

Phase 1 Manual Language

1) Regulation Signal

The following section will appear in Manual 12 – Balancing Operations as §4.4.2 Regulation Signals.

4.4.2 Regulation Signals

- RegA – Real-time instantaneous resource owner fleet regulation signal (+/- MW). This signal is used to move traditional regulating resources in the owner's fleet within the fleet capability (+/- TReg). This value will be sent on a 2 second scan rate.
- RegD-Real-time instantaneous resource owner fleet regulation signal (+/- MW). This signal is used to move faster moving regulating resources in the owner's fleet within the fleet capability (+/- TReg). This value will be sent on a 2 second scan rate.

2) Performance Score Calculation

The following section will appear in Manual 12 – Balancing Operations as §4.5.6 Performance Score Calculation. This is a new section.

4.5.6 Performance Score Calculation

Delay and Accuracy Score

For each 10 second interval starting from Time 0 +10, PJM will calculate a *Delay Score* to quantify the delay in response between the regulation signal (RegA) and the resource change in output. To calculate the match, use the statistical correlation function (σ), which measures the degree of relationship between the two signals. By shifting the time periods to compare the signals, delay (δ) is defined at the point in time of the maximum correlation between the two signals. This can generate both an Accuracy and Delay Score as

$$\text{Accuracy Score} = \max_{\delta=0 \text{ to } 5 \text{ Min}} \sigma_{\text{Signal, Response } (\delta, \delta+5\text{Min})}$$

$$\text{Delay Score} = \text{Abs} \left| \frac{\delta - 5 \text{ Minutes}}{5 \text{ Minutes}} \right|$$

where the Delay score allows a 10 second latency for signal propagation delay for regulating resources.

Precision Score

For each 10 second interval starting from Time 0 +10, PJM will calculate a *Precision Score* as a function of the difference in the energy provided versus the energy requested by the regulation signal while scaling for the number of samples. For each 10 second sample, PJM calculates the Precision Score as the absolute error (ϵ) as a function of the resource's regulation capacity, as

$$Error = \frac{Response - Signal}{Assignment \cdot MW}$$

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

Where n is the number of samples in the hour and the precision allows a 10 second latency for signal propagation delay for regulating resources.

Performance Score

For each 10 second set of calculations the performance score will be averaged over a five minute period for PJM will determine a composite *Performance Score* per resource as a unit-less scalar ranging from 0 to 1. The Performance Score will be a weighted average of the performance score components, as

$$Performance \text{ Score} = A * \left(\frac{Delay}{Score} \right) + B * \left(\frac{Accuracy}{Score} \right) + C * \left(\frac{Precision}{Score} \right)$$

The component scalars may range from 0 to 1, but must total to 1.

3) Determining Hourly Eligibility for a Regulating Resource

The following section will appear as a bullet in Manual 11 – Energy & Ancillary Services Market Operations, §3.2.10 Settlements

- A resource's regulation performance score for the hour or the portion of the hour it is regulating will determine the resource's eligibility for regulation credit and lost opportunity cost for that hour. A resource whose performance score for the hour or the portion of the hour is below 25% will forfeit regulation credit and Lost Opportunity for that hour.

4) Disqualification and Requalification of a Regulating Resource

The following section will appear in Manual 11 – Energy & Ancillary Services Market Operations, §3.2.1 Regulation Market Eligibility Settlements

- New resources must pass an initial performance test (minimum 75% compliance required). PJM will rely on owner's data for initial qualification. Current resources that are qualified on the date of implementation of regulation market changes do not need to re-qualify, though the

initial qualification does not preclude a resource from being disqualified from the regulation market for non-performance.

The following section will appear in Manual 12 – Balancing Operations as §4.5.5. This replaces current §4.5.5 – Continued Verification of Regulation Resources.

4.5.5 Disqualification and Requalification of a Regulating Resource

Regulating resources that are not performing over a specified time period will be disqualified and must re-qualify to offer into the regulating market. The disqualification threshold is based on a 100 hour rolling average with an average performance score below 40%. When a regulating resource falls below this threshold PJM will notify the resource owner and the resource will no longer be eligible to bid into the regulation market. The resource owner may schedule a re-test as soon as practicable. When a regulating resource re-tests it will follow the testing procedure described in Manual 12, §4.5.1-4.5.4.

Upon successful completion of requalification, the regulating resource performance score starts a new rolling average without any hours from the previous period counting towards the current period's rolling average.

PJM Actions:

- Tracks rolling average of a regulating resource's performance score.
- Alerts the regulating resource's owner when performance falls below threshold.
- Removes the disqualified resource from the market.
- Monitors re-testing of the regulating resource
- Re-qualifies regulating resource,
- Notifies LSEs of a resource's certification for Regulation within three business days.

Member Actions:

- Schedules re-test to re-qualify as regulating resource status if desired while adhering to regulation testing guidelines.

5) Regulation Limited Ramp Rate

The following bullets will appear in Manual 11 – Energy & Ancillary Services Market Operations, §3.2PJM Regulation Market Business Rules

3.2.1 Regulation Market Eligibility

- Resources should give priority to the regulation signal by not allowing the sum of the regulating 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 net of the economic base point and the regulation ramp rate to follow the energy signal.

3.2.7 Regulation Market Clearing

- Economic ramp rate must be separated into the energy portion and the regulation portion to determine if a regulating resource is capable of meeting its regulation offer. The segment specific ramp rates should be calculated from the economic ramp rate as follows:

$$\text{Regulation Ramp Rate} = \frac{\text{Cleared Regulation Capacity (AREG)}}{5 \text{ minutes}}$$

$$\text{Energy Ramp Rate} = \text{Economic Ramp Rate} - \frac{\text{Cleared Regulation Capacity}}{5 \text{ minutes}}$$

Where Cleared Regulation Capacity = $\min(\text{Economic Ramp Rate} * 5 \text{ Minute response}, \text{Cleared Regulation Capacity})$

The regulation MW offer is capped at the lesser of the economic ramp rate multiplied by the 5 minute response or the regulation offer to prevent a resource from over bidding.

6) Regulation Requirement

The following bullet will appear in Manual 11 – Energy & Ancillary Services Market Operations, §3.2.4PJM Regulation Requirement Determination

- The PJM RTO on-peak Regulation Requirement is equal to .9% of the forecast peak load for the PJM RTO for the day. The PJM RTO off-peak Regulation Requirement is equal to .9% of the forecast valley load for the PJM RTO for the day.

The following bullet will appear in Manual 11 – Energy & Ancillary Services Market Operations, §6.1.1PJM Regulation Requirement

- The PJM RTO on-peak Regulation Requirement is equal to .9% of the forecast peak load for the PJM RTO for the day. The PJM RTO off-peak Regulation Requirement is equal to .9% of the forecast valley load for the PJM RTO for the day.

Phase 2 Language – Regulation Market Clearing Process

The following bullet will appear in Manual 11 – Energy & Ancillary Services Market Operations, §3.2.1 Regulation Market Eligibility as data that must be supplied through the eMKT system.

- Regulation Mileage offer.

The following section will appear in Manual 11 – Energy & Ancillary Services Market Operations, §3.2.6 Regulation Offer Period.

- Resource owners wishing to sell regulation service must at least supply a cost-based regulation offer price that reflects both the Regulation capability offer cost and the mileage cost by 6:00 p.m. the day prior to operation, and the remainder of the necessary data prior to Regulation market closing as stated above in the Regulation Market Date Timeline section.

The following section will appear in Manual 11 – Energy & Ancillary Services Market Operations, §3.2.7 Regulation Offer Period.

1.1 Regulating Capability

For each resource, PJM will calculate a performance-adjusted Capacity Cost, as

$$\text{Adjusted Regulating Capability Cost} = \frac{(\text{Regulating Capability Offer Price } \$/\text{MW})}{(\text{Historic Performance Score})}$$

Dividing the regulating capability offer MW by the performance score, poorer performing resources appear more costly to the clearing process.

1.2 Mileage

Mileage is the summation of movement requested by the two second regulation control signals. In Mileage is the total length of the line depicting the regulation control signal. This will be calculated for the duration of the market hour for each regulation control signal (i.e. RegA and RegD).

$$\text{Mileage}_{\text{RegA}} = \sum_{i=0}^n \text{RegA}_i - \text{RegA}_{i-1}$$

$$\text{Mileage}_{\text{RegD}} = \sum_{i=0}^n \text{RegD}_i - \text{RegD}_{i-1}$$

PJM will calculate a performance-adjusted Mileage Cost, as

$$\text{Adjusted Mileage Cost} = \frac{\left(\frac{\text{Mileage Offer Price}}{\Delta MW} \right) * \left(\frac{\text{Expected Mileage Ratio of Offered Resource}}{\frac{\Delta MW}{MW}} \right)}{\left(\frac{\text{Historic Performance Score}}{\text{Factor}} \right)}$$

Similar to the *Adjusted Regulating Capability Cost*, the *Adjusted Mileage Cost* scales the offered MW by the performance of the resource such that poorer performing resources will appear more costly per MW of capacity. A faster moving resource will provide more movement for the same amount of regulating capacity, so the cost-per-MW of ACE correction would appear cheaper to the market. The expected mileage would be a rolling 30-day average for the type of market hour 1 for traditional units and 3 for fast units based on the ratio of 12 divided by 4 from the latest analysis. The additional Benefits Factor serves to make faster units appear more desirable to the market. Determination of this factor will be based on off-line simulations with various proportions of fast and traditional regulation resources.

1.3 Lost Opportunity Cost

As part of the market clearing process PJM calculate a *Lost Opportunity Cost (LOC)* per resource which represents the impact of moving the resource out of energy operating limits to regulation operating limits. When regulating, SCED will dispatch the resource to a maximum base-point of *Regulation High Limit* minus the *Regulation Assignment (AREG)*. Lost Opportunity is settled after-the-fact as a function of the assignment, LMP and economic dispatch over the hour, and hourly average regulation signal (regulation bias) of the resource. The Lost Opportunity Cost will not be adjusted by the Performance Score.

1.4 Total Offer and Market Clearing

PJM will rank the resources for clearing as it does today, in \$/MW, as

The *Adjusted Total Offer* of the resource would be

$$\text{Rank Order } \$/MW = \left(\frac{\text{Adjusted Regulation Capability Cost}}{\$} \right) + \frac{\left(\frac{\text{Lost Opportunity Cost}}{\$} \right)}{\left(\frac{\text{Regulation Capability Offer}}{MW} \right)} + \left(\frac{\text{Adjusted Mileage Cost}}{\$} \right)$$

PJM will clear the market against two requirements, a *Regulation Capability Requirement* and a *Mileage Requirement*. The *Regulation Capability Requirement* sets the amount of regulating reserves that PJM believes it would need to absorb sustained RTO ACE deviations caused by interchange error, forecasting error, or other sources. The market will assign units until the capacity requirement constraint is met, or

$$\text{Regulation Capability Requirement}_{MW} \leq \sum_{i=0}^n \text{Regulation Capability Offer } MW_i$$

The *Mileage Requirement* would be defined as the amount of resource movement that PJM believes it would need to absorb short-term RTO ACE deviations caused by frequency error, or other sources. The market will assign units until the mileage requirement constraint is met, or

$$\text{Mileage Requirement}_{\Delta MW} \leq \sum_{i=0}^n \left[\text{Regulation Capability Offer } MW_i * \left(\frac{\text{Expected Mileage of Offered Resource}}{\Delta MW / MW} \right)_i \right]$$

When both constraints are satisfied, the *Rank Order \$/MW* of the last assigned resource sets the *Regulation Market Clearing Price (RMCP)*.

This single RMCP provides the basis for creating the clearing price to value both the capacity and mileage, PJM will compute two additional components clearing prices as follows:

$$\text{Mileage Clearing Price}_{\$/MW} = \max_{\text{Assigned Resources}} \left(\frac{\text{Mileage Offer Price}}{\$/MW} \right)$$

$$\text{Regulation Capability Clearing Price}_{\$/MW} = \left(\frac{\text{Regulation Market Clearing Price}}{\$/MW} \right) - \left(\frac{\text{Mileage Clearing Price}}{\$/MW} \right)$$

The following section will appear in Manual 28 – Operating Agreement Accounting, §4.2 Regulation Credits. This will replace the current section.

2 Regulation Market Settlement Process

After the resource has been assigned in the clearing process, and performed in real-time operations, PJM will compensate the resources in settlements. All regulation market settlements will be computed on an hourly basis using historical calculated values effective in that given hour.

For each resource, PJM will calculate an hourly *Regulation Capacity Credit* similar to today's credits. The credit would be defined as

$$\text{Regulation Capacity Credit} = \left(\frac{\text{Assignment}}{\text{MW}} \right) * \left(\frac{\text{Capacity Clearing Price}}{\$/\text{MW}} \right)$$

In real-time, the resource will move to follow the regulation signal, generating mileage in ΔMW proportional to its assignment. The credit would then be

Regulation Mileage Credit

$$= \left(\frac{\text{Assignment}}{\text{MW}} \right) * \left(\frac{\text{Actual Mileage of Resource Type}}{\Delta\text{MW}/\text{MW}} \right) * \left(\frac{\text{Actual Performance Score}}{\text{Score}} \right) * \left(\frac{\text{Mileage Clearing Price}}{\$/\text{MW}} \right)$$