PJM Package Summary

Regulation Market Design Senior Task Force

July 2023

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Contents

1. PJM Proposed Package

A. Regulation Signal

A1. Signal Type: Single Signal – Resource Agnostic/Neutral, Signal Manages ACE

Under the regulation signal design, PJM is proposing moving from the current two-signal design (RegA/RegD) construct to a one-signal design. This single signal would be sent to all resources providing regulation service. A single-signal regulation design will allow PJM to better reflect the system needs to the regulation fleet to provide regulation service to PJM rather than the current two-signal design that uses the RegA signal to recharge RegD batteries during certain conditions. The one signal allows for additional transparency for the system operation to operate and track; the status quo RegA/RegD construct is not always clear on what regulation is available. The one-signal proposal allows simplicity in the Regulation Market clearing, pricing, operation and settlement because the complexity and implementation challenges associated with the RegA/RegD megawatt translation in the clearing, pricing, operation and settlement will be eliminated. This change to a one-signal design would be moving in a different direction than other RTOs adding fast-frequency regulation, but PJM believes removing the accommodations for limited-energy resources will be beneficial in the future.

Furthermore, according to case studies, the proposed single signal that all regulation resources will follow will be faster than the current RegA signal but slower than the current RegD signal.

Additional information on this design component can be found at these links:

RMDSTF Item 03 - Regulation Signal Presentation - January 24, 2023

RMDSTF Item 03 - PJM Signal Design Option - November 15, 2022

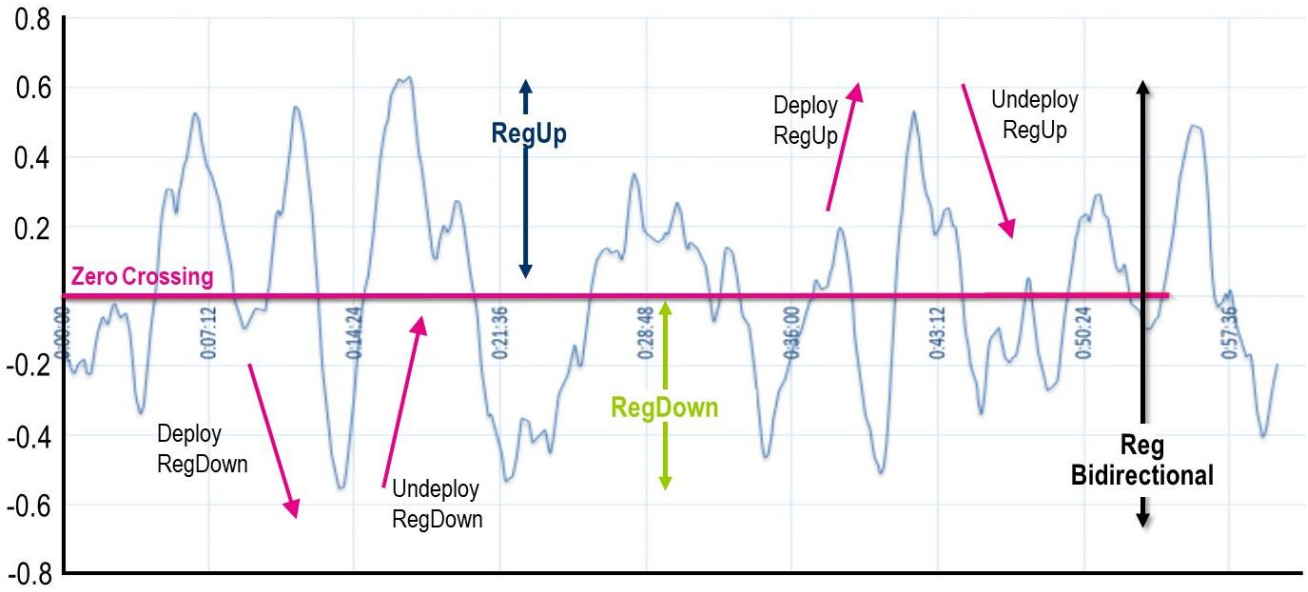
RMDSTF Item 04 - Regulation Signal Analysis - October 19, 2022

A2: Product Type: Regulation Up (RegUp) and Regulation Down (RegDn)

For the product type, PJM is proposing to replace the status quo, bidirectional market product with a separate RegUp and RegDn market products. Under this design, regulation resources would be able to clear for either RegUp or RegDn, or both products (RegUp and RegDn), in the same commitment interval. Resources committed for RegUp would only follow the positive half (above the zero crossing) of the regulation signal, and resources committed for RegDn would only follow the negative half (below the zero crossing) of the regulation signal. Resources committed for RegUp and RegDn would operate in a bidirectional nature (similar to status quo today). Essentially, the PJM proposal for RegUp/RegDn has not taken anything good away from the status quo; instead, it is adding more value and more flexibilities to the Regulation Market.

RegUp and RegDn products would be procured and priced separately and allow the associated regulation megawatt requirements to be set based on system needs.

Figure 1. RTO Regulation Single Signal With RegUp and RegDn Products



Analysis has projected that despite the separate requirement megawatts for the RegUp and RegDn products, the regulation service total cost would be lower or remain the same as the current bidirectional system.

Some of the benefits of RegUp/RegDn include but are not limited to:

i. More flexibility – Megawatt requirements can be different between the two products, and suppliers can have options to provide either or both products.

ii. Less barrier of entry – More resource can be eligible to provide either or both products.

iii. Lower overall system cost through lower total production cost – Lower opportunity cost as fewer megawatts are withheld for regulation and more megawatts are freed up for energy; consequently, lower ancillary service market clearing price and lower energy Locational Marginal Price (LMP).

iv. Adaptively meet future system needs of more resource flexibilities.

A Regulation Market clearing example, which includes the regulation set point for a scenario of a RegUp/RegDn and the lost opportunity cost calculation scenarios in the 5-minute pricing, is covered in the Appendix.

Additional information on the RegUp/RegDn design component can be found at these links:

RMDSTF Item 04 - Regulation Up/Down - March 21, 2023

RMDSTF Item 04 - Regulation Up/Down - January 24, 2023

B. Regulation Requirement

PJM is proposing modifications to the regulation requirement to better reflect operational needs, with consideration both to historic and future system conditions.

The regulation requirement laid forth in the RMDSTF proposal includes:

i. Establishment of a baseline regulation requirement schedule of the same format as the status quo schedule with the following modifications:
   (a) Redefinition of the days classified under various seasons
   (b) Modification to the magnitude of regulation procured during "high" (formerly "on-ramp") and "low" (formerly "off-ramp") hours
   (c) Redefinition of the hours considered "high" regulation and "low" regulation (formerly labeled as "on-ramp" and "off-ramp" hours)

ii. Establishment of an annual adjustment methodology that should take effect after the first year of implementation, being applied first to the baseline requirement schedule, for all years thereafter

Baseline Requirement Schedule

The baseline requirement schedule proposed by PJM is as follows:

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 9 – 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 9 - 17	550

Modifications to this schedule versus the status quo include the reclassification of several dates under different seasons using monthly correlations of the "typical" ACE deviation profile, where more similar months were grouped based on similarity. Changes also included a shift in Sept. 1–15 days into the summer class given operational observations of summer conditions during that period. Certain HEs were reclassified as either low or high regulation megawatts based on average hourly control metrics and operational input.[1]

The magnitude of requirement megawatts in the baseline schedule were adjusted from 800 MW to 750 MW and from 500 MW to 550 MW to address operational observations of tight regulation conditions in low-classified hours and

[1] RMDSTF Item 03 – Regulation Requirement – April 18, 2023

sufficient historic control in high-classified hours. A transitional hour at 650 MW was added to the schedule to aid in the step-down periods from high to low hours. Hours remain grouped in this baseline schedule (i.e., multiple hours grouped together having the same megawatt level), but for the purposes of future adjustments, will be allowed to move independently based on their observed operational data and the criteria laid out in the annual adjustment methodology.

Annual Adjustment Methodology

The RMDSTF proposal sets forth an annual adjustment process that takes control metrics and uses thresholds or conditions as a set of rules to determine whether the requirement megawatts for a given hour-ending will be "adjusted" going forward. Data from the same hour for all days in a given season will be considered for analysis.[2] Metrics proposed for determining raise or lower needs on a season-hourly basis are:

- **ACE Time Out of Bounds (TOB):** Time Net ACE spends "out of bounds," where Net ACE is the current control ACE with total regulation "added back" to approximate regulation-free control conditions. Bounds for Net ACE are set as outside of the 2*NERC L10 value for the historic period for the PJM Balancing Authority – also known as CPS2. See NERC BAL-001.
- **BAAL Minutes (BAAL)**: Sum of BAAL minutes in the interval. This metric seeks to reflect PJM's negative impact on system frequency. See NERC BAL-001.
- **Regulation Utilization (RU):** Average hourly RU is a percentage of (∑ REGMW / ∑ TREG) for all 5-minute intervals in each period. This metric seeks to quantify how PJM typically relied on regulation during a period of time.
- **Min/Max Deployment:** Cumulative time that regulation is pegged in either direction, measured as a percentage of total minutes over the given period. This metric intends to quantify the severity of operational need during a period of time.

Evaluation criteria will be applied to determine each metrics' impact on the relevant season-hour. The rules established to assess these metrics are laid out in the June 2023 RMDSTF presentation[3] and are described in the following table:

[2] For example, all hours ending in 7 occurring in "Summer" days will be used to calculate the metric that determines the adjustment of the following year's Summer-HE7, so as to produce one requirement megawatt for each hour in a seasonal requirement schedule. All days in the same season will have the same requirement megawatt schedule.

[3] RMDSTF Item 03 – Regulation Requirement – June 13, 2023

Table 1. Regulation Requirement Annual Adjustment Methodology

	Δ Requirement			
	-25 MW	**No Change**	**+25 MW**	**+50 MW**
ACE TOB (>2*L10)	< 10%	> 10% and < 50%	50%	60%
BAAL	NA	< 50 Min.	50 Min.	75 Min.
RU	< 20%	> 20% and < 80%	80%	90%
Min/Max Deploy	NA	< 7.5%	7.5%	10%

Column titles indicate the respective requirement adjustment to be applied if the conditions in the respective rows are met. Each row refers to the metrics discussed earlier in this section, and the criteria which, if observed, would trigger the adjustment indicated by the column. Cells containing "NA" signify that that metric will not adjust the requirement to the degree indicated by the column under any circumstance. Adjustments are additive, i. e. if multiple criteria are triggered for a given hour, each adjustment is applied to the base requirement megawatts of the given hour.

Step Down Constraint

There is an additional constraint applied to the results of the above adjustment methodology: a step-down constraint protecting the hour-to-hour change in requirement megawatts. To produce the ultimate effective requirement during the adjustment process, the four metrics will be calculated and the table above will be used to determine each season-hour's megawatt adjustment. After doing so, the resulting hourly profile on a seasonal basis will be examined and *if there is any hour adjusted such that its result is more than 150 megawatts less than the prior hour (a "step-down"), that hour's requirement will be capped at the megawatt level equal to 150 megawatts less than the prior hour.* This is a constraint designed to guard against what would otherwise be an operationally challenging output of the adjustment process.

C. Benefits Factor (BF) or Marginal Rate of Technical Substitution (MRTS)

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

D. Lost Opportunity Cost (LOC)

Regulation lost opportunity cost covers 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. Regulation lost opportunity cost is calculated for pool-scheduled regulation resources that are providing energy along with regulation service.

Under the lost opportunity cost design components, the PJM package is proposing the following three changes that make the current related business rule language in the governing documents unjust and unreasonable.

According to the PJM Operating Agreement, Schedule 1, section 3.2.2 (d) and the parallel provisions of the Tariff, Attachment K-Appendix, section 3.2.2 (d):

"In determining the Regulation 5-minute clearing price for each Regulation Zone, the estimated unit-specific opportunity costs of a generation resource offering to sell Regulation in each regulating hour, except for hydroelectric resources, shall be equal to the product of

(a) the deviation of the set point of the generation resource that is expected to be required in order to provide Regulation from the generation resource's expected output level if it had been dispatched in economic merit order times,

(b) the absolute value of the difference between the expected Locational Marginal Price at the generation bus for the generation resource and the lesser of the available market-based or highest available cost-based energy offer from the generation resource (at the megawatt level of the Regulation set point for the resource) in the PJM Interchange Energy Market."

The proposed changes are:

1 | For the energy schedule used to calculate the regulation opportunity cost, rather than "the lesser of the available market-based or highest available cost-based energy schedules from the generation resource ...," the PJM package proposes, for online resources, the schedule on which the resource is committed, or for offline resources, the cheapest of the price-based or cost-based available energy schedules.

2 | The generation resource's expected output level when following economic dispatch does not account for the ramp capability of the resource. The PJM package proposes to use "tracking" desired megawatts at LMP ramp rate limited rather than keeping the status quo of desired megawatts at LMP, which over-value the LOC, or other proposed desired megawatts at LMP ramp rate limited, which at times under value LOC.

3 | The current formula for calculating RegLOC is including the unburned fuel in the calculation. The PJM package proposes to remove the unburned fuel from the calculation.

RMDSTF Item 05 - Regulation Lost Opportunity Cost Overview - September 20, 2022

RMDSTF Item 06 - Tracking Desired MW at LMP Ramp Rate Limited - February 22, 2023

E. Performance Scoring

Performance Score Changes

In the PJM package, the performance score will consist of only the precision component that is the instantaneous error between the control signal and the regulating unit's response. Accuracy and delay components will be eliminated from the performance score.

In addition, the precision calculation will be modified. The main difference between the status quo and the newly proposed calculation is its denominator. In the status quo, the denominator is 100% $\text{HourlySignal}_{AvgAbs}$, and in the new proposed calculation, it is 50% $\text{HourlySignal}_{AvgAbs}$ and 50% AREG.

The proposed performance score (precision-only calculation):

$$Error = Avg\ of\ abs\left(\frac{Abs(Response_{10sec} - Signal_{10sec})}{0.5 * HourlySignal_{AvgAbs} + 0.5 * AREG}\right)$$

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

Regulation Testing Changes

- Regulation test requirements to score 75% or more in performance score remain the same.
- The number of regulation certification tests for new resources will decrease from three (3) tests to two (2) tests. New resources are considered resources that are new to the Regulation Market. A resource can choose one option that is more preferable for the resource:
  - First Option: One self-scheduled test and one PJM-administered test
  - Second Option: two PJM-administered tests
- The number of regulation certification tests for disqualified resources will decrease from three (3) tests to one (1) test. This one test has to be a PJM-administered test. Disqualified resources are resources that were disqualified from the Regulation Market due to their historic performance score dropping below the established 40% threshold.
- The self-scheduled test is recommended for new resources to determine capability and basepoint megawatt values and will resolve any technical issues that can be worked out on the member's side.
  - PJM will provide a testing template for resources to score their self-scheduled test results. A new resource must satisfy all test requirements and provide self-scheduled test results to PJM for the final confirmation.
  - In order to be considered for a valid self-scheduled test, results must be submitted to PJM within ten (10) business days of the test.

- A resource must pass self-scheduled test before scheduling PJM-administered test if the resource chooses one (1) self-scheduled test + one (1) PJM-administered test option.

- A PJM-administered test is required for resources to ensure communication is working between a resource and PJM. PJM will score the test. If it's a successful test, then PJM will enter megawatt capability and performance score in PSCE.
- Resources that change in communication path, whether it's an existing owner or new owner, will have the same set of rules in terms of performance score. Resources that have a change in communication path for an existing owner or new owner will receive a new performance score. The number of regulation tests will remain the same such as one (1) PJM-administered tests.
- Uprate will be renamed to Change in Capability to accommodate either an uprate or downrate of megawatt capability. Number of regulation tests will remain the same such as one PJM-administered tests.
- Below language from Manual 12 will be removed under a new proposal.
  - Certifying multiple combustion turbines or hydro units operating under a single plant control system:
    - Must have a minimum of three tests of the control system
    - Performance of each of the units being certified must be demonstrated in at least one of these tests.

Figure 2. Regulation Testing Status Quo

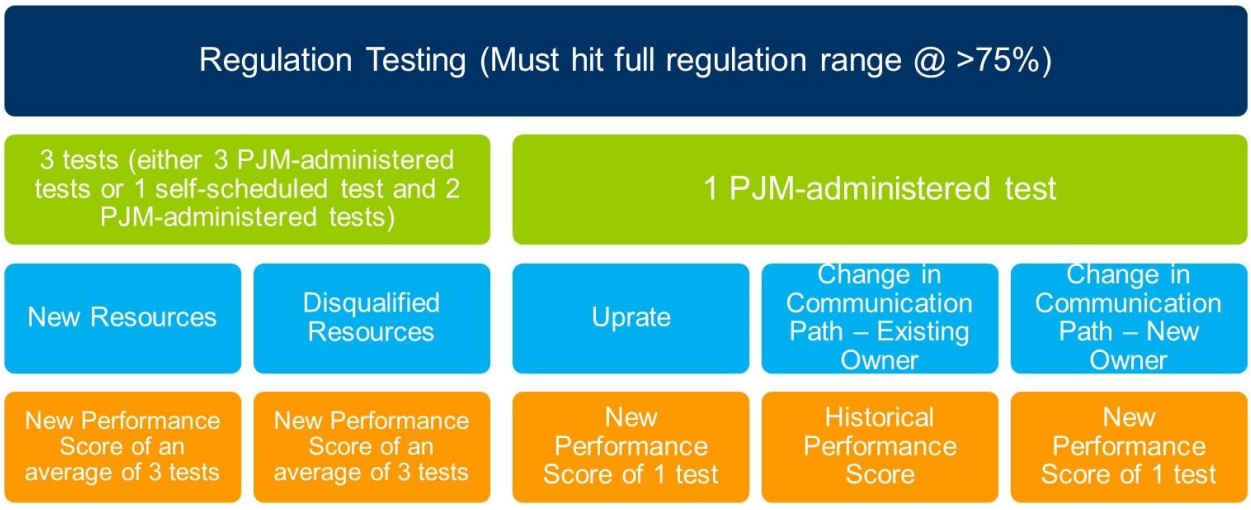
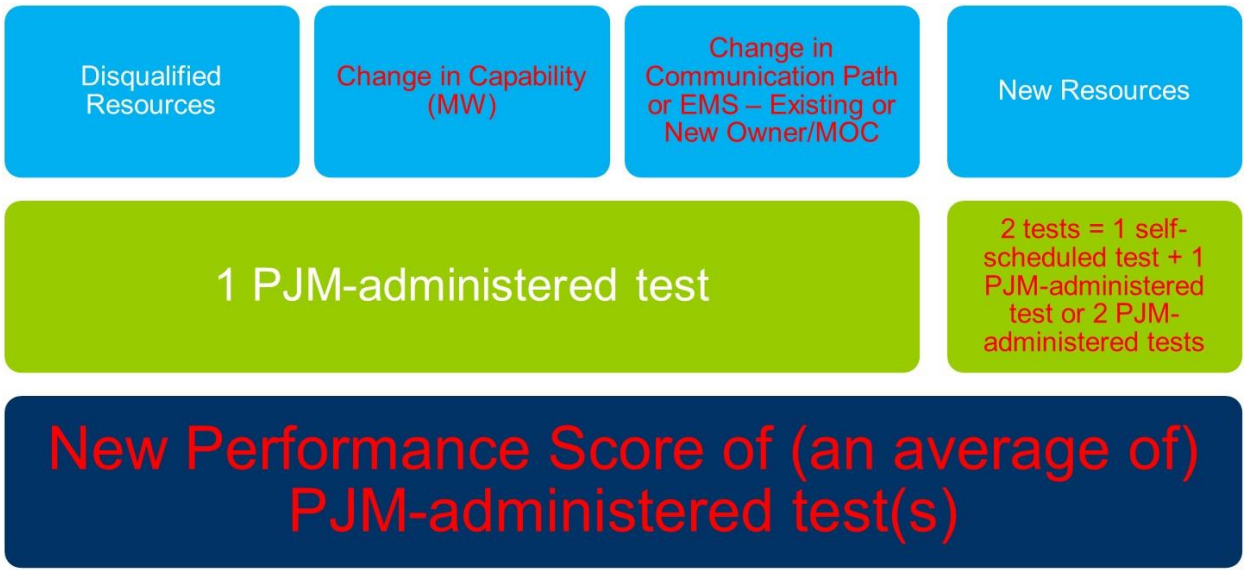


Figure 3. Regulation Testing Proposal



Regulation Certification and Signal Following

- A resource certified for RegUp signal only can offer as RegUp only and may follow only the RegUp signal.
- A resource certified for RegDn signal only can offer as RegDn and may follow only the RegDn signal.
- A resource certified for both RegUp and RegDn signals or certified for the reg-bidirectional signals can offer as RegUp or as RegDn or as both. Reg offer megawatts for RegUp may or may not be the same as RegDn.
- Regulation offer megawatts shall be less than or equal to but cannot exceed the latest regulation certified megawatts for the applicable direction, up or down.

Additional information:

RMDSTF Item 05 - Proposal on Performance Score - February 22, 2023

RMDSTF Item 05 - Regulation Testing Process Proposal - October 19, 2022

17 – Minimum Allowable Participation Threshold

PJM is proposing to keep the existing minimum allowable participation threshold of 40%. The threshold is based on the historic performance score. The historic performance score is a rolling average actual hourly performance score for the last 100 hours a resource has operated, or a weighted average of the average of the three initial or requalification scores that are then averaged with available actual hourly performance scores. When the historical performance score falls below 40%, PJM will notify the resource owner, and the resource will no longer be eligible to offer into the Regulation Market until it requalifies.

18 – Minimum Allowable Compensation Threshold

PJM is proposing to keep the minimum compensation threshold at 25% for the interval. A resource whose performance score for the Real-time Settlement Interval falls below 25% will forfeit regulation credit and lost opportunity for that interval.

18a – Change in Cleared Commitment

PJM proposes that participants who self de-assign a resource's cleared regulation commitment will receive a zero performance score for the specified period. However, any de-assignment action taken by PJM Dispatch will not impact the performance score for the specified period. The intent of this design component is to incentivize resources to accurately represent their capability and perform according to their regulation commitments.

G. Mileage

Mileage is defined as the absolute sum of movement of the regulation signal in a given time period, with a dimension of (Δ MW / MW). Unlike the RegA and RegD signals where RegA may be used to support the conditional neutrality of RegD, all signal movement of a single signal or RegUp and RegDn signals will be in support of ACE control. A full cycle of the single signal represents four miles. A full deploy and un-deploy of either the RegUp or RegDn signals represents two miles. RegUp mileage will be separate from RegDn mileage.

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

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

The mileage for the RegUp product will be the 5-minute interval measure of the control signal movement when it is above the zero crossing.

Likewise, the mileage for the RegDn product will be the 5-minute interval measure of the control signal movement when it is below the zero crossing.

Regulation clearing and pricing 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 (dimensionless) of the 5-minute product signal actual mileage to the product historic mileage for the Regulation Mileage (Performance) credit. PJM is proposing to rebrand the Performance price/credit to the Mileage price/credit to make it clear which component of the settlement credit accounts for the actual mileage, consistent with FERC's

Order 755. The benefit of this design component is that is leads to a consistent use of mileage in clearing, pricing and settlement.

For RegUp: $\frac{RegUp\ signal\ actual\ 5-minute\ mileage}{RegUp\ historical\ mileage\ for\ the\ operating\ day}$

For RegDn: $\frac{RegDown\ signal\ actual\ 5-minute\ mileage}{RegDown\ historical\ mileage\ for\ the\ operating\ day}$

References:

RMDSTF Item 04 - PJM Proposed Package Summary - April 81, 2023

RMDSTF Item 03 - Regulation Mileage Overview - March 21, 2023

H. Offer Structure

FERC Order 755 requires performance-based regulation compensation hence the capability and performance components of regulation offers and settlements today.

Updates are proposed to:

- Create the required divergent offer formation due to the operational differences of the Up and Down products.
- Emphasize the intent of the performance offer to be based on mileage of the product.
- Modify the adjusted performance and capability offer formulas to remove the concept of benefits factor as it is no longer needed to translate between RegA and RegD for clearing and pricing.
- Remove elements that are accounted for in other markets such as VOM, which is a form of "double-counting" of costs for most unit types from their energy offer.
- Better reflect market conditions since regulation offer formation was last reviewed.

Key Takeaway: Change to Up/Down construct does not inherently mean that cost of regulation would be double or even more expensive. Limiting VOM costs and removing portions of the "Fuel Cost Increase and Unit-Specific Heat Rate Degradation due to Operating at Lower Loads" portion of the Capability Offer will lower-cost offers. Splitting of Margin Adder will balance costs between two products. Performance-based costs will be unchanged in other areas than VOM due to the appropriation of mileage. Mileage Offer Formation for Energy Storage resources will be unchanged.

Summary of Changes:

Change	Rationale/Impact/Benefit
Eliminate the "Fuel Cost Increase and Unit-Specific Heat Rate Degradation due to Operating at Lower Loads" portion of Capability Offer for RegUp resources	Is not applicable to capture in a RegUp product since the concept of "operating at lower loads" would only apply to the RegDn product Results in accurate, simplified offer formation
Split the Margin Risk Adder	To have balanced cost recovery between the two products
Eliminate the "Cost Increase in VOM" portion for all unit types except Reg.-Only Energy Storage	Eliminates potential "double counting" of costs from their energy offer for most unit types
Rename Offer components to "Mileage" and "Capability"	To emphasize the intent of the performance offer to be based on mileage of the product
Modify the adjusted performance and capability offer formulas to remove the concept of benefits factor	No longer needed to translate between RegA and RegD resulting in simplified formulas only relying on proven metrics such as mileage and performance scores

Figure 4. Regulation Offer Structure

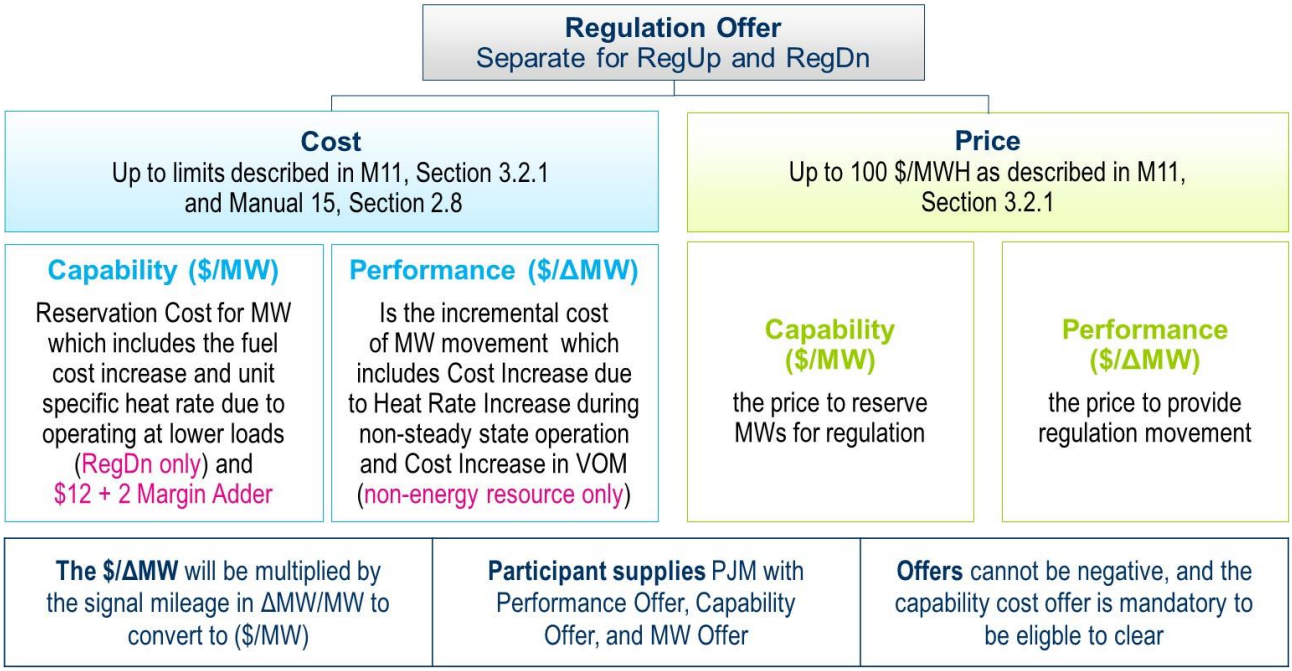
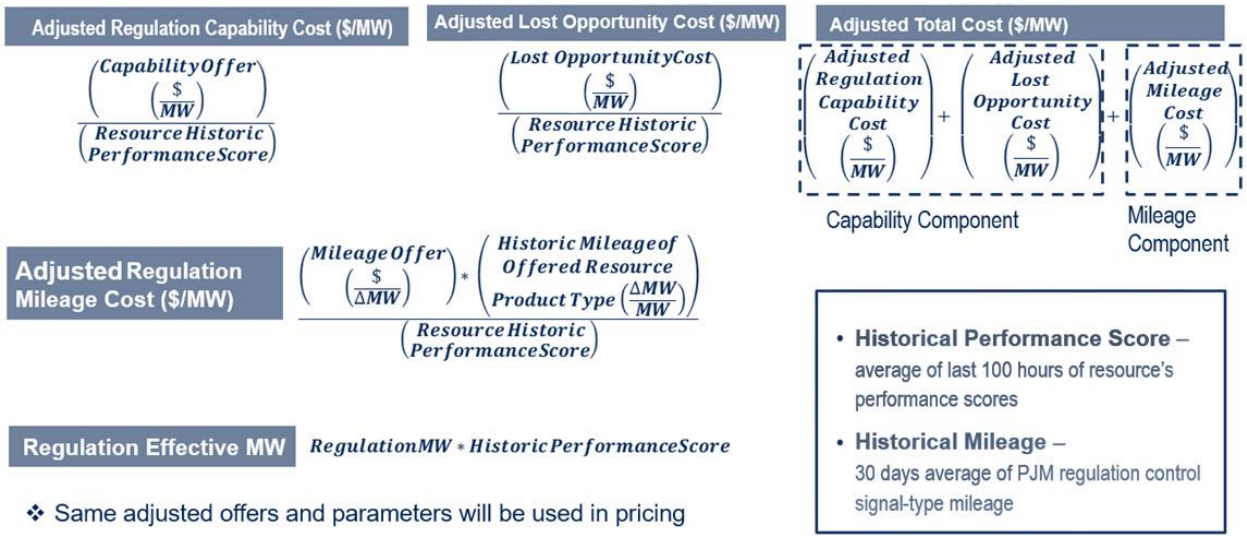


Figure 5. Effective Megawatt and Adjusted Cost Conversion



Reference:

[RMDSTF Item 04 - Regulation Cost Offer Formation - February 22, 2023]

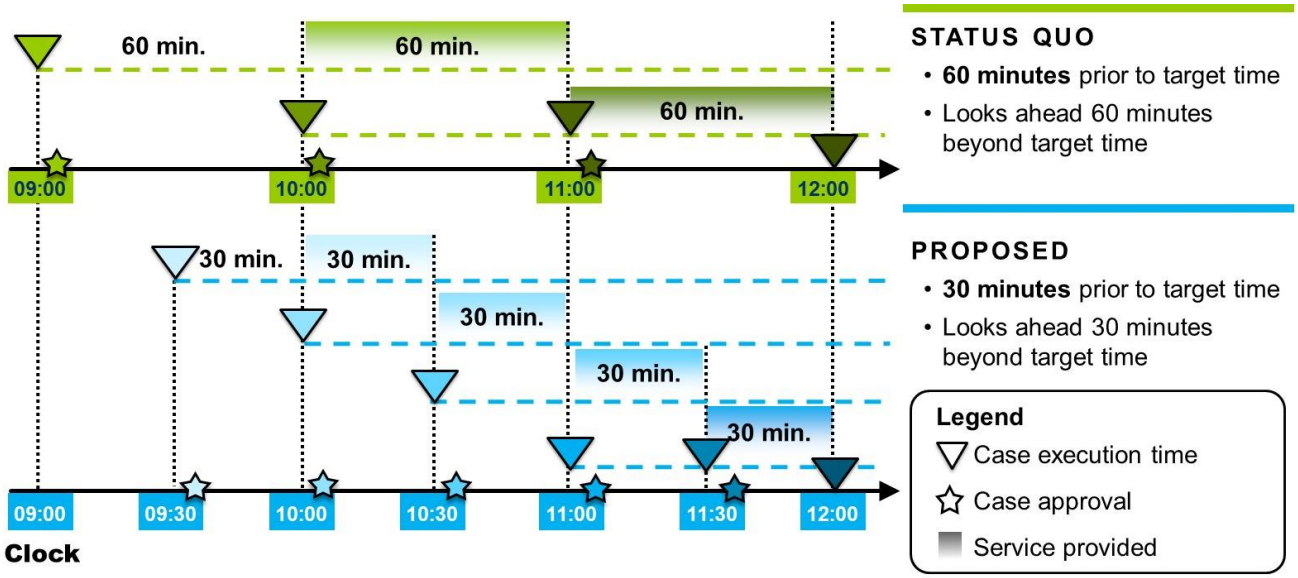
Regulation Commitment Period and Duration Design Component

The Ancillary Services Optimizer (ASO), which is an hour-ahead Market Clearing Engine, optimizes the RTO dispatch profile, which includes load, generation, interchange and transmission security constraints, among others, and forecasts LMPs to determine hourly commitments of regulation and inflexible synchronized reserves to meet the respective product requirements. Using the dispatch profile and forecasted LMPs, an opportunity cost is estimated for each of the eligible resource offerings into the Regulation Market for the hour. The estimated lost opportunity cost is then added to the resource regulation offers to create the merit order price. All available and eligible regulating resources are then ranked in ascending order of their merit order prices, and the lowest cost set of resources necessary to meet the PJM regulation requirement in that hour while satisfying the overall production cost is determined (see section 3.1 of M11 for details).

The issue observed over several years is that some of the resources committed for regulation are not the most economical to provide the service during the actual operating hour. Analysis indicated that the forecasted LMP and therefore estimated lost opportunity cost used for clearing could change drastically in real time.

The PJM package proposes to convert the ASO to a half-hour-ahead regulation and inflexible synchronized reserve-clearing engine, and with a 30-minute commitment period. This proposal will help to mitigate the disparity in the resource opportunity cost estimated in the clearing with that in actual real-time operation. In addition, the design may serve as a 30-minute neutrality that allows the limited energy resources to reset when necessary and get back in the Regulation Market.

Figure 6. Move to a 30-Minute Clearing Time and Commitment Duration



F. Settlement

Regulation settlement will be for both the RegUp and RegDn products:

1. RegUp Settlement
    a. RegUp capability clearing price credit
    b. RegUp mileage clearing price credit
2. RegDn Settlement
    a. RegDn capability clearing price credit
    b. RegDn mileage clearing price credit

Make whole for regulation settlement will be done on a resource basis; RegUp settlement or RegDn settlement or Reg bidirectional settlement.

Capability Clearing Price (CCP) credit = (Actual Reg assigned MW x Actual Performance Score x CCP) / 12

Mileage (formally Performance) Clearing Price (PCP) credit = (Actual Reg Assigned MW x Actual Performance Score x Actual 5-min Product-Type Mileage Ratio x CCP) / 12

- The 5-minute product-type mileage ratio is the ratio of the product-type actual 5-minute mileage to the product-type historic mileage for the operating day.
    - For RegUp: $\frac{RegUp\ signal\ actual\ 5-minute\ mileage}{RegUp\ historic\ mileage\ for\ the\ operating\ day}$
    - For RegDn: $\frac{RegDn\ signal\ actual\ 5-minute\ mileage}{RegDn\ historic\ mileage\ for\ the\ operating\ day}$
        - ❖ Note that the ratio is dimensionless.

G. Implementation and Transition Plan

The PJM package proposes a two-phase implementation.

Phase one (1) will cover all changes except the RegUp/RegDn products. These are changes that have a shorter development lead time. The first phase will also help orient the fleet with the new signal and performance requirements before splitting the market clearing and operational signals. Resources will not need to requalify for the phase one implementation of the new signal development.

Phase two (2) will implement the comprehensive reform to RegUp and RegDn product types. This is an approximately two-year development effort for PJM and Market Participants.

PJM will have large changes to the clearing engine, AGC, telemetry and settlements.

Market Participants will have large changes in telemetry and expected other modifications.

Requalification efforts will be required for the RegUp/RegDn market, and a testing window will be developed no less than three months before go-live. An abbreviated testing option will be available for existing regulation resources (e.g., one test vs. two).

Appendix

Scenario – RegUp/RegDn Lost Opportunity Cost Calculation

TDLR	Tracking desired-megawatt at LMP ramp rate limited of the resource is then economic dispatch megawatt of the resource absence of the resource providing regulation service.
RSP	Regulation set point is the point within the resource defined regulation range where it needs to be at the point in time to provide regulation service.
LMP	Locational marginal price at the pricing node of the resource
MC	Marginal cost of the resource at the regulation set point
RegUp (RegDn) MW	The assigned regulation megawatt. A resource committed for RegUp would only follow the positive half (above the zero crossing) of the regulation signal, and a resource committed for RegDn would only follow the negative half (below the zero crossing) of the regulation signal.
RegLo	RegLo is the higher of the resource Economic Minimum or the Regulation Minimum.
RegHi	RegHi is the lower of the resource Economic Maximum or the Regulation Maximum.
Reg range	Regulation range (reg range) is bounded by RegLo and RegHi.
Reg Bias Factor	Captures the utilization of the regulation assigned megawatts (increasing or decreasing output of a resource while regulating). It is used to adjust the "initial" regulation set point for the purpose of settlement LOC calculation.

1. *Economic Dispatch is calling for the unit to lower as much as possible.*

The resource is duly certified and offered to provide RegUp, RegDn or Reg Bidirectional products.

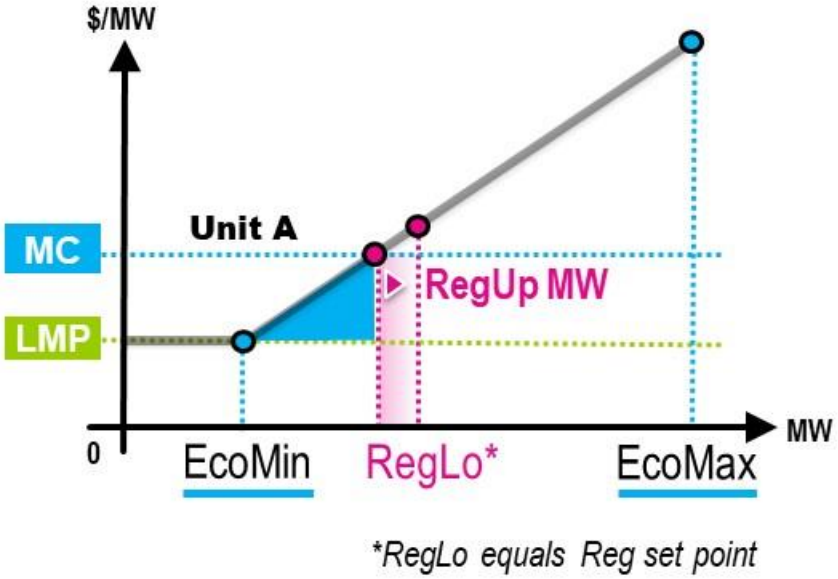
To provide RegUp only – Resource would need to be moved uneconomically to RegLo as the reg set point.

The RegUp LOC (or uplift) is the area of the triangle, calculated as:

$$RegUp\ LOC(or\ uplift) = \frac{0.5 * |TDLR - RSP| * |LMP - MC|}{RegUpMW}$$

RegUp Bias Factor will capture the average of the RegUp signal over time (5 min) and add to the reg set point.

Figure 7. To Provide RegUp Only Example



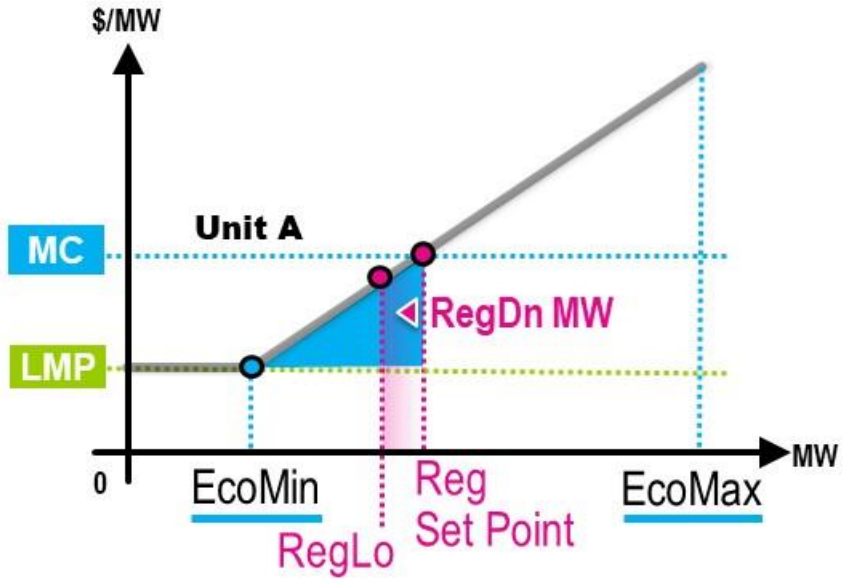
To provide RegDn only – Resource would need to be moved uneconomically to RegLo plus RegDn MW as the reg set point.

The RegDn LOC (or uplift) is the area of the triangle, calculated as:

$$RegDn\ LOC(or\ uplift) = \frac{0.5 * |TDLR - RSP| * |LMP - MC|}{RegDnMW}$$

RegDn Bias Factor will capture the average of the RegDn signal over time (5 min) and subtract from the reg set point.

Figure 8. To Provide RegDn Only Example



To provide RegUp and RegDn (Reg Bidirectional) – Resource would need to be moved uneconomically to RegLo plus RegDn as the reg set point.

The RegUp LOC (or uplift) is the area of the triangle, calculated as:

$$RegUp\ LOC(or\ uplift) = \frac{0.5 * |TDLR - RSP| * |LMP - MC|}{(RegUpMW + RegDnMW)}$$

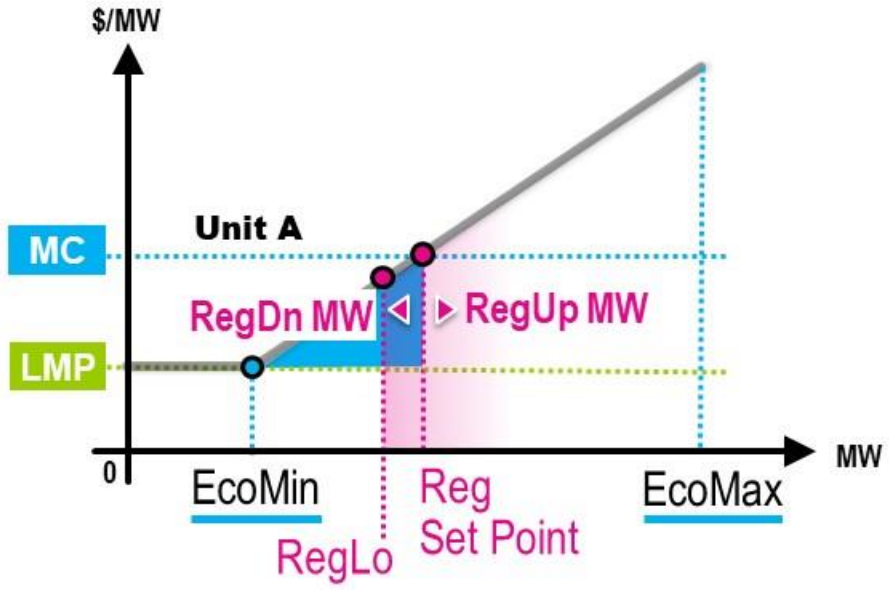
RegUp Bias Factor will capture the average of the RegUp signal over time (5 min) and add to the reg set point.

The RegDn LOC (or uplift) is the area of the triangle, calculated as:

$$RegDn\ LOC(or\ uplift) = \frac{0.5 * |TDLR - RSP| * |LMP - MC|}{(RegUpMW + RegDnMW)}$$

RegDn Bias Factor will capture the average of the RegDn signal over time (5 min) and subtract from the reg set point.

Figure 9. To Provide RegUp and RegDn (Reg Bidirectional) Example



2. Economic Dispatch is calling for the unit to raise as much as possible.

The resource is duly certified and offered to provide RegUp, RegDn or Reg Bidirectional products.

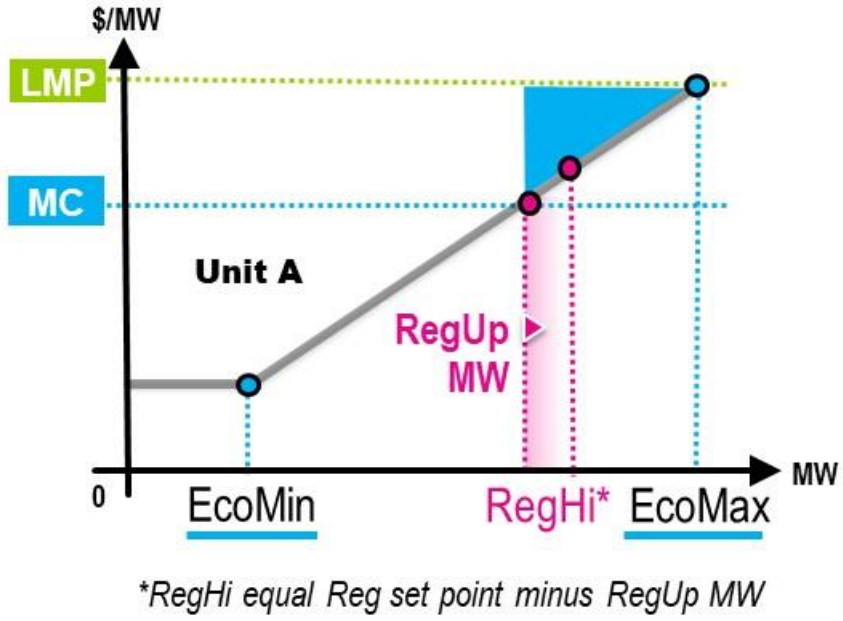
To provide RegUp only – Resource would need to be moved uneconomically to RegHi minus RegUp MW as the reg set point.

The RegUp LOC is the area of the triangle, calculated as:

$$RegUp\ LOC = \frac{0.5 * |TDLR - RSP| * |LMP - MC|}{RegUpMW}$$

RegUp Bias Factor will capture the average of the RegUp signal over time (5 min) and add to the reg set point.

Figure 10. To Provide RegUp Only Example



*RegHi equal Reg set point minus RegUp MW

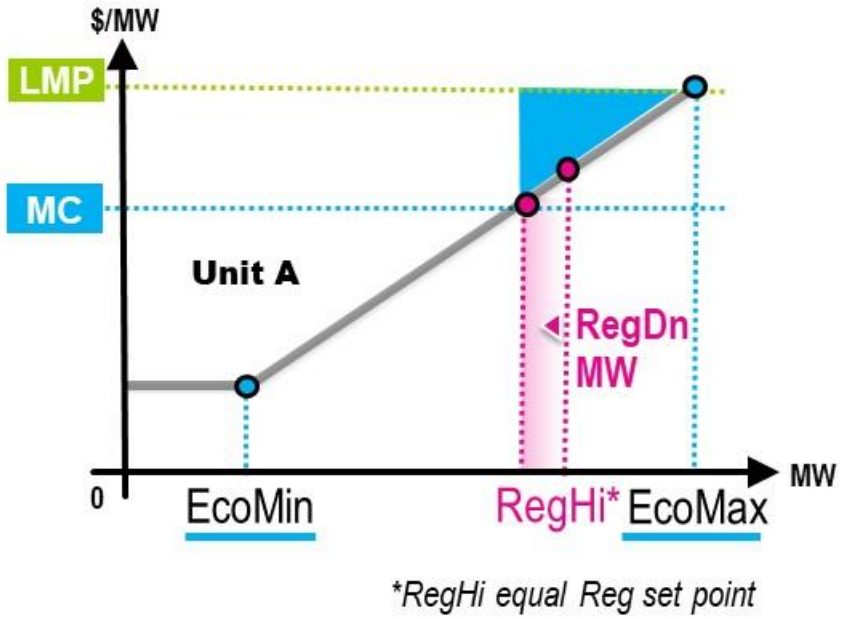
To provide RegDn only – Resource would need to be moved uneconomically to RegHi as the reg set point.

The RegDn LOC is the area of the triangle, calculated as:

$$RegDn\ LOC(or\ uplift) = \frac{0.5 * |TDLR - RSP| * |LMP - MC|}{RegDnMW}$$

RegDn Bias Factor will capture the average of the RegDn signal over time (5 min) and subtract from the reg set point.

Figure 11. To Provide RegDn Only Example



To provide RegUp and RegDn (Reg Bidirectional) – Resource would need to be moved uneconomically to RegHi minus RegUp as the reg set point.

The RegUp LOC is the area of the triangle, calculated as:

$$RegUp\ LOC = \frac{0.5 * |TDLR - RSP| * |LMP - MC|}{(RegUpMW + RegDnMW)}$$

RegUp Bias Factor will capture the average of the RegUp signal over time (5 min) and add to the reg set point.

The RegDn LOC is the area of the triangle, calculated as:

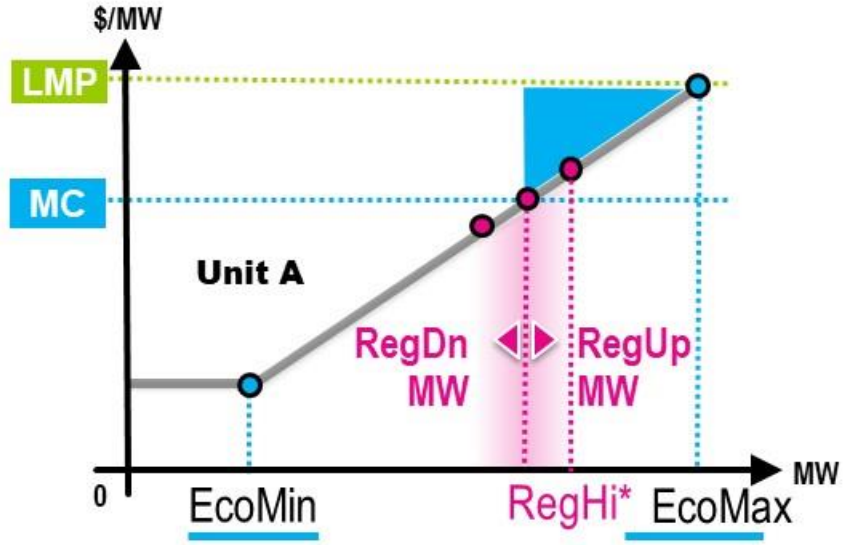
$$RegDn\ LOC = \frac{0.5 * |TDLR - RSP| * |LMP - MC|}{(RegUpMW + RegDnMW)}$$

RegDn Bias Factor will capture the average of the RegDn signal over time (5 min) and subtract from the reg set point.

Note that for the Reg Bidirectional, the sum LOC (or uplift) is the ratio of the RegUp LOC and RegDn LOC weighted by the RegUp MW and RegDn MW respectively. This is done to avoid LOC double counting.

Also, note that the regulation pricing engine calculate resource RegUp or RegDn LOC separately for the purpose of RegUp and RegDn products marginal clearing price setting. Settlement, for regulation credit purpose will combine the RegUp and RegDn in a case of a resource providing regulation bidirectional.

Figure 12. To Provide RegUp and RegDn (Reg Bidirectional)



**RegHi equal Reg set point minus RegUp MW*