PJM Proposed Package

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Real-Time Market Operations

Regulation Market Design Senior Task Force

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## MATRIX ITEMS:

A: Regulation Signal
1. Signal type
2. Product type

https://www.pjm.com/-/media/committees-groups/task-forces/rmdstf/2023/20230124/item-03-reg-signal-presentation-1242023.ashx

https://www.pjm.com/-/media/committees-groups/task-forces/rmdstf/2023/20230124/item-04-regulation-regupdown-1242023.ashx

- A single signal regulation design will allow PJM to better reflect the system needs to the regulation fleet to provide regulation service.

  - Resource agnostic signal aligned with system needs

  - Allows a simpler implementation for dispatch to operate and track; today's Reg A/D construct is not always clear on what regulation is available.

  - Allows for additional products to be developed (regulation up/down). Removing the two signal complexity would allow for an easier transition to RegUp and RegDn under one signal

- Implement Regulation Up and Regulation Down Products
  - One market two separate products with separate requirements and clearing prices
  - Resources would be able to offer, clear and provide both products together, or can provide just one product within the same regulation clearing duration

- Regulation up/down products will allow PJM to better address system needs in the future
  - PJM would have the ability to procure more or less of one product, depending on changing system needs
  - RegUp/Dn products would allow the broadest set of resources to provide regulation service
  - Market efficiency on available resource capabilities, minimized LOC and overall production cost
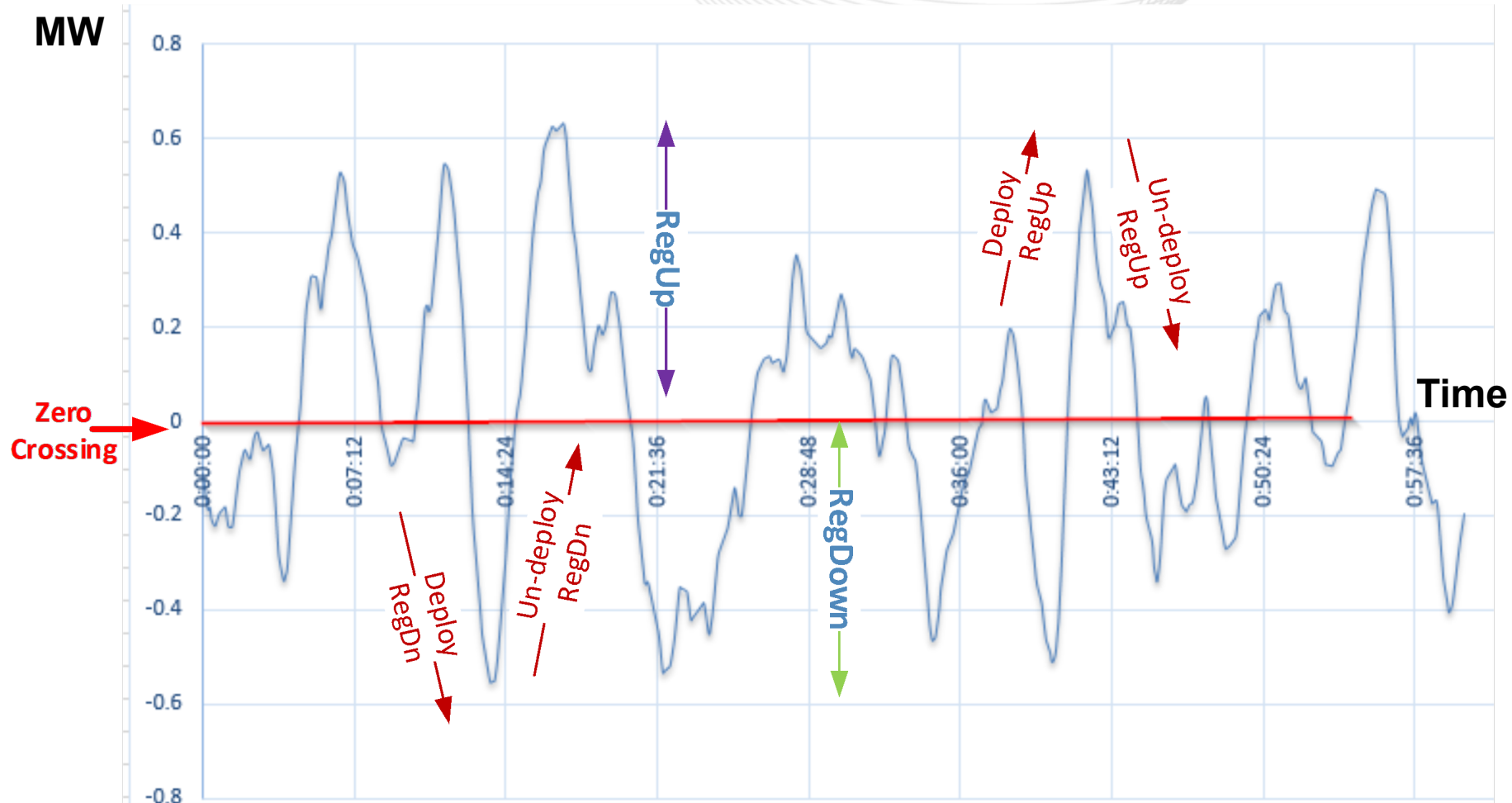
- RegUp product operates above the zero crossing

- RegDn product operates below the zero crossing

- Operationally, one product will be fully deployed and un-deployed before the other product is asked to respond to an AGC signal

A	MW	Offer Price
EcoMin	10	10
	20	20
	30	30
EcoMax	40	40
Reg offer	15	0

A

COAL POWER PLANT

B	MW	Offer Price
EcoMin	10	50
EcoMax	30	150
Reg offer	10	0

B

NATURAL GAS POWER PLANT
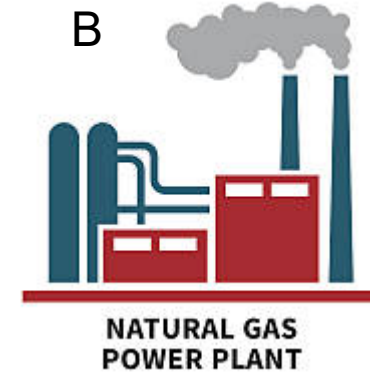
Scenario	Load	Reg Req.	Energy, MW (price)		Reg, MW (price)		LMP ($/MWh)	LOC ($/MWh)		Total Production Cost ($)
Resources			A	B	A	B				
1	50	5	35 (35)	15 (75)	5 (0)	0 (0)	75	40	0	3950
2	50	20	30 (30)	20 (100)	10 (0)	10 (0)	100	70	0	6400

LOC (1A) = |LMP – MC| x (Desired MW @ LMP – Reg-Set-point) / RegMW = (75-35)*(40-35)/5 = 40

Total Production Cost (1) = Energy Cost + Regulation Cost = (50*75) + (5*40) = $3950

Total Production Cost (2) = Energy Cost + Regulation Cost = (50*100) + (20*70) = $6400

Two Units Example (RegUp/Dn Design)

A	MW	Offer Price
EcoMin	10	10
	20	20
	30	30
EcoMax	40	40
RegUp offer	30	0
RegDown offer	30	0

COAL POWER PLANT

A

B	MW	Offer Price
EcoMin	10	50
Ecomax	30	150
RegUp offer	20	0
RegDown offer	20	0

NATURAL GAS POWER PLANT

B
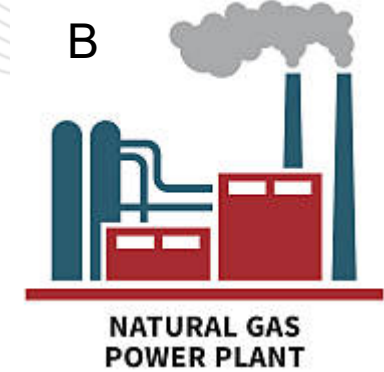
Assume Requirement RegUp=RegDown

Scenario	Load	Reg Req.	Energy, MW (price)		RegUp, MW (price)		RegDn, MW (price)		LMP	RegUp LOC		RegDn LOC		Total Production Cost
Resources			A	B	A	B	A	B		A	B	A	B	
1	50	5	40 (40)	10 (50)	0 (0)	5 (0)	5 (0)	0 (0)	50	0	0	0	0	2500
2	50	20	40 (40)	10 (50)	0 (0)	20 (0)	20 (0)	0 (0)	50	0	0	0	0	2500

LOC (1ADn) = |LMP – MC| x (Desired MW @ LMP – Reg-Set-point) / RegMW
$\quad$ = (50-40)*(40-40)/5 = 0

Compared with bi-directional design:
- Less Energy Cost
- Less Regulation/LOC Cost

- Differentiate system needs – Different Up/Down Requirements

- Promote new market entry

- Provide flexibility of supply

- Potential decrease on system production cost, LOC and Regulation clearing price

MATRIX ITEMS:
B: Regulation Requirement

https://www.pjm.com/-/media/committees-groups/task-forces/rmdstf/2022/20221220/item-04---rmdstf-pjm-regulation-requirement-proposal-data-review.ashx

https://www.pjm.com/-/media/committees-groups/task-forces/rmdstf/2023/20230222/20230222-item-03---pjm-regulation-requirement-proposal.ashx

https://www.pjm.com/-/media/committees-groups/task-forces/rmdstf/2023/20230418/20230418-item-03---regulation-requirement.ashx

- Similar to status quo, bi-level regulation requirement MW dependent on season and hour of day

- Influenced by recent ACE and CPS historic data (2022)

- Modifies to the status quo to align with observed control outcomes

  1. Shifts in seasonal definitions based on grouping months with similar hourly profiles

  2. Changes in "high" and "low" designated hours

  3. Minor change in "high" and "low" designated MW levels

Season	Dates	Hours Ending	Requirement MW
Winter	Nov. 1 – Feb. 28	HE 5 – 10, HE 17 – 24	800
		HE 1 – 4, HE 11 - 16	500
Spring	March 1 - April 30	HE 19 – 1, HE 6 – 9	800
		HE 2 – 5, HE 10 – 18	500
Summer	May 1 – Sept. 15	HE 5 – 15, HE 20 – 1	800
		HE 2 – 4, HE 16 - 19	500
Fall	Sept. 15 – Oct. 31	HE 6 – 9, HE 18 – 24	800
		HE 1 – 5, HE 10 - 17	500

MATRIX ITEMS:
C: Benefits Factor or Marginal Rate of Technical Substitution

This design component is not developed because PJM proposed package is based on a single signal design rather than RegA and RegD or two signal design. As such, the conversion relationship between signals is no longer relevant.

MATRIX ITEMS:
E: Performance Scoring
14. Qualification testing
15. Type specific testing
16. Components of performance scoring and weight
16c. Precision score calculation
17. Minimum allowable participation threshold
18. Minimum allowable compensation threshold

https://www.pjm.com/-/media/committees-groups/task-forces/rmdstf/2022/20221019/item-05---regulation-testing-process-overview.ashx

https://www.pjm.com/-/media/committees-groups/task-forces/rmdstf/2023/20230321/20230321-item-05---performance-score-data-march2023.ashx

Disqualified Resources

Change in Capability (MW)

Change in Communication Path or EMS – Existing or New Owner/MOC

New Resources

1 PJM-administered test

2 tests = 1 self-scheduled test + 1 PJM-administered test or 2 PJM-administered tests

New Performance Score of (an average of) PJM-administered test(s)

16. Components of performance scoring and weighting

– 100% Precision score

– Precision score calculation will be status quo precision score formula

❖ The instantaneous error between the control signal and the regulating unit's response

$$Error = Avg \ of \ Abs \left| \frac{Response - Regulation \ Signal}{Hourly \ Average \ Regulation \ Signal} \right|$$

$$\frac{Precision}{Score} = 1 - \frac{1}{n} \sum Abs(Error)$$

17. Minimum allowable participation threshold - status quo

– 40% historic performance score (average across last 100 operating hour)

18. Minimum allowable compensation threshold – status quo

– 25% performance (precision) score for the interval

MATRIX ITEMS:
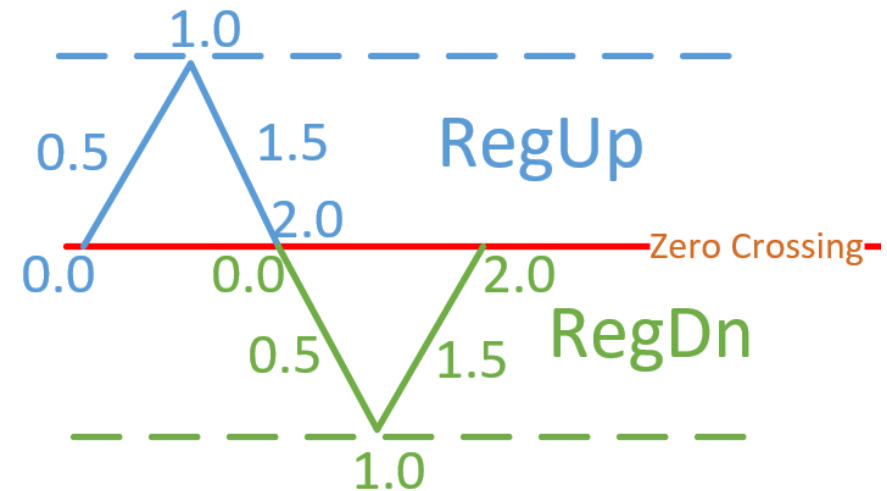### G: Mileage
21. Calculation of Mileage

21. Calculation of Mileage

- Mileage is the signal movement in support of ACE control

- Mileage will be calculated as the absolute sum of movement of the regulation control signal in a given time period.

- RegUp mileage will be separate from RegDn mileage

$$Mileage_{RegUp} = \sum_{i=1}^{n} \left| RegUp_i - RegUp_{i-1} \right|$$

$$Mileage_{RegDn} = \sum_{i=1}^{n} \left| RegDn_i - RegDn_{i-1} \right|$$

A full deploy and un-deploy = 2 miles

- Regulation <u>clearing</u> and regulation <u>pricing</u> will use the daily (historical) product signal mileage for the mileage offer price adjustment

  – Historical mileage is a rolling 30-day average by the product signal type

- Settlement will use the ratio of the 5-minute product signal actual mileage to the product historic mileage for the Regulation Mileage (Performance) credit

  – For RegUp: $\dfrac{RegUp\ signal\ actual\ 5-minute\ mileage}{RegUp\ historic\ mileage\ for\ the\ operating\ day}$

  – For RegDn: $\dfrac{RegDn\ signal\ actual\ 5-minute\ mileage}{RegDn\ historic\ mileage\ for\ the\ operating\ day}$

    ❖ Note that the ratio is dimensionless

    ❖ Proposing to rebrand Performance price/credit to Mileage price/credit

MATRIX ITEMS:

D. Lost Opportunity Cost
12. Schedule used for LOC
13. Use of desired MW at LMP vs desired MW at ramp limited

https://www.pjm.com/-/media/committees-groups/task-forces/rmdstf/2022/20220920/item-05---regulation-lost-opportunity-cost---overview.ashx

https://www.pjm.com/-/media/committees-groups/task-forces/rmdstf/2023/20230222/20230222-item-06---regloc---enhanced-calculation-of-the-desired-mw-at-lmp-ramp-rate-limited.ashx

- Energy schedule used for LOC

  – For online resources, the schedule on which the resource is committed and running for energy

  – For offline resources, the cheapest of the price-based or cost-based available energy schedules

- Total LOC Calculation

  Area bounded by <u>LMP</u>, <u>tracking desired MW @ LMP ramp limited</u>, <u>marginal cost @ Reg set point</u> and <u>MW @ Reg set point</u> minus area bounded by <u>energy schedule curve</u>, <u>tracking desired MW @ LMP ramp limited</u>, <u>marginal cost @ Reg set point</u> and <u>MW @ Reg set point</u>.

- The <u>Desired MW at LMP</u> is not ramp limited, and not based on the initial MW of the unit – status quo:

  – Generally overvalues LOC

- The <u>Desired MW @ LMP Ramp Limited</u> is based on the Initial MW and the ramp capability of the unit:

  – When a unit does not follow the dispatch signal well, the Dispatch MW at Ramp Limited does not reflect where the unit should have been.

    ❖ The LOC is at times undervalued

  – The Desired MW at LMP Ramp Limited should account for the resource's pnode LMP profile and impact of the confined regulation range
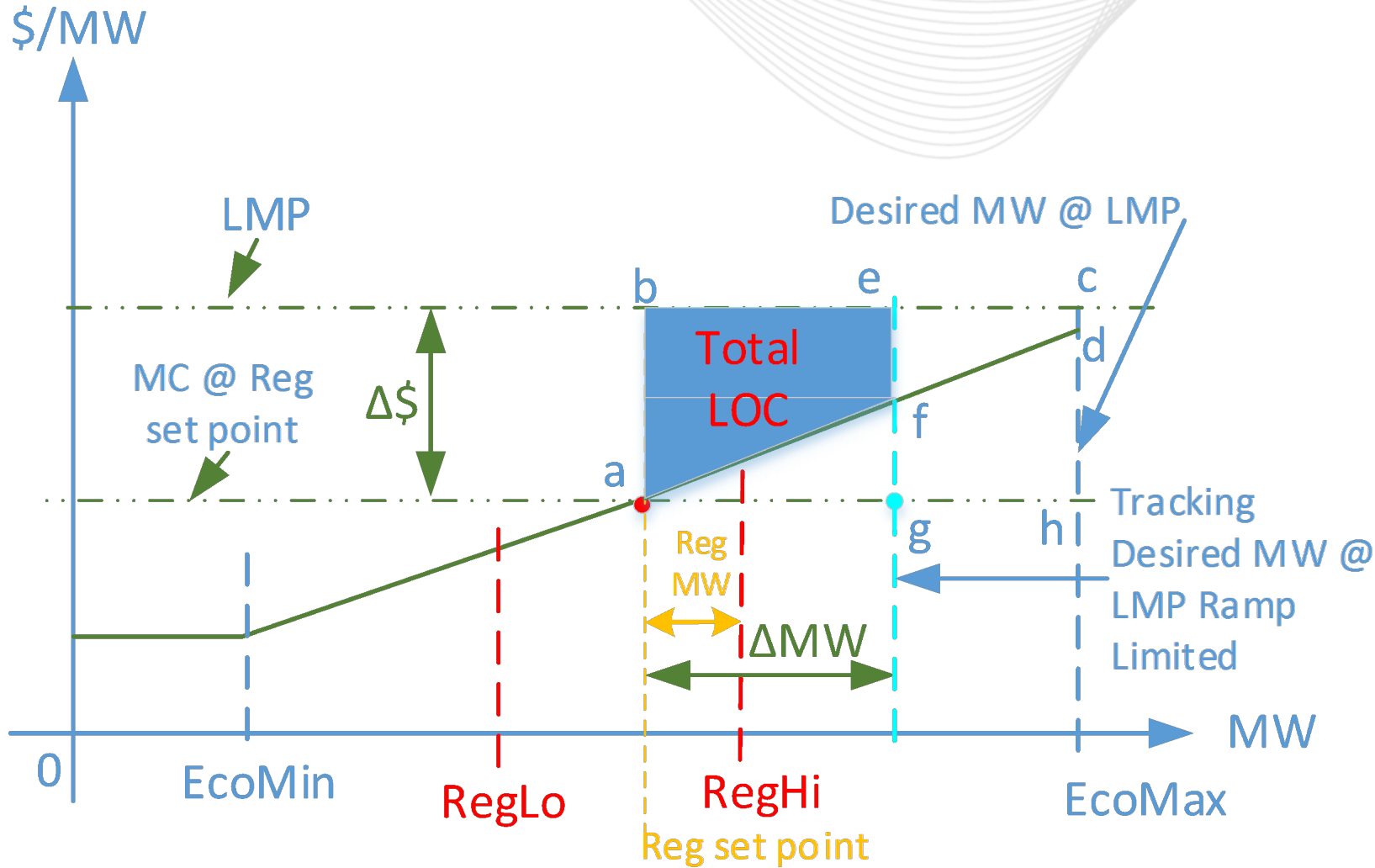
- A Tracking Desired MW @ LMP Ramp Limited will incorporate consecutive market conditions to create the profile that units should have achieved if they had been following each dispatch signal based on their ramp rates.

  - This metric will calculate continuously from when a unit comes online, using its ramp rates, energy schedule, and independent of the initial MW at each interval.

Ramp Rate = 10 MW/min	Reg Set point = 300 MW	Marginal Cost @ Reg set point = $30/MWh

Total LOC (LMP) = |LMP − MC| x (Desired MW @ LMP − Reg Set-point)

Total LOC (LMP_RL) = |LMP − MC| x (Desired MW @ LMP_RL − Reg Set-point)

Total LOC (LMP_TRL) = |LMP − MC| x (Desired MW @ LMP_TRL − Reg-Set-point)

LMP	Desired MW @ LMP	Desired MW @ LMP Ramp Limited	Tracking Desired MW @ LMP Ramp Limited	Total LOC @ LMP	Total LOC @ LMP Ramp Limited	Total LOC @ Tracking LMP Ramp Limited
23	230	250	280	490	350	140
38	380	350	330	640	400	240
55	500	350	380	5000	1250	2000
47	470	350	430	2890	850	2210

PJM package proposes area abeg minus area afg.

The LOC ($/MW) = (area abeg minus area afg)/RegMW

MATRIX ITEMS:

H: Offer Structure
22. Components of Offer
22a. Inclusion of VOM in Regulation Offer
22b. Adjusted capability offer definition
22c. Adjusted performance offer definition
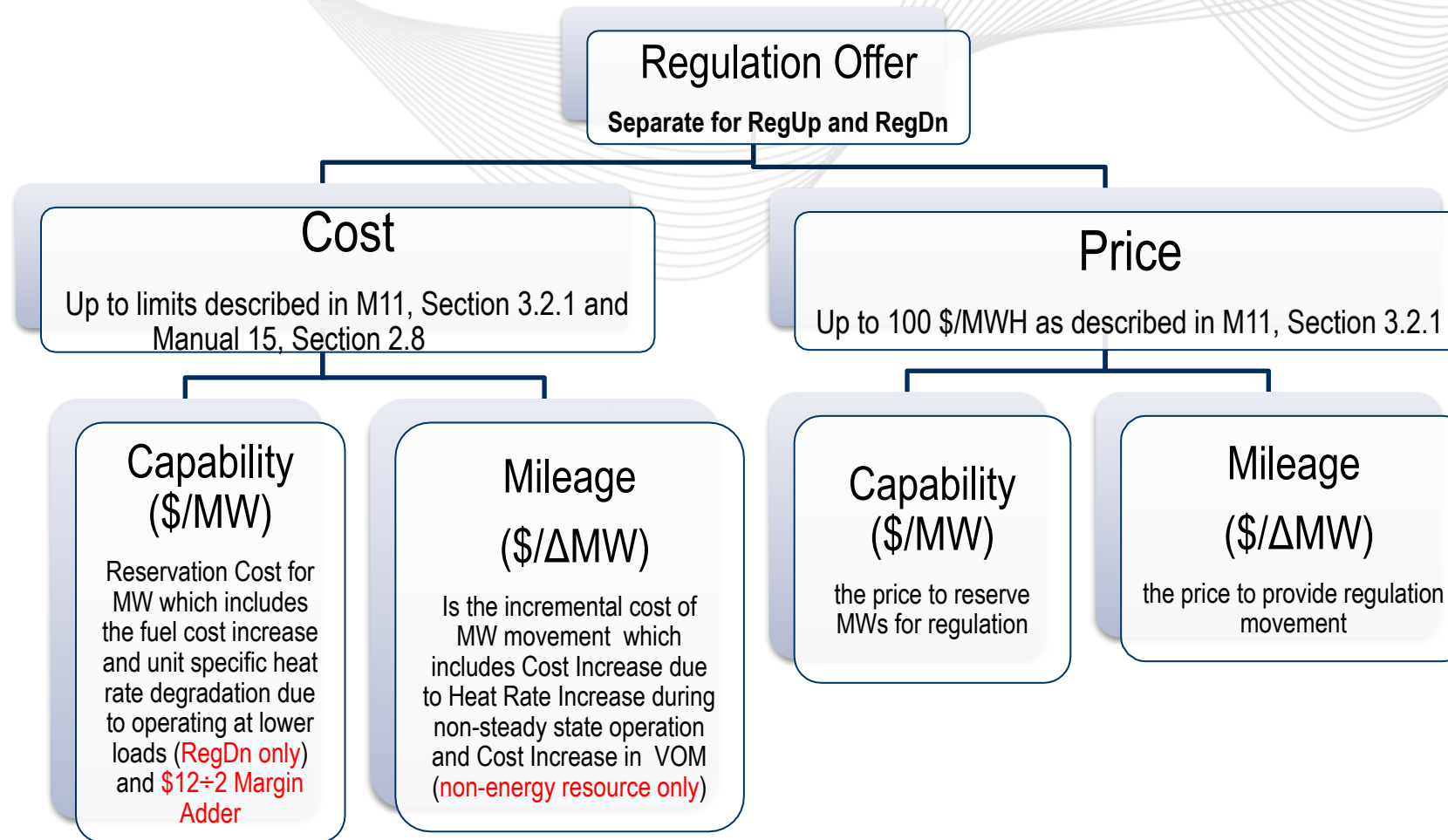**23. Dual offer capability/process**
24. Clearing timing
24a. Regulation range
25. Commitment process

https://www.pjm.com/-/media/committees-groups/task-forces/rmdstf/2023/20230222/20230222-item-04---rmdstf-regulation-cost-offer-formation.ashx

https://www.pjm.com/-/media/committees-groups/task-forces/rmdstf/2023/20230124/item-05-regulation-clearing-process-enhancements-01242023.ashx

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                          ┌─────────────────────────┐
                          │     Regulation Offer     │
                          │  Separate for RegUp and RegDn │
                          └─────────────────────────┘
                     ┌──────────────┴──────────────┐
         ┌───────────────────────┐       ┌───────────────────────┐
         │         Cost          │       │         Price         │
         │ Up to limits described│       │ Up to 100 $/MWH as    │
         │ in M11, Section 3.2.1 │       │ described in M11,     │
         │ and Manual 15, Section│       │ Section 3.2.1         │
         │ 2.8                   │       └───────────────────────┘
         └───────────────────────┘
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Cost — Up to limits described in M11, Section 3.2.1 and Manual 15, Section 2.8

- **Capability ($/MW)** — Reservation Cost for MW which includes the fuel cost increase and unit specific heat rate degradation due to operating at lower loads (RegDn only) and $12÷2 Margin Adder

- **Mileage ($/ΔMW)** — Is the incremental cost of MW movement which includes Cost Increase due to Heat Rate Increase during non-steady state operation and Cost Increase in VOM (non-energy resource only)

Price — Up to 100 $/MWH as described in M11, Section 3.2.1

- **Capability ($/MW)** — the price to reserve MWs for regulation

- **Mileage ($/ΔMW)** — the price to provide regulation movement

- The $/ΔMW will be multiplied by the signal mileage in ΔMW/MW to convert to ($/MW)
- Participant supplies PJM with Performance Offer, Capability Offer, and MW Offer
- Offers cannot be negative, and the capability cost offer is mandatory to be eligible to clear

Adjusted Regulation Capability Cost ($/MW)

$$\dfrac{Capability\,Offer\;\dfrac{\$}{MW}}{Resource\,Historic\,Performance\,Score}$$

Adjusted Lost Opportunity Cost ($/MW)

$$\dfrac{Lost\,Opportunity\,Cost\;\dfrac{\$}{MW}}{Resource\,Historic\,Performance\,Score}$$

Adjusted Total Cost ($/MW)

$$\left(\begin{array}{c}Adjusted\\Regulation\\Capability\\Cost\\\dfrac{\$}{MW}\end{array}\right) + \left(\begin{array}{c}Adjusted\\Lost\\Opportunity\\Cost\\\dfrac{\$}{MW}\end{array}\right) + \left(\begin{array}{c}Adjusted\\Mileage\\Cost\\\dfrac{\$}{MW}\end{array}\right)$$

Capability Component   Mileage Component

Adjusted Regulation Mileage Cost ($/MW)

$$\dfrac{Mileage\,Offer\;\dfrac{\$}{\Delta MW}\;*\;\substack{Historic\,Mileage\,of\\Offered\,Resource\\Product\,Type\;\dfrac{\Delta MW}{MW}}}{Resource\,Historic\,Performance\,Score}$$

Regulation Effective MW

$$Regulation\,MW\,*\,Historic\,Performance\,Score$$

- **Historical Performance Score** – average of last 100 hours of resource's performance scores

- **Historical Mileage** – 30 days average of PJM regulation control signal-type mileage

❖ Same adjusted offers and parameters will be used in pricing

- RegUp only resource will follow regulation signal above the zero crossing only

- RegDn only resource will follow regulation signal below the zero crossing only

- RegUp/RegDn resource may submit offers into (and clear in) both RegUp and RegDn markets for the same interval

    – Option available for Market Participants around the clearing constraint

- Self de-assign will result in zero performance score in the regulation market interval

- PJM dispatch de-assign does not impact performance score in the regulation market interval
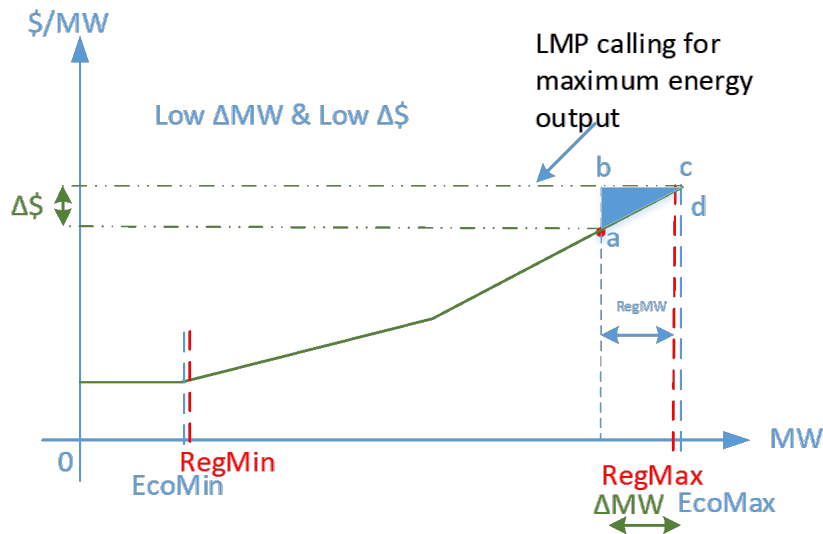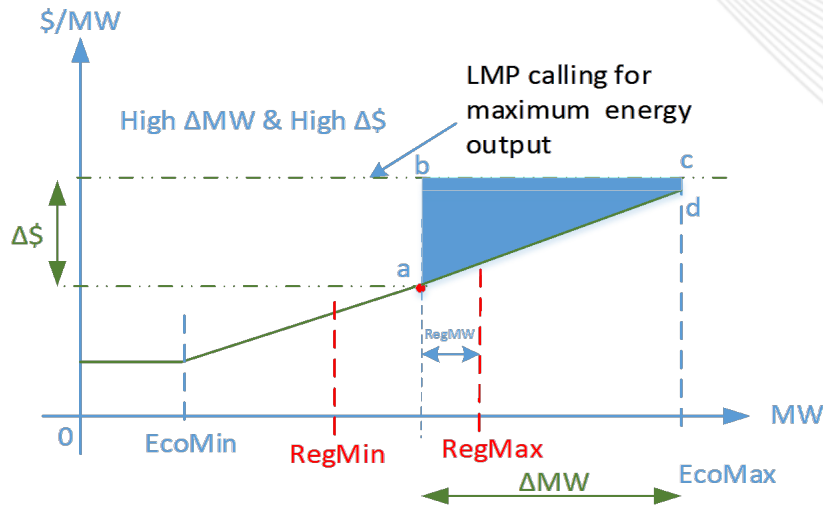
- All resources participating in both energy and regulation must submit:

  – EcoMin = RegMin and EcoMax = RegMax

  – Exception request with documentation if physical operational limitation exist

    ❖ Must renew annually

- Resources with large separation between Eco-range and Reg-range incur higher LOC or uplift, and increases overall production cost

  – Reduces clearing opportunity

- Resources with small or no separation between Eco-range and Reg-range incur low or no LOC

  – Increases change of clearing
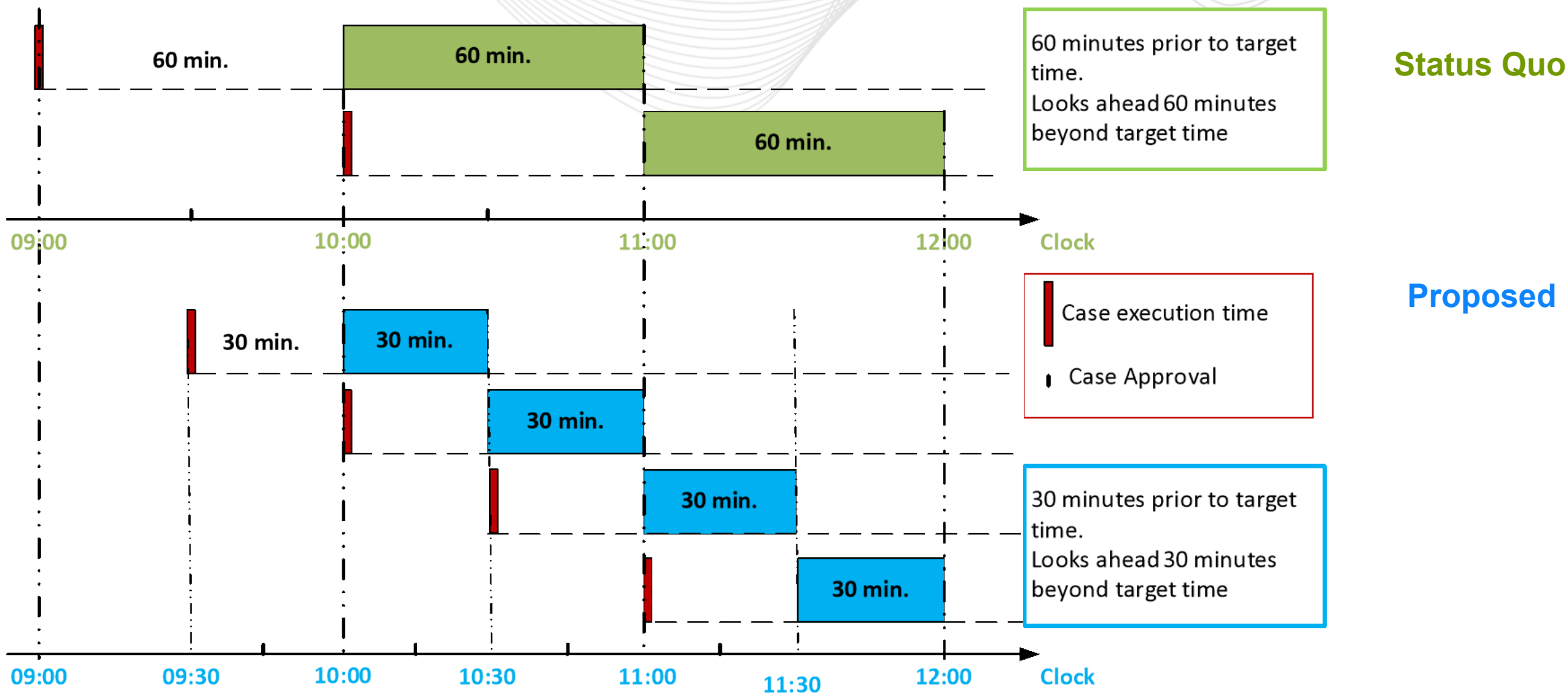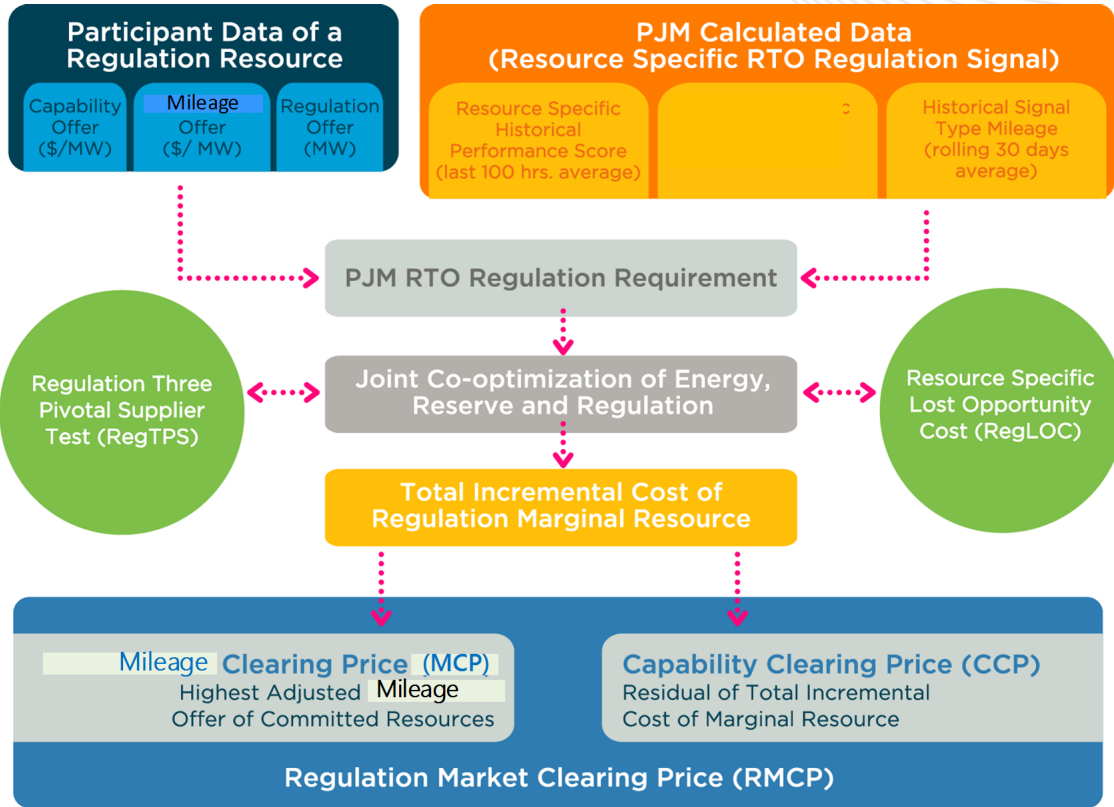
MATRIX ITEMS:

F: Settlement
20. Settlement components

- 5-minute pricing (status quo)
- RegUp Settlement
  - RegUp capability credit
  - RegUp mileage credit
- RegDn Settlement
  - RegDn capability credit
  - RegDn mileage credit

- Capability Credit = <u>5-minute integrated Regulation MW</u> x <u>5-minute performance score</u> x <u>5-minute Capability Clearing Price</u> / 12

- Mileage Credit = 5-minute integrated Regulation MW x 5-minute performance score x $\dfrac{signal\ actual\ 5-minute\ mileage}{signal\ historic\ mileage\ for\ the\ operating\ day}$ x 5-minute Mileage Clearing Price/ 12

  ❖ Proposed Implementation: starting value of each signal's historic mileage = 1

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