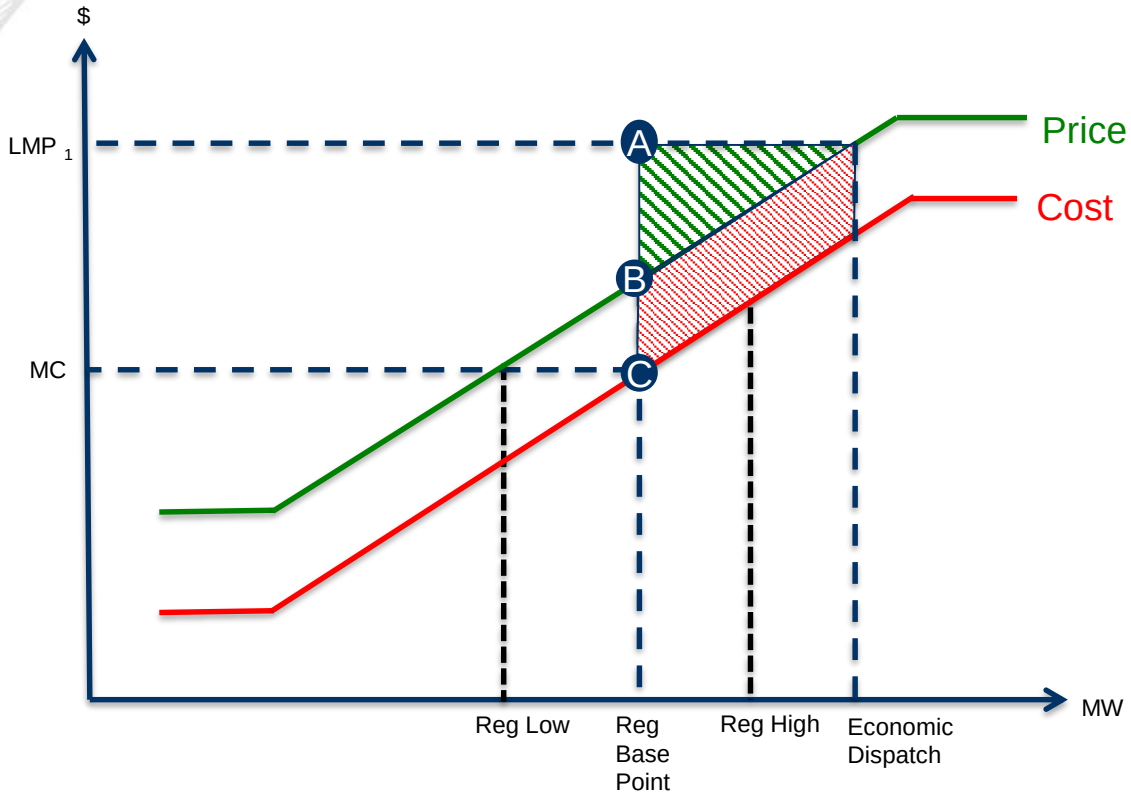
- Unit is running for energy on Price Schedule
- Reg LOC is calculated using Cost Schedule

$$LOC = |LMP_1 - MC| * |Economic\ Dispatch - Reg\ Basepoint|$$

$$LOC_{price} = |\$A - \$B| * |Economic\ Dispatch - Reg\ Basepoint|$$

$$LOC_{cost} = |\$A - \$C| * |Economic\ Dispatch - Reg\ Basepoint|$$

- Resource is paid the green + red portion
- Resource should only be paid the green portion
- In this case, we are overvaluing the cost of the resource to provide regulation



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RegLOC Schedule – Scenario 2 (Uplift)

$$RegLOC\ Schedule = Least\left\{\begin{matrix} available\ price - based\ energy\ scheduled, \\ greatest\ (available\ cost - based\ energy\ schedule \end{matrix}\right\}$$

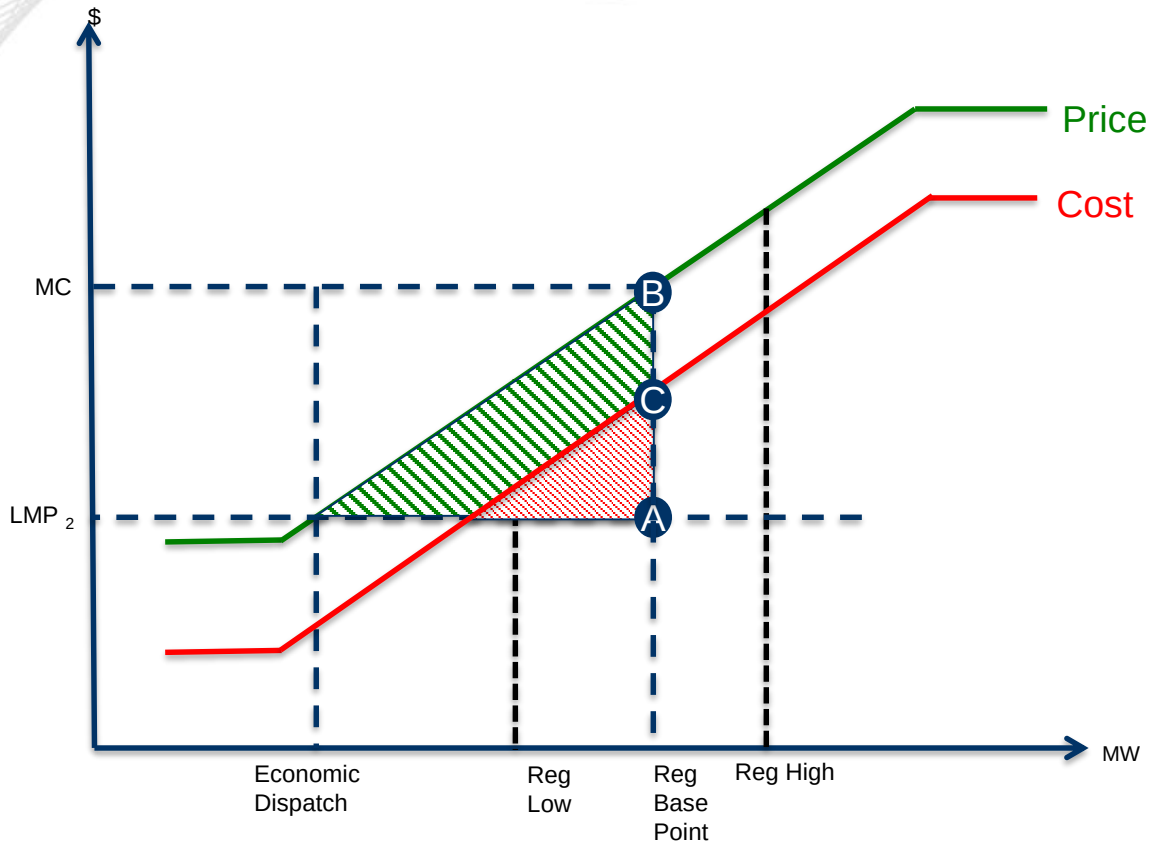
- Unit is running for energy on Price Schedule
- Reg LOC is calculated using Cost Schedule

$$RegLOC = |LMP_2 - MC| * |Reg\ Basepoint - Economic\ Dispatch|$$

$$RegLOC_{price} = |\$A - \$B| * |Reg\ Basepoint - Economic\ Dispatch|$$

$$RegLOC_{cost} = |\$A - \$C| * |Reg\ Basepoint - Economic\ Dispatch|$$

- Resource is paid the red portion
- Resource should be paid the green + red portion
- In this case, we are undervaluing the cost of the resource to provide regulation



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Impacts of Schedule Used in Reg LOC Calculation

- If the marginal resource is backed down uneconomically to provide regulation, the RMCP is likely inflated
- If the marginal resource is raised uneconomically to provide regulation, the RMCP is likely suppressed
  - Resources are still compensated in settlements to cover costs after-the-fact
- RMCP in these cases may not send the correct market signal

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Total LOC Outcome: Desired MW @ LMP vs Desired MW @ Ramp Rate Limit

Reg Assigned = 45 MW; RegLo = 165 MW; RegHi = 274 MW

Initial MW	SCED MW	LMP $/MWh	Marginal Cost $/MWh	Desired MW @ LMP	Desired MW @ Ramp Rate Limit	TOTAL LOC @ LMP $	TOTAL LOC @ RRate $	Diff $
267.2	229	49.28	47.43	247.1	247.1	36.74	36.74	0
267.2	229	50.94	47.43	263.2	263.2	132.01	132.012	0
265.7	229	58.1	47.43	284	265.7	644.6	430.12	214.48
275.4	229	58.41	47.43	284	275.4	663.3	559.58	103.72
229.9	229	57.98	47.43	284	254	637.45	289.75	347.7
232.4	229	60	47.43	284	254	759.55	345.25	414.3
221.3	229	70.64	47.43	284	254	1402	637.25	764.7
208.4	229	61.26	47.43	284	254	835.45	379.75	455.7

Total LOC(LMP) = Adjusted LOC x (Desired MW @ LMP – SCED MW)

Total LOC(RRate) = Adjusted LOC x (Desired MW @ Ramp Rate Limit – SCED MW)

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Summary of Desired MW @ LMP vs @ Ramp Capability

- The use of desired MW at the resource ramp capability may* provide more accurate RegLOC
  - *other scenario exist that may leave some money on the table
- The use of desired MW at the resource ramp capability should account for the resource resource's pnode LMP profile and impact of the confined regulation range

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Other Regulation Service Processes That Impact RegLOC

- Impact of hour ahead regulation clearing
  - Some of the committed resources may no longer be economic during the regulation hour
- Impact of hourly clearing and commitment
  - Some of the committed resources may not be economic through the regulation hour

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