Working to Perfect the Flow of Energy

PJM Manual 12:

Balancing Operations

Revision: 37

Effective Date:

Prepared by Chris Pilong

Dispatch

PJM Manual 12:

Balancing Operations

Approval

Approval Date: Effective Date:

Chris Pilong, Manager Dispatch

Current Revision

Revision 37 (xx/xx/2017)

- Revisions to Section 3.1.2 PJM Control Implementation and Section 4: Providing Ancillary Services: Incorporation of RMISTF Solution Package

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Section 3: System Control

3.1.2 PJM Control Implementation

PJM uses the PJM ACE signal to establish the required control signals that are sent to each PJM Member whose generating resources come under the direction of PJM. PJM develops two types of control signals as follows:

- Regulation

- Dispatch

Regulation Signals

PJM calculates two Regulation signals, as shown by Exhibit 3.

- o RegA- is the low-pass filter of the regulation control signal, developed with consideration to minimize accelerated ramp rate, sent to traditional regulating resources

- o RegD- is the residual of the regulation control signal, developed with consideration to minimize net energy demands, sent to dynamic regulating resources

Regulation signals are currently constructed with a 30 minute conditional neutrality bias that calculates an offset to the RegA signal, when headroom is available to help manage state of charge for RegD resources.

- ~~RegA- low pass filter of ACE for traditional regulating resources, and,~~

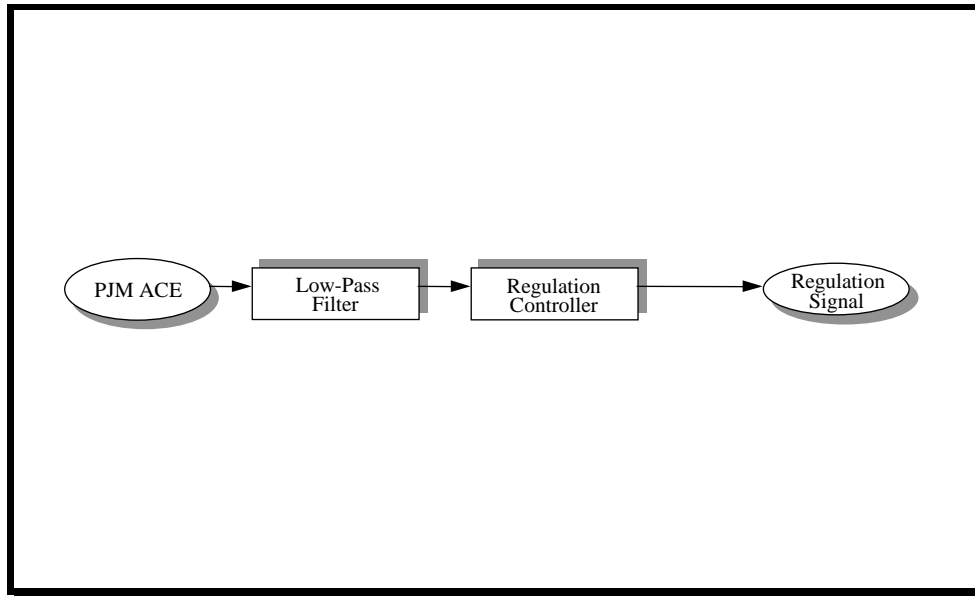- ~~RegD- high pass filter of ACE for dynamic or fast response resources~~

Exhibit 1: PJM Regulation Signals

At present, PJM sends the Regulation signal in the following form to the participating Resource Owners:

- Digital — The Digital Regulation signal is sent to each Resource Owner. The Generation Owners receive this signal and then send the appropriate signal to each regulating resource.

Dispatch Signals

The dispatch signals that are calculated by PJM are intended to direct dispatchable generating resources to "follow" the PJM RTO's requirement. The strategy that is used by PJM is to first develop a PJM price signal from the raw PJM ACE calculation. Exhibit 4 shows how the Dispatch Rate and MW signals are calculated for each participating Generation Owner.
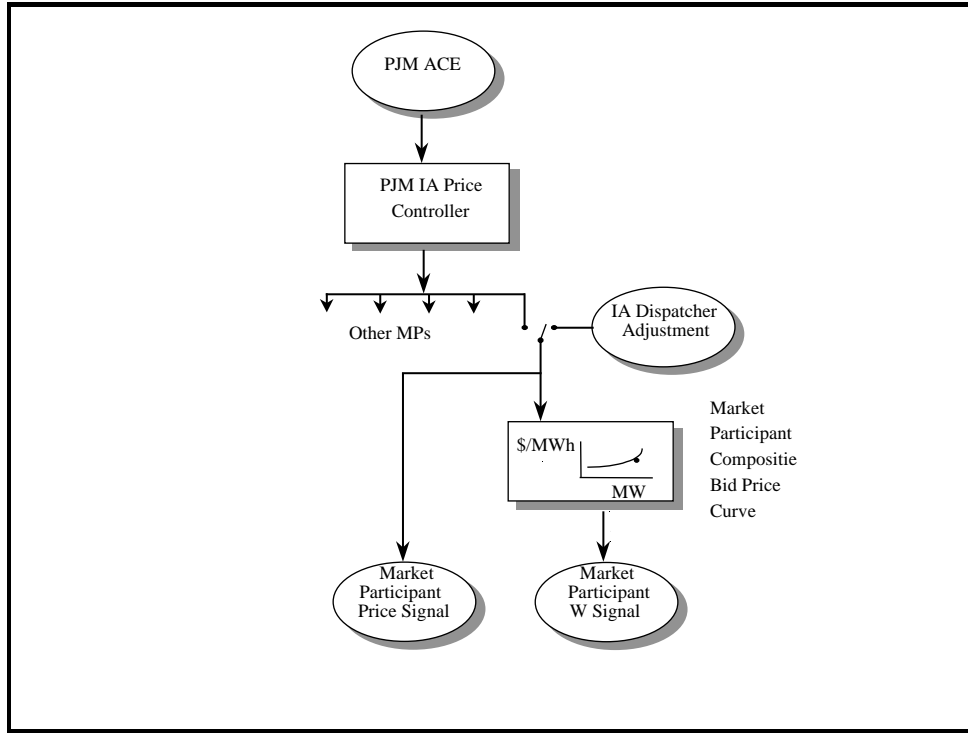
Exhibit 2: Calculation of Dispatch Price and MW Signals

- Step 1 — A common PJM price signal is developed by the RT-SCED tool which acts on load, interchange, transmission constraints and PJM dispatcher input.

- Step 2 — In the event of transmission congestion or other security issues; RT-SCED in conjunction with the PJM dispatcher may recalculate the dispatch price signals for the effected PJM transmission zones. The price signal for a particular PJM Member is then applied to the generation bid prices for that PJM Member.

- Step 3 — The MW versus price relationship is developed by PJM for each participating Generation Owner. The MW versus price relationship is developed by PJM using the scheduled generator offers submitted day-ahead via eMarket. Exhibit 7 shows how the various generation resources are correlated with respect to bid prices in order to develop this total MW versus price relationship.
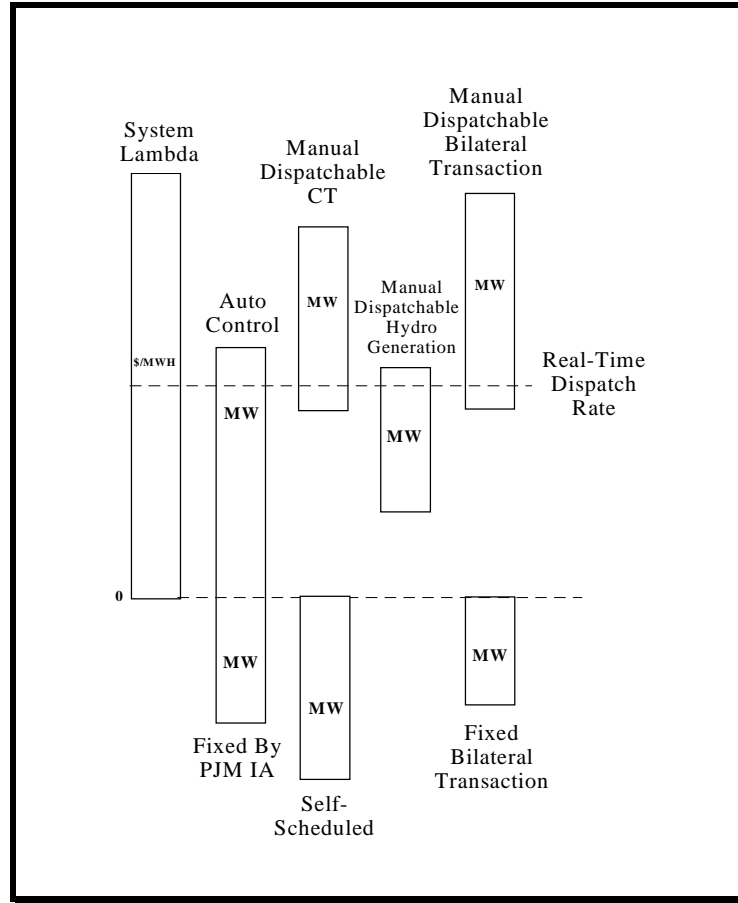
Exhibit 3: Resource Dispatching

It is important to emphasize that the MW versus price relationship applies to manually dispatched, as well as automatically controlled generating units. Since there is a wide mixture of slow and fast responding units and manually dispatched units in the PJM Balancing Area, the Dispatch Rate signal is adjusted slowly by PJM dispatcher in order to avoid unnecessary generation adjustments.

- Offers not properly submitted are rejected. The PJM member is notified of the reason for rejection and the PJM member may then take action to submit a new offer.

Section 4: Providing Ancillary Services

Welcome to the *Providing Ancillary Services* section of the **PJM Manual for Balancing Operations.** In this section you will find the following information:

- How PJM monitors and restores reserves (see "Reserves").

- How PJM determines and assigns Regulation (see "Regulation").

- How a generating resource is tested and qualified for Regulation service (see "Qualifying Regulating Resources").

- How PJM ensures and monitors Black Start Service (see "Black Start Service").

4.4 Regulation

The PJM RTO is a single Balancing Area consisting of multiple Control Zones. Resource owners providing Regulation are required to comply with standards and requirements of Regulation capability and dispatch, as described in this section.

PJM requires that all regulating generation resources be equipped with an Automatic Generator Control (AGC) scheme to receive, process and respond to regulation signals. Demand response resources providing regulation must have a similar control system.

4.4.1 PJM RTO Regulation Market Obligations

The Regulation Requirement for the PJM RTO can be found in this manual in Section 4.4.3 Determining Regulation Assignment. The resources assigned to meet this requirement must be capable of responding to the ~~AR~~ Rregulation signal immediately, and at a minimum, achieve their bid capability within five minutes and must increase or decrease their outputs at the ramping rates that are specified in the data that is submitted to PJM.

The PJM RTO requires that the Regulation range of a resource is at least twice the amount of Regulation assigned, and that the resource ~~can~~ symmetrically provides the total amount of Regulation assigned (a full raise and lower of assigned regulation from set-point) as illustrated in Exhibit 12 below.

Demand Response resources providing Regulation are required to fulfill the same regulation range requirements without injecting energy into the Bulk Electric System (BES).
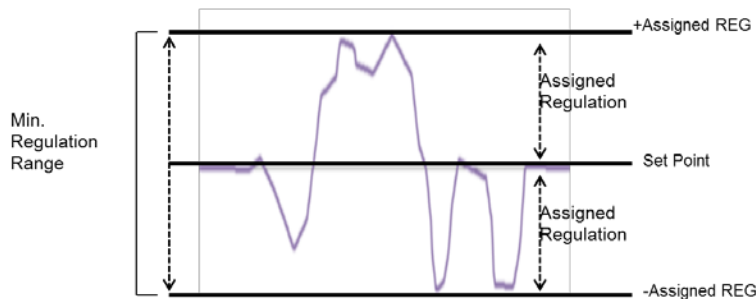

Exhibit 4: Assigned Regulation and Regulation Range requirements

A resource capable of automatic energy dispatch that is also providing Regulation reduces its energy dispatch range by the regulation assigned to the resource. This redefines the energy dispatch range of that resource. (The resource's assigned regulation subtracted from its regulation maximum forms the upper limit of the new dispatch range, while the resource's regulation minimum plus its assigned regulation forms the lower limit of the new dispatch range.) Exhibit 13 illustrates the limit relationship.
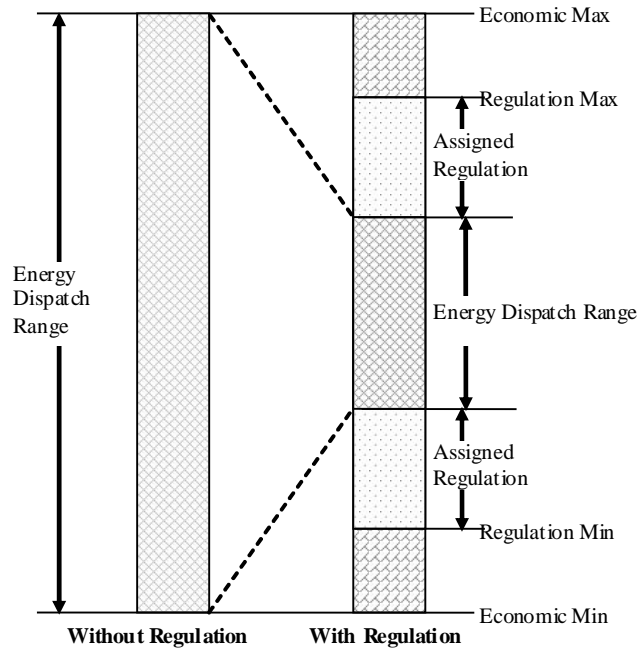
Exhibit 5: Limit Relationship for Regulation

Resource owners wishing to provide Regulation in the PJM balancing area are required to submit offer data as detailed in Section 3.2 of Manual 11 – Energy & Ancillary Services Market Operations.

4.4.2 Regulation Signals

Resource owners will receive from PJM:

- Assigned Regulation (ARegA or ARegD) - This is the assigned hourly regulation quantity (MW) that is cleared from the regulation market system. It is assigned for each individual resource that is qualified to regulate in the PJM market. This value, although typically static for the hour, will be sent on a 10 second scan rate. Resources will receive a separate assignment for RegA and RegD if the regulating resource is dual qualified, but the regulating resource will be assigned to follow only one signal for the hour.

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

  - o RegA is the is the low-pass filter of the regulation control signallow filter ACE signal, developed with consideration to minimize accelerated ramp rate, sent to traditional regulating resources

  - o RegD- is the residual of the regulation control signalhigh filter ACE signal, developed with consideration to minimize net energy demands, sent to dynamic regulating resources

Resource owners will send to PJM:

- Total Regulation (TRegA or TRegD)-This is the real-time fleet regulation capability (MW) that represents the active resource owner's ability to regulate. Ideally the value of this quantity should be the sum of the resource owner's non-zero AReg quantities for the majority of the hour, but must reflect any reductions in regulating capability as they occur (resource's AGC limit restrictions, resource "off control" conditions, etc.). This value shall be calculated every 2 seconds and sent on a 2-second scan rate. A fleet owner must separate the fleet so resources following RegA report TRegA and resources following RegD report TRegD.

  - o A fleet TReg value of zero signifies that the fleet is not regulating. This status suppresses the normal telemetry used to send the Regulation signal, so any fleet sending a TReg=0 will not receive the control regulation signal and automatically receive a zero performance score for the time in which they are assigned active Regulation.

- Current Regulation (CRegA or CregD) - This is the real-time fleet regulation feedback (+/- MW) that represents the active position of the fleet with respect to the +/- TReg capability. Ideally, the value of this quantity will track the RegA signal if the regulating fleet is responding as prescribed. This value shall be calculated every 2 seconds and sent on a 2-second scan rate. A fleet owner must separate the fleet so

resources following RegA report CRegA and resources following RegD report CRegD.

- For hydro resources that have no economic offer these resources must submit the resource(s) midpoint.

- Demand Response resources and regulation only resources are expected to provide PJM with a MW-value basepoint (LOADBP) in which the resource is regulating around. The LOADBP is expected to accurately represent the MW-value the resource is base loaded at and regulating around and should not change more than once every 5 minutes.

Resource owners may send the following to PJM if the resource owner will be using a performance group as described in Section 4.5.7-Performance Group of this manual for evaluation:

- Resource Allocation – Individual unit allocation may be sent to evaluate resource response. Allocation should be sent as percent allocation for each individual regulating resource of the resource AReg. When the resource is not assigned it will send either a 0 %. Resources without an associated allocation signal will be scored on a proportional basis.

- Operational Midpoint – the point around which the regulating resource (unit, plant or registration) operates.

If the above signals are not sent, then PJM will use proportional allocation and economic setpoint.

4.4.3 Determining Regulation Assignment

The PJM RTO's Regulating Requirement is 525 effective MW during non-ramp hours and 800 effective MW during ramp hours. The ramp and non-ramp period will be determined seasonally, based on system conditions, and posted on PJM.com at:

http://www.pjm.com/markets-and-operations/ancillary-services.aspx

PJM dispatch may increase or decrease the regulation requirements as needed to accommodate system conditions.

Each LSE is required to provide a share of the PJM Regulating Requirement. An LSE's actual hourly Regulation obligation is determined for the hour, after-the-fact, based on the LSE's total load in the PJM RTO, as follows:

$$\text{LSEs Regulation Obligation} = \begin{pmatrix} \text{LSEs Load Allocation \% } \times \\ \text{PJM Assigned Regulation} \end{pmatrix}$$

An LSE may satisfy its Regulation obligation by any of the following methods:

- Self-Scheduled Resources — An LSE can satisfy its Regulation obligation by self-scheduling Regulation.

- Bilateral Transaction — An LSE can make contractual arrangements with other PJM Members that are able to provide Regulation service.

- PJM Regulation Market Purchases — An LSE can purchase its Regulation obligation from the PJM Regulation Market, i.e., from the excess Regulation capability provided to PJM by Resource owners.

All Regulation offers reported to PJM must provide Regulation from qualified Regulation resources that has a quality standard of 75% or greater, as established by verification testing.

PJM Actions:

- PJM will notify the Transmission Owners and Generation Owners via the PJM ALL-CALL of changes to the regulation requirement and the expected duration of such change.

PJM Members Actions:

- Each LSE determines its estimated Regulation Obligation for the operating day based on its own forecast load and the information received via the PJM ALL-CALL.

- Resource owners view the hourly regulation market results via Markets Gateway (available at least a half an hour before the operating hour) as to those resources to which regulation has been assigned. Resource owners that have self-scheduled Regulation on any of their resources inform the PJM dispatcher when those resources are on line and able to provide the self-scheduled Regulation.

- Once regulation on a resource is self-scheduled by a resource owner, it is no longer eligible to participate as a pool assigned regulating resource for the current operating day.

- For Regulation transaction requirements see Manual 11 Section 3.2.3.

- If purchasing Regulation from another entity, the buyer and seller negotiate the transaction and the buyer submits the transaction through the Regulation Bilateral page of Markets Gateway. The seller must then confirm the transaction via Markets Gateway by 4:00pm the day after the operating day. The rules for these transactions are described in more detail later in this section of the manual.

4.4.4 Dispatching Regulation

PJM obtains the most cost efficient Regulation Ancillary Service available, as needed, to meet the PJM RTO's Regulation Requirement. PJM assigns Regulation in economic order based on the total cost of each available resource to provide Regulation, including real time opportunity cost and the resource's Regulation offer price. The AR Rregulation signals are then automatically sent to the Resource Owners via Automatic Generator Control (AGC). Resource Owners are responsible for maintaining unit regulating capability. Exhibit 14 shows how the Regulation is assigned to the resources.
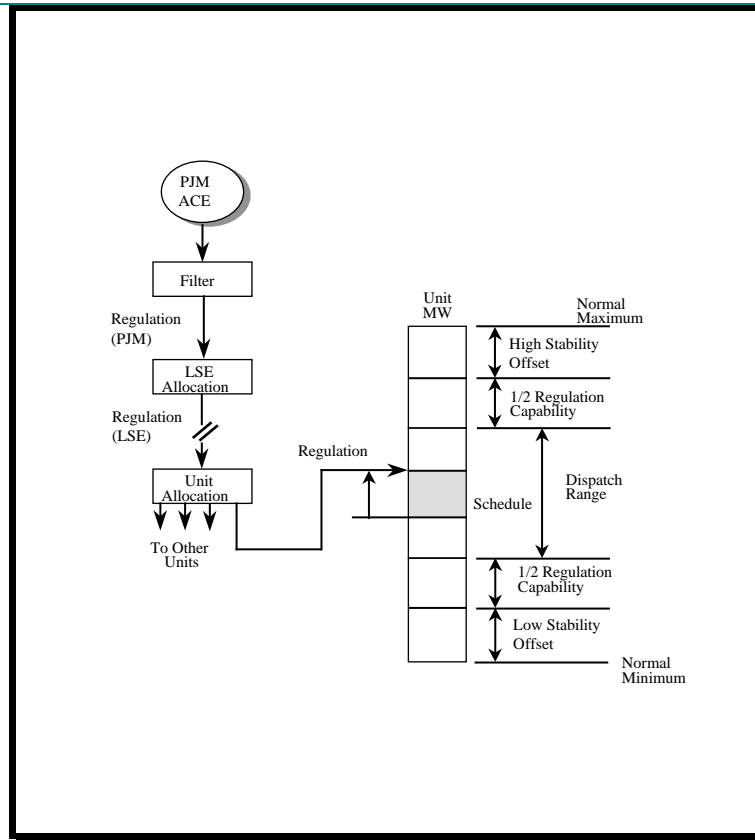
Exhibit 6: Area Regulation Assignment

PJM dispatcher re-assigns regulating capability as necessary to meet the PJM Balancing area's Regulating Requirement. Market Sellers must comply with Regulation dispatch signals that are transmitted by PJM. Market Sellers must operate their regulating resources as close to desired output levels, as practical, consistent with Good Utility Practices.

Regulation Deficiency

After the initial Regulation assignments are made, and throughout the operating hour, PJM Members report changes to their resource's regulating capabilities either by a phone call to PJM or by virtue of the TReg signal(s) each company sends to PJM. If a resource becomes unable to supply its assigned amount of Regulation, the PJM dispatcher must de-assign deficient resources and assign replacement Regulation to ensure that the total Regulation requirement is met. Such assignments are made economically based on each available resource's total cost to provide regulation, including real time opportunity cost and the resource's regulation offer price.

If, after assigning all available Regulation, the PJM Regulating Requirement is still not met, PJM dispatcher operates the system without the required amount of Regulation, logging such events.

In the event there is a loss of EMS communication between PJM and a resource owner, Current Regulation Assignments must be reassigned to another Resource Owner until EMS communication is reestablished.

Regulation Excess

If during the period an excess in assigned Regulation occurs and the total PJM RTO Regulation value exceeds the objectives by 15 MW or more, PJM dispatcher de-assigns Regulation economically based on each resource's total cost to provide regulation, including real time opportunity cost and the resource's regulation offer price.

PJM Actions:

- PJM dispatcher continuously monitors the Regulation deviation to assess Resource Owner fleet capability and reassigns Regulation as required.

- PJM's accounting staff determines the billing for the regulating service, according to the procedures in the **PJM Manual for Operating Agreement Accounting (M-28)**.

PJM Member Actions:

- When initial assignments and reassignments are made, each affected Resource Owner dispatcher then updates the entity's regulating capability as defined by the Resource Owner TReg value.

- Participants report to the PJM dispatcher changes (of at least +/- 1 MW for duration greater than 15 minutes) to assigned Regulation capability.

Bilateral Transactions

One PJM Member may sell Regulation Ancillary Service to another PJM Member. The two members participating in the Bilateral Transactions must operate in accordance with PJM Manual 11 Section 3.2.3 Regulation Bilateral Transactions.

4.5 Qualifying Regulating Resources

In order to ensure the quality of Regulation supplied to control the PJM RTO, a quality standard is developed. A resource must meet the quality standard to be permitted to regulate.

In general, there are two phases to qualifying a regulating resource:

- Certifying the resource

- Verifying regulating capability

An Area Regulation (AR)A Rregulation test is used for both certifying and verifying regulating capability for a resource.

Note: It must be emphasized that the Regulation test is not intended to test a resource's governor response to power system frequency changes.

PJM Actions:

- PJM Performance Compliance will evaluate test results against the PJM RTO Regulation Market Obligations as described in Section 4.4.1 &score the test using the performance score calculation as described in Section - 4.5.6 Performance Score Calculation of this manual within three business days of the test.

- PJM Performance Compliance will send results of test to the resource owner within three business days.

- PJM maintains a historical database of individual resource Regulation test results and calculates all appropriate compliance information. Individual test results are provided via email to the participant within three business days to facilitate a review and validation of results at the participant level.

- PJM Dispatcher determines if a self-scheduled test or PJM administered test can be performed based on system conditions.

4.5.1 Regulation Qualification Test

A separate set of tests are defined for qualification for the traditional signal (RegA) and the dynamic signal (RegD). The test follows a simulated Rregulation signal for the specified signal type. ~~Traditional Resource Test~~ Resources must complete a separate set of tests to qualify for the traditional signal (RegA) and/or the dynamic signal (RegD).

The ~~AR~~ Rregulation test is run during a continuous 40-minute period when, in the judgment of PJM test administrator, economic or other conditions do not otherwise change the base loading of the resources that are being tested. All resources performing a Rregulation test must set and hold ~~for the test duration~~ the MW-value base point that the resource is regulating around. This value must be held constant for the entire test duration. Changes in base loading for a resource during the test period invalidates the test for that resource. During a Rregulation test, the resource will not receive an AREG value from PJM and is not expected to set the fleet TReg value during the test. ~~A separate set of tests are required for qualification for the traditional signal (RegA) and the dynamic signal (RegD). The test follows a simulated regulation signal. The test will last for 40 minutes.~~

~~Once an Ar test is announced, a Resource Owner is not permitted to change any resource's Regulation assignment.~~

Following the testing period an initial evaluation will be performed to ensure all underlying regulation obligations and testing requirements have been met. This will include verifying the resource (1) was providing regulation for the duration (40 minutes) of the test, (2) can achieve its full and symmetrical regulation testing range (+/- TREG), (3) has held it's regulation base loading for the full duration of the test and (4) that no other resources within the testing fleet were in the regulation market during the testing period. Tests not adhering to the initial evaluation criteria are subject to test disqualification or failure.

Scoring the ~~AR~~ rRegulation test is based on compliance to the Performance Score Calculation as described in Section 4.5.6 - Performance Score Calculation of this manual. The score is evaluated on the entire 40 minute test period.

~~Dynamic Resources~~

~~The qualification test procedures described above for resources that will follow the dynamic regulation signal (RegD) are the same as the qualification test for RegA. For each test, resources will follow a signal for 40 minutes and be scored using the performance score calculation. Resources must complete a separate set of tests to qualify for the traditional signal (RegA) or the dynamic signal (RegD).~~

Changes to the Signal Path Re-Test – New Resource Owner

For previously qualified resources that are ~~either~~ purchased by a new resource owner which would constitute a change in the regulation signal path, resource owners must conduct a single, successful re-test to verify that each unit is able to respond to the regulation signal under the new resource owner. This test will be PJM administered and must meet threshold for certification as described in Sections 4.5.2-4.5.3. During the transition, resources will not be qualified to offer regulation. After the retest, the resource performance score will be set to the re-test qualification score.

Changes to the Signal Path Re-Test – Existing Owner

For previously qualified resources where an existing resource owner ~~who~~ makes changes to the Energy Management System (EMS) or Generation Management System (GMS) or other changes, which would constitute a change in the regulation signal path, resource owners must conduct testing based on mutual agreement with PJM. This includes but is not limited to EMS/GMS database, Inter-Control Center Communication Protocol (ICCP) server, and Communication Front End (CFE) replacements and/or upgrades. After system verification, the resource's historic performance score will be maintained. This test must be administered by PJM.

PJM Actions:

- PJM Performance Compliance will certify a resource after it achieves Regulation market qualification or requalification. ~~three consecutive successful tests of 75% or better.~~ After this requirement has been met, the change will be made to enable regulation offers to reflect the new certification within 1 business day.

PJM Member Actions:

- Contact PJM Performance Compliance at least a day prior to testing stating a Regulation test will occur and include the following information: the resource name and identification number, the time of the test, the amount of MWs being tested, basepoint, and what signal type the resource will test on.

- Contact~~s the~~ PJM Dispatch at least 60 minutes in advance of a PJM administered test for test scheduling and approval. Contacts PJM Performance Compliance at least 24 hours before the start of the test to ensure that test can be scored by the Performance Score Calculation Engine (PSCE).

- For a new resource owner, schedules a re-test by contacting RegulationTesting@pjm.com for each unit in a manner similar to the guidelines above when a new owner takes control of an already qualified regulation.

- For an existing resource owner, schedules system verification by contacting RegulationTesting@pjm.com based on mutual agreement with PJM Staff when an existing resource owner changes the control signal path (e.g. EMS or GMS is changed or upgraded).

4.5.2 Certifying Regulating Resource

A resource may be certified only after it achieves three consecutive scores of 75% or above. Resources providing dispatchable energy and regulation service needs to provide testing at the low economic and high economic regulation limits.

The first of these tests may be performed internally by the member following the PJM Regulation test procedure. To perform a self-test the member must use the PJM test shape posted on the Markets and Operations> Ancillary Services>Market Based Regulation page fed into the resource owner's EMS. Additionally, the member must notify the PJM Performance Compliance at least 24 hours before the test. The Resource owner should also notify PJM Dispatch who will make a determination whether the test can be run. The resource should be set to unavailable during the test, though the other units may continue to regulate. Up to three self-administered tests may be performed on a resource each day.

The remaining tests should be administered by PJM Dispatch. The resource owner should contact PJM Dispatch and PJM Performance Compliance at least 24 hours before the test. For a PJM administered test, all resource(s) within the regulation fleet will need to be taken out of the regulation market for the specific signal type. PJM Dispatcher makes the final determination about whether a PJM administered test can be performed. Only one PJM administered test may be performed on a resource each day.

For resources testing for dual-qualification (RegA and RegD), only one test will be required for qualification on the second signal type. Resources must complete one separate test to qualify for the traditional signal (RegA) or the dynamic signal (RegD).

PJM Actions:

- PJM Performance Compliance will certify a resource after three consecutive successful tests of 75% or better. After this requirement has been met, the change will be made to enable regulation offers to reflect the new certification within 1 business day.

PJM Member Actions:

- Before a self – administered test, resource owner notifies PJM Performance Compliance and PJM Dispatch. Before a PJM administered test, the resource owner notifies PJM Performance Compliance and PJM Dispatch 24 hours prior to testing.

- For any tests performed by the members for the purpose of certification, the member will supply the resource, the time of the test amount of MW being tested, the MW-value basepoint the unit will be regulating around, and the signal type the resource is following to RegulationTesting@pjm.com.

- Resource owner uses posted test shape on Markets & Operations>Ancillary Services>Market Based Regulation http://www.pjm.com/markets-and-operations/ancillary-services.aspx for self administered test.

- Resource owner will set the resources specific operation setpoints for each resource to test around.

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4.5.3 Certifying Multiple Combustion Turbines or Hydro Units at a Single Site

Combustion Turbines and Hydro-generators operating under a single plant control system must have a minimum of three tests of the control system. In addition, the performance of the each of the units being certified must be demonstrated in at least one of these tests. The test format must follow PJM Regulation test procedure. High and low band requirements do not apply for CTs and Hydro units being certified. The resource will be evaluated based on the Operational Midpoint of the grouped resources and the Resources Allocation as described in Section 4.4.2 Regulation Signals of this manual.

4.5.4 Increasing Regulation Capability on a Resource

One Regulation Certification Test is required for each market resource to increase the Regulating Capability on the resource. This test must be administered by PJM. Additionally, the member must notify the PJM Performance Compliance and PJM Dispatch at least 24 hours before the test. The resource should be set to unavailable for Rregulation during the test, and no other units in the regulation fleet can provide regulation for the given hour.

Testing to increase regulation capability on a resource can be performed no more than one time per month.   , though the other units may continue to regulate.

PJM Actions:

- PJM will update the regulation bidding availability to reflect the new certification within 1 business day after one successful test of 75% or better.

PJM Member Actions:

- The resource owner notifies PJM Performance Compliance and PJM Dispatch before a PJM administered test.

- For any tests performed by the members for the purpose of increasing certification, the member will supply the resource, the time of the test, amount of MW being tested, the MW-value basepoint the unit will be regulating around, and the signal type the resource is following to RegulationTesting@pjm.com.

- Resource owner will set the resources specific operation setpoints for each resource to test around.

4.5.5 Disqualification and Re-Qualification of a Regulation Resource

Regulating resources that have not met performance thresholds over a specified time period will be disqualified and must re-qualify to offer into the regulating market for applicable signal type (RegA or RegD). The disqualification 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. The hourly performance score calculation is described in section 4.5.6 Performance Score Calculation of this manual.

When the historic performance score falls below the set threshold of 4050% by signal type, PJM will notify the resource owner and the resource will no longer be eligible to offer into the Rregulation market for the applicable signal type.

The resource owner may schedule a re-test retesting activity as soon as practicable. When a regulating resource re-tests it will follow the testing procedure described in Sections 4.5.1-4.5.3 of this manual. 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.

When a regulating resource has no historic performance available, either because it is a new resource or a resource that has re-qualified, the average of the qualification test scores will be used as proxy for the historic performance rolling average as follows:

$$Hour = \frac{X * Qualification\ Performance\ Score + Y * Actual\ Performance\ Score}{100}$$

Where 100 – X = Y and Y is the number of hours after qualification. After 100 hours of actual performance scores X $\longrightarrow$ 0.

PJM Actions:

- Tracks rolling average of a regulating resource's performance score by signal type.

- Alerts the regulating resource's owner when performance by signal type falls below threshold of 4050%.

- Blocks the disqualified resource from offering into 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.

4.5.6 Performance Score Calculation

PJM will calculate an hourly performance score which reflects a Rregulation resource's accuracy in increasing or decreasing its output to provide frequency Rregulation service in response to PJM's dispatch signal. With the Performance Score Calculation Engine (PSCE), PJM will collect Rregulation signal data every 10 seconds and resource operating

parameters that will be inputs into the performance score. The performance score calculation (PSC) evaluates each resource's accuracy in following the AGC signal.

PSCE Assumptions

Unless a resource owner elects to send additional data to detail operational decisions, it is assumed that resources are allocating the Rregulation control signal(s) proportionally and operating around the PJM Individual Generator Dispatch (IGD) setpoint (basepoint). If a resource elects to use other than proportional dispatch the resource must send Operation Midpoint and Resource allocation described in Section 4.4.2 Regulation Signals of this manual.

Delay and Correlation 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 (r), 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 generates both a Correlation and Delay Score as:

$$\underset{\delta=0 \text{ to 5 Min}}{Correlation\ Score} = r_{Signal,Response\ (\delta,\delta+5Min)}$$

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

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

Correlation and Delay are determined together by finding the 10 second interval with the highest coincident Correlation and Delay score. The 10 second interval that will determine Correlation and Delay for each scoring period is:

$$\underset{\delta=0 \text{ to 5 Min}}{\max} (Delay\ Score + Correlation\ Score)$$

Correlation during Periods of Zero Slope

If the standard deviation of the regulation signal is less than a threshold value, then the Correlation shall be calculated as the 1 - absolute difference between the slope of the regulation signal and the slope of the response. The performance score for Correlation and Delay will be calculated by using linear regression to find the slopes of the regulation signal and the resource response.

Performance Score Calculation Precision Score

For each 10 second interval starting from Time 0 +10, PJM will calculate a Precision performance Scorescore as a unit-less scalar ranging from 0 to 1. The performance score will be calculated as a function of the difference in the energy provided versus the energy requested by the Rregulation signal while scaling for the number of samples. For each 10 second sample averaged over an hourly basis, PJM calculates the Precision

~~Score~~performance score as the absolute error (ε) as a function of the resource's regulation capacity, as:

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

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

$$Error = MIN_{t0-t10}\left(Avg\ of\ Abs\ \left| \frac{(Response\ -\ Regulation\ Signal)}{0.5 * Hourly\ Averag\ Regulation\ Signal + 0.5 * AREG} \right|\right)$$

$$Performance\ Score = 1 - \frac{1}{n}\sum |Error|$$

Where n is the number of samples in the hour and the precision is evaluated at 0 and 10 seconds, to allow for~~allows a 10 second~~ latency for signal propagation delay for regulating resources.

For periods when assigned regulation is 0, no score will be calculated. Null scores will not be included in the hourly average performance score.

~~Performance Score Calculation~~

~~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:~~

$$\overline{\frac{Performance}{Score}(t) = \max_{i=0\ to\ 5min}\left[A * \frac{Delay}{Score}(t+i) + B * \frac{Correlation}{Score}(t+i)\right] + C * \frac{Precision}{Score}(t)}$$

~~The component scalars will be weighted equally with each at one-third (1/3). For periods when assigned regulation is 0, no score will be calculated. Correlation, Delay and Precision will be calculated with all applicable samples. Null scores will not be included in the hourly average performance score.~~

PJM Actions:

- PJM will calculate the ~~Performance~~ performance ~~Score~~ score for each regulating resource after the operational hour and report the score to resource owners.

Member Actions:

- None

4.5.7 Use of Performance Groups in the Performance Score

Resources may elect to use a performance group for performance score evaluation. Performance groups can only be created for resources that satisfy one of the following criteria:

- Resources not eligible for LOC and total to less than or equal to 10 MWs across Transmission Owner boundaries.

- A performance group can be any number of resources not eligible for LOC inside a transmission owner's boundary.

- Resources within a fleet with equivalent applicable offers and point of interconnection.

Resources that are part of a performance group will send the Operational Midpoints and Resource Allocation of the group TReg for the grouped resources by signal type as described in Section 4.4.2 - Regulation Signals. Each resource will be metered independently.

PJM Actions:

- PJM will receive additional control data to be used in the performance score calculation Performance Score Calculation to be reflected resource owner's dispatch.

Member Actions:

- Resource owners will notify PJM via RegulationTesting@pjm.com that they satisfy one of the Performance Group criteria.

- Resource owners will add required information to their data transfer link to PJM.

4.5.8 Performance Scores for Regulation Resources during a Synchronized Reserve Event

Regulation Resources choosing to respond to a Synchronized Reserve event will receive synchronized reserve compensation based on Manual 11, Section 4.2.11.

Resources that choose to respond to a reserve event for their reserve zone in an hour when they are cleared or assigned regulation Regulation are expected to return to their regulating band within 10 minutes of the end of the Synchronized Reserve event. From the start of the event, through the event, and for the 10 minutes after the end of the event, the performance scores for all regulating resources in the reserve zone where the Synchronized Reserve Event takes place will be null.

PJM Actions:

- PJM logs the time of the start and end of a Synchronized Reserve event.

- PJM will score performance for all regulating resources as null for the period during the Synchronized Reserve event and 10 minutes after the end of the event for those resources in that reserve zone.

PJM Member Actions:

- If the resource owner chooses to respond to an event the resource will return to the regulating band as soon as possible after the end of the reserve event.

4.5.9 Performance Scores during Periods with Insufficient Data

In rare cases of data disruption, circumstances may arise when PJM does not have sufficient data to calculate performance scores. During these disruptions, PJM will calculate performance scores for all intervals with at least fifteen contiguous minutes of sufficient data. All intervals with performance scores, and only those intervals, will contribute equally to the hourly performance score. In the event that an operating hour does not contain fifteen contiguous minutes of sufficient data, the historical score will be used as the hourly performance score for that operating hour.

PJM will also use the historical score as the hourly performance score for an operating hour when a partial-hour regulation assignment does not result in fifteen contiguous minutes of sufficient data.

PJM Actions:

- PJM uses current operating day historical performance score for an operating hour where input data for performance scores calculations lasts for greater than 15 minutes.

- PJM will use operating day historical performance score when partial hour regulation assignment results in less than 15 minutes of data.

4.5.10 Performance Scores for Regulation Assignments with Limited Notification

Performance Scoring will begin ten minutes after PJM Dispatch logs a resource to provide regulation service. This will not impact the length of time a resource is considered to be providing regulation service for settlement calculations. For purposes of scoring under section 4.5.9, the fifteen contiguous minutes condition will begin ten minutes after PJM Dispatch logs a resource to provide regulation service.

PJM Actions:

- PJM Dispatch logs the time of the start for the regulation assignment.

- PJM will score performance starting ten minutes after PJM Dispatch log indicates resource start time.

Revision History

Revision 36 (02/01/2017)

- Update to Section 4.4.3 to update regulation requirement definition.