Regulation Redesign Manual 11 Draft

Real-Time Market Operations Department

June 2025

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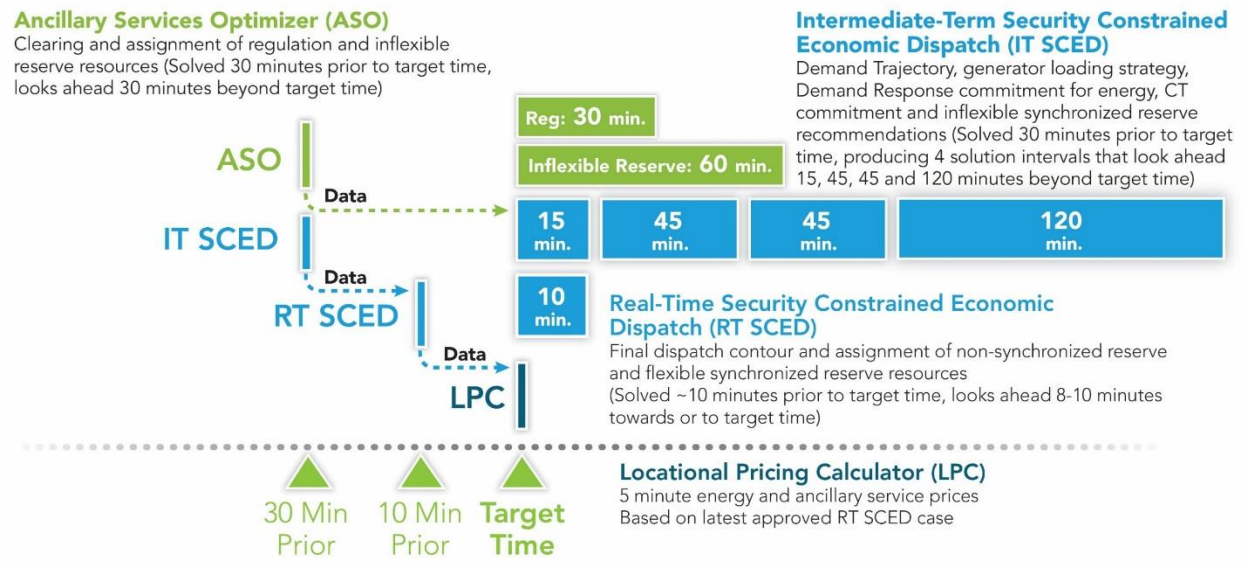
Contents

2.5 Real-time Clearing Engines

To conduct the Real-time Markets, a multi-module software platform is utilized by PJM to dispatch Energy and ensure adequate Reserves in ~~r~~Real ~~-~~time and Regulation in near time (see the image below). The Real-time Market Clearing Engines and various other applications communicate jointly, and the most recent information from each application is stored~~,~~ and, upon request, provided to each application. To run the Real-time Market, data is processed from the markets database and other PJM systems.



The applications jointly optimize the products for a defined target time to ensure that all system requirements are met using the least~~-~~cost resource set, therefore minimizing production cost.

2.5.1 Ancillary Service Optimizer (ASO)

The Ancillary Services Optimizer (ASO) 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. The ASO case is executed one ~~(1)~~ ~~-~~half~~-~~hour prior to the beginning of an operating half~~-~~hour interval and is normally solved and approved up to ~~thirty (30~~10~~)~~ ~~-~~minutes prior to the operating half~~-~~hour interval. Upon case approval, the assignments are posted in the Markets Gateway system. In the event ~~the~~ a new ASO case is not approved, previous assignments are effective into the next half~~-~~hour interval. The ASO engine uses the hourly offers for Energy, Reserves and Regulation that are effective at the target time for each case solution and also performs the Regulation Three~~-~~Pivotal Supplier (TPS) Test. ASO does not calculate final market clearing prices.

Section 3: Overview of the PJM Regulation Market

Welcome to the overview of the PJM Regulation Market section of the PJM Manual for Energy & Ancillary Services Market Operations. In this section you will find the following information:

- An overview description of the PJM Regulation Market (see “Introduction to Regulation”)
- A list of the PJM Regulation Market Business Rules (see “PJM Regulation Market Business Rules”)

- An overview of PJM's Regulation Megawatt Requirements (see "Regulation Requirements")
- An overview of PJM's Regulation Market Power Mitigation mechanisms (see "Regulation Market Power Mitigation")
- An overview of the concept of Regulation Mileage (see "Regulation Mileage")
- An overview of the concept of Lost Opportunity Cost (see "Regulation Lost Opportunity Cost")
- An overview of PJM's Regulation Clearing and Pricing mechanisms (see "Regulation Clearing and Pricing")
- An overview of Operations Regulation actions (see "Regulation Market Operations")
- An overview of Regulation Obligation Fulfillment (see "Regulation Obligation Fulfillment")
- An overview of Settlements in Regulation (see "Regulation Settlements")

3.1 Introduction to Regulation

The PJM Regulation Market provides PJM participants with a market-based system for the purchase and sale of the Regulation ancillary service to meet the applicable NERC regions' Regulation Zone requirements. Resource owners submit specific offers for Regulation capability and Regulation mileage, and PJM utilizes these offers together with energy offers and resource schedules from the Markets Gateway System as input data to the Ancillary Service Optimizer (ASO), which is a half-hour ahead Market Clearing Engine. ASO optimizes the RTO dispatch profile and forecasts LMPs to determine the most economical half-hourly commitment of Regulation service to meet the Regulation Requirement. In real time, a single bidirectional signal is sent to all resources providing Regulation service.

The Real-time Security Constrained Economic Dispatch (RT SCED) program jointly optimizes Energy and Reserves subject to transmission constraints, Reserve Requirements and prior committed Regulation and inflexible ancillary service assignments. For more information on how RT SCED uses Regulation commitments in the joint optimization, please refer to Section 2.5 of this Manual. The five-minute Regulation Market Clearing Price (RMCP) and Regulation Market Mileage Clearing Price (RMMCP) are calculated by the Locational Price Calculator as described in Section 3.7.6 of this Manual and are used to derive the five-minute Regulation Market Capability Clearing Price (RMCCP). These clearing prices are then used in market settlements to determine the credits awarded to providers and charges allocated to purchasers of the Regulation service.

3.2 PJM Regulation Market Business Rules

3.2.1 Regulation Market Eligibility

Regulation offers may be submitted only for those resources electrically within the PJM RTO.

To regulate, a resource must meet the following criteria:

- All Resources must be able to provide at least 0.1 MW of Regulation capability in order to participate in the Regulation Market.
- Generation resources must have a governor capable of automatic generation control (AGC).
- All resources must be able to receive and respond to an AGC signal. A resource's megawatt output must be telemetered to the PJM control center in a manner determined to be acceptable by PJM.

- New resources must pass an initial set of performance tests as described in Section 3.2.2.
- Resources must demonstrate minimum performance standards, as set forth in PJM Manual 12: Balancing Operations, Section 4: Providing Ancillary Services.

3.2.2 Regulation Qualification, Disqualification and Requalification

To qualify for Regulation service, new eligible resources must pass at least two qualification tests, either one self-administered test and one PJM-administered test, or two PJM-administered tests.

Any resource will be disqualified from Regulation if their historic performance score falls below 40%.

Resources will be required to complete and pass one PJM-administered test for the following scenarios:

- To reenter the Regulation Market after disqualification
- Increase in megawatt capability
- Change in communication path or energy management system (EMS) – existing or new owner/Market Operations Center (MOC)

Further details regarding testing including impacts to a resource's historic performance score upon qualification and requalification can be found in PJM Manual 12: Balancing Operations, Section 4.4: Qualifying Regulation Resources.

3.2.2.1 Performance Scoring

Performance scoring is based solely on a resource's precision score and is calculated as the lowest of the absolute error between the signal at t_0 and the response at t_0 and t_{10}. The denominator in the precision calculation is the average of the Regulation award and the absolute average interval signal.

Further details can be found in PJM Manual 12: Balancing Operations, Section 4.4.5: Performance Score Calculation.

3.2.3 Regulation Market Data Timeline

The following information must be supplied through the Markets Gateway System:

- Resource Regulating Status (Economic, Unavailable, Self-Scheduled)
- Regulation Capability (above and below Regulation midpoint, megawatts)

The following information is optional to be supplied through the Markets Gateway System:

- Regulation Maximum and Minimum values, considering any necessary offsets (megawatts)

Daily cost-based and price-based Regulation offer(s) and any applicable cost information must be supplied prior to 14:15 the day prior to the Operating Day. To accurately reflect each resource's capability during the Operating Day, the following information may be submitted on an hourly basis and/or changed up until 35 minutes prior to the start of the operating hour, at which time the ability to update the following parameters closes:

- Regulation offer megawatts
- Regulation Maximum and Regulation Minimum

Market Participants who did not elect to opt out of Intraday Updates as detailed in Section 9.1.1 of this Manual may also submit and/or change:

- Regulation Capability Offer ($/MWh)
- Regulation Mileage Offer ($/ΔMWh)

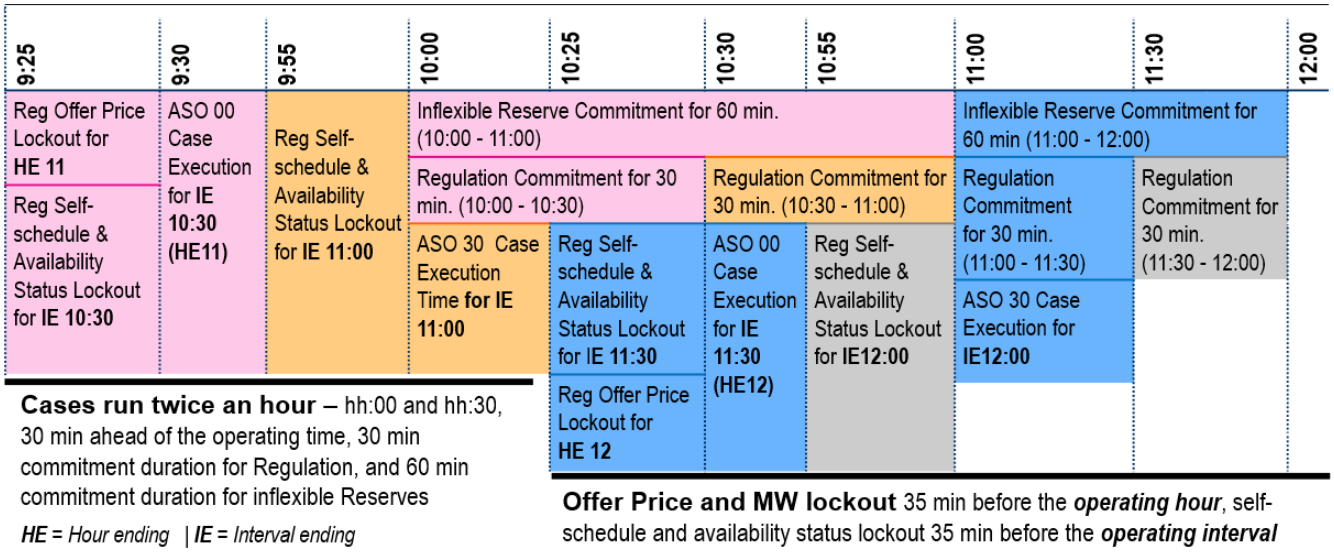
To accurately reflect each resource's availability during the Operating Day, the following information may be submitted on a half-hourly basis and/or changed up until 35 minutes prior to the start of the operating interval, at which time the ability to modify Regulation Market availability closes:

- Resource Regulating Status Availability (Unavailable, Economic, Self-Scheduled)

Daily Regulation offers submitted for a capacity resource on the Regulation Offers page in Markets Gateway are automatically carried over from one day to the next unless updated. Changes made on the Regulation Updates pages of Markets Gateway are not carried over into the next day. Any changes made to the Regulation Updates pages supersede the values on the Offers page. The Real-time Market Clearing Engines will use the bid-in parameters as inputs as detailed in Sections 2.5 and 2.7 of this Manual.

- Should a resource choose not to participate in the Regulation Market in any given period on the Operating Day, the following update should be made at least 35 minutes prior to the operating hour in the Regulation Updates page of the Markets Gateway System:
  - Set Offer MW to zero.
- The following update should be made at least 35 minutes prior to the operating interval in the Regulation Availability page of the Markets Gateway System:
  - Set Resource status to Unavailable.
- Should a resource's Regulation operating parameters change after the Regulation Market update window closes for an operating interval, the following changes may be made through direct communication with the PJM Generation Dispatcher:
  - Resource Regulating Status if a resource becomes unavailable:
    - Request PJM Dispatch to deselect resource if before case approval.
    - Request PJM Dispatch to deassign resource if after case approval with performance score impacts as described in Section 3.8.2.
  - Regulating capability decreases or changes to Regulation Minimum and Maximum
    - Request PJM Dispatch to modify assignment downward to reflect latest parameters that are verbally communicated.

An example of the Regulation Market data timeline is in the figure below.



3.2.4 Regulation Offer Structure

A Regulation offer consists of the following data: Regulation offer megawatts, Regulation capability price and cost, Regulation mileage price and cost, Regulation maximum and minimum (optional), and Regulation status/availability. Regulation offer prices and megawatts cannot be negative. If a resource submits offers into both the Regulation and Reserve Markets in the same hour, the Regulation offer receives higher priority in the market clearing process, meaning if economic for both markets, the unit is committed for Regulation rather than Reserves.

3.2.4.1 Cost-Based Regulation Offer

The cost-based Regulation offer ($/MWh) is validated using the unit-specific operating parameters submitted with the Regulation offer and the applicable $12/MWh Regulation margin adder. The cost-based offer has two components, including:

- Regulation capability portion capturing the reservation cost for megawatts, which includes the fuel cost increase and unit-specific heat rate degradation due to operating at lower loads (non-hydro generation resources only) and the applicable $12/MWh Regulation margin adder
- Regulation mileage portion representing the incremental cost of megawatts movement, which includes: (1) cost increase due to heat rate increase during non-steady state operation, (2) cost increase in VOM (applies to non-energy Regulation-only resources), and (3) energy storage unit losses (applies to energy storage resources only)
    - The $/MW value is derived by converting from $/ΔMW by multiplying the value by the historic mileage ΔMW/MW for that offer.

In addition to the cost-based Regulation offer price, each Market Participant may also submit additional information to support the cost-based offer price. Using the calculations in PJM Manual 15: Cost Development Guidelines, Section 2.8: Regulation Service, PJM validates the cost-based Regulation offer price to ensure that it does not exceed actual regulating cost as determined by this Manual, plus the applicable Regulation margin adder.

The Markets Gateway System rejects any cost-based capability or mileage offer price that exceeds the calculated values using the resource-submitted parameters. An example of this calculation is available on the Markets and Operations > Ancillary Services page on the PJM website.

If a Market Participant does not submit a cost-based Regulation offer price, participation in the PJM Regulation Market is not permitted until such offer has been validated. A non-null capability offer cost is required for ASO to clear a resource for Regulation. Any participants that do not submit any of the supporting parameters below will have their cost-based Regulation offer price capped at the margin adder of $12/MWh.

The following optional parameters may be submitted in the Markets Gateway System to support the cost-based Regulation offer price. If any of these parameters are not submitted, they are defaulted to zero.

- Heat Rate @ Eco Max [BTU/kWh]: The heat rate at the default Economic Maximum for a resource. The Economic Maximum that corresponds to this rate value is the default Economic Maximum shown on both the Daily Regulation Offers and Unit Details pages.
- Heat Rate @ Reg Min [BTU/kWh]: The heat rate at the default Regulation Minimum for a resource. The Regulation Minimum that corresponds to this rate value is the default Regulation Minimum shown on both the Daily Regulation Offers and Unit Details pages.
- VOM Rate [$/MWh of Regulation]: The increase in VOM resulting from operating the Regulating resource at a higher heat rate than is otherwise economic for the purpose of providing Regulation (applies to non-energy resources only).
- Fuel Cost [$/MBTU]: The fixed fuel costs of the resource. This value is used to determine the heat rate adjustments during steady-state and non-steady-state operation for the purpose of providing Regulation (applies to non-hydro generation resources only).

3.2.4.2 Price-Based Regulation Offer

The price-based offer ($/MWh) is capped at $100/MWh and its submission is optional. The price-based offer has two components, including:

- Regulation capability portion capturing the resource owner's price to reserve megawatts for Regulation in $/MW
- Regulation mileage portion capturing the resource owner's price to provide Regulation movement in $/ΔMW
  - The $/MW value is derived by converting from $/ΔMW by multiplying the value by the historic mileage ΔMW/MW for that offer.

3.2.4.3 Regulation Final Offer

A regulating resource's Final Offer for use in clearing and pricing is determined by the following criteria:

If the supply passes the Regulation Three Pivotal Supplier (RegTPS) Test as described in Section 3.4, the price-based offer ($/MWh) will be used as the Final Offer if one exists. If no price-based offer ($/MWh) is entered, then the cost-based Regulation offer will be used as the Final Offer.

If the supply fails the RegTPS Test as described in Section 3.4, the resource is offer-capped at the lesser of their cost-based or price-based Regulation offer price for that half hour. This then becomes the resources' Final Offer.

Resource owners can view their Final Offer used in the clearing via the Reg Price Offer Used column on the Regulation Award tab on the Market Results page in Markets Gateway.

3.2.5 Regulation Market Offer Period Timing

Regulation Market Participants must at least supply a daily cost-based Regulation offer reflecting both Regulation capability offer cost of the resource by 14:15 the day prior to the Operating Day, and the remainder of the necessary data prior to the Regulation Market closing as stated above in Section 3.2.3 of this Manual.

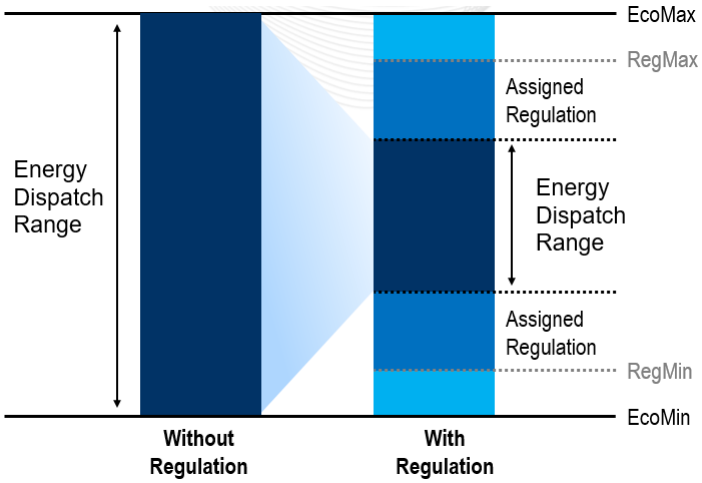
Daily Regulation offers are locked as of 14:15 the day prior to the Operating Day. The markets database is generally unavailable for updates to offers for the next Operating Day between 11:00 and the time PJM posts the results of the Day-ahead Energy Market for that Operating Day while the Day-ahead Market is being cleared. Hourly updates to Regulation offers, as defined in Section 3.2.3 of this Manual, can be submitted up to 35 minutes prior to the start of the operating hour. Half-hourly updates to Regulation Availability, as defined in Section 3.2.3 of this Manual, can be submitted up to 35 minutes prior to the start of the operating interval. All resources listed as available for Regulation with no offer price have their offer prices set to zero.

3.2.6 Regulation Range Limits

Regulation Market clearing is bound by both the Regulation and Economic limits submitted into Markets Gateway. Under normal conditions, submitted limits typically follow the below order of entry:

$$\text{Eco Min.} \leq \text{Reg Min.} \leq \text{Reg Max.} \leq \text{Eco Max.}$$

The adjustment of economic limits can affect the valid Regulation range of a resource. In the event that the Regulation Maximum and Regulation Minimum limits are not the most restrictive for a given resource (i.e., the Regulation Maximum is not the lowest of all the high limits and/or the Regulation Minimum is not the highest of all the low limits), the ASO will utilize the most restrictive minimum and maximum of all applicable limits.



The greater the separation between the defined Regulation range and defined Economic range, the lower the chance of Regulation clearing for a resource due to the potential energy megawatt displacement for the purpose of providing Regulation.

Regulation capability is calculated as follows:

Reg. MW Capability = min (Offer MW, (Reg Hi – Reg Lo) / 2)

Where Reg Hi = min (Eco Max, Reg Max)

And Reg Lo = max (Eco Min, Reg Min)

Regulation resources are allowed to provide Regulation service within the PJM-validated parameters defining the Regulation range, Reg Lo to Reg Hi, as defined above.

Any dispatchable resource, except hydro, utilizing the Fixed Gen Flag in the Markets Gateway system is ineligible to provide Regulation service.

Hydropower resources do not enter Regulation Minimum and Maximum limits and are bound by their Economic limits per the following formula:

Hydro Reg. MW Capability = min (Offer MW, (Reg Hi – Reg Lo) / 2)

Where Reg Hi = Eco Max

And Reg Lo = 0

Resource owners can view their validated megawatt capability used in clearing via the Reg Offer MW column on the Regulation Award tab on the Market Results page in Markets Gateway. After the validations performed on capability as described above, this value may be less than the participant submitted Offer MW.

3.2.7 Economic Load Response Participation

To provide Regulation, Economic Load Response resources must meet the following criteria:

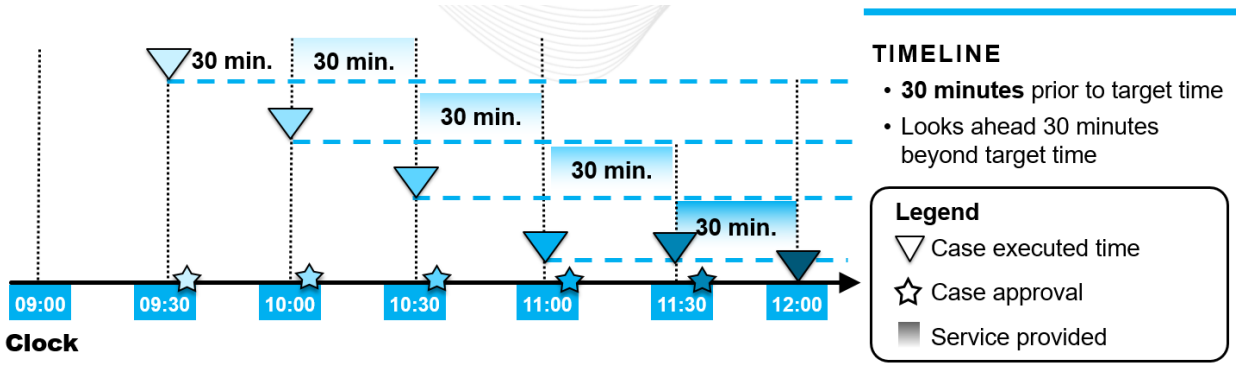
- Economic Load Response resources must be able to provide at least 0.1 MW of Regulation capability.
- Economic Load Response resources must be able to receive and respond to an AGC signal. A resource's megawatt output must be telemetered to the PJM control center in a manner determined to be acceptable by PJM.
- Economic Load Response resources must successfully complete Ancillary Services certification in PJM's DR Hub system to participate in PJM's Regulation Market.
- Curtailment Service Providers must complete initial and continuing training on the Regulation Market as documented in PJM Manual 40: Certification and Training Requirements, Section 3.2.4: Training Requirements for Demand Response Resources.
- Curtailment Service Providers must submit valid Economic and Regulation Maximum and Minimum MW limits respectively for their Economic Load Response resources participating in the PJM Regulation Market. Regulation Maximum and Minimum MW limits must not be negative.

When an Economic Load Response resource that is assigned in the Regulation Market is called for a mandatory Emergency or Pre-Emergency Load Management Event, it is de-assigned from Regulation for any intervals that overlap with the Load Management Event, starting from the notice time of the Load Management Event, unless otherwise approved by PJM. PJM will not assign the resource to Regulation for the remainder of the mandatory portion of the Load Management Event.

The estimated opportunity cost for Economic Load Response resources is zero. Economic Load Response resources are limited to providing 25% of the Regulation Requirement.

3.2.8 Ancillary Service Optimizer

The Ancillary Services Optimizer (ASO), which is a 30 minute-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 30-minute commitments of Regulation and hourly inflexible synchronized reserves to meet the respective product requirements.



Using the dispatch profile and forecasted LMPs, an opportunity cost is estimated for each eligible resource offer into the Regulation Market for the half hour. The estimated Lost Opportunity Cost is then added to each resource Regulation offer to create a 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 are cleared in that half hour while minimizing the overall estimated production cost. The estimated prices resulting from ASO are non-binding and non-public with the actual clearing prices determined in real time via the Locational Pricing Calculator (LPC) pricing engine reflecting actual system conditions.

3.3 Regulation Requirements

The total PJM Regulation Requirement for the PJM RTO is determined in whole megawatts based on the season and time-of-day criteria detailed on the Markets and Operations > Ancillary Services page on the PJM website.

Further details, including the annual adjustment methodology to these requirements, can be found in PJM Manual 12: Balancing Operations, Section 4.3.3: Determining Regulation Assignment.

PJM Dispatch may increase or decrease the Regulation Requirement as needed to accommodate system conditions. Any changes to these requirements are communicated via the Markets Gateway system.

3.4 Regulation Market Power Mitigation

PJM utilizes the TPS Test in the Regulation Market to mitigate market power as detailed in Attachment K-Appendix, Section 3.2.2A.1 of the PJM Tariff. The test is applied on a Regulation supplier basis, not a resource-by-resource basis. The test is performed on all valid and available supplies within 150% of cost-based RMCP. Any supply greater than 150% of cost-based RMCP as calculated by ASO is ineligible for the test and thus ineligible to clear for Regulation service.

In each ASO interval, each supplier, from one to n, is ranked from the largest to the smallest offered megawatt of eligible Regulation supply adjusted by the resource-specific performance score in each half hour. Suppliers are then tested in order, starting with the three largest suppliers. In each iteration of the test, the two largest suppliers adjusted by the resource-specific performance scores are combined with a third supplier adjusted by the resource-specific performance score, and the resulting combined supply is subtracted from total effective supply adjusted by their resource-specific performance scores.

The resulting net amount of eligible supply is divided by the Regulation Requirement for the half hour adjusted by the resource-specific performance scores (D). Where j defines the supplier being tested in combination with the two largest suppliers (initially the third largest supplier with j=3). The equation below shows the formula for the residual supply index for three-pivotal suppliers (RSI3):

$$RSI3_j = \frac{\sum_{i=1}^{n} S_i - \sum_{i=1}^{2} S_i - S_j}{D}$$

Where j=3, if RSI3j is less than or equal to 1.0, then the three suppliers are jointly pivotal and the suppliers being tested fail the TPS Test. Iterations of the test continue until the combination of the two largest suppliers and a supplier j result in a RSI3j greater than 1.0. When the result of this process is that RSI3j is greater than 1.0, the remaining suppliers pass the test.

- Any resource owner that fails the TPS Test is offer-capped for that half hour.
- Resource owners can view their TPS Test results via the TPS Result column on the Regulation Award tab on the Market Results page in Markets Gateway. A failed test result does not prevent resource clearing.
- Regulating resources belonging to a resource owner that fails the TPS Test are offer-capped at the lesser of their cost-based or market-based Regulation offer price for that half hour. This then becomes the resources' Final Offer for use by ASO.
- An offer-capped resource will only be offer-capped for a single half hour at a time as the TPS Test is rerun for each half hour of the day.
- Resource merit order price ($/MWh) = Resource Regulation offer plus estimated resource opportunity cost per megawatt-hour of capability adjusted by the resource-specific performance score.

3.5 Regulation Mileage

Mileage is the absolute summation of movement requested by the Regulation control signal a resource is following in a given time period. It is calculated for the duration of the market interval for the Regulation control signal. Dimensions are in ΔMW/MW. One full cycle of movement from a full raise movement to a full lower movement and back to neutral represents four miles. Historic mileage is a rolling 30-day daily average and is used for clearing in ASO via adjusted offers and for pricing in LPC. PJM Market Settlements utilizes the dimensionless ratio of the five-minute actual mileage to the historic mileage to calculate the Regulation mileage credit.

$$Mileage = \sum_{i=1}^{n} | Reg_i - Reg_{i-1} |$$

3.6 Regulation Lost Opportunity Cost

A primary goal in operating ancillary service markets, such as Regulation, is to ensure that resources are indifferent to providing energy or the ancillary service. Thus, to ensure such indifference, Regulation clearing prices account for the foregone above-cost revenue (i.e., profit) or increase in costs relative to the energy market associated with providing Regulation and not Energy. In other words, resources are compensated for their lost opportunity costs when being committed to provide Regulation. This ensures that when PJM dispatches a resource off its current energy assignment so that it can provide Regulation, the resource will follow dispatch and be capable of providing the Regulation needed.

Regulation Lost Opportunity Cost (LOC) refers to the cost of providing Regulation instead of energy. Resources not eligible or with no LOC associated with providing Regulation for the purposes of committing resources, setting clearing prices, or in settlement are:

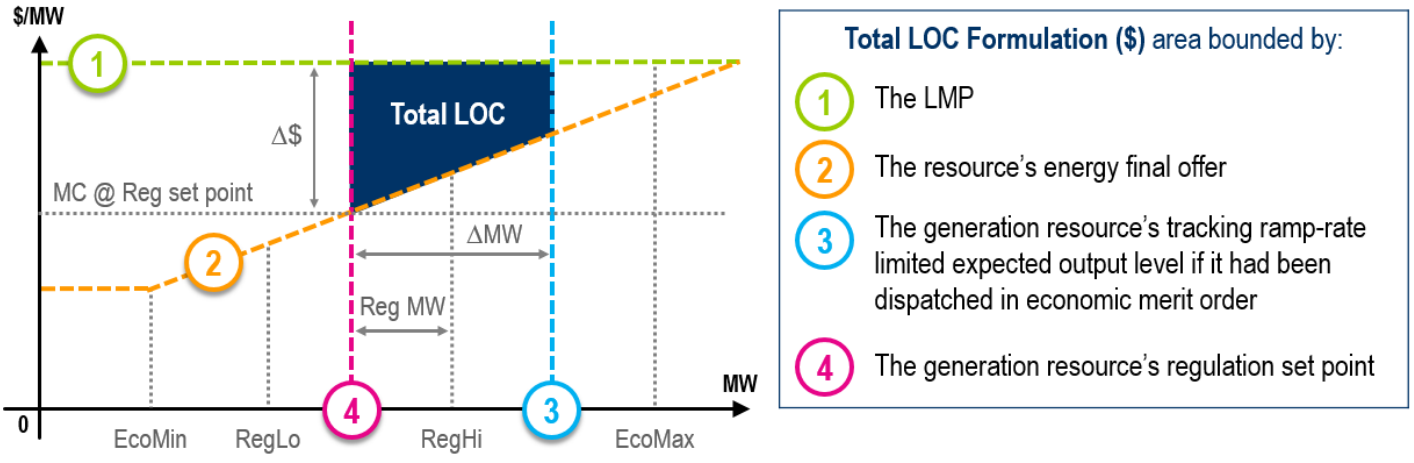
- Energy resources that are self-scheduled to provide Regulation
- Economic Load Response resources
- Non-Energy Regulation-Only resources

Notwithstanding the above, resources that do not submit an energy offer curve will have a Lost Opportunity Cost of zero. Please refer to Section 4.2 "Regulation Credits" of PJM Manual 28: Operating Agreement Accounting for additional details on how LOC is used in settlements.

3.6.1 General LOC Calculation

To calculate LOC, the energy schedule used is as follows:

- For online resources, the schedule on which the resource is committed and running for energy, i.e., the resource's "Final Offer." A unit with no logged energy schedule cannot clear for Regulation.
- For offline resources that need to be brought online to provide Regulation, the cheapest of the price-based or cost-based available energy schedules.



The Total LOC calculation is derived by first calculating the area bounded by: (1) the Locational Marginal Price (LMP) at the generation bus for the regulating resource, (2) the "Tracking Desired MW at LMP Ramp Limited," (3) the resource's marginal cost at its Regulation set point, and (4) the megawatt value at its Regulation set point.

Next, the area bounded by: (1) the resource's energy schedule curve, (2) the "Tracking Desired MW at LMP Ramp Limited," (3) the resource's marginal cost at its Regulation set point, and (4) the megawatt at the Regulation set point is removed, leaving the blue shaded geometric area bounded by the resource's Final Offer curve as the calculated LOC as shown in the figure above.

PJM utilizes this approach for determining both the lost opportunity cost used in LPC and subsequently settlements via actual prices and the inter-temporal opportunity cost used to price and select resources for commitment in ASO via estimated prices. Further, in the final settlement, PJM calculates a resource's specific opportunity cost for purposes of determining its Regulation credit (i.e., payment) using the formula outlined above, and then adjusting for the performance score, such that the bounded area is multiplied by the resource's performance score for that interval to account for the actual benefit (i.e., performance) the system received from this resource during the Regulation intervals and that the clearing calculated opportunity cost accounts for the historic performance of the resource.

In addition, Regulation resources are also credited for lost opportunity costs for the foregone revenue and increased costs incurred in their "shoulder intervals" when a resource deviates from its economic output level in preparation for providing Regulation service and returning to their economic output level following the provision of Regulation service. The "shoulder intervals" are defined as the two five-minute Real-time Settlement Intervals prior to and immediately following the provision of service, and LOC is calculated for these "shoulder intervals" as the product of (1) the deviation between the resource's set point and "tracking expected ramp-rate limited output" and (2) the absolute value of the difference between the generation bus LMP and resource's "Final Offer, at the MW level of the Regulation set point for the resource." RT SCED will pre-position steam units approaching an upcoming Regulation assignment during the "shoulder intervals" prior to the assignment.

Please refer to Section 4.2 of PJM Manual 28: Operating Agreement Accounting for additional details on how LOC is used in settlements.

3.6.2 Tracking Ramp-Limited Desired Megawatt Concept

The determination of an opportunity cost necessarily must consider the resource's ability to actually follow the energy market price signal. That is, the amount of megawatts the opportunity cost determination posits that a resource could produce at any given moment must be achievable and consider the resource's "ramp rate," i.e., the speed at which the resource can produce additional energy, or whether the resource is consistently following the PJM energy dispatch signal.

To account for the degree to which a resource is actually foregoing revenues to provide Regulation, PJM evaluates the resource along its offer curve in accordance with the resource's ramp rate. PJM considers the energy market megawatts the Regulation resource would have produced if it had been economically dispatched based on its ramp rate, and using the last energy dispatched megawatts, as determined by PJM's RT SCED engine, rather than the resource actual energy output. This is effectuated in the Total LOC Calculation using the "Tracking Desired MW @ LMP Ramp Limited" metric.

The Tracking Ramp Limited Desired MW at LMP (TRLD) incorporates consecutive market conditions in creating the real-time energy dispatch profile that a unit should have achieved based on its bid-in ramp rates and economic limits,

the energy schedule on which the unit is logged and running, the dispatch-run LMP at its pnode, and is independent of its initial megawatt at each interval.

TRLD is calculated in the post-processing in LPC every five-minute interval. TRLD is not used to dispatch a unit, but for tracking only, for the purpose of the Regulation opportunity cost calculation in Market Operations and in Settlements utilizing data from the RT SCED dispatch-run solution for megawatts and LPC pricing-run solution for prices. Tracking starts at the earlier of the resource attaining their Economic Minimum or when a unit's startup plus notification time is met, is calculated continually as long as the unit is online (not just when the unit is regulating), and restarts when a unit comes back online after being offline. In the event of PJM being "OFF SCED" as described in Section 2.10, the TRLD will reset to the dispatch megawatt value of the first approved RT SCED case following the "OFF SCED" period and continue calculation thereafter.

The Tracking Ramp Limited Desired MW at LMP is calculated per the following formula:

$$D_t^{lmp} = D_{t-1} \pm Ramp_t$$

where D_t^{lmp} is the tracking ramp limited desired MW for the target interval

D_{t-1} is the tracking ramp limited desired MW of the previous interval

t is the target interval

$t-1$ is the previous interval

$ramp$ is the five-minute increase or decrease in output capability of the unit based on system conditions, the latest available unit's ramp rate data and the latest available unit's incremental offer curve data the unit is logged and running in real-time as submitted by the resource owner.

3.6.3 Hydro Opportunity Cost Calculation

Since hydropower units operate on a schedule and do not have an energy bid, opportunity cost for these units is calculated as follows. If a hydropower resource is enrolled in the ESR participation model, LOC is calculated via the standard means described in Section 3.6.1. Only hydropower units not enrolled in the ESR participation model are considered in the rules below.

During those hours when a hydropower unit is in spill, the ED value (the average of day-ahead LMP for the applicable on-peak or off-peak day-ahead market hours) is set to zero such that the opportunity cost is based on the full value of LMP. During the Operating Day, the operating company is responsible for communicating this condition to the PJM Master Coordinator and indicating this condition on the Regulation Updates page of the Markets Gateway System.

If a hydropower unit is committed day-ahead with megawatts greater than zero, the formula includes the ED value as an average of the day-ahead LMP at the hydropower unit bus for the appropriate on-peak (07:00–22:59) or off-peak (00:00–06:59, 23:00–23:59) period, excluding those hours during which all available units at the hydropower plant were operating. If this average day-ahead LMP value is higher than the actual LMP at the generator bus, the opportunity cost is zero. Day-ahead LMPs are used for the purpose of estimating opportunity costs for hydropower units, and actual real-time LMPs are used in the lost opportunity costs for settlement for hydropower units.

If a hydropower unit is brought on out of schedule to provide Regulation or not committed in the Day-ahead Market with megawatts greater than zero, the opportunity cost is equal to the average LMP (calculated as stated above) minus the actual LMP at the generator bus. If the actual LMP is higher than the average, the opportunity cost is zero.

These rules are summarized in the figure below.

Hydro Type & Condition	Energy Schedule	RegLOC
Pump Storage & Run-Off River	Scheduled MW > 0	Max[LMP – ED, 0]
	Scheduled MW <= 0	Max[ED – LMP, 0]
Spill Condition	RegLOC = Max[LMP, 0]	

LMP

- LMP at the hydro unit pnode
- Forecasted value is used in the regulation clearing in ASO
- Actual value is used in the real-time 5-minute pricing in LPC and Settlement

ED

- The average of LMPs at the hydro unit pnode for the appropriate on-peak or off-peak period excluding those hours during which all available units at the hydro plant were operating
- Day-ahead LMPs are used to calculate ED in the regulation clearing and in the real-time pricing
- Real-time LMPs after-the-fact are used in Settlement

PJM maintains the authority to adjust hydropower unit schedules for those units scheduled by the owner when determined to be economically beneficial, assuming the owner has also submitted a Regulation offer for those units and made the units available for Regulation.

An example of Regulation Hydropower Lost Opportunity Cost Calculations can be found on the Markets and Operations > Ancillary Services page on the PJM website.

3.7 Regulation Market Clearing & Pricing

PJM uses resource schedules, Regulation offers, and Energy offers from the Markets Gateway System as input data to the ASO to provide the lowest-cost alternative for the procurement of Regulation for each half hour of the operating day. The lowest cost alternative for this service is achieved through a simultaneous co-optimization with Synchronized Reserves, Non-Synchronized Reserves, Secondary Reserves and Energy. Within the co-optimization, an RTO dispatch profile is forecasted along with LMPs for the market interval.

Using the dispatch profile and forecasted LMPs, an opportunity cost, adjusted by the applicable performance score, is estimated for each resource that is eligible to provide Regulation. The estimated opportunity cost for Economic Load Response resources is zero. The adjusted lost opportunity cost is added to the adjusted Regulation capability cost and the adjusted Regulation mileage cost to make the adjusted total Regulation offer cost. The adjusted total Regulation offer cost is then used to create the merit order price.

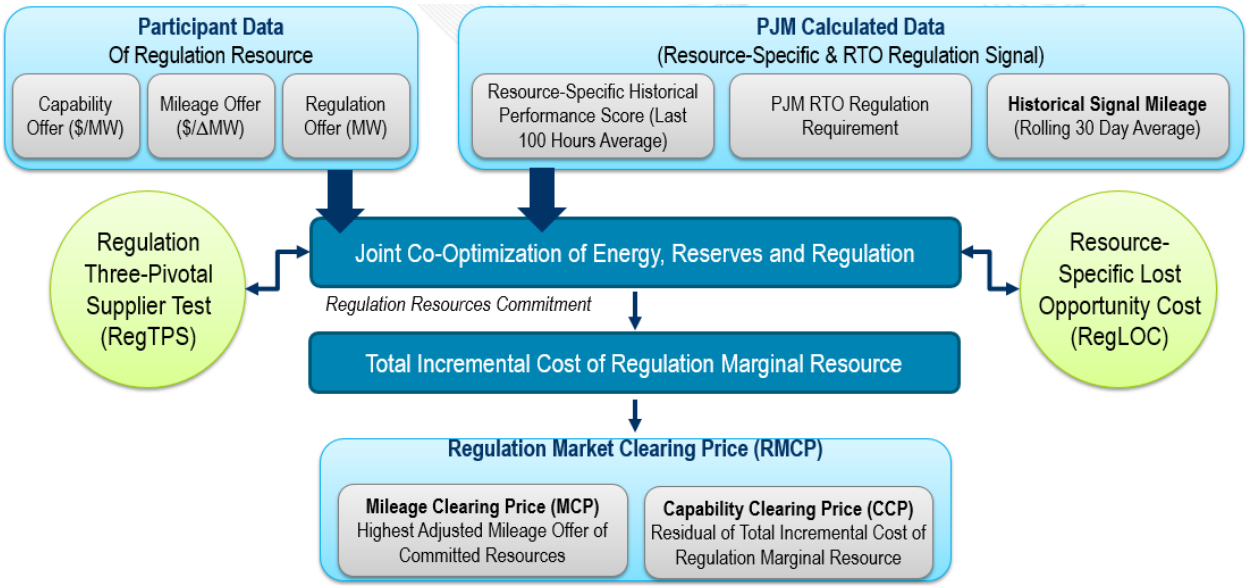
Each PJM Market Clearing Engine, as described in Sections 2.5 and 2.7 of this Manual, ranks all available regulating resources in ascending order of their merit order prices, and the lowest cost set of resources necessary to simultaneously meet the PJM Regulation Requirement, PJM Synchronized Reserve Requirement, PJM Primary Reserve Requirement, and PJM 30-minute Reserve Requirement and provide Energy in that interval is determined

taking into account any resources self-scheduled to provide any of these services. The Rank Price is determined as follows:

$$\text{Rank Price} = \frac{\text{Adjusted Total Offer Cost (\$)}}{\text{Capability (MW)}}$$

Should a Market Clearing Engine be unable to fulfill both the Regulation and Reserve Requirements, Regulation receives the higher priority.

PJM clears the market to meet the Regulation Requirement as defined in Section 3.3. The Regulation Requirement sets the amount of regulating capability that PJM believes it would need to absorb sustained RTO ACE deviations adjusted by resource's historic performance scores. The historic performance score is discussed in PJM Manual 12: Balancing Operations, Section 4.4.4: Disqualification and Requalification of a Resource. PJM will clear and assign resources until the Regulation Requirement is met by the sum of cleared resource's Effective MWs as described in Section 3.7.2. This is summarized in the figure below.



If there is an excess of self-scheduled and/or zero-cost offers over and beyond the Regulation Requirement or a tie between resources' non-zero adjusted offers to be the marginal resource, PJM uses resource-specific historic performance scores, selecting those resources with the highest performance scores, as a tiebreaker to determine which set of resources to commit to meet the Regulation Requirement. The least-cost set of Regulation resources identified through this process are then committed.

The historic performance score is calculated upstream of the market clearing process as discussed in PJM Manual 12: Balancing Operations, Section 4.4.4: Disqualification and Requalification of a Resource. If the daily historic performance scores for an Operating Day are not available due to a system failure or other issues that affect the calculation of the historic performance scores for all resources, the latest available historic performance scores from the last three days is used. If no historic performance scores are available from the last three days, then the latest available Regulation qualification or Regulation requalification test score for each resource is used.

3.7.1 Regulation Offer Price Conversion and Validation

3.7.1.1 Adjusted Regulation Capability Cost

For each resource, PJM calculates an adjusted capability cost as:

Adjusted Regulation Capability Cost ($/MW)

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

3.7.1.2 Adjusted Regulation Mileage Cost

For each resource, PJM calculates an adjusted mileage cost as:

Adjusted Regulation Mileage Cost ($/MW)

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

More detail about mileage is found in Section 3.5 of this manual. More detail about the mileage offer cost is found in Section 3.2.4 of this manual.

3.7.1.3 Regulation Adjusted Lost Opportunity Cost

For each resource, PJM calculates an Adjusted Lost Opportunity Cost as:

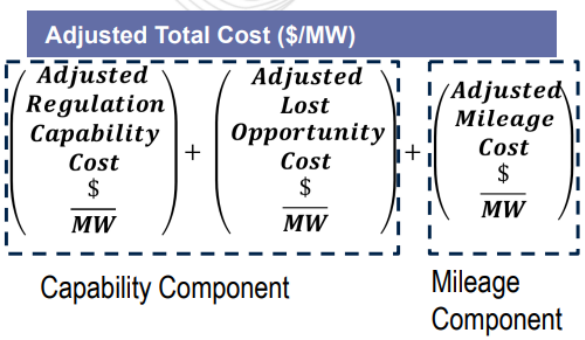
Adjusted Lost Opportunity Cost ($/MW)

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

More detail regarding Regulation Lost Opportunity Cost is found in Section 3.6 of this manual.

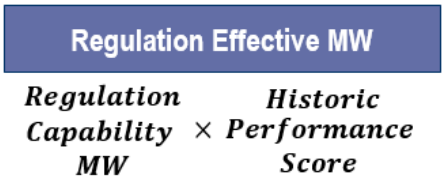
3.7.1.4 Regulation Adjusted Total Cost

Each resource must be ranked based on the total expected cost of that resource regulating. PJM calculates the adjusted total offer of the resource as:



3.7.2 Regulation Offer Megawatt Conversion and Validation

A resource must not submit a capability Offer MW for a value greater than what certified for during the Regulation testing process. Each resource will have a calculated Effective MW value for use by ASO per the following formula:



3.7.2.1 Minimum Offer Megawatt Parameter

Resources have available the optional "Minimum Offer MW" field in the Markets Gateway system. When a non-null value is entered, the resource owner is declaring they must clear at least that amount or not at all. The "Minimum Offer MW" must be less than or equal to the submitted Offer MW.

3.7.3 Regulation Self-Scheduling

Generation and Economic Load Response resource owners may self-schedule Regulation on any qualified resource. Resources that self-schedule are not guaranteed to clear if they do not meet eligibility criteria including but not limited to (1) not having a valid Regulation range or (2) having a performance score below 40%. The merit order price for any self-scheduled Regulation resource is zero, which supersedes any non-zero Final Offer as described in Section 3.2.4.3.

If there is an excess of self-scheduled offers over and beyond the Regulation Requirement, the RMCP will be zero, and PJM will use resource-specific historic performance scores, selecting those resources with the highest performance scores, as a tie breaker to determine which set of resources to commit to meet the Regulation Requirement. In the after-the-fact settlement, any resources self-scheduled to provide Regulation are compensated based on the processes described in PJM Manual 28: Operating Agreement Accounting.

3.7.4 Regulation Clearing of Offline Resources

PJM via ASO may call on resources not otherwise committed in order to provide Regulation, in accordance with PJM's obligation to minimize the total cost of Energy, Operating Reserves, Regulation and other Ancillary Services. If a resource is called on by PJM for the purpose of providing Regulation from an offline state, the resource is eligible for recovery of Regulation Lost Opportunity Costs as well as startup, no-load and energy costs. Resource owners should call PJM Dispatch prior to coming online to fulfill the Regulation award to confirm the assignment and inform PJM Dispatch of the specific time of synchronization.

ASO may clear a resource from an offline state if it is a more economical alternative to reducing an already online resource especially in Minimum Generation conditions. For offline resources, Minimum Run Time must be less than or equal to 30 minutes and the startup plus notification time must be less than or equal to 10 minutes if the unit is being brought online from an offline state to provide Regulation.

3.7.5 Regulation Clearing and Posting Timing

PJM via ASO clears the Regulation Market taking into account forecast load, transmission constraints and product requirements for the half-hour interval 30 minutes prior to the start of the operating interval, and PJM typically posts the results no later than 10 minutes prior to the start of the operating interval in the Markets Gateway System.

3.7.6 Regulation Pricing

With the Regulation Megawatt Requirement constraint satisfied, the Rank Price ($/MW) of the highest merit order price resource associated with the complete set of regulating resources sets the Regulation Market Clearing Price (RMCP). This RMCP is used to derive the clearing price for the Regulation capability and Regulation mileage components. First the Regulation Market Mileage Clearing Price (RMMCP) is calculated by finding the maximum adjusted mileage offer from the set of all regulating resources' adjusted mileage offers. Next, the RMMCP is subtracted from the RMCP to calculate the Regulation Market Capability Clearing Price (RMCCP), which is the residual between the RMCP and RMMCP.

Prices for Regulation are calculated simultaneously with Energy and Reserves every five minutes by the Locational Pricing Calculator (LPC) in the pricing run. LPC prices Regulation by calculating actual LOC using real-time prices versus the estimated LOC calculated with estimated prices in ASO. The five-minute Regulation Clearing Prices, calculated using the pricing run of LPC, are posted in the Data Viewer user interface public view. RMCP(s) and other billing determinant information is also available via PJM's Data Miner 2 tool: http://dataminer2.pjm.com/feed/ancillary_services_fivemin_hrl.

3.7.6.1 Determination of Regulation Market Clearing Prices ~~d~~During a Market Suspension

For Market Suspensions where the suspension is less than or equal to ~~twenty-four (~~24~~)~~ consecutive hours, which may span up to two Operating Days, and PJM is assigning Regulation:

- The resources providing Regulation at the direction of PJM will be compensated based on a calculated Regulation Mmarket -Cclearing Pprice (RMCP). ~~-~~ R~~egulation~~ MCPs for each Real-time Settlement Interval associated with the Market Suspension will be the average of the preceding and subsequent hour R~~egulation~~ MCPs.

For Market Suspensions where the suspension is greater than ~~twenty-four (~~24~~)~~ consecutive hours, and PJM is assigning Regulation:

- Resources providing Regulation at the direction of PJM will be compensated based on a calculated R~~egulation~~ MCP, which will be determined by calculating a Regulation clearing cost (Regulation offer plus opportunity cost) for the online resources providing Regulation during the Market Suspension, as further described in Operating Agreement, Schedule 1, section 3.2.2 and the parallel provisions of Tariff, Attachment K-Appendix, section 3.2.2.
- The highest cost resource, based on this Regulation clearing cost, will set the R~~egulation~~ MCP for each hour of the Market Suspension.

During a Market Suspension, the following Regulation components for all Real-time Settlement Intervals in the Market Suspension period will be determined as follows:

- If the ~~regulation~~ Regulation performance score cannot be calculated during a Market Suspension, the ~~100-hour rolling average~~ historic performance score will be used for the Market Suspension period.
- ~~If the unit-specific benefits factor cannot be calculated during a Market Suspension, a historical average unit-specific benefits factor will be used for the Market Suspension period, as further described in Operating Agreement, Schedule 1, section 3.2.2(iii) and the parallel provisions of Tariff, Attachment K-Appendix, section 3.2.2(iii).~~

Below is a table that highlights the different Market Suspension categories based on duration along with the corresponding business rules:

Market Component Determination of:	SUSPENSION TIME (CONSECUTIVE HOURS)		
	≤ Six	> Six but ≤ 24	> 24
Regulation Market Clearing Prices (RMCP)	Use average of preceding and subsequent hour R~~egulation~~ MCPs		Use calculated Regulation clearing cost (Regulation offer + opportunity cost), where highest cost resource will set R~~egulation~~ MCP

During a Market Suspension, if PJM is not assigning Regulation, then the R~~egulation~~ MCP will be set to $0/MWh for all Real-time Settlement Intervals in the Market Suspension period and no resource-specific opportunity cost will be calculated.

3.8 Regulation Market Operations

3.8.1 Regulation Dispatch and Reduced Energy Ramp Rate

A resource's economic ramp rate must be adjusted when resources provide Regulation to minimize the conflict between Energy and Regulation services. The segment-specific ramp rates should be calculated from the economic ramp rate as follows:

$$\textit{Reduced Energy Ramp Rate} = \max\left(0,\ \textit{Economic Ramp Rate} - \frac{\textit{Cleared Regulation Capacity (AREG)}}{5\ \textit{Minutes}}\right)$$

Market Sellers may declare use of an optional member-entered parameter in the Markets Gateway system to further reduce this value, which is the minimum unit-specific percentage of the bid-in economic ramp rate used for the reduced energy ramp rate logic when a unit is providing both Energy and Regulation. Entered values must be whole numbers, and negative values are not allowed. If no value is entered in the Market Gateway system for the resource, a default of zero is used. For example, if zero is entered (the default value) then 100% of the assigned Regulation Megawatt (divided by five) will reduce the bid-in energy ramp rate for SCED.

To increase consistency in the Individual Generator Dispatch (IGD) set point sent by PJM while a unit is regulating, the IGD set point will only move up when the RT SCED LMP justifies raising the resource and the resource has a non-zero reduced energy ramp rate. The IGD set point will only move down when the RT SCED LMP justifies lowering the resource and the resource has a non-zero reduced energy ramp rate.

Resources should give priority to the Regulation signal by not allowing the sum of the Regulation ramp rate and energy ramp rate to exceed the economic ramp rate. Only after a regulating resource has accounted for the Regulation capability may a generator use the net of the dispatch signal and the Regulation ramp rate to follow the energy signal.

The PJM Energy Management System (EMS) will send an RTO-based signal(s) to each Local Control Center (LCC) as well as signals to individual resources or plants as requested by the owner.

3.8.2 Self and PJM De-Assignments

Participants can request to de-assign (self de-assign) a resource's cleared Regulation commitment by calling PJM Dispatch. In order to incentivize resources to accurately represent their capability and perform according to their Regulation commitments, the resource will receive a zero performance score for the specified period of self de-assignment. To maintain system reliability, PJM Dispatch may de-assign resources from Regulation. Any de-assignment action taken by PJM Dispatch will not impact the performance score of the resource for the specified period.

3.8.3 Intra-Interval Manual Assignments

PJM Dispatch periodically evaluates the set of resources providing Regulation and makes any adjustments to Regulation assignments deemed necessary and appropriate to maintain system reliability.

In the event of a Regulation deficiency, PJM Dispatch uses the Intermediate-Term Security Constrained Economic Dispatch (IT SCED) application to select resources to provide Regulation beginning with the lowest-cost resource currently not providing Regulation and moving upward assuming the resource evaluated to provide Regulation is not a detriment to system reliability. The RMCP and therefore RMMCP and RMCCP may change based upon regulating resource adjustments made in real time.

PJM Dispatch communicates any change in resource regulating assignments to individual LCCs. Company total in-service regulating capabilities are then telemetered back to the PJM EMS via the PJM data link or other approved methods.

3.8.4 Unapproved or Missing Intervals

If PJM is not able to approve the Regulation Market and new results are not posted to the Markets Gateway System for a Regulation interval, PJM will continue and carry forward the current assignments, as needed, into the following unposted intervals. PJM will make notification of this condition to maintain current assignments via All-Call.

If PJM is able to approve the Regulation Market, but new results are not able to be posted to the Markets Gateway System for a Regulation interval, resource owners should receive their new assignment via ICCP/DNP communications which are described in PJM Manual 1, Section 3.

There will be no impact to the price calculation. The Regulation Clearing Prices continue to be calculated by LPC every five minutes in real time and are used for settlement.

3.9 Regulation Obligation Fulfillment

Hourly participant Regulation Obligations are determined after the fact, based on the LSE's actual load ratios. Participants can estimate their share of the PJM Regulation Requirement in advance by comparing their hourly load forecast to the PJM hourly load forecasts provided by PJM.

LSEs may fulfill their Regulation Obligations by:

- Self-scheduling the entity's own resources
- Entering contractual arrangements with other Market Participants
- Purchasing Regulation from the Regulation Market

3.9.1 Regulation Bilateral Transactions

Regulation Bilateral Transactions must be reported to PJM. Such reported Regulation Bilateral Transactions must be for the physical transfer of Regulation and must be reported by the buyer and subsequently confirmed by the seller through the Markets Gateway System no later than 13:30 the day after the transaction starts. Regulation Bilateral Transactions that have been reported and confirmed may not be changed; they must be deleted and re-reported. Deletion of a reported bilateral transaction is interpreted as a change in the end time of the transaction to the current hour, unless the transaction has not yet started.

The buyer on the transaction submits the megawatt amount, the seller, and the start and end time of the transaction via the Markets Gateway System. The seller confirms the transaction via the Markets Gateway System by 13:30 the day after the start date of the bilateral transaction.

Payments and related charges associated with the Regulation Bilateral Transactions reported to PJM shall be arranged between the parties to the bilateral contract.

A buyer under a bilateral Regulation contract reported to PJM agrees that it guarantees and indemnifies PJM, PJM Settlement and the Market Participants for the costs of any purchases by the seller in the Regulation Market, as determined by PJM, to supply the reported bilateral transaction and for which payment is not made to PJM Settlement by the seller.

Upon any default in obligations to PJM or PJM Settlement by a Market Participant, PJM shall not accept any new bilateral reporting by the Market Participant and shall terminate all of the Market Participant's reporting of Markets Gateway schedules associated with its Regulation Bilateral Transactions previously reported to PJM for all days where delivery had not yet occurred.

PJM calculates and posts Regulation Zone preliminary billing data on which Market Participants can use as a resource for pricing Regulation Bilateral Transactions. The data can be found in PJM's Data Miner 2 tool: http://dataminer2.pjm.com/feed/ancillary_services_fivemin_hrl and

https://dataminer2.pjm.com/feed/reg_zone_prelim_bill/definition.

3.10 Regulation Settlements

Regulation credits are paid to Market Participants that supply their resources to PJM to provide Regulation service based on the performance-adjusted Regulation megawatts provided. Cost of Regulation service is charged to the Load Serving Entity's real-time load ratio share.

A resource's Regulation performance score for each five-minute Real-time Settlement Interval it is regulating will determine the resource's eligibility for Regulation credit and lost opportunity cost for that interval. A resource whose performance score for the Real-time Settlement Interval that is below 25% will forfeit Regulation credit and lost opportunity for that interval.

Please refer to PJM Manual 28: Operating Agreement Accounting, Section 4: Regulation Accounting, for complete settlement details.

4.4 Reserve Market Clearing

PJM schedules resources as needed to meet the Reserve Requirements of each Reserve Zone and active sub-zone via joint optimization with energy in both the Day-ahead and Real-time markets. Resources are scheduled based on the resource-specific offer data submitted as defined in Section 4.2 of this Manual and the product substitution cost of providing energy or any other product the resource is capable of providing. The joint optimization seeks to procure and minimize the total production cost of energy and meeting the various reserve requirements as described in Section 4.3 of this Manual, and in the Real-time Market, the Regulation Requirement as described in Section ~~3.2.4~~3.3 of this Manual.

Reserves and energy will be co-optimized the same way in the Day-ahead and Real-time m~~M~~arkets.

The same reserve zone configuration will be modeled in the Day-ahead and Real-time markets unless there is an operational emergency requiring it to be changed in the Real-time market.

4.4.3 Real-T~~t~~ime Reserve Market Clearing

~~Sixty~~ Thirty ~~(60)~~ minutes prior to the operating hour, PJM executes the Ancillary Services Optimizer (ASO). The ASO jointly optimizes Energy, Synchronized Reserves, Non-Synchronized Reserves, Secondary Reserves~~,~~ and Regulation based on forecast system conditions to determine an economic set of inflexible reserve resources to commit for the operating hour. While ASO solves twice per hour, only cases with a target time for the top of the hour commit inflexible reserves with assignments valid for the whole hour. Inflexible resources are defined as those resources that physically require an hourly commitment due to minimum run time constraints or staffing constraints. Inflexible resources include:

- Synchronous condensers that are operating in condensing mode solely for the purpose of providing Synchronized Reserves
- Energy Storage R~~r~~esources enrolled in the ESR participation model (unless the resource has elected to be flexible)
- Economic Load Response that is~~are~~ prepared to curtail in response to a PJM Reserve Event (unless the resource has elected to be flexible)

Any inflexible self-scheduled offers for Synchronized Reserves that are available at the time of the ASO execution are assumed valid and committed for the hour.

Any reserve commitments on inflexible resources that are made are locked for the operating hour and communicated via Markets Gateway's Market Results page.

- Condensers and Inflexible Economic Load Response resources that are cleared d~~D~~ay ~~-~~ahead will have their commitments carried to r~~R~~eal ~~-~~time.
  - These resources need to have a minimum run time (minimum down time for ELR resources) no greater than one hour and notification time between ~~ten~~ 10 and ~~thirty~~30 minutes.

- The reserve commitment is carried over unless in rReal -time the resource is committed to provide energy or another ancillary product.

The following reserve information will typically be posted to Markets Gateway thirty (3010) minutes prior to the operating hour from the approved ASO case:

- Preliminary Reserve Requirements for the RTO and active Sub-Zone.
- Total projected rReserve megawattsMW transferrable from the RTO into the active Sub-Zone.
- Total preliminary assigned reserve megawattMWs for the RTO and active Sub-Zone.
- Total preliminary self-scheduled Reserves for the RTO and active Sub-Zone.
- Forecasted reserve deficit megawattMW quantities for the RTO and active Sub-Zone.

The following resource - specific reserve information will typically be posted to Markets Gateway thirty (30) 10 minutes prior to the operating hour from the approved ASO case:

- Reserve Offer offer megawattsMW for the applicable product
- Inflexible Reserve Awarded megawattsMW for the applicable product
- Inflexible Synchronized Reserve Self-scheduled megawattsMW

Additional Real-time Reserve commitments may be made on flexible reserve resources by the RT SCED application and additional inflexible reserves resources recommendations by the IT SCED application. Commitments on flexible reserves resources may change with each execution of the RT SCED application, while commitments on inflexible reserve resources will respect the minimum run time of those resources. The PJM oOperator, if necessary, may manually request an inflexible resource previously committed for reserves to provide energy. Such reasons include but are not limited to constraint control. Such action will automatically terminate the resource's reserve assignment.

- Flexible reserve resource commitments will be posted to Markets Gateway on the Dispatch Lambda page and will be telemetered via ICCP or other communication protocol to resource owners.
- Additional inflexible resource commitments will be communicated to the resource owners via ICCP or other communication protocol.

PJM utilizes resource - specific offers together with energy offers and resource schedules from the Markets Gateway System, as input data to the Ancillary Service Optimizer (ASO). ASO then optimizes the RTO dispatch profile and forecasts LMPs to determine hourly reserve commitments for inflexible resources.

Although the ASO considers all available resources during its commitment process, the hourly commitments for Reserves from the ASO are limited to inflexible resources only and may only represent a portion of PJM's Reserve needs for the hour.

IT SCED has the ability to project conditions further out into the future and make a recommendation to commit additional inflexible resources for reserves where they are economic.

The Real-time Security Constrained Economic Dispatch (RT SCED) program jointly optimizes the remaining RTO Reserve needs simultaneously with Energy while honoring effective regulation Regulation assignments. For more information on how RT SCED uses Reserve commitments in the joint optimization, please refer to Section 2.5 of this

Manual. The Locational Pricing Calculator (LPC) calculates a clearing price for Reserve every five ~~(5)~~ minutes as described in Section 2.7 of this Manual. Five~~ (5)~~ minute, Real-time, Synchronized Reserve Market Clearing Prices (SRMCP), Non-Synchronized Reserve Market Clearing Prices (NSRMCP)~~,~~ and Secondary Reserve Market Clearing Prices (SecRMCP) are used for market settlement.

During each execution of RT SCED, additional Reserve megawatt~~MW~~s may be committed to meet the Reserve Requirements from flexible resources for all services based on forecasted system conditions by re-dispatching online generating resources. In addition, RT SCED will commit offline resources to meet the balance of the Primary Reserve Requirement and 30-minute Reserve Requirement.

PJM may call on resources not otherwise scheduled to run in order to provide Reserves, in accordance with PJM's obligation to maintain reliability. If a resource is called on by PJM for the purpose of providing Reserves, the resource is guaranteed recovery of applicable Reserve lost opportunity costs as well as start-up, no-load and energy costs. Please refer to PJM Manual 28: Operating Agreement Accounting for additional settlements details.

The Real-time Market Reserve clearing prices are set based upon the offer prices submitted by the selected resources, together with the summation of the applicable product shadow prices in the joint-optimization process from the pricing run.

Resources cannot clear the Real-time Reserve and Regulation Markets for the same interval. The requirement for Regulation is first met before reserves because Regulation is a higher priority service.

9.3 Hydropower Operation (Moved from Regulation to Scheduling Section)

The eDART Hydro Calculator application is used to generate and coordinate hydropower schedules within PJM. Generation information collected includes pumping and generation megawatts, river flows and pond/reservoir levels. Generators submit schedules directly into the Hydro Calculator application or generators information is obtained from the Day-ahead commitment. This allows PJM Dispatch~~ers~~ the ability to determine when the units are scheduled to come online/offline. PJM Dispatch~~ers~~ may adjust hydropower schedules based on generation owner request or weather conditions and river levels.

During normal operations hydropower generation owners may:

- Follow their Day-ahead commitment.
- Request to bring on additional hydropower generation or pumping outside of the Day-ahead commitment.
  - Additionally, PJM Dispatch may request to bring on additional hydropower generation or pumping outside of the Day-ahead commitment.
- Come online for reliability such as Synchronous Reserve Events.

Depending on system conditions, PJM may accommodate changes in schedule. To facilitate these actions in RT SCED, PJM Dispatch~~ers~~ may enter the anticipated generation or pumping output of the hydropower resource as a hydropower schedule. This hydropower schedule is used to replace the State Estimator value in anticipation of system conditions and utilized as input in RT SCED as defined in Section 2.5.3.5 of this Manual.